Does Innovation Matter for LDCs? Discussion and New Agenda

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1. Introduction

The annual Global Competitiveness Report 2006-7, associated with the World Economic Forum in Davos, this year contained an interesting discussion about the role of innovation in countries at different stages of development. We take this discussion as the starting point for the paper, because it is broadly representative for the way in which innovation in less developed countries is generally perceived. The GCR 2007 divides countries in three groups: (i) a relatively small group of high-income countries, (ii) an intermediate group; and (iii) a group of low-income countries. The report argues that different factors ("pillars") are critical to productivity and competitiveness for these three different groups. Innovation is among the pillars most critical for the group of high-income countries. In order to sustain their high wages, these countries have to compete on the basis of their innovation and business sophistication. These countries are called "innovation driven". On the other hand, the second group, which is in the so-called "efficiency-driven" stage, supposedly competes on the basis of higher education and training, market efficiency, and technological readiness which includes aspects such as FDI inflows. For the low-income countries, which are at the "factor-driven" stage, it is said to be most critical to pay attention to institutions, infrastructure, macroeconomy, health and primary education in order to improve productivity and compete (WEF, 2007).

In this view, then, innovation is something that is only significantly undertaken, and is indeed only possible and needed, once a country has reached a considerable level of economic advancement. To date, this privileged status has only been achieved by a select group of high-income countries. Singapore and Hong Kong are the closest to developing country status present in this group. According to the GCR, then, innovation is not a particularly relevant, important and useful activity for the great majority of low and medium income countries.

This WEF view seems to be underscored by publications such as UNIDO (2002), RAND (Wagner et al, 2005), UNDP (2001) and Archibugi and Coco (2004), all of whom have developed indices that attempt to capture countries' technological and scientific performance by means of rankings based on various statistics. These rankings invariably suggest that the great majority of less developed countries (LDCs) do not innovate substantially or even at all. The 23 countries commonly identified as *leaders* in these studies do not contain any LDCs.

Should we conclude from this body of evidence that LDCs hardly innovate, and also that innovation is not relevant, desirable, or necessary to pursue for their socio-economic development?

In this paper we challenge this view. We review literature specifically focused on innovation and technical change in LDCs, which brings out that innovation in that context is much more widespread than the earlier-mentioned studies seem to suggest, but that it embraces many assimilation-related activities that are not captured by conventional innovation measures. Furthermore, the developing-country innovation literature indicates that assimilation is not merely important for the efficient use of foreign technologies in the short term, but that is also crucial for technological capacity building, which is a key determinant of long-run economic development. Countries that have given central attention to stimulation and facilitation of these processes have shown impressive development and catch up performance over the past decades. In the light of these findings, GCR and associated studies have adopted restricted definitions of innovation, which limits their scope and conclusions.

These past LDC studies still hold useful lessons for future action. At the same time, it is becoming increasingly clear that past technology accumulation strategies that are predominantly focused on assimilation and catch up to western technological frontiers have major limitations in the present era which is characterised by unprecedented challenges in areas like resource depletion, energy supply, environmental degradation, population pressure, and so on. In several areas, the technological trajectories that have been followed by western countries have encountered major pitfalls, and it is imperative that developing countries should not repeat the same experiences, both in their own and in the worldwide interest. There are also a number of areas in which the established western knowledge base is insufficient to address current problems faced by developing countries. For these reasons we argue that it is pertinent for developing countries to develop innovation capacities that go well beyond assimilation and adaptation of western technologies even when they are at relatively early stages of development. We highlight the need for innovation in developing countries in important sectors, and illustrate our discussion with some examples from specific sectors where significant progress is already under way. In section 2 we review the main lessons from the post WWII development experience with respect to technological change and innovation. In section 3 we identify recent developments and challenges in the new millenium that call for a reconfiguration of the innovation debate with respect to LDCs. In section 4 we illustrate these issues with three case studies of successful innovation programmes. Section 5 concludes.

2. Innovation in LDCs: Lessons from the post WWII period

Recognition of the existence of, or need for, indigenous technological activities in LDCs dates back to the late 1970s. Earlier research conceptualised technological progress in LDCs as a completely externally driven process, consisting of straightforward selection, implementation and use of western technology. The role of the receiving countries was essentially passive. The dominant view was that technological backwardness could be overcome by adopting more efficient technologies developed in the technologically advanced countries (Stewart and James, 1982; Bell and Albu, 1999)

The restrictive and unrealistic neoclassical assumptions required for this model to work were challenged on both theoretical and empirical grounds by an alternative, more dynamic learning-based approach that began to emerge in the second half of the 1970s. Its starting point was that the existence of adequate local capacity for effectively absorbing more advanced technologies in developing countries could not be taken for granted. This idea emerged as a result of observing remarkably contrasting performances in plants using imported technologies in different developing country settings. Detailed plant-level studies revealed that these differences could be traced to differences in local technological capability - the skills, knowledge and organisation needed for assimilating technologies. While technological hardware can be transferred from abroad, the capability to make effective use of that hardware cannot be transmitted so easily. It has to be developed locally through indigenous efforts - the investment of time and resources for the purpose of assimilation and adaptation. While technology imports can serve as the starting point for this kind of process, it is by no means automatic. In some countries (especially in Africa), the policy and institutional environment present almost insurmountable barriers for undertaking such investments, while in other countries (notably in East Asia) conditions have been much more favourable (e.g., Katz, 1987; Lall, 1987, Amsden, 1989).

This view of technological development is consistent with evolutionary economic theory, with its notion that knowledge cannot be fully articulated. The implications of technological tacitness for developing countries have been described well by Lall (1992). Just to acquire mastery over a given technology requires efforts to assimilate it, because its underlying principles can only be fully understood through practice. Problems may also arise from so called 'circumstantial specificities' (Evenson and Westphal, 1994). Technologies tend to have environment-specific elements, and simple replication across different environments is usually insufficient to ensure adequate functioning. There is usually only imperfect advance knowledge about which specificities will turn out to be important in a particular local setting, and which local adaptations and modifications will work in a particular local context. Often, local conditions are quite different from the contexts in which the technologies were originally developed (Dahlman and Westphal, 1981).

However, a lot of efforts to assimilate and adapt technologies were found to fall outside the rubric of formal innovation activities. They predominantly took place on the shop floor, taking the form of debugging, tweaking, trial and error, and so on. Thus, informal indigenous technological activity, often incremental and adaptive rather than science-driven R&D, has been critical for achieving efficient utilisation of modern technologies at low levels of development. This has been crucial for productivity growth, competitiveness and rising incomes in the longer term. Secondly, and even more important, these informal activities have led to cumulative learning and induce learning to learn, which has been the key to developing dynamic competitiveness based on full-fledged R&D-driven innovation capabilities in the longer term. In other words, active involvement in what one could call 'proto-innovation' processes have constituted the process by which countries have climbed the technological ladder and acquire true innovation-driven competitiveness. In the light of these findings, the suggestion contained in the GCR, that low-income countries should focus on infrastructure, basic education, institutions, macro-economy and health, is too limiting from this perspective. Sorting out these factors will lay an important foundation for economic growth, but will not pay off without complementary investments in technological assimilation and learning, pertaining to successively technologically complex activities (Bell, 1984; Lall, 1992).

There are specific actors that play a particularly important role in local technology accumulation in the broad sense outlined above. In particular, the crucial role played by a local capital goods industry has been widely noted. Firms in this sector are best equipped to assimilate technology transferred from more advanced countries. Several peculiar characteristics of the capital good sector make it special. Firstly, the production of new and improved products and processes in an economy generally calls for new or improved machinery and equipment to be supplied by the capital goods sector (Rosenberg, 1963, p. 416). Capital goods producers are also initiators of innovation in their own right; an important incentive is that their innovations create obsolescence in downstream industries. By pushing innovation, capital goods producers boost their market by creating demand for more modern machines and equipment among users of capital goods (Stewart, 1977, p. 152). Innovations in the capital good sector also have much higher externalities than innovations generated elsewhere in an economy, for example, through inter-sectoral movement of skilled workers (Fransman, 1984, Pack, 1981, Rosenberg, 1963; James, 1991). Since the innovations end up with producers rather than consumers, they often cause further innovations to be undertaken in user-industries. Adjustments in user-technology may be required because the new equipment is different in scale from the old equipment, or because operating requirements are different (Stewart, 1977, p. 152). The need for such adjustments often gives rise to further improvements in the new capital goods themselves in turn. This may lead to iterative close interactions between capital goods producers and users over prolonged periods, leading to processes of incremental technological change whose economic impact can be highly significant in the long run (von Hippel, 1988; Lundvall, 1988). Rosenberg (1963) indicates that such cumulative causation processes over time create significant generic innovation capacity. In his words, "a significant dimension of the transition to economic growth lies in the ability of the capital goods sector to assimilate and develop proficiency in the new machine technology and thus both to generate, and to adapt itself to, the continually altering technological requirements of an industrializing economy" (Rosenberg, 1963, p. 417).

Although Rosenberg's observation concerned the historical experience of western countries that were industrializing in the 19th century, researchers probing the role of capital goods producers in developing countries in the post WWII period have shown that his argument has been just as valid there, even if technological change in these countries does not generally take the form of original innovations. In developing countries, a local capital goods sector has been found to be crucial for the effective mastery of foreign technology through reverse engineering and copying, as well as for its adaptation and modification to make it suitable for local requirements. In other words, in developing countries the capital goods sector has been a crucial nexus for the development of local technological capability.

User-producer interaction has been found to be vitally important in that setting, because it is the main mechanism through which foreign technology is successfully adapted to specific production conditions (Fransman, 1985). Technology tends to have tacit elements. User firms tend to experience the need for local adaptations only when they actually start using the technology. An exporter or manufacturer located in a far-away western country cannot foresee these needs, and even if it could, it would have little incentive to engage in the required modifications for a small market with special needs, which has little scope for making large profits. This obstacle is all the greater because the equipment concerned is often of older vintage, with the models in question no longer being manufactured and serviced in western markets. This translation function is thus better taken up by local companies in close consultation with its client-firms (e.g., Pack, 1981).

Up to the early 1980s, it was common practice for developing countries, even small and very poor ones, to employ a battery of protective policies to nurture their indigenous infant capital goods sectors. The need and desirability for such protection was widely recognised in academic and international policy circles, in view of lengthy learning curves, strong positive externalities, and lack of minimum efficient scale due to initially small markets (Chudnovski and Nagao, 1983). However, the issue all but disappeared in the development debate after the onset of structural adjustment policies in the early 1980s. The protection policies and the underlying infant industry argument were incompatible with the neo-liberal development thinking and practices of the day. In the era of the Washington Consensus, emphasis shifted to regaining macro-economic stability and promoting competitiveness through liberalisation, outward orientation, privatisation, and public sector reform. There was no room for policies to promote a sector that is pre-eminently important for countries to develop long-run dynamic competitive advantage, but whose short-run performance is typically beset by a host of problems. In the great majority of countries, support for the sector – and for manufacturing more broadly – was completely abolished.

In the neo-classical view, inefficient protected sectors should merely be left to disappear as part of a restructuring process in which resources are reallocated to more productive uses. A well-known World Bank report about industrial adjustment in Africa (Meier and Steel, 1989) is illustrative of the thinking prevailing in that period. The entire report devotes exactly one paragraph to the issue of technology, and in this there is no mention at all to any need for technological capability building. Instead, it evokes the old debate about high capital-intensity of modern imported technologies, and suggests the need for policy reform to redress this bias and stimulate greater competitiveness through more efficient allocation of investment resources. It totally brushed aside the vast accumulated body of evidence about the role of technological learning in economic growth, merely observing that "… the means by which technology can be adapted and transferred … are less clear." (p. 24).

There were of course understandable reasons for this policy shift. Local capital goods industries in many developing countries - particularly in Africa, but also in Latin America and parts of Asia - had performed dismally during the 1960s and 70s, and had become a heavy drain on public resources and international aid budgets. The design of Structural Adjustment interventions was designed to rectify these imbalances. However, the principle of infant industries promotion itself came to be seen as the main cause of failure. Only a few scholars (notably Bruton, 1989) called for making a distinction between policy principles and implementation strategies in practice. In the course of the 1990s the validity of this outsider view has been borne out by overwhelming evidence that different infant industry promotion practices adopted in different developing countries have yielded radically different results, pointing up the importance of governance standards and policy-implementing capacity. Detailed studies about industrial development in the East Asian Tiger economies brought out the importance of conditionality in the support, in which producers were both facilitated and nurtured but simultaneously pressurised to meet increasingly demanding performance targets. Furthermore, these carrot & stick policies were highly selectively targeted and strictly monitored, and implemented by a rather capable bureaucracy (Wade, 1990; Amsden, 1989; Kim, 1997). This policy model contrasts drastically with the African experience, where lavish unconditional protection by governments with limited capacities for fair implementation and enforcement induced widespread rent-seeking and misuse. This prompted a spate of studies about contrasting governance models and possible explanations. The most well known is Peter Evans' work about the embedded autonomy theory of the state in East Asian countries, versus predatory states in African countries (Evans, 1995).

Meanwhile, a second lesson emerged from the mixed experiences with the neo-liberal policy strategies themselves. Structural adjustment has shown the best results in terms of increasing efficiency, productivity, and economic growth in countries that had already achieved some level of independent capacity for technology absorption and adaptation, mainly in certain middle-income Asian countries and some parts of Latin America. In these countries, producers were able to take advantage of improved access to modern technology and new market opportunities created by trade, investment and financial reform. In contrast, in countries with low levels of technological capacity, structural adjustment policies have had disappointing and sometimes outright disastrous results. The limitations of the neo-liberal policy model have now even been plainly acknowledged by one of its leading architects, the World Bank (2005). Yet, its most recent think-piece "Economic growth in the 1990s: Learning from a Decade of Reform" (2005) still offers few concrete ideas about the best way forward at this point. Even in this latest report, one still reads that governments should be focused on improving standards of governance and institutional functioning for the purpose of facilitating efficient markets. Government capacity building for purposes that go beyond these basic prerequisites for growth, and that serve to create dynamic competitive advantage in more direct ways, remains taboo.

We argue that, in hindsight, it should be quite clear that the disappointing and uneven performance record in large parts of the developing world during the past two-and-a-half decades did have something to do with inadequate attention for technological capacity building in policy and strategy, and that this has been highly problematic for economic development. There are thus good reasons why it would be useful to put capability building – or in other words innovation – back on the development policy agenda.

3. Arguing the case for innovation in LDCs in the new millennium

We have seen that the old argument for technological capability building rested on the notion that industrialisation is the key to development, and that building dynamic competitive advantage in industry, more specifically in manufacturing, constituted the essential strategy for achieving this. The underlying development model was essentially one of modernization: countries should strive to develop by catching up with industrial leaders. The policy focus on a local capital goods sector that could support the technological development of the manufacturing sector derived from this perspective.

Our argument that capability building in LDCs should be revisited does not, however, imply that we should uncritically revert to these old notions. Of course, western countries are still in many ways the sources of radically new technology, and constitute the main regions where radical R&D is being conducted. Catch up to western technological standards remains important in many sectors, and industrialisation remains an important aspect of the development process. At the same time, there are several reasons why the old focus on capital goods and manufacturing industry does not serve us well enough in the new millennium.

First, the recent emergence of new sectors can form additional engines of economic growth for developing countries, besides manufacturing which has been the traditional stepping stone towards industrialization and catch up. ICT-based services and biotechnology are two notable examples of sectors in which developing countries can and do participate, even at levels of development that are still a long way away from GCR's innovation-driven stage. These new sectors require a support infrastructure which in some ways has different characteristics from capital goods for manufacturing. These new sectors are different from the sectors that played the key roles in earlier technological transformations, which were developed quite often from the shop floor by engineers. The technologies underlying the newly emerging sectors are those where the connection with basic science is much deeper. That implies that one can no longer expect to climb the technological ladder and achieve competitiveness by following only incremental learning trajectories as have been pursued by countries in the 19th and 20th centuries. Countries need to pay attention to developing locally contextualised basic science (Desai, 2002).

Within the ICT sector, software holds particularly good potential for developing countries in view of its comparatively high labour intensity and its modest initial capital investments (Heeks, 1996, pp. 23–24). In comparison with manufacturing technology, development of a local software sector in particular is much less prone to problems associated with diseconomies of small scale, and there is less need for prolonged protection. In biotechnology, too, it is possible to start up without initial large R&D budgets and giant facilities – as in the conventional pharmaceutical industry. Many small firms are successfully competing on the basis of innovation in countries like India and China (see, e.g., Morris and Basant, 2006).

Forceful arguments have been made by prominent institutions, best exemplified by the World Bank, that it is imperative for developing countries to adopt western best practices in order to achieve competitiveness in the world economy (Schware and Kimberley, 1995). However, others have reservations about this belief in the advantages of such straightforward catch up. First, technological solutions in many advanced countries tend to reflect market distortions, and do not constitute 'best practice' in a technological sense. Urging developing countries to adopt these models impedes their ability to evaluate new technologies critically, especially from the perspective of their own needs and requirements. It merely diverts their attention from exploring locally effective solutions. Second, wholesale adoption of technologies and required accompanying organisational and economic practices that emanate from a very different socio-economic context may not even be feasible in the face of specific circumstances in local society. Third, it has been observed that catch up strategies do not automatically culminate in a competitive international position, because it promotes homogeneity in knowledge and skills rather than the creation of unique home grown capabilities (Avgerou, 1998).

Therefore, some important similarities with the old infant industries argument remain. In particular, without building adequate local technological capabilities, countries cannot take full advantage of the emerging market opportunities in these sectors. For example, with reference to the software sector, experts have observed that "… to compete and share in the dynamism of these large global industry, countries with potential dynamic competitive advantage must move beyond … common prerequisites [including] public policies that support openness, competition, digital literacy and private-sector led ICT infrastructure" (Tessler *et al.* 2003). With respect to biotechnology, too, it has been argued that the key to success for developing countries lies in "…clear focusing of resources on particular niches that allow them to address local health needs …, then build the necessary infrastructure around that, rather than shooting off in all directions" (*The Economist*, 9 December 2004). Such highly selective targeting and promotion is reminiscent of the technological learning strategies pursued by successful East Asian countries. These authors clearly point towards the necessity of pursuing a more interventionist, learning-oriented stance than the views advocated by the GCR and the World Bank (2005) in favour of merely promoting basic growth fundamentals like general infrastructure and elementary education.

Furthermore, in order to build capabilities effectively, a sole export-focused strategy is considered to be undesirable. Here too, there is an important analogy in the old infant industry debate, in which the development of a domestic market (i.e. import substitution) was seen to be an essential first step in a learning process that would ultimately culminate in indigenous capacity to innovate and achievement of international competitiveness on export markets. Similarly, Tessler *et al.* (2003) argue with reference to the software services industry that export success cannot be achieved without the simultaneous development of local producer-user linkages. A domestic sector is necessary for experimenting with new ideas, develop innovations, test products, and serve as reference sites (p. 7). Moreover, experience with managing local software projects and serving local users are often necessary for entering export markets (Schware, 1992). Even countries that have become known for their export success only (such as India, Israel and Ireland), did start off with projects to develop a local market (Tessler *et al.,* 2003, p. 10). In that sense, then, the lessons from the old capital goods promotion debate are still valid. Face-to-face interactions and local learning remain crucial, even in a globalising world with hugely improved long distance communications. We conclude that the issue of innovation in developing countries has only gained more relevance over time due to the emergence of new sectors and the new opportunities for capability building that these present.

A second reason for refocusing the discussion about capability building beyond capital goods for manufacturing industry is more fundamental, because it is concerned with the meaning of development itself. The old infant industry argument was firmly rooted in the structuralist paradigm of the 1950s and 60s, which did not question the primacy of western technology and saw its assimilation and mastery as the primary development goal. The limitations of this type of approach have since been questioned by range of intellectual movements including poverty-focused Basic Needs thinking in the 1970s, followed by Human Development-focused theories in the 1990s and onwards (notably Sen, 2001; and UNDP's annual *Human Development Report*), and the Millennium Development Project (Sachs, 2005). Common threads in their arguments have been the limited effectiveness of the 'trickle down' mechanism in all but a handful of developing countries. The more radical among these approaches have also challenged the presumed existence of a trade off (which lies at the heart of development theories in the immediate post WWII period) between a focus on redistribution and poverty alleviation and economic growth. While using different arguments, all have pointed to the necessity for the adoption of development approaches which imply more emphasis on improving basic conditions of common people, even at early stages of development. Arguably the most far-reaching argument has been made by Amartya Sen, that the main goal of development should be to enhance the capability of people to lead full and productive lives. His approach is based on the concept of positive freedom, which refers to the opportunity and ability to act to fulfill one's own potential. He contrasts this with negative freedom (for example, as in freedom from slavery, freedom of the press, freedom to vote), which is meaningless in the absence of actual conditions in which individuals can exercise true freedom of choice (Sen, 2001).

From the Human Development point of view, modernisation-inspired technological accumulation strategies have major drawbacks. Western R&D has failed to address major problems that impede citizens of developing countries from attaining positive freedom, because research in these areas has been unattractive for western researchers. In such cases, there is a clear case for local innovation. Local researchers have both more incentive and opportunity to pursue solutions, and can come up with more appropriate and more affordable innovations. Notable examples are diseases that are prevalent in the tropics such as malaria and tuberculosis, lack of access to clean water, and inadequate sanitation facilities. The area of pharmaceutical research is particularly affected by the low level of investment in problems that occur in tropical countries (Mrazek and Mossialos 2003). The Task Force on Science, Technology and Innovation of the UN Millennium Development Project notes that "… investing in research on underfunded issues of relevance to developing countries is particularly important in fields such as agricultural production, environmental management, and public health" (United Nations, 2005, p. 129). The same sentiment has been expressed in the Johannesburg Summit on Sustainable Development, in which five priority areas were defined, namely water and sanitation, energy, health, agriculture and biodiversity (WEHAB). In this respect, "… participants underscored the importance of national capacity-building in science and technology in developing countries and international cooperation to facilitate access for developing countries to technology and corresponding knowledge … Centres of excellence and institutions of higher learning should be established to build capacity for technological development at the national level. Such technology should be appropriate to national situations and circumstances. For example, information and communication technologies are currently a strong engine of growth around the world, but the developing countries are being left behind" (United Nations, 2002, p. 126).

The third reason for wanting to move the technological capability debate away from straightforward catch up is that the technological development trajectory that has been followed by the developed countries is coming under ever increasing strain associated with lack of environmental sustainability. It is becoming evident that developing countries - particularly large countries like India, China and Brazil - will need to do better than their western counterparts if they are to attain development levels similar to current developed-country standards without this endangering the finite natural resources and absorptive capacity of the planet. This calls for inventive solutions in areas that are of key importance for economic development and social well-being, in particular in enabling infrastructure technologies in areas such as energy, drinking water, sanitation, agriculture and management of natural resources, but also in industry and transport. Changing unsustainable patterns of production and consumption, the protection and management of the natural resource base, and poverty eradication, already constituted the three overarching objectives of, and essential requirements for, sustainable development as defined in the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 (United Nations, 1992). These goals were reaffirmed at the Johannesburg Summit on Sustainable Development, where also a link was made between these challenges and the need to develop cleaner production technologies and eco-efficient technologies and enhance relevant research capacity, both in advanced and in developing countries (1992, p. 14). It outlines a 10 year programme "… to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, de-linking economic growth and environmental degradation through improving efficiency and sustainability in the use of resources and production processes and reducing resource degradation, pollution and waste" (2002, p. 13).

From this point of view, climbing the technological ladder with the developed west as the model is a mixed blessing. On the one hand, it helps actors in developing countries to build up essential absorption and innovation skills, which are needed in order to acquire generic technological capabilities with broad application possibilities, especially for meeting people's needs for basic goods and services. At the same time, however, too much reliance on assimilating western technological knowledge carries the risk of lock-in to well-established technological regimes that have already proved to be sub-optimal and are themselves in need of change. This is a particularly pertinent issue in key sectors of infrastructure where the life-span of capital investments (and thus also the accompanying knowledge base) is very long. Once the investments have been made it is hard to switch to smarter alternatives even when these become feasible and attractive. Seen in this light, there is also a need for local original innovation in developing countries to develop smart low-cost technologies in fields like bio-energy, waste water treatment, drinking water harvesting and purification, development of draught-resistent crops, erosion prevention, treatment and prevention of common diseases, communication devices, transport, and so on. Arguably, countries in GCR category 3, which have the least developed innovation capabilities, are the ones that are most in need of these innovations.

In view of all these the emerging issues, some recent attempts by international development organisations to revive the interest in the promotion of technological progress in developing countries still show a lack of imaginative thinking. Take, for example, the UNCTAD's *Least Developed Countries Report 2007*, which is specifically dedicated to the countries that are classified as low-income in the GCR. While it is heartening to note that the need for technological development takes centre stage in the report, the major issues discussed above essentially remain unaddressed, because the report does not distinguish between economic and technological catch up. The need for economic catch up is undeniable. However, we argue that the manner in which this is to be achieved should be open to debate: Should it revolve around an uncritical wholesale adoption of western technological trajectories, or should there be more emphasis on exploring indigenous technological growth paths that are designed to address domestic requirements. This issue is not recognised in the UNCTAD report. It discusses the familiar themes of learning through policies to stimulate technological catch up with leading western nations, and recommends to take advantage of international knowledge transfer mechanisms such as imports of capital goods, FDI, and licensing. Similar lines of thinking pervade the World Development Report 1998/99, *Knowledge for Development* (World Bank, 1999). Most seriously, policies that are being promoted to foster technology and innovation policies for economic growth are essentially divorced from poverty reduction strategies, and too little attention is being given to promotion of S&T capacity building in developing countries themselves (Mackintosh, Chataway and Wuyts, 2007; King, 2004; InterAcademy Council, 2004). It is telling that Kofi Annan linked the lack of progress towards the achievement of the MDGs to the need for a "true partnership of developed and developing countries … that includes S&T" (Annan, 2004, p. 925). In his words, in order to address the critical problems and challenges facing us in the 21st Century, "… no nation can afford to be without its own independent S&T capacity" (p. 925). A recent report commissioned by Kofi Annan presents a strategy for strengthening the UN in its attempts to help build worldwide scientific and technological capacities for achieving the MDGs (United Nations, 2005).

4. Three illustrations of successful innovations

We will illustrate the need for new approaches to innovation in LDCs by means of an example of innovation in a particular sector. We discuss one illustration for each of the three issues discussed above. We structure our discussion around the following points: (a) the developmental importance of innovation in the sector; (b) a brief characterisation and developmental potential of some examples of innovation(s) that is(are) taking place in the sector; and (c) the extent to which their success required indigenous technological solutions that differ significantly from western approaches. Possible policy implications are also considered.

Case 1: Local innovation for ICT infrastructure building

Our first case addresses the recent emergence of new sectors that can form additional engines of economic growth and development for developing countries. We take the example of innovations in ICT infrastructure, because there are a number of interesting recent developments in this domain. The idea that ICT technologies have tremendous potential to transform the lives of the poor is widely shared among international agencies such as the UN, the International Telecommunications Union, the G8, international and national NGOs, state- and local governments, and private companies. ICT technologies are being credited with the potential for even the poorest developing countries to leapfrog traditional problems of development (e.g., Keniston, 2002). Providing access to information and telecommunications would bring a range of basic services within reach of local populations. It would especially empower people in rural areas, where the majority of the population in developing countries still lives. Consequently, ICTs have raised expectations that they could significantly help reach the realisation of MDG targets (Brown, 2001).

At the same time there is considerable scepticism as to whether this potential can actually be achieved. Most importantly, implementing extant ICT technologies based on western technologies is simply too costly, especially in thinly populated rural areas inhabited by people with very low purchasing power. Access to the more advanced ICT services is also problematic for people with low literacy without adequate assistance. Limited demand for the services in turn inhibits network externalities from kicking in. As Kofi Annan has noted '… the gap between information "haves" and "have-nots" is widening, and there is a real danger that the world's poor will be excluded from the emerging knowledge-based economy.'[1]

Some recent innovation initiatives emanating from developing countries, especially India, are contributing in a significant way to the bridging of that digital divide. What they share is significant efforts to achieve big cost reductions through innovations on ICT hardware combined with the introduction of locally appropriate organisational delivery models. Not only do they have low operating costs, but also low initial costs, which lowers investment barriers to the establishment of the infrastructure. Moreover, they are suited to functioning in a harsh environment of high temperatures and power fluctuations.

One of the most noteworthy examples is CorDECT Wireless in Local Loop (WLL) developed by the Indian Institute of Technology (ITT) Madras in Chennai. "This WLL technology gives to a subscriber a fixed wireless (not mobile) connection at home or office, providing both a telephone as well as a 35/70 kbps internet connection at the same time" (Jhunjhunwala, 2001). At the time of its launch in 2000, it was the world's only telecom technology that could be used for both voice and data transmission simultaneously. Its key feature is the multi-carrier time division multiple access system (MC-TDMA), which separates internet traffic from voice traffic. This thus avoids congestion of the telephone network, which is a huge problem in India (Ibid, 2001). This locally adapted WLL technology is a less expensive version of western WLL technologies, and a superior technology for smaller towns and rural areas (Prasad, 2003). A compact base station mounted on a pole or rooftop is used for wireless transmission to subscribers. According to inventors, "… it is worth noting that such a service cannot be provided by any other product in the world today at even double the cost" (Jhunjhunwala, 2001). Others have estimated potential cost savings compared to equivalent western technologies of up to a factor of 4.[2]

This cost reduction, however, is not merely due to the innovative technology, but also to a low-cost decentralised delivery system at the village level. The system has a tiered structure. The company that is commercialising the technology on behalf of IIT (called n-Logue) sets up a franchise relationship with a Local Service Provider (LSP) in every area in which it operates. The LSP functions as a local access centre of node around which Internet Kiosk operators are clustered across an area of 2000 sq. km. The individual Kiosk operators are independent small entrepreneurs who offer a variety of telecom services to the village population. N-Logue provides low-cost kiosk hardware, as well as training and support services to the local franchise owners. The kiosk owners are free to determine their own marketing strategy. There are examples of people offering computer training, recording and selling music CDs, and screening movie DVDs in their kiosks. This freedom and flexibility appears to be crucial to the viability of the entire model (James, 2003, p. 470; Howard *et al.*, 2001).

After a prolonged period of fierce competition from foreign telecom technologies which were being pushed by powerful parties with vested interests, the Indian Government has decided to deploy CorDECT on a large scale, based on its superior ability to meet local needs and requirements (Prasad, 2003). In addition, CorDECT is being deployed in a growing number of other developing countries which include South Africa, Nigeria, Kenya, Brazil, Russia, Argentina, Madagascar, Fiji, Philippines, Indonesia, Angola, Tunisia, Yemen, Iran and Egypt.[3]

CorDECT went well beyond incremental adaptation of western technology. The IIT faculty describes it as a "disruptive technology", which required "…total mastery of current knowledge in the area and a lot of innovations" (Jhunjhunwala, 2001, p. 3). They also say that it is the requirement of bringing down the costs of telecom services by a factor of 3 to 5 which is the R&D task now facing developing countries like India, because such radical innovations alone will make the products widely affordable to their populations. Only then may we expect people's lives to be transformed by ICT (Ibid, p. 10). It is this choice to embark on a different technological trajectory than what has been followed by western countries before them, that will make the difference. In the words of the CorDECT's team leader, "… the point is that by just following what is being done in the West, we will always remain only the followers. What we need to do is to understand our requirements, and master technologies to work towards our requirements -- this different starting point in technology development would enable us not only to develop technologies to satisfy our requirements, but also to eventually become technology leaders" (Ibid, p. 10).

It is important to note that CorDECT is not a lone exception, but rather a forerunner of an emerging LDC innovation model. There are an increasing number of cases being reported of similarly radical ICT innovations emanating from the developing world. Many of them emanate from India, but not exclusively. Notable examples include a low-cost computing device (the Simputer, India), low-cost, rugged telecom switches (developed by the Centre for Development of Telematics, India), small low-cost ISP providers (Minnow, India), and wifi technology being deployed to connect entire towns to the internet using the same principle of fixed wireless (developed by UniNet, South Africa).

The UniNet wifi innovation revolves around low-cost communal internet access through computers installed in schools, libraries, and municipal offices. UniNet's CEO confirms the CorDECT experience. "Typically those [networks in developed countries] are mesh wireless networks … our requirements are very different and we wouldn't be able to scale via mesh. So we developed .. largely a cellular system, where you have repeaters a bit like cell-phone masts, and you have customers who connect via fixed terminals. It's actually like a cable service which happens to work over wireless. … It's a very different paradigm from a traditional, mesh network model that the developed world has developed" (Cieslak, 2007).

Moreover, UniNet's CPE is rugged, weather resistant, easy to install, needing only relatively unskilled labour, remotely manageable, and solar-powered if needed. UniNet's solutions were partly designed in Maputo conditions where theft is a big problem, where power cuts are common, and temperatures frequently go over 40 degree Celcius. A system designed to work under these conditions had to be able to work independently of any of these factors, and literally had to be designed from the ground up (UniNet, 2007). UniNet has been recognised as a world leader in the delivery of open access solutions by the World Bank (Cieslak, 2007).

Case 2: Strengthening local R&D capacity for treatment of neglected tropical diseases
There is widespread concern with the lack of research to effectively combat common diseases that afflict large numbers of poor people in developing countries. While malaria, pneumonia, diarrhoea and tuberculosis together account for 21% of the global disease burden, they receive a mere 0.31% of all public and private funds devoted to health research (GFHR, 2004, p. 122). Of the 1556 new medicines approved between 1975 and 2004, only 18 were specifically indicated for tropical diseases (Chirac and Toreelle, 2006). Although several initiatives have been launched over the past 10 years to improve the funding situation, the Bill and Melinda Gates Foundation being the most notable example, these are being criticised for favouring research undertaken in developed countries. Increasingly, leading experts working with different organisations are pointing out that this is by itself insufficient to solve the current crisis, and call for a strengthening of the scientific infrastructure and empowerment of research leadership in the disease endemic countries themselves (WHO, 2007; UN General Assembly, 2005; Csaszar and Lal, 2004; Chitr and Ratana, 2000). The WHO has gone so far as to adopt a new strategy, which is "to foster an effective global research effort on infectious diseases of poverty in which disease endemic countries play a pivotal role" (WHO, 2007, p. 13).

Their main argument is that researchers in developing countries would be more inclined to direct their efforts to neglected priority needs that are not adequately addressed elsewhere (WHO, 2007). In-house S&T capacity also enables researchers to take account of local and national cultural, socio-political and institutional conditions and local needs that must inform best practices needed combat these diseases in different countries. An HIV-AIDS programme in Thailand should aim to address problems associated with the sex trade, while an equivalent programme in Russia should focus on intravenous drug use (Csaszar and Lal, 2004). This argument is analogous to the issue of 'circumstancial specificity' raised by Evenson and Westphal in the context of industrial-technological development. Indigenous research capacity also enables developing country researchers to better interact with their counterparts in the economically advanced world. In addition to aiding their absorptive capacity, this also helps them to be participate more prominently in international S&T collaborations, which are so often needed in health research because of the large resource requirements. Moreover, it would prepare developing countries to respond effectively with newly emerging diseases such as SARS, which constitute potentially cause pandemics of global proportions (Csaszar and Lal, 2004), and to better set their own health research agendas (WHO, 2007). In addition, it enables developing countries to effectively harness their indigenous health knowledge systems for poverty alleviation and economic development.

These concerns are slowly beginning to be reflected in several international efforts to help support the enhancement of domestic research capacity and improve the research environment in the developing countries (for details, see Chitr and Ratana, 2000). We briefly report on one of these, an international project that builds on ancient indigenous Chinese malaria treatment with herbal means. The project is a collaboration, since 2003, between Ranbaxy Laboratories Ltd, India's largest pharmaceutical firm best known for the manufacturing of cheap generic drugs, and Medicines for Malaria Venture (MMV), a non-profit organization dedicated to reducing the burden of malaria in disease-endemic countries, funded by a large range of international and national agencies and companies. In 2004, the partnership announced that Ranbaxy would initiate clinical trials for OZ, a synthetic peroxide which is though to have similar characteristics as Artemisinin, the most effective anti-malaria drug currently in existence. Artemisinin is a herbal medicine extracted from the Artesiminia annua plant. Its main disadvantage is high cost, because of the costly and lengthy extraction process from the plant. Extant common chemical anti-malaria drugs are only about one-tenth the cost, but their effectiveness is eroding due to increasing resistance against the drugs.[4] As a result of lack of affordable effective treatment options, more people are dying from malaria today than 30 years ago. It is currently one of the most persistent and deadly diseases in over 90 countries that represent 40% of the world's population, claiming the lives of more than one million people annually.[5]

Ranbaxy, which ranks among the world's top 10 global generics companies, is scaling up its capacity as a research-based health care company. Because it is based in a country where malaria is present, Ranbaxy says that it deeply identifies with the continuing crisis that widespread diseases like malaria are causing in developing countries. The company has therefore committed its R&D expertise towards a breakthrough in malaria treatment. This commitment would not easily be expected of western pharmaceutical companies, because investment in this line is unattractive since the customers of the product are among the poorest in the world. In order to ensure widespread uptake, prices need to be low.

China is embarking on similar initiatives. In 2006, the country unveiled plans to spend US$ 12.5 m for projects meant to develop new treatments for diseases such as HIV/AIDS and Malaria. The projects build on China's expertise as the world's leading producer of herbal remedies. Low cost is again the dominant guiding factor. According to China's Ministry of Science and Technology, it is much cheaper to develop a new herbal medicine than a western one. The programme will also seek to develop objective standards for determining efficacy, over which there is a lack of international consensus (Chong, 2006).

Currently only a few large developing countries have the capacity to mount sizeable initiatives of this kind, but south-south cooperation promises to be a major benefit of these Asian initiatives. The Chinese programme has already initiated official collaboration for testing an Artisiminin-based herbal drug in East Africa (Lague, 2007).

Case 3: R&D on renewable energy technologies in developing countries

Energy constitutes a major dimension of the environmental sustainability problems facing the world today. By 2030 the world is projected to consume two-thirds more energy than today. By this time, the industrialising economies in the developing world will have replaced the western developed countries as the group of largest energy consumers (Dorian et al., 2006, p. 1984). These trends cannot be supported with current energy technologies. Only 3% of current world energy demand was being met by renewables in 2005 (excluding biomass, which is often used in an unsustainable manner) (IEA, 2007). Five major energy challenges will need to be confronted in the coming decades (see, e.g., Dorian *et al.,* 2006; Wang and Feng, 2002; Ni and Johansson, 2004; Chendo, 1994), namely:

- growing scarcity of finite oil and gas resources, and increasing cost of exploration and mining (Dorian et al., 2006);
- the need to increase diversity of energy supply sources in the face of security concerns associated with over-dependence on sources in the politically unstable Middle East (Dorian et al., 2006);
- the need to combat energy environmental degradation and climate change (Dorian et al., 2006) -- the dominant technological trajectory that has been followed by the developed

countries is coming under ever increasing strain associated with lack of environmental sustainability; and

- meeting the fast-growing energy requirements of the emerging developing world, in the face of rising energy consumption associated with higher living standards and economic growth (Dorian et al., 2006);
- meeting the needs of the 2.4 billion people who currently rely on traditional biomass for cooking and the 1.6 billion people who do not have access to electricity; much greater access to energy services essential to alleviate poverty and to support the achievement of the MDGs (UN-Energy, 2005). The link between lack of modern energy access and poverty is so close in the developing world that the World Bank and the Asian Development Bank have devoted large parts of their programmes to address the problem (Dorian *et al.*, 2006).

We illustrate the need for R&D in LDCs and its achievements by means of the case about the emergence of small-scale biomass gasification technology in India. The rationale behind this technology is that biomass in developing countries like India is utilised with a very low end-use efficiency. Gasifier technologies convert biomass into so-called producer gas, an energy carrier, which can then be burnt for delivering heat or electrical power in an efficient manner (Larson and Kartha, 2000). The resulting gas has a higher energy density and is easier to handle than traditional biomass like wood. The potential is enormous. India produces an estimated 600 m tonnes of agricultural residue per annum. According to its Ministry of Non-Conventional Energy Sources (MNES), there is potential for producing gas to the tune of 1,700 MW (requiring about 13 m tons of agricultural residue). This would be sufficient to power 125,000 villages that currently do not yet have access to electricity (Rao, 2007).

Gasification is a thermo-chemical process that converts solid fuels into combustible gases at a temperature of between 800-1400 ^{o}C with a limited air supply and under pressure. The process produces contaminants that are filtered out through cyclones and scrubbers (ABETS, 2003). The technology is reasonably complex to design and maintain. It needs careful monitoring and control, since deviations from the ideal conditions lead to low gas yield, excessive ash production and corrosion of the equipment (Ravindranath *et al.*, 2004). Hence, it is a big challenge for countries like India to design and develop gasifier systems that are suitable for use under rural conditions.

R&D on gasifiers for energy applications started in India in the early 1980s. The (then) Department of Non-conventional Energy Sources' (DNES, now MNES) initiated a subsidy-driven dissemination program in 1987, which helped to place about 1200 gasifier systems for irrigation pumping. A renewed programme was instituted in the 1990s, based on an improved subsidy structure and a certification regime. This led to the dissemination of approximately 600 additional gasifiers for a range of rural and commercial applications. An additional estimated 400 gasifiers were installed by an emerging private producer sector operating outside the MNES program (Ghosh *et al*., 2004).

The gasifier development programme of the Indian Institute of Science (IISc) is exemplary in the sense that it has achieved significant improvements in small-scale biomass gasifier technology that have made India into a world leader in this field. By 2004, the IISc had successfully developed gasifiers up to 500 kW through indigenous efforts, which are not only being used within India but also being exported to Europe, the USA, Japan, and developing countries in Asia and Latin America (Mukhopadhyay, 2004; Mukunda, 2007).

The former leader of the gasifier research group at the IISc notes that liberalisation, globalisation and privatisation have made it difficult for local manufacturers to compete. However, using imported technologies - whether through importation of equipment designs or licensing arrangements - have certain disadvantages, including unfavourable financial terms of transfer and disdainful treatment of the technology receiver by the technology supplier.

Moreover, this pattern of western technology-driven technological advance reinforces continued dependency on developed nations by doing the same thing or similar thing indigenously (i.e. imitation). At the most, this gives rise to wage cost advantages arising from domestic manufacture. This is not conducive to building technological self-esteem within the country (Mukunda, 2007).

The gasifier research programme has been a successful attempt to break out of that straightjacket. It arose from, and has been supported by fundamental research and scientific laboratory work, and independent verification by scientists in India and abroad (including Switzerland, which has awarded a patent to the IISc). The IISc hosts an international training programme in which about 30 scientists from 10 countries have acquired the knowledge by coming to the institute.

The IISc gasifiers are small in scale, which makes them especially suitable for use in poor villages. The oldest model was installed in Hosahalli in 1988, a village close to Bangalore, where it was used for electricity generation, which powered cheap domestic lighting, irrigation services and drinking water supply. This allowed the scientists to test the technology under real-life conditions, and generated knowledge for incremental improvement in the design. This close and ongoing contact between the scientists and the users allowed the design to become adapted to local conditions, requirements and limitations (Ravindranath *et al.*, 2004). The equipment performed rather well for 18 years, but was unfortunately dismantled due to the extension of free electricity from the central grid to the village. The technology is highly competitive compared to other energy sources. The only reason that central grid electricity is favoured by the villagers is that this is provided free of charge (for political reasons), and does not require local operation and maintenance, although the quality of central grid supply is quite bad (de Visser, 2007). It also compares favourably to other renewables. It has been calculated that biomass gasification generates 1 MW of power at around 20-30 m Rupees, compared to 350-400 m Rupees for photovoltaic energy (Rao, 2007). The latest development which testifies to the success of the technology is that the IISc has now teamed up with a large Indian manufacturer, Cummins India, to commercialise its system (Rao, 2007).

Conclusion

Our review of historical experiences with technological change in developing countries brings out that innovation, broadly defined, has been indeed important for economic catch up of these countries. It has also highlighted that the traditional focus has been on the value of incremental learning rather than radical R&D, reflecting the successful experiences of East Asian countries which used technological learning strategies based on this notion.

While the need for, and importance of innovation, for durable competitive advantage of countries has only increased in the new millennium, one may question whether these old-style incremental technological learning strategies on their own will still be sufficient for the achievement of development of current-day LDCs. Three major trends suggest the need for broader approaches to innovation that give more prominence to science-based radical innovations alongside incremental learning. These are: (1) the emergence of new sectors, in which technological advance is more science driven than in traditional manufacturing sectors; (2) the world's large-scale problems of poverty, which cannot be overcome without radical new solutions that emerge in the developing world itself, informed by essential local knowledge and incentives; (3) the environmental limits to growth based on extant western technologies.

One important issue arising from these trends, which is illustrated by the three case studies discussed in this paper, is that LDCs also require radical innovation to break out of their technological dependence. We would argue that there is a need to separate the desirability of economic catch up from the notion that this would automatically require a strategy of technological catch up based on imitation and adaptation of western technology. The current uncritical preoccupation with adopting western technological trajectories is constraining the intellectual and policy space for debating alternative growth strategies. The illustrations highlighted in this paper show what can be achieved when people break out of this conventional way of thinking.

The development debate needs to take cognisance of these issues. First of all, institutions like the World Bank and the WEF, which represent the more orthodox neo-classical side of the spectrum, should start by acknowledging the need for more policy space for innovation in LDCs to begin with. Others, notably UNCTAD, who have adopted a more evolutionary / structuralist perspective on development, need to acknowledge the need to infuse their approaches with new insights arising from contemporary issues as discussed above.

The primary aim of this paper was to set out important new issues for debate. We do not pretend to be able to come up with detailed policy guidelines that would address all these issues. However, a few pertinent policy elements do emerge from the discussion. First, there is a clear need to adopt a systems perspective towards stimulating innovation. Radical innovation does not only require good science, but also prototype design and development, and capability to initiate manufacturing. The case study about CORdect in particular illustrated India's limitations of its manufacturing sector to function as a mature innovation partner, forcing the IIT scientists to team up with a US semiconductor manufacturer. A second insight relates to the need for independent science funding, so as to avoid priority setting by western powers, be they international institutions or TNCs, or local politicians who are influenced by these parties. Third, there is a need to encourage mentality change in favour of indigenous technology development, both locally in developing countries, as well as among western aid organisations. Fourth, it is clear that only a minority of large developing countries will be able to develop significant science-driven innovation capacity in the foreseeable future. However, this is also very important for other developing countries, since the innovation emerging from other LDCs are likely to address their needs better than many western technologies. Therefore we see big potential for south-south technology transfer and co-operation.

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