Innovation, Sustainability, Development: A New

MANIFESTO

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

The Global Redistribution of Innovation: Lessons from China and India

Adrian Ely and Ian Scoones

Redistribution

STEPS centre

About the paper

In the 40 years since the original "Sussex Manifesto", the global landscape of science, technology and innovation has altered radically. The emergence of new centres of innovation in many of what were in 1970 grouped as "developing countries" has important implications not only for those interested in maintaining the competitiveness of the more established economic powers, but more importantly for addressing global challenges of poverty alleviation and environmental sustainability. Taking as examples the world's two most populous nations, China and India, this background paper highlights the vital need to consider divergent social, political and economic contexts in understanding the global redistribution of innovation and its consequences both locally and more broadly. Drawing upon ideas, experiences and lessons from each country, the paper points to a number of remaining challenges for redirecting innovation policy towards the goals of equitable development and environmental sustainability. Underlying all of these, it argues, is the need to ensure that mechanisms for open and accountable governance are firmly embedded within - and indeed drive - systems of innovation, enabling more diverse, but currently under-recognised forms of innovation to flourish and ensuring that the dramatic changes in these nations contribute to broader social and environmental goals at multiple levels.

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About the Manifesto project

In 1970 a radical document called The Sussex Manifesto helped shape modern thinking on science and technology for development. Forty years on, we live in a highly globalised, interconnected and yet privatised world. We have witnessed unprecedented advances in science and technology, the rise of Asia and ever-shifting patterns of inequality. What kind of science and technology for development Manifesto is needed for today's world? The STEPS Centre is creating a new manifesto with one of the authors of the original, Professor Geoff Oldham. Seeking to bring cutting-edge ideas and some Southern perspectives to current policy, the New Manifesto will recommend new ways of linking science and innovation to development for a more sustainable, equitable and resilient future.

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The STEPS Centre (Social, Technological and Environmental Pathways to Sustainability) is an interdisciplinary global research and policy engagement hub that unites development studies with science and technology studies. Based at the Institute of Development Studies and SPRU Science and Technology Policy Research at the University of Sussex, with partners in Africa, Asia and Latin America, we are funded by the Economic and Social Research Council.

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INTRODUCTION

In the 40 years since the original Sussex Manifesto (Singer et al 1970) the global landscape of science, technology and innovation has radically altered. The original Manifesto was developed in a time when scientific research and development (R&D) was concentrated in a small number of rich states. The Manifesto showed how (excluding the centrally planned economies), developing countries were responsible for only 2% of world R&D expenditure (Singer et al 1970: Table 1) The subsequent 40 years were characterised by an innovation 'race' between the Cold War superpowers, leading to US technological and economic dominance from the 1980s. Through the Washington Consensus, the international institutions began to encourage the extension of neo-liberal, technology-focussed economic strategies for development, and with them increased investments in science and technology (S&T). Partly as a result of these changes, the same countries that made up 2% of global R&D in 1970 now make up approximately a fifth of global expenditure, with the emerging Asian economies accounting for a disproportionate share.[1] At least in terms of the inputs to certain types of innovation, therefore, there has been a significant global redistribution.

By the early 1990s, China and India had both increased their gross expenditure on R&D (GERD) to pass the original Sussex Manifesto's target (for 1980) of 0.5 per cent of GDP, and many of the newly industrialised Asian countries such as South Korea were spending more than three times that rate (OECD 2008a). In considering a 'New Manifesto' on innovation, sustainability and development, we are thus faced by a radically different context, although some remarkably persistent debates, dilemmas and challenges remain.

Those highlighting a global redistribution in innovation point to a broad body of evidence, including both input and output S&T indicators and wider economic consequences. For example:

Input:

- According to the OECD (2007a), China's GERD in 2006 was ranked third in the world after the USA and Japan, and represented 1.43 per cent of GDP, up from 0.6 per cent in 1995.
- The European Commission (2008) estimates that India is currently spending around 1.14 per cent of GDP on R&D. The Indian Planning Commission indicates that S&T budgets will triple in the years of the XIth Plan (2007-2012) compared to 2005-06 figures.

Output:

- In the ten year period 1997-2007, China ranked sixth in the world, Russia ninth in the world, India 13th and Brazil 17th in the number of articles published in ISI journals (InCites 2007).
- According to the World Intellectual Property Organisation, between 2000 and 2006, there was a significant increase in the number of patent filings originating from China, India and the Republic of Korea. The total number of patents originating in China increased by an average rate of 26.7 per cent per year between 2000 and 2006, increasing China's share of total worldwide patent filings from 1.8% to 7.3% (mostly due to increases in domestic patent filings) (WIPO 2008: 7)

[1] For further examination of these statistics, see Martin Bell (2009) *Innovation Statistics and Innovation System Models: Policy Tools and Policy-Making in Developing Countries* paper in this series

Partly as a consequence:

- China increased its share of high technology exports from 8 to 30 percent between 1996 and 2005 (OECD, 2007b: 14)
- In 2001 Goldman Sachs predicted that by 2010 the BRIC economies (Brazil, Russia, India and China) would account for 10 per cent of global GDP at purchasing power parity (PPP). But even by 2007 their share was already 14 per cent. They now expect China's GDP to surpass America's before 2030 (*The Economist* 2008a)
- In 2008 62 emerging market companies were listed in the Fortune 500 rankings, up from 31 in 2003 (*The Economist* 2008c)

We discuss in Section 3 below how these measures are subject to discussion, both in terms of their meaning and significance for other parts of the world. As widely discussed in the voluminous literature on economic globalisation, however (see for example Kaplinsky and Messner 2008), this change in context does have implications for technology, trade and competition, especially with the current pressing concerns associated with global environmental change.

China and India are the most populous of these emerging centres of innovation, and are taken as examples in this paper in order to illustrate common implications, but also the importance of contextual differences, in discussions of the global redistribution of innovation. Increasing awareness of the growing capabilities in S&T in China and India has been greeted by a number of responses, both positive and negative, and generated a series of policy narratives about science, technology and globalisation.

NARRATIVES OF GLOBALISATION AND TECHNOLOGY

A number of narratives about globalisation and technology are evident in popular, media and academic debates. These present the issue in starkly different ways, with hugely different implications for future science, innovation and development policy. The following sections offer – in a stylised manner – five.

THE FUTURE IS ASIAN

This narrative – perhaps the most well rehearsed of the five - identifies the global shifts in innovation capacity to Asia. The argument runs that existing technological capacities are currently based on outsourcing but are being upgraded, and that Asian firms (and not just Asian-based arms of USA- or Europe-based multinationals) are investing in basic R and D (research and development) capacity. No longer is the business model based on transferred technology, generics or piracy, but on new innovation, underpinned by intellectual property rights and patents. The firm base for such a take-off (or catch-up), it is argued, has been set through substantial top-down investment in both human resources – through education and training – and capital infrastructure for globally competitive R&D. This narrative very much focuses on the large-scale, formal, research-intensive sectors, in which a few iconic examples are forwarded. These include the great success stories of the Indian information technology (IT) sector, such as Infosys and Wipro, as well as emerging Chinese companies operating on the global stage, such as Lenovo and Haier. In addition, it is argued that on the demand side the economic conditions are right. There is a huge and growing demand from a burgeoning and increasingly rich middle class. Demand is for high-technology consumer, health and other products which were until recently unaffordable. Such a scenario will, it is sometimes implied, provide wider societal benefits through overall growth, increases in tax

receipts, employment boosts – and, in the end, a trickle-down effect on the poor and marginalised. As perhaps the most dominant narrative in recent policy discourse, it is reflected with various degrees of nuance in different literatures, policy work and media commentary.[2]

BOTTOM OF THE PYRAMID FORTUNES

This second narrative extends the first. This argues that such S&T-based growth in Asia is further supported by an even larger consumer base among the (relatively, but not extreme) poor. The 'fortune to be made through demand from consumers at the bottom of the pyramid' (Prahalad 2004), it is argued, can provide the demand drive for a massive take-off in science-led innovation and the investment in new products designed particularly for this large and growing group of consumers, particularly in populous countries like India and China. Again, iconic examples include the US$2500 Tata Nano car from India or the US$100 laptop, as well as the already massive growth of mobile telephony among poorer people. Here, the argument runs, a new type of consumer-driven capitalism (and associated R&D) will emerge which does not mimic the models of the West to sell the same products to a rich Asian middle class, but instead creates a wholly new innovation system geared to different needs and with different technologies. A variant of this narrative – focussing on 'below the radar' innovation serving markets outside the Asian drivers – has been put forward by researchers at the Open University in the UK (Clark et al 2009).

BORDERLESS CAPITALISM

The first two narratives are countered by a third which argues that the Asian success stories must be put in a wider context of the restructuring of global capitalism and associated technological capacities. With a neo-liberal, free trade regime dominating, a form of borderless capitalism has emerged dominated by a few multinational companies whose place of origin is less relevant compared to the scale and flexibility of these massive, vertically-integrated and often highly diversified operations. A phase of unprecedented mergers and acquisitions in a range of sectors – from seeds to pharmaceuticals – means that only a few big companies dominate the market; and indeed the whole value chain from upstream R&D to marketing. Such companies operate on the basis of the lowest cost wins, and will move operations to different parts of the world where labour and production costs are low and regulations are limited. Moving finance, skills and technology capacity around is the key to success. The move to Asia in the last decade or more has, it is argued, been a consequence of the cost advantages of emerging economies, rather than any more fundamental, long-term shift in innovation capacity. With value extracted from such operations across extended and diversified chains, the benefits to local economies may be limited, with such companies taking full advantage of export zones, tax breaks and legal loopholes to reduce costs. That some (few) Asian companies have joined the ranks of the US and European registered multinationals (and been involved in some large-scale deals) is, it is argued, not so relevant: they have simply joined an elite club who are able to benefit from contemporary global capitalist relations, where a particular innovation and technology trajectory supports the interests of a few large multinational corporations.

OUTSOURCING AND NICHE MARKETS

[2] See, for example, extracts from the World Development special issue on Asian Drivers (Vol 36, Issue 2), reports by DEMOS as part of their Atlas of Ideas project and much over the coverage in media such as the Financial Times, Economist, and equivalents in India

A fourth narrative offers a more positive angle to implications of the global shift in location to the 'developing world' of multinational capital, without making claims about new innovations or serving the poor. Here the argument runs that exploiting comparative advantages – in skills, language, time zone, technological capacity and, bottom line cost – allows substantial benefits for poorer countries and emerging economies if they can successfully hook into the global economic system, providing services and products to the West. This outsourcing model has resulted in the massive growth in businesses based on software engineering, network support, call and service centres and back-office processing in cities like Bangalore in India. Such businesses are based on highly-skilled, English-speaking employees backed by a technological infrastructure and capacity of global standards (in terms of phone connections, computer support and so on) acquired or 'transferred' from overseas. The growth in the software industry in India, for example, has largely been driven by such outsourcing arrangements, linked to larger companies particularly in the USA. The software model has been extended to other areas as diverse as clinical trials, medical transcription and USA tax returns. As well as creating employment for a well-educated urban population – both men and women – so the narrative goes, this has been an important driver of economic growth in India, which in the past decade has been impressive.

THE DARKER SIDE: ENVIRONMENTAL DEVASTATION, INEQUALITY AND CONFLICT

A final narrative presents a deeper critique of the others, pointing to the darker sides of contemporary technology-led global capitalism in emerging economies. Here the argument runs that headline figures of impressive growth are all well and good (if they are all to be believed), but if this is resulting in environmental degradation or growing inequalities then this is storing up problems for the future.

The negative environmental consequences of growth in the developing countries are not new, but problems of energy/resource use intensity and pollution have received increased attention recently in both India (Dyson et al 2005) and China (Economy 2004). These domestic concerns, combined with the impacts of the two giants' development on the global environment has led to their increased demonisation as international environmental offenders, despite the relatively small per capita environmental footprint of their citizens. The ecological impacts of their industrialisation (which has proceeded along pathways similar to those seen in the West) have been by exacerbated the continued 'transfer' of technology rendered obsolete in Western markets by improving environmental standards (see, for example, Sims Gallagher 2006 on the automotive industry in China).

In addition, it is argued that the massive disparities between those areas and sections of society which are 'catching up', and therefore cashing in on the growth in some sectors of the economy and those who are left behind is not acceptable. Social welfare standard operating procedures are insufficient, and conflict and unrest may result if deeper structural inequalities are not addressed,. Here there is a broader link evident in the relationship between forms of capitalism and democracy. In democratic systems (of whatever type) where the disparate voices of the majority are heard and taken into account, such inequalities cannot be sustained. A more equitable form of development must be central to building a fairer and, in the end, more stable society. A top-down, dirigiste stance focused on growth at all costs may be feasible for a while, but ultimately will unravel, as Amartya Sen (2006), Ashish Nandy (2006) and others have argued for India, and Will Hutton (2007) and others have argued for China.

In addition to these arguments in favour of equality, rights and justice, there are other perspectives that add to the critique of the 'Asian success story' meta-narrative. One that has come to the fore in the context of the global financial crisis questions the sustainability of

the existing economic model for long-term national development. With much of the growth in China and India being fuelled by a consumer boom in the West, in turn supported by massive national debt, financial speculation and an artificial real estate bubble, the question is how sustainable are the businesses based on such demand? The answer has come in the past year, as demand has collapsed, forms of protectionism have emerged, and questions have arisen about the long-term viability of prevailing forms of global capitalism. In Bangalore, the outsourcing capital of India, and in Chinese high-tech industrial hubs like Shenzhen, company closures and redundancies have been numerous. Such developments threaten to exacerbate existing inequalities and contribute to serious civil unrest. The already questionable and limited trickle down has been drying up, and alternative, more secure and resilient models for economic development are once again being discussed.

Each of these narratives compete in policy and public debates about the future options for science, technology and innovation. Of course none are exclusive, and an array of permutations and combinations are evident in any discussion. However, they do present some stark choices. What direction should be promoted at national and international levels? Who gains and who loses from different potential pathways? And what array of options should be followed in order to secure the widest gains and the greatest resilience to shocks and stresses? There are of course no easy answers. The rest of the paper will examine some of the dilemmas in more depth, reflecting on the important shifts in the way this debate must be framed 40 years on from the original Sussex Manifesto of 1970.

A NEW GEOGRAPHY OF INNOVATION? THREATS OR OPPORTUNITIES?

As discussed in the introduction, the locational distribution of R&D activity – even if it is outsourced by companies with bases elsewhere – has dramatically shifted since 1970. While the innovation centres of the USA, Europe or Japan undoubtedly still dominate the global landscape, new players in China, India, South Korea and Brazil are seen as increasingly important (Leadbeater and Wilsdon 2007). But to what extent do these moves within the world of science and technology signify a shift in *innovation*? And what are the potentials and dangers of this new geography of innovation?

In 2004 China surpassed the US in information and communication technology (ICT) export value, with around US$300 billion exported in 2006 (OECD 2008b).Chinese companies such as Lenovo, Huawei Technologies and the Haier Group, among many others, have purchased western companies and established themselves as leading technology industry players (Altenburg 2008). The number of researchers in China is higher than the enlarged EU and second only to the USA (Huang and Soete 2007: 9). There are also around 500,000 postgraduates in science, medicine and engineering (Wilsdon and Keeley 2007:4).

Similarly, in India while R&D spending remains relatively lower, impressive gains have been made. The long-term investment in education underpins the success. Around 350,000 engineers graduate every year in India from thousands of engineering colleges across the country. At the same time between 5,000 and 6,000 science PhDs graduate and enter a high-skill job market (Bound 2007). Six Indian corporations are represented in the Fortune Global 500. Big companies, such as Tata Group, Arcelor Mittal, and Infosys, are also making waves in the international scene, with a number of important take-overs (Altenberg 2008).

But some caution must be added to these impressive headline figures. As Altenburg et al (2007) point out there is much less evidence of new innovation capacity in emerging economies than is sometimes claimed. Most data point to large increases in inputs into R&D

systems, both public and private, but less to the achievements and outcomes in terms of innovation capabilities. In terms of publication records, scientific citations and patent metrics[3], India and China perform less impressively, certainly on a national per capita basis (Bound 2007; Altenburg et al 2007: 333). From this perspective, these fragmentary data therefore suggest that the global redistribution in *innovation* (limited to S&T–focussed innovation), while undoubtedly underway, has a long way to go before innovation capabilities are comparable to those in the established centres. Outside the S&T-focussed arena, the picture is even less clear.

Yet these qualifications and caveats often go unheeded. Often in political statements, the popular media and in some academic writing too, a generic threat from the East is constructed. This is portrayed, for example, as the challenge of 'Chindia' (Sondergaard 2007), against which firms in the USA and the EU need to equip themselves and develop new strategies by which to maintain a competitive edge. This requires, it is argued, more investment in S&T to keep pace with the vast scale of Indian and Chinese capacity and, more threateningly, potential. Investments in education and skills, business support and diplomatic efforts are thus seen as vital. Of course much of this rhetoric is wildly overblown, but the image of the Asian behemoth undermining the economic dominance of the West is a powerful one, with much political traction. It generates a policy response which in turn emphasises competition and high-tech solutions, pushing S&T-focussed innovation pathways in the North, often with progressively higher barriers to entry.

The growth of the Asian economic – and so political – clout has also been seen as representing potential threats to the poorer parts of the world, notably Africa. For example, the rise of the 'Asian drivers' has had important implications for other developing countries wishing to boost exports and upgrade technological capabilities in manufacturing. Drawing on evidence from the garment and textile sector, Kaplinsky and Morris (2007) argue that the emergence of China, and to a lesser extent India, threatens to exclude sub-Saharan Africa's exports from global markets, as well as presenting challenges to their industries within domestic markets. There are wider implications across sectors and for other developing countries competing with Asian drivers in international markets. Economic dominance in fragile economic and political settings can also result in the take-over of highly valuable primary resources. The growing demand for key commodities – energy, food, and minerals – in Asia to fuel rapidly growing economies could result in the emergence of extractive economic relationships, described by some as new forms of colonialism.

Yet the new geographies of innovation also are seen to offer opportunities in mainstream discussions of technology and globalisation. First, these include the potential for exporting patented technologies or licensing intellectual property to emerging firms in China or India, although of course such a technology transfer trade policy relies on emerging economies developing infrastructures compatible with those already established in the West. Efforts at building intellectual property regulatory capacity since the countries' accessions to the WTO serve to strengthen this opportunity. Much enthusiasm in the UK, for example, centres on the potential of export of low-carbon technologies to emerging economies, in compliance with international agreements on climate change mitigation (FCO 2007).

Second, 'more' innovation is seen as an opportunity for collaborative (S&T-focussed) responses to global challenges. Analyses have focussed on possibilities for traditional centres (e.g. the UK) to act as hubs for collaboration, especially around global good technologies (Leadbeater and Wilsdon 2007). From a not unreasonable assumption that

[3] As with bibliometrics, these have their downsides. See, for example, Li (2008) *Patent Counts as Indicators of the Geography of Innovation Activities: Problems and Perspectives*, South Centre Research Paper 18, Geneva, Switzerland: South Centre

'more brains, working on more ideas, in more places around the world, are good news for innovation', Leadbeater and Wilsdon suggest that the UK should leverage this innovation potential by acting as a magnet to the best global talent. Others argue that, as a result of the increasing ease with which scientific knowledge circulates the world, new forms of social network generated between traditional and emerging centres of innovation may serve to accelerate innovation for welfare, especially in developing countries (Wagner 2008).

Third, the rise of China has been viewed as an opportunity for developing countries (e.g. in Africa) to link with new aid/trade partners, who in some cases do not place strict governance conditions like traditional donors (Davies et al 2008). The 2006 Forum on China-Africa Cooperation (FOCAC) Summit announced the intention to establish five preferential trade and industrial zones for Chinese business entry in to Africa. The next FOCAC summit to be held in late 2009 (by which time aid to the continent is planned to have doubled) is likely to focus on other ways of opening African economies to Chinese firms. In the agricultural field, China has been particularly active, announcing on 25 March 2009 a US$30 million trust fund to boost the food output of developing countries, focussing largely on the provision of technical assistance to Africa (FAO 2009). Despite fears that this growth in productivity is primarily to provide exports back to China (Baudet and Clavreul 2009); the Chinese government has pledged *not* to purchase large areas of African farmland (Blas 2009).

Whether or not seen as threats or opportunities, much of the mainstream debate about the globalisation of technology and production, echoed across academic articles and media outlets, has been framed around the *rate*, *scale* and *location* of innovation, and is presented with the old metaphors of 'transfer' and 'catch up' around dominant (Western) pathways. Established technological trajectories, along with their associated institutional, social and environmental changes, are largely taken for granted. Discussions of innovation and globalisation have thus focused on the questions of 'how much', 'how fast', and 'where' innovation is happening – and less on questions about the *direction* of innovation ('innovation to what ends?') and the *distribution* of its benefits ('innovation for whom?').

As the discussion of competing narratives above has highlighted, these questions have huge consequences for the type of innovation efforts that are pursued and prioritised, posing questions about 'transfers' of what for which purpose, 'catching up' to what for whose benefit or 'leapfrogging' from where to where? The problem is, when innovation is treated simply in a scalar fashion as a component necessary for economic competitiveness, rather than as an activity to be targeted at the objectives of poverty reduction and environmental sustainability, a somewhat limited debate unfolds.

This dominant framing of contemporary policy discussion, we argue, has had damaging consequences, and obscures a wider discussion about alternative development pathways. In particular, a lack of emphasis on *directionality*, *distribution* and *diversity* results in the neglect of key issues. For example, the serious challenges faced in mitigating and adapting to climate change, responding to global health challenges or building global and local food security may be missed. But the global redistribution of innovation opens new opportunities: new innovators are potentially able to explore and stake out radical new pathways, unencumbered by outdated institutions, infrastructures and socio-technical regimes that developed prior to the recognition of a need to avoid anthropogenic environmental change. In addition, rapid social and political changes may spawn new institutions that enable S&T to better serve the needs of the poor, rather than directions of innovation remaining under the control of powerful elites.

Therefore wider questions of sustainability – and its environmental, social and political dimensions – must be brought to the fore, and the contribution of science, technology and

broader forms of innovation to addressing them are central. It is key to shed the emphasis on technology catch-up and transfer in favour of debates about *direction*, *distribution* and *diversity* as an important first step . We return to the implications of these arguments at the end of the paper.

CONTEXTS MATTER

As we have seen, some of the discussion about economic globalisation and the implications for S&T is strangely out-of-context. Generic categories are constructed – such as 'Chindia' – or massive areas like 'Asia', constituting half of humanity – are referred to in one breath in the discourse, without reference to particular places, cultures and politics. The lack of attention to context of course feeds into narratives based on generic 'threat' (or indeed assumed 'opportunity'), as well as ways of seeing the world as solely driven by universal – and universalising – global economic forces. Yet, of course, contexts do matter. And, within particular places, there have been diverse national, or even city or region-specific narratives at play about economic and technological competitiveness and the implications for development.

Histories matter too. Emerging Asian economies are incredibly diverse, with different historical relationships between capitalism, technology and the nation state. Different national and sub-national governance arrangements play an important part in determining the ways in which innovation is being experienced by various sections of the population. In particular, different political traditions have a major impact on how notions of innovation direction, distribution and diversity are seen.

Played out in different places – and sharply contrasting in India and China as we will discuss below – there are multiple visions of (global) capitalism and its relationship to technology and development. National as well as more local politics are influenced by such visions, and these are, in turn, deeply intertwined with the historical relationship between the state (in its multiple forms, both national and more local) and diverse styles of capitalism. The particular construction of the state itself is of course fundamentally based on these historical interactions, in turn informing attitudes towards technology, economic development and democracy.

Thus, for example, different styles of capitalism may be driving processes of economic change, and in turn relying on technology and processes of innovation in different ways. Following Baumol et al (2007), entrepreneurial capitalism, where free markets and an entrepreneurial culture drive innovation, contrasts with big firm capitalism where large corporations dominate, contracting in expertise and capacity. Such big-firm capitalism, typified perhaps by multinational-dominated sectors, can merge into what Baumol et al term 'oligarchic capitalism', where limited, well-connected firms capture and control the market and innovation system. This in turn can overlap in some settings with state-led capitalism where the state provides the foundation for both S&T-led innovation and economic activity.

Different histories and political and policy cultures of course value and support these different styles of innovation and capitalism in different ways. While the neo-liberal, free market discourse of recent decades in the US and Europe has celebrated entrepreneurial capitalism by big firms and small and medium enterprises, China's urban centres, for example, have exemplified a much more state-led approach since the opening of the economy in the late 1970s. In post-Soviet Russia, oligarchic forms have emerged which have proved highly successful under the prevailing political and economic conditions. Other places, perhaps notably India, have seen a more hybrid approach, with a selective embrace of

economic reform and neo-liberal policies, but with strong state support and some important big firm players too (both long-standing, such as Tata and Reliance, but also emerging, such as Infosys and Wipro). While the entrepreneurial and big firm capitalists may be the ones celebrated in most commentaries, it is perhaps the examples of what Baumol and colleagues term 'bad capitalism' that dominate the global economy. The ten largest Fortune Global 500 companies from emerging markets – all with annual revenues of over US$50 billion - are mostly state or oligarch-controlled resource based industries, where the potentials for patronage and corruption are evident.

How such economic-technological systems intersect with the global changes discussed above, involving the massive up-scaling of S&T based economic activity and its relocation to different parts of the world is highly dependent on the particular economic and political histories. For this reason (and rather obviously) the absurdities of talking in sweeping terms about emerging economies, Asia or 'Chindia', are all too apparent. Of course the successes of Japan or South Korea (with state-led *keiretsu* and *chaebol* respectively) cannot be exported to China and India, which show massively different contexts and trajectories.

Attention to context forces a rather more fundamental examination of the particular, historically-contingent relationships between state, market and technology; and how these play out in very different ways in different places. The story is of course not as simple as the standard narratives about science, technology and globalisation seem sometimes to suggest. Thus, for example, there is no neat relationship between 'more' S&T leading to 'more' economic growth and so 'more' development and poverty reduction, as the most simplistic narratives about 'progress' might imply. Instead, as stressed in the original Sussex Manifesto, the institutional context through which S&T (and other forms of knowledge) are created, deployed and diffused is critical. Factors such as the local economic and political histories, the nature of the state and the form of capitalism that is encouraged are at the core of determining the 3Ds of innovation: *directionality*, *distribution* and *diversity* (Stirling 2009). In the next two sections we – very briefly and necessarily very partially – describe the contexts of China and India – two countries in the world where the changes in the last 40 years have been (in some places, for some people) perhaps the most dramatic – in order to examine how such contexts have, continue to, and potentially might shape future pathways to sustainability.

CHINA: CONSUMER BOOM

As one of 13 of the 64 emerging economies that are in transition (Wright et al 2004), China offers lessons for others moving from centrally planned to market economies, and from authoritarian to more liberal polities. At the same time, its size, heterogeneity and history make it unique. Here we briefly discuss China's rise as a centre of innovation, as well as its domestic sustainability (environmental and social) objectives, their relationship with global trade concerns and associated S&T policy implications.

The entry of more than a billion consumers to the international economic system has transformed China's society. The country's impressive and oft-cited GDP growth has, on the downside, also brought the country 'to the top table' in terms of negative domestic and global environmental impacts: in terms of gross CO_2 emissions and polluted cities, China now leads the world. In addition, the numbers in absolute poverty in China (measured in dollar a day terms) have recently been upgraded from 128million to 330million because of the World Bank's 2007 revised PPP conversion rates (Keidel 2007). Inequality has also grown as growth in coastal regions has outpaced that in the poorer West. Premier Wen Jiabao's idea of 'the scientific outlook on development' which hopes to link socially equitable and environmentally sustainable development goals and sees an important role for science and

innovation, is put forward as a response to these challenges. Premier Wen described this concept in an interview with Bruce Alberts, editor of *Science*, in 2008:

> The number-one principle is to put people first. The second is comprehensive development, the integration of economic development with social development, the integration of economic reform with political reform, the integration of an opening-up and inclusive approach with independent innovation, and the integration of advanced civilization with traditional Chinese culture. Thirdly, we need to resolve the disparities—rich-poor disparity, regional disparity, and urban-rural disparity—in our country's developmental process. Fourthly, sustainable development: That is, to meet the challenges of population, resources, and environmental protection faced by a population of 1.3 billion in its modernization process.
>
> (Wen 2008: 363)

Social sustainability concerns are at least as prescient to the Chinese Communist Party as environmental impacts of the current form of growth. Some international commentators, like Will Hutton, have argued that the Chinese approach to capitalism without significant constitutional change risks social unrest, echoing calls from senior academics within China:

> In the next decade or two, China will likely enter a period of frequent social conflict. Peasants are likely to join hands with workers and members of the lower intellectual class and confront the elitist alliance that dominates society, creating political, economic and social upheaval in China. To prevent social unrest from triggering a revolution, it is imperative to address issues of social injustice as well as create the effective channels for their expression. Such a mechanism must be built upon fair constitutionalism and reform of the core values in Chinese society.
>
> (Yu 2007: 3)

There are signals to indicate that these pleas are being heeded, at least in that the central committee intends the policy making culture to move to a more consultative mode (in addition to expanding the formal role of the Chinese Peoples' Political Consultative Conference). However, fundamental deficits in transparency (for example around R&D funding decisions) and problems of public accountability remain.

So what kinds of approaches have the Chinese government attempted to introduce to address these environmental and social challenges? Specific policies to foster the environmental aspects of the 'scientific outlook' (mandated top-down by Beijing) include a goal for GDP growth to be accompanied by a 4 per cent decrease in energy consumption and a 2 per cent reduction in chemical oxygen demand and sulphur dioxide emissions each year. As China struggles to build a regulatory state, reaching these goals will be difficult. At the same time, the government has been unable to implement a national green GDP appraisal framework for cadres due in part to resistance from certain provinces. In the absence of central initiatives, other cities/provinces (e.g. Shenzhen) have been taking the lead; through an approach characteristic of China's incrementalism. In the same vein, 'circular economy' or resource-saving/environmentally friendly cities such as Wuhan are being used as experiments in eco-development to inform wider national policy. Recent work has shown that in order to deliver a quicker slowdown in growth in emissions of CO_2, radical innovation is required at a system level, rather than just through the adoption of new technologies in the current system (Wang and Watson 2009).

Through the centuries China has been no stranger to radical innovation; yet over the recent decades, the focus on bottom-up and top-down sources has shifted periodically. China has

stunned the world with the pace of technological progress within centralised programmes (e.g. in space technology) since its reform and opening up 30 years ago. As well as these nation-building 'big-science' projects, the government has also targeted technologies aimed at the poorer sections of Chinese society. The technocratic approach through which leadership narratives around science, technology and development have been implemented has led to impressive results in centralised, state-backed projects or firms such as in publicly-funded agricultural biotechnology leading to spin-off firms like Biocentury, whose products have been adopted by millions of Chinese farmers (Keeley 2003). The Beijing government realises, however, that these are not enough to deliver global competitiveness, and is also looking for ways to stimulate R&D intensity in private industry to resemble levels found in OECD countries. At the same time, the decentralised entrepreneurialism that has delivered China's staggering growth over the past 20 years now faces a plateau as the state begins to re-tighten its control, and some of the township and village enterprises so central to China's growth to date reach the point where informal investment and unregulated activities are no longer sufficient (Huang 2008).

Whilst optimising the conditions for certain innovation pathways, a more top-down approach risks crowding out other activities (e.g. innovations from outside dominant urban centres) and reinforcing the regional inequalities currently observed. An alternative vision continues to rely on township and village enterprises delivering goods and services to diverse local markets, drawing on user innovation as well as formal R&D and informal experimentation. The vast numbers of consumers potentially acting as a market for localised innovation in China bring great potential for poverty-alleviating growth, especially if the government can encourage spending and resist centralising innovative activities. One initiative that has attempted to foster such 'bottom-up' innovation, or at least entrepreneurship, is the 'Spark' programme, which offers government co-funding to enterprises at the local level that promise to introduce new technologies. Away from the gaze of government, *shanzhai* innovations are delivering cheap alternatives to Chinese consumers, drawing upon (whilst not paying for) foreign ideas.[4] An additional challenge in China will be to enable diverse and distributed, user-led innovation across the country, for example by harnessing local (traditional) knowledge. As well as, and in combination with adapting technologies received from elsewhere, this includes the development of innovations pioneered by the poor, often in marginalised communities (Xu and Mikesell 2003).[5] The broader political means by which this will be accomplished across the country are far from clear under the current system.

As well as enabling local innovation to flourish at home, China is already making in-roads internationally. The participation of Chinese firms in global value chains has delivered growth, but only in very few cases (e.g. Lenovo) have these so far become lead firms, accruing the major proportion of value-added through control of key intellectual property or brands. In contrast, much of China's manufacturing is still largely focussed on outsourcing for Western multinationals. For example, economists from the Universities of California in Berkeley and Irvine have shown that Apple's iPod, largely manufactured, and entirely assembled and tested in China, was sold for about US$224 wholesale in 2005. Of that, US$80 in gross profit went back to Apple in California. China's innovation policies are focussing intently on upgrading to overcome these obstacles (OECD 2007b) and through

[4] The term *shanzhai* derives from 'mountain hide-out' and is used to describe products activities over which the government has no control. Often seen as synonymous with pirated foreign intellectually property, *shanzhai* is sometimes seen by nationalistic Chinese youth as a sign of strength amongst Chinese firms. Other netizens suggest that *shanzhai* should be seen as a characteristically Chinese innovation culture and promoted.

[5] One example may be seen in Yunnan province, where ancient paper-making techniques have been patented by a group representing the Naxi minority. Organisations like CBIK (Kunming) are supporting such initiatives.

initiatives such as 'Go Global', launched in 2000, have been supporting domestic firms expanding overseas. State support for such Chinese fledgling multinationals may provide protection from foreign firms in the domestic market, where they are favoured by Chinese consumers, but it is unclear whether it can bring success in other major markets.

In addition, China recognises that its focus on applied rather than basic research and its low proportion of inventive patents are a potential weakness. In the 15 year programme for S&T unveiled in 2006, leaders made 'indigenous innovation' a priority. Cutting dependence on foreign, patented components is seen as an important step towards bringing more of the added value embodied in exports into the domestic economy. At the same time, China has responded to the 'wintelist' (Borrus and Zysman 1998) approach to directional dominance pioneered by US firms by introducing its own competing standards (e.g. in mobile telecommunications – see Xinhua 2009) in the hope of channelling technological trajectories towards those favoured by large, primarily state-supported enterprises. However, environmental considerations seldom feature, if ever, in the setting of these standards, partly because of the relative absence of any co-ordination at the international level. Firms from new and old innovation centres seldom compete on the basis of environmental upgrading, although there are limited encouraging examples.

While in many cases the drive for more environmentally-friendly growth is party-led (at various levels), in others it is helped by lead firms outside China attempting to 'green' their supply chain. International trade is in such cases forcing a rise in standards domestically (as has been witnessed in workers' rights in the case of Walmart (Bruetsch and Wang 2009), or Sony's Green Partner certification scheme, for example). However, from the Chinese point of view, such environmental or labour standards from richer nations are sometimes viewed as protectionist 'green barriers', pulling the ladder away from emerging competitors. These unfortunate sentiments are likely to increase as worsening financial conditions raise pressures for non-tariff trade barriers in importing countries. Promoting domestic consumption is widely seen as a response to diminishing overseas markets, but any associated lowering of environmental standards by Chinese firms (avoiding 'green barriers') would in the long-term disadvantage both China and the international community. Strong environmental regulation domestically is imperative if China's indigenous innovation is to continue in a direction that delivers long-term sustainability and international competitiveness. Indeed, recent work on 'environmental leapfrogging' for low-carbon growth has suggested that creating an 'enabling legislative, financial and regulatory environment' is as important as a focus on supporting specific technologies themselves (Sauter and Watson 2009). At the same time, that environmental performance delivers competitiveness is not a given. Changes to international agreements that govern trade and environmental regulation in order to foster an innovation 'race to the top' rather than 'to the bottom' (in terms of environmental or social sustainability standards), should be a priority.

The risk that China responds to raising environmental standards overseas by adopting a protectionist stance reinforces the importance of existing calls for more open, collaborative investments in R&D and cross-border innovation (elsewhere referred to as a cosmopolitan approach to innovation, see Leadbeater and Wilsdon 2007), especially in low carbon innovation (see Tyfield and Wilsdon 2009), environmentally sound technologies and other public goods. At the same time, large cross-border investments, for example into carbon capture and storage, threaten to create or perpetuate unsustainable globally-dominant trajectories that will crowd out alternative, potentially more sustainable development pathways emerging from Chinese localities or indeed from other parts of the world. Attention to, appreciation of, and support for this diversity of potential pathways will be necessary to avoid increasing lock-in to some of the unsustainable system configurations that characterise much Western development and are rapidly emerging in China. It is very

difficult to imagine this possibility within current framework of the G8 or G20 negotiations, or in a multilateral trading system dominated by just a few players.

INDIA: STRENGTH IN DIVERSITY

The image of India as a growing technological superpower has captured the imagination. An Economist Intelligence Unit briefing from September 2008 waxed lyrical:

> India's growing power will reshape the world as we know it. India's real GDP has surged by an annual average of nearly 9% in the past five years, and across all measures of influence -from military might to diplomatic sway to economic weight - the country's clout will continue to strengthen. India is on track to be the fastest-growing economy in the world in 2008-30, averaging annual expansion of 6.3%. It will also overtake China to become the most populous country in the early 2030s.
>
> (*The Economist* 2008d)

Certainly, as already discussed, the statistics are impressive. Until the global credit crunch and financial crisis, the Mumbai stock market had seen huge gains year on year. Technology stocks were particularly favoured, and some of India's IT companies had become the darlings of the international circuit – from Davos to Washington. There was much talk in the Indian media about the transformation of India into a knowledge economy, taking on the West and China. India, according to some, was shining. A bright future beckoned.

The export-focused software industry in particular has shown huge growth, contributing substantially to overall GDP. With headquarters in Bangalore, Hyderabad, Pune, Guragon and other smaller centres, the high levels of technical expertise, built through years of investment in quality technical education, was deployed to great effect. Software companies were able to exploit India's comparative advantage and insert themselves into the value chain, reporting big profits and massive share price increases.

The outsourcing model defined the perfect niche. In addition to the software support for big companies in the US and Europe, this was in turn extended to back-office processing efforts, call centres and other services. While some criticised this model as representing a new generation of 'IT coolies' or 'IT body shopping', it certainly resulted in significant economic returns and substantial employment. NASSCOM, the Indian software industry body, estimates that over a million professionals are employed in the industry, with several million more engaged in business process outsourcing, with significant multiplier effects across urban India.[6] The exports of India's most famous IT firms –(TCS, Wipro and Infosys) grew by 36 per cent last year (not including other back-office services) reaching a total of US$18 billion and employing around 560,000 people. They have struck a number of high-profile deals each worth over US$300 million (with companies such as Skandia, General Motors, United Biscuits and British Telecom) and profits are still substantial, despite the economic downturn (*The Economist* 2007a).

But of course the success came from somewhere. The science, technology and innovation infrastructure of India has been built over generations. From the establishment of the elite Indian Institute of Science a century ago, to the public and private investments in engineering colleges, software training schools and so on, the education system has been key. While much complained about today, the city infrastructures – of roads, electricity supply, and more recently fibre optic cables and the rest – has been the result of sustained

[6] http://www.nasscom.in/

public support. State backing for technology has extended to tax breaks, the building of science parks, and special economic zones. This has assisted the development of S&T clusters – around biotechnology, pharmaceuticals and other areas.

This shift was not therefore simply technology-driven as the 'technology transfer' or 'catch-up' narratives perhaps suggest. Nor was it solely market-driven, as the proponents of liberalisation and neo-liberal reform argue. Although economic liberalisation – from the late 1980s, and significantly from 1991 – was important, this was a negotiated affair with state and private sector involvement always in a hybrid balance, and local political concerns very much driving the process (Jenkins 1999).

The state, even in the post 1991 neo-liberal era, had an important role to play in facilitating and inducing, acting, in the terms of Peter Evans, as a midwife (Evans 1995). The state thus needs be seen as 'embedded' in networks of actors jointly committed to a transformational project. But which project, for whose ends? How did a particularly vision of technology-led development emerge in India? We return to this question below, but the politics of creating such a development pathway are clearly not straightforward, with state, private sector and public interests competing in the policy process (cf. Scoones 2005 for the case of biotechnology).

Thus, India's technology-led success story derives from a number of interacting factors. A combination of large market size, sustained economic growth, substantial flows of foreign direct investment, high levels of skilled human capital, including links into international professional and entrepreneurial networks, and consistent backing from the state have made the difference in the shift to a so-called knowledge based economy (Altenberg et al 2008). A key feature of recent economic success stories has been the networks between Indian innovation systems and the international science-business diaspora. Highly skilled, some very rich, non-resident Indians (NRIs) have been important in providing intellectual, entrepreneurial and capital investments in India. These networks have been vital for a number of both start-up and more established companies, providing links to new sources of knowledge and finance in the USA and Europe. While most PhD students graduating from elite institutions such as the Indian Institute of Science (IISc) in Bangalore leave the country for post-doctoral appointments or employment overseas, many return – some temporarily, others more permanently – tempted back by new housing, tax breaks and family connections. Thus the fluid nature of the knowledge economy means that the one-way 'brain drain' which characterised the situation 40 years ago is more complex today.

But a note of caution must also be added to this generic and positive diagnosis. The figures on state support to S&T can be misleading, and tell a particular story. Public good science – and state support for this – has clearly been important, but the welter of figures on the growth of state R&D budgets often quoted need to be interrogated. Indian 'public' science budgets from the Ministry of Science and Technology particularly focus on defence, space and nuclear applications, and lately some substantial investments in biotechnology through the Department of Biotechnology (DBT). Most of the returnee NRIs discussed above of course do not return to the public sector, and are engaged in commercial enterprises where the broader public good value, if not commercial returns, may be limited. As many commentators concede, public sector science in India remains uncoordinated and ineffective in terms of innovation outcomes; even if very high quality, internationally-regarded science (in bibliometric and other terms) is carried out in top-rank places like IISc and the National Centre for Biological Sciences (NCBS) in Bangalore NCBS. Without effective integration into innovation systems this means that such efforts may have relatively little effect on economic growth and development (Bound 2007).

So has all the success in the technology sector had any real effects on the scourge of poverty and ill-being in India? There have clearly been reductions in poverty in some areas, and opportunities for some created by the rapid growth of the economy. But the statistics are much disputed, and there are also major inequalities. Big divides exist between regions – between the west and south with the majority of new investments and the north and east with relatively few; and of course between urban areas where growth has taken off and the rural hinterlands which have stagnated, with a deep agrarian crisis affecting many regions[7]. These inequalities are now increasingly on the political agenda – with rural suicides, regular conflicts, protests and unrest in the large, poor rural vote banks. In the democratic context of India, these issues cannot be ignored – even though they remain outside the elite circuits of power which generate the mainstream discourses about technology-led growth. Indeed, many commentators suggest that these issues swung the 2009 election in favour of the Congress party. As the global economic downturn begins to bite, such discontents are spreading to the urban areas, which have profited from the boom to date, as lower-skilled workers, very often women, are laid off as technology companies contract or close due to USA business drying up. In the six month period prior to May 2009, 1.5 million jobs in the industrial export sector had been lost, with major consequences for livelihoods (*The Economist* 2009).

The hope and hype of the technology-led revolution has been popularised by the media and the promotion of a number of iconic heroes. Imagining India as the future technology superpower helps obscure India's wider and increasingly deepening, social and economic problems. The IT and biotech icons from Bangalore – Naryan Murthy, Nandan Nidelkani and Kiran Muzumdar Shaw perhaps being the most lionised – portray a hopeful, ambitious elite imagination of the future. They can point to tangible successes of course as multi-millionaires in charge of some of the country's most successful businesses.

But the politics of this innovation pathway is hotly contested. While the successes of the outsourcing model cannot be denied, is this resulting in a longer-term shift to more embedded innovation? Or is India, as some have argued, just selling Indian IQ on the cheap for the benefit of foreign intellectual property (IP)? Some argue that there is evidence of growing India-based innovation capacity, where Indian companies gain more of the value of the innovation process (Schmitz 2007). But this is slow in coming, even in the software industry. India's exports of its own software, or the licensing of its own intellectual property, amounted to just US$450 million in 2008, a very small proportion of total export revenues (*The Economist* 2007a).

There was much fanfare associated with the acceptance of the TRIPS regime in India in 2005 through the revision of the 1970 Patent Act. This was to herald a transformation of the technology industry towards an IP-driven innovation system that would add value, and put India on par with its global competitors. No longer was India to be the best at imitating things (notably generic drugs which represents a large and successful technology-based industry), but it would innovate in its own right. However, this transformation has not, as yet, occurred. Indeed, in some people's views it has been a retrograde step. As *The Economist* (2007b) pointed out:

> The new regime has not proved its worth. Over 17,000 patent applications were filed in India in 2004-05, almost 40% more than the year before. But only 3,500 were by Indians. Of the 49 most prolific filers in the past decade, 44 are either foreign

[7] See results from the National Sample Survey; but see also Datt and Ravaillion (2002); Ravaillion and Datt (2002); Deaton and Dreze (2002); Kijima and Lanjouw (2003); Bhanumurthy and Sinha (2004) among others for debates on the interpretation of the official statistics

> companies or subsidiaries. Of the five Indian firms, all are either government-sponsored institutes or generic-drug companies, which did fine before TRIPS

The Economist continues:

> India's generic drug makers are models not laggards. They invest in just enough know-how to exploit the rest of the world's discoveries. Thanks to them, Indians enjoy some of the world's cheapest medicines. But the larger cost lies in the opportunities for unabashed imitation that India has now forgone. These lost opportunities might be quite big. Had Indian firms been prevented from copying fluoroquinolones, for example, the Indian public would have been worse off by the equivalent of $255m year
>
> (*The Economist* 2007b)

The 'success' model promoted by the science-business-political elite in India – and echoed by much media commentary and the reports of think-tanks around the world – is perhaps not so convincing after all. How does it stand up to the claims that this is the best route to reducing poverty? Again, there are some big question marks. It assumes a classic trickle-down effect – more growth, more employment, more state revenues, more social programmes etc. Yet there is good econometric analysis on the relationships between growth and poverty reduction in India which shows that trickle down does not automatically happen (Ravaillon and Datt 2002; Datt and Ravaillon 2002). This is because many new 'knowledge industries' are not generating much employment - and certainly only at the high skill level (hence all the demand for returnee diaspora labour) - or much tax revenue, in part because of all the breaks and concessions. And also, as we have already discussed, positive effects of private sector-led growth on poverty reduction are highly dependent on prior conditions, including long-term, state-led investment in basic education, agrarian reform, infrastructure, and so on. It is no surprise that the best effects are found in West Bengal and Kerala, which have had long-term political commitments to more egalitarian approaches to development, backed by substantial state investments.

What alternatives are there to the high-tech growth narrative? The World Bank in its report Unleashing India's Innovation, urges India to get better at what it is already good at. It calculates that India's national output could be 4.8 times bigger than it is if only enterprises were 'to absorb and use the knowledge that already exists in the economy' (Dutz 2007). This means using existing technologies and linking them to small and medium enterprises, but making these more effective and efficient in a more coordinated innovation system. This of course was the basis for much earlier technology-led innovation where, for example, a variety of engineering and other businesses benefited from state-run industries such as Hindustan Aeronautics Ltd. in Bangalore (Pani 2008).

But there are other alternative narratives and dissenting imaginations too which suggest other pathways of innovation. These have a long history in India from the *swadeshi* movement before Independence to the alternative energy and technology approaches since the establishment of ASTRA (Application of Science and Technology for Rural Areas) by Amulya Reddy in 1974 on the IISc campus in Bangalore[8]. Indigenous technological innovation has in particular been celebrated by the Honey Bee network (Gupta 2006; Gupta 2009), whose members have illustrated the importance of technical ingenuity and new discoveries in diverse areas from transport engineering to agriculture. The allure of the high-tech vision and its promise of many riches has thus hidden from debate a more concerted debate about alternatives – alternative agricultures, alternative biotechnologies, alternative

[8] For example, see the Centre for Sustainable Technologies website - http://www.cst.iisc.ernet.in/

health care remedies, alternative energy and transport systems. Yet these are all very much alive and well in India – in the villages, in small workshops, and on the margins of some esteemed institutions (Indian Institutes of Technology (IITs), Indian Institutes of Management (IIMs) and even IISc). But their marginalisation, and often the unhelpful posing of these as in opposition to the mainstream, remains firmly entrenched. For such alternatives are not anti-technology or anti-growth. Far from it, they just suggest a different pathway of innovation – with different implications for *direction*, *distribution* and *diversity* – and so a different politics of technology and development.

Perhaps in contrast to China, it is this diversity, rooted in a strong democratic tradition, that remains India's often unsaluted strength. As many have suggested (cf. Leadbeater and Wilsdon 2007), India's democracy may be better equipped to allow continuing innovation and improvement in ways that are able to respond to contingencies and circumstance in flexible and sustainable ways.

INCORPORATING DIRECTIONALITY, DISTRIBUTION AND DIVERSITY?

The expectation and hype about the Asian knowledge economy is certainly fuelled by media hyperbole, venture capital speculation and policy spin, but what are the obstacles? Can it be sustained? For example, with intellectual property rights often tied up by multi-national companies based in the global North, there are some, but relatively few, options for local start-ups and businesses to move up the value chain. And innovation systems in India and China for example – where private and public basic research is linked to business and market applications – remain weak and uncoordinated. It must be asked: is the public or private commitment and resources really there to really make these systems the lead innovators in a global economy?

The 'race to the top' of the global economy is an alluring goal – and the relative successes of India and China in some sectors are seen as models for many poorer nations – but will these pathways of development result in broad based growth and the reduction of poverty for hundreds of millions of people? Are there not other pathways which need to be explored, where S&T and locally-rooted innovation systems respond to the more immediate livelihood needs of poorer people? These alternatives are largely off the radar in much policy debate – but need much greater attention: not only in Africa where the issues of poverty and deprivation are so stark, but also in Asia, where poverty and inequality remain a major block on human well-being and development (Leach and Scoones 2006).

In very different ways, leaders in both China and India have indeed indicated that environmentally sustainable, equitable development is a priority. It is not all about the drive to economic growth, they claim. Poverty, the environment, equity and social justice do matter. Challenges have arisen through electoral upsets and rural unrest, and so this wider agenda cannot be ignored. In both countries, national leaders are struggling to translate these objectives into concrete innovation and development policies, vital if more environmentally sustainable - including low carbon - pathways are to emerge (Ockwell 2009). What are some of the challenges being wrestled with, and how might a wider perspective on innovation – centred on the 3Ds – be developed? Here we outline four challenges.

First is the widening of the aspects of the innovation system on which policy currently focuses – beyond the elite, high-tech focus, driven by external export markets. With growing consumer demand for diverse products, delivered at low cost and fashioned for local tastes and needs, there is, as we have already discussed, a vast potential. The market 'at the bottom

of the pyramid' is indeed vast, but it is also choosy and has its own requirements. This requires a responsive innovation system with a better connection to local markets and technology users, new financing systems (including the micro-credit models that have proven successful in parts of South Asia and informal loan systems currently contracting in China) that allow technology development to respond and a political and institutional commitment to an innovation system that goes beyond the iconic cases of cheap cars and computers to other dimensions. This must go beyond inappropriate notions of 'catch up' to a more radical vision of new directions for innovation pathways. Of course much is already going on in the workshops, farms and villages beyond the well-known urban technology centres. But such diversified innovation systems neither get the recognition nor the support they warrant, and may present an important set of new opportunities given the global reconfiguration of innovation. While China has adopted 'indigenous' or 'independent' innovation (*zizhu chuangxin*) as a mantra, the Indian state is yet to adopt such a focus, rhetorically or otherwise. The recent financial crisis may be driving a rethink however, across emerging economies, especially in Asia. While the late 1990s economic crisis in Asia resulted in a lack of trust in foreign banks and capital, the recent economic downturn has highlighted the need to switch away from a reliance on foreign demand and consumers. A focus on local markets and economies, and so a business and innovation system more geared to local or regional demand, is seen as the way forward.

Second and related, is the challenge of making the most of indigenous technologies and these wider innovation systems. Unleashing local innovation and inventiveness may have major consequences, not only in local economies but across the world. People regularly make use of a huge variety of what may loosely be termed 'indigenous knowledge' (i.e. not derived from formal scientific research) for all sorts of activities, whether farming, health care or business. As argued by the Honey Bee network in India and groups such as The Center for Biodiversity and Indigenous Knowledge (CBIK) in China,[9] such indigenous knowledge is something upon which innovation can build. Investments need to be encouraged in efforts to record, safeguard, and most importantly, promote the *use* of indigenous knowledge (such as traditional medicines or crops), while establishing institutional mechanisms through which the traditional 'owners' of this knowledge may share some of the benefits from its exploitation.[10] Both India and China have invested in cataloguing local traditional medicines - the Indian Traditional Knowledge Digital Library, for example, now lists in encyclopaedic detail 200,000 traditional treatments (*Guardian* 2009). China is investing heavily in traditional Chinese medicine but knowledge and associated biodiversity are still disappearing. Such innovation pathways, embedded within these diverse indigenous knowledges and practices (and in associated genetic or other resource endowments), can confer substantial resilience if used as a foundation upon which to build diverse and economically vibrant innovation systems.

Third is the challenge of green growth and the transition to a low carbon economy. This is recognised as a central global challenge for innovation systems everywhere, but is perhaps particularly critical in the rapidly emerging economies (UNDP 2008). The directions being set at this stage in China and India's technological and economic development will continue to influence the form of innovation for decades to come, and shape the basis upon which they will compete with and relate to, the rest of the world. Various existing and emerging regulatory regimes (the WTO Sanitary and Phytosanitary Agreement, international carbon markets, Kyoto and post-Kyoto mechanisms) have the potential to drive future technological

[9] See the CBIK website - http://www.cbik.ac.cn/Get/English/About%20Us/150936709.html

[10] E.g. the new, third amendment to Chinese Patent Law includes clause requiring filing to disclose the source of any associated genetic resources, in line with the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources.

competition on the basis of environmental performance rather than through 'races to the bottom', but could be better co-ordinated to realise these goals. Conscious shaping of technological regimes and planning infrastructures around environmentally-sound principles - taking into account *directionality* in respect to environmental goals - may indeed provide emerging economies with lasting competitive advantage as these markets develop. At the same time, maintaining *diversity* in such regimes will enable flexibility and resilience in response to technological, environmental and social change.

Fourth is the challenge of effective regulation of technology for the wider public good. As has been demonstrated by the scandals around children's toys, drugs and milk in China, for example, regulatory systems based on closed, top-down command and control approaches are often grossly ineffective. The scale of counterfeit products is unknown, but in the pharmaceutical sector it is recognised to be massive. According to the Organisation for Economic Co-operation and Development (OECD), between 39 and 81 per cent of all counterfeit drugs seized by European Union officials from 2005–2007 originated in China or India, with major consequences globally (*SciDev* 2009). Effective regulation – where products are trusted and safe – is essential for any innovation system, and in this sense the gaps in China and India are widely acknowledged. One response is to turn to draconian interventions to shore up the effectiveness of regulatory bodies. The execution of regulatory officials in China is perhaps the most extreme example. Yet such responses are usually short-lived and ineffective. There remains an urgent challenge of building national institutions governing S&T based on transparency and public accountability. While the technological and commercial dimensions of innovation systems have raced ahead to much acclaim, the wider governance challenges often remain unaddressed. Just as with the deployment of the metaphors of 'transfer' and 'catch-up' in the technological realm, these are equally inappropriate when relating to regulation and governance. It is not just a matter of copying regulatory frameworks for biosafety, food safety and wider product and process regulatory systems from the OECD in a bid towards harmonisation (Van Zwanenberg et al 2008). Appropriate frameworks need to be responsive to particular contexts and built for particular social and political settings.

But individual countries – even ones as large and complex and with such huge potential and capacity as China and India – cannot go it alone. The challenges discussed above must be met in a broader global context – where trade rules, regulatory frameworks and international agreements all impinge, defining options and pathways in particular ways. The next section looks at this wider international challenge, and asks if a more optimistic, cosmopolitan outlook on science, technology and innovation can provide a route to new innovation pathways that meet the challenge of sustainability and the 3Ds?

THE WORLD IS NOT FLAT: COLLABORATION IN THE GLOBAL TRANSITION TO SUSTAINABILITY

Despite the geographic and scalar shifts in innovation capacity and location, there remain huge disparities within and between countries. The world is clearly not flat. While Thomas Friedman was appropriately impressed by Infosys and the high-tech vistas of Bangalore (Friedman 2005), the idea that global capitalism had removed the hierarchies and barriers to development was of course absurd. Indeed many of the inequalities between the North and South (and perhaps increasingly the differences within regions and nations of the global South) that were highlighted in the Sussex Manifesto in 1970 remain pertinent. Also the call to international collaboration, or what others have dubbed more recently a 'cosmopolitan approach' to innovation to address these inequalities, remains highly relevant, although with new twists and emphases. This section looks at some of these challenges, both old and new.

As the original Sussex Manifesto of 1970 argued, international collaboration on S&T is necessary both for solving global problems and for avoiding competitive tensions. There is already close and growing collaboration - as well as fierce competition for collaboration - between the emerging economies and traditional centres of innovation, in particular the USA. We have entered a period of unprecedented international change in technology and associated knowledge and institutions, which needs to be harnessed to address global and local challenges. This raises questions of how knowledge sharing can be facilitated, and how we can ensure that all forms of knowledge and innovation relevant to a global transition are afforded adequate attention.

As climate and food challenges become more urgent, access to proprietary innovations (e.g. in low carbon energy generation) will need to be further facilitated. Current global regimes around intellectual property still act as a barrier to the diffusion of vital new technologies and, as argued elsewhere, reform is urgently needed to expand access to technologies, reducing barriers to technology transfer, adoption and adaptation (CIPR 2002)[11]. The original Sussex Manifesto put forward the idea of a technology transfer bank as a partial solution to the problems of access. A range of other options can also be imagined – and many are already being tested in different ways. For example, changes in international law to allow for development-oriented patent restrictions; global public investments to buy up intellectual property for particular products and places; new incentives for technology development exchange (including prizes, tax breaks and public-private partnerships) and the facilitation of open source platforms for innovation. As we have seen, simple market solutions are insufficient: new roles for states and international agencies are required, and must be central to the New Manifesto.

Making the best of S&T for innovation for development and sustainability is a valuable goal, but technology access per se may be less of an issue than sometimes supposed. A recent World Bank study (World Bank 2008) showed how adoption of new technologies very much depends on longer histories of investment, often in very basic and unglamorous infrastructure. Thus, as summarised in *The Economist*:

> On a country's capacity to absorb and benefit from new technology depends on the availability of more basic forms of infrastructure. This has clear implications for development policy. Building a fibre-optic backbone or putting plasma screens into schools may be much more glamorous than building electrical grids, sewerage systems, water pipelines, roads, railways and schools. It would be great if you could always jump straight to the high-tech solution, as you can with mobile phones. But with technology, as with education, health care and economic development, such short-cuts are rare. Most of the time, to go high-tech, you need to have gone medium-tech first.
>
> (*The Economist* 2008b)

This of course does not apply to everything. But we should not be fooled by the mobile phone story, so often used as the example to demonstrate how rapid adoption of new technologies can transform the landscape. Mobile phones had particular attributes (of low cost, simple infrastructure and vast demand) which do not always play out for other cases.

[11] A recent example was the Beijing Declaration on Sustainable Development, developed by civil society representatives at the 2008 Asia-Europe People's Forum, which affirmed 'the critical role of technology, the need for technological cooperation and technology transfer to developing countries' with regard to mitigation and adaptation to climate change. (CIPR 2005: paragraph 18 on climate change and energy security)

Alongside the need for enabling infrastructure, trained individuals play a vital role. In 1970, the Sussex Manifesto recommended the reorientation of developed countries' S&T efforts in order to counter the brain drain, both internal and external. Specifically, the original Manifesto argued that it was not only necessary 'to increase the supply of scientific workers, but also to create the capacity to "absorb" them and to provide them with the conditions for getting scientific and technological knowledge applied'. However in retrospect, this external brain drain - the movement of expertise to international locations - has had some benefits. The personal and professional networks of what Anna Lee Saxenian (2005) calls the 'New Argonauts', the global knowledge workers, have been critical in both India and China's successes in the knowledge economy.

But while such sharing of scientific, business and entrepreneurial skills between the Silicon Valley of California and its counterparts in Beijing, Bangalore or Hyderabad is important, what forms of knowledge exchange are missing with this emphasis on the science-business elite? Will the economic benefits of this brain circulation automatically extend to objectives of poverty alleviation and environmental sustainability? In thinking about alternative knowledges and innovation pathways, the importance of South-South co-operation (rather than adoption of technologies from the global North or even the emerging innovation centres), informal exchange (outside of the corporate/higher education/government domain), and social movements for bottom-up innovation (such as the Honey Bee network, which has also started working between India and China) present different, often under-appreciated, answers to this question. Those offering their traditional knowledge to the informal global innovation partnership have more recently begun to gain a voice, aided by civil society. The 'Anchorage Declaration' that emerged from the Indigenous Peoples' Global Summit on Climate Change in Anchorage, Alaska on 24 April 2009, reiterated the need for collective action and sharing of knowledge relevant to addressing climate change between indigenous peoples and the rest of humanity (Anchorage Declaration 2009). The need to define and support an international innovation system that fosters collaboration around global challenges, but that is also able to accommodate, nurture and at the same time draw strength from these diverse knowledges is a central challenge. This particular example highlights the role of civil society groups in acting as knowledge brokers in this regard.

A focus on 'elite' knowledges alone (even if within new international alliances focussing on environmental goals) may also create or sustain dominant technological trajectories that crowd out possibilities for diverse innovations emerging from elsewhere, some of which might serve to address regional problems or locally specific notions of sustainability. Care must be taken that international collaboration in the global transition to sustainability leaves room for multiple, diverse pathways, and foresight will be required to ensure that emerging technologies do not present inequitably-distributed costs or risks (Van Zwanenberg 2009). Future approaches must identify ways in which locally-relevant 'niches' based on emerging technology and/or indigenous/traditional knowledge can be identified, supported, and where necessary protected from dominant, in some cases less-sustainable regimes. In order to do so, those closest to these niches must be brought to the discussion table.

In sum, alongside the current increase in collaboration between established and emerging centres of innovation (which is to be welcomed), a more purposive agenda is required. A move towards 'cosmopolitan innovation' needs to align with the 'cosmopolitan goal of a participatory global politics of innovation' (Tyfield and Wilsdon 2009: 12). This will also require more intense engagement of developing countries (from outside the G20) including both governments and civil society in standard-setting and in international negotiations that impact on innovation, with more attention to the alternatives that they have to offer.

CONCLUSION

In mainstream debates about science and innovation for development many questions are left unanswered. The future may well be Asian, but what direction is it going in, and who benefits, with what consequences for sustainability? If innovation is not only focussed on driving economic growth, then what are its objectives and goals, and who is setting them? What are the distributional effects of such rapid technology-led growth? What are the down-side consequences of the knowledge industry boom? What new politics of exclusion and disenfranchisement are generated, and how can they be avoided? And at the international level, what collaborative, cosmopolitan forms of interaction will facilitate alternatives?

As the simple narrative of 'technology=growth=development' becomes increasingly challenged, a potential opens up to radically redefine the relationships between science, technology and economic change. Technology can be liberating and emancipatory, as well as simply a functional contributor to aggregate economic activity. As the background paper for the India Knowledge Society Debates argues:

> There is more to the talk of 'knowledge society' than R&D budgets alone. The directions taken by innovation embody wider political choices and carry more pervasive social implications....Visions of the 'knowledge society' thus present nothing less than templates for the fashioning of new institutions and practices, new power structures and new ways of life.
>
> (STEPS Centre 2008: 1)

What are these competing visions in different places? And how do they play out? A particular dominant version hooked into a neo-liberal vision of a globalised market solution may be countered by other, more diverse counter-currents. In exploring the diverse facets of the global distribution of innovative activity and the new geographies of innovation this implies – these alternative narratives and 'dissenting knowledges' – about innovation and its direction, this paper has argued, may be equally important in the debate about pathways to sustainability and more equitable or environmentally sustainable growth.

Fostering such alternative innovation pathways may require support and assistance, for example in building local capabilities outside top-down R&D systems, to allow them to flourish. Here the state – perhaps in alliance with international support – becomes crucial. But this is not only a question of funds. Perhaps more important is the wider context within which such debates about innovation policy and support occur – and the recognition of dissenting voices within this context –, and so how science, technology and innovation pathways are negotiated. As this paper has shown, the dominant narratives emphasise growth and competitiveness, not direction and distribution. The consequence, as we have seen, is that alternatives are marginalised and inequality becomes entrenched, with many negative consequences for social and political stability, as well as people's livelihoods. These social and political dimensions are only really becoming recognised now, as the more negative consequences of the new geographies of innovation are becoming increasingly apparent. A New Manifesto thus must respond to these issues, highlighting the importance of embedded national and international innovation policy debates within transparent, deliberative, participatory, inclusive and accountable processes. Failure to do so means suppressed dissent, conflict and ultimately disappointment.

A collaborative – even cosmopolitan – outlook to science, technology and innovation is necessary for the future. A New Manifesto for science, innovation and development must seek ways of responding to the old agendas of unequal distributions of skills and knowledge, technology and infrastructure, as well as the new ones of ensuring that the directions of

innovation are firmly geared towards meeting the challenges of sustainability, and in particularly the transition to a low carbon economy. But this vision must not simply be a technical one – of skills and technology transfer, of databases and foresight exercises, of metrics and evaluation methods. Any response to a fundamentally reconfigured distribution of global innovation activity must also be political. It must be about ensuring that the success is not just about growth and GDP contribution, but also about equity, distribution and justice. It must be about ensuring that mechanisms for open and accountable governance are firmly embedded within – and indeed drive – systems of innovation, enriching the range of potential pathways. It must also be about fostering economies and societies that are more accepting of dissenting knowledges and alternative pathways, and that embrace more multivalent ways of thinking about S&T, with a stronger emphasis on diversity in options and choices.

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