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Science, Technology and Development:

Emerging Concepts and Visions

Luc Soete

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Luc Soete

UNU-MERIT,

University of Maastricht,

The Netherlands

Introduction

When discussing Science and Technology for development, it has often been tempting to talk about the radical nature, the paradigm shift, of new scientific breakthroughs or technological inventions which appear to offer new windows of opportunity for economic development and might eradicate at once world poverty, diseases and decades of lack of development in many less developed countries. Despite the caution of Sanjaya Lall in warning that such "miracle" growth opportunities warrant quite explicit industrial policies[1], there has been a tendency, certainly within the new global era of digital communication and world market transparency, to take those new technologies catching-up opportunities for granted, waiting so to say as "technology transfer manna" from the North to be implemented in the South.

As argued below, the analytical shift from science and technology to innovation which has occurred over the last ten to twenty years brings in a new vision on development: one which now acknowledges the fully "endogenous" nature of innovation, rather than the old, neo-classical external view of technological change and technology transfer. That process of innovation is actually much more complex and challenging in a developing country context than in a developed country one. As has only recently become recognized in the endogenous growth literature[2], and vindicating many of Lall's earlier writings on technological capabilities, the appropriate innovation policy challenge for a country will be closely associated with its level of development.

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[1] As in his most explicit criticism of the World Bank 1993 study on the East Asian Miracle, Lall (1994).

[2] This view of the philosophy and aims of innovation policies differing amongst countries according to their level of development, reminiscent of many of the arguments of the old infant industry type arguments has now become very popular in the endogenous growth literature. See Aghion and Howitt (2005).

In a high income country context, the innovation policy challenge will increasingly become directed towards questions about the non-sustainability of processes of "creative destruction" within environments that give increasingly premiums to insiders, to security and risk aversiveness; ultimately to the maintenance of income and wealth. In an emerging, developing country context, by contrast, and as argued by Lall already thirty years ago[3], the innovation policy challenge appears first and foremost more directed towards "backing winners" industrial science and technology policies. How to further broaden an emerging national technological expertise in the direction of international competitiveness and specialisation. Such broadening will have to involve a strong recognition on the part of policy makers of the importance of engineering and design skills and of accumulating "experience" rather than just Research and Development (R&D) investments.

1. Technology and the emergence of formalized industrial research activities

The strong focus on industrial R&D as factor behind economic growth and development is of relatively recent origin. Up to the late 50's, it was barely recognised by economists, despite the recognition that "something" (a residual, a measure of our ignorance) was behind most of the economic growth in the 20th Century and the post-war period in particular. But, of course, long before the 20th Century, experimental development work on new or improved products and processes was carried out in ordinary workshops[4]. However, what became distinctive about modern, industrial R&D was its scale, its scientific content and the extent of its professional specialisation. Suddenly a much greater part of technological progress appeared attributable to research and development work performed in specialised laboratories or pilot plants by full-time qualified staff. It was also this sort of work which got officially recorded in R&D statistics; if only because it was totally impracticable to measure the part-time and amateur inventive work typical of the nineteenth century (Freeman and Soete, 2006).

As historians have argued the industrial research "revolution" was hence not just a question of change in scale. It also involved a fundamental change in the relationship between society on the one hand and technology and science on the other. The expression

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[3] See Lall (1978) and (1992).

[4] As we noted elsewhere: "The early classical economists were well aware of the critical role of technology in economic progress even though they used a different terminology. Adam Smith (1776) observed that improvements in machinery came both from the manufacturers of machines and from "philosophers or men of specialisation, whose trade is not to do anything but to observe everything". But although be had already noted the importance of "natural philosophers" (the expression "scientist" only came into use in the nineteenth century), in his day the advance of technology was largely due to the inventiveness of people working directly in the production process or immediately associated with it: "... a great part of the machines made use of in those manufactures in which labour is most subdivided, were originally the inventions of common workmen" (Smith, 1776, p. 8). Technical progress was rapid but the techniques were such that experience and mechanical ingenuity enabled many improvements to be made as a result of direct observation and small-scale experiment. Most of the patents in this period were taken out by "mechanics" or "engineers", who did their own "development" work alongside production or privately. This type of inventive work still continues to-day and it is essential to remember that is hard to capture it in official R&D statistics." (Freeman and Soete, 1997)

"technology", with its connotation of a more formal and systematic body of learning, only came into general use when the techniques of production reached a stage of complexity where traditional methods no longer sufficed. The older, more primitive arts and crafts technologies continued to exist side by side with the new "technology". But the way in which more scientific techniques would be used in producing, distributing and transporting goods led to a gradual shift in the ordering of industries alongside their “technology” intensity.

Thus, typical for most developed industrial societies of the 20th Century, there were now high-technology intensive industries, having as major sectoral characteristic the heavy, own, sector-internal R&D investments and low-technology intensive, more craft techniques based industries, with very little own R&D efforts. And while in many policy debate, industrial dynamism became as a result somewhat naively associated with just the dominance in a country’s industrial structure of the presence of high-technology intensive sectors, the more sophisticated sectoral studies on the particular features of inter-sectoral technology flows, from Pavitt (1984) to Malerba (2004), brought back to the forefront many of the unmeasured, indirect sources of technical progress in the analysis. Unfortunately, many of those insights have not been translated in attempts at broadening the policy relevant concept of R&D.

2. From industrial R&D to innovation: a paradigm shift?

As acknowledged by many recent innovation studies scholars ranging from economists such as Paul David and Dominique Foray to science and technology studies scholars such as Mike Gibbons and Helga Novotny, a major shift in one’s understanding of the relationships between research, innovation and socio-economic development has occurred. It is interesting to note that both the more economically embedded innovation research community as well as the more STS embedded research community more or less converged on this issue: in each case the perception of the nature of the innovation process has changed significantly.

Innovation capability is today seen less in terms of the ability to discover new technological principles, but more in terms of an ability to exploit the effects produced by new combinations – one is reminded of Schumpeter’s already old notion of “neue Kombinationen” – and the use of pieces from the existing stock of knowledge (David and Foray, 2002). This alternative model, closely associated with the emergence of numerous knowledge “service” activities, implies in other words a more routine use of an existing technological base allowing for innovation without the need for particular leaps in science and technology, sometimes referred to as “innovation without research”.

This shift in the nature of the innovation process implies a much more complex structure of knowledge production activities, involving a greater diversity of organizations having as explicit goal knowledge production. The previous industrial system was based on a relatively simple dichotomy between knowledge generation and deliberate learning taking place in R&D laboratories, including engineering and design activities, and activities of production and consumption where the motivation for acting was not to acquire new knowledge but rather to produce or use effective outputs. As argued elsewhere (Ghosh and Soete, 2006), the collapse (or partial collapse) of this dichotomy has led to a proliferation of new places having as an explicit goal the production and use of new knowledge which may not be readily observable from national R&D statistics but which appear nevertheless essential to sustain innovative activities in a global environment.

In short, traditional R&D-based technological progress, still dominant in many industrial sectors ranging from the chemical and pharmaceutical industries to motor vehicles, semiconductors and electronic consumer goods has been characterized by the S&T system's ability to organise technological improvements along clear agreed-upon criteria and a continuous ability to evaluate progress. At the same time a crucial part of the engineering research consisted, as Richard Nelson put it, "of the ability to hold in place": to replicate at a larger industrial scale and to imitate experiments carried out in the research laboratory environment. As a result it involved first and foremost a cumulative process of technological progress: a continuous learning from natural and deliberate experiments.

The more recent mode of technological progress described above and more associated with the knowledge paradigm and the service economy, with as extreme forms the attempts at ICT-based efficiency improvements in e.g. the financial and insurance sectors, the wholesale and retail sectors, health, education, government services, business management and administration, is much more based on flexibility and confronted with intrinsic difficulties in replication. Learning from previous experiences or from other sectors is difficult and sometimes even misleading. Evaluation is difficult because of changing external environments: over time, among sectors, across locations. It will often be impossible to separate out specific context variables from real causes and effects. Technological progress will be much more of the trial and error base yet without as in the life sciences providing "hard" data, which can be scientifically analysed and interpreted. The result is that technological progress will be less predictable, more uncertain and ultimately more closely associated with entrepreneurial risk taking. Attempts at reducing such risks might involve, as Von Hippel (2004) has argued, a much greater importance given to users, already in the research process itself.

3. Innovation for development implications

The implications of this new mode of technological progress for development are straightforward. As argued above, they bring to the forefront the importance of endogenous innovation processes in developing country situations. In the old industrial S&T model, the focus within a context of development was quite naturally on technology transfer and ***imitation***: imitation to some extent as the opposite of innovation. In the new model, innovation is anything but imitation. Every innovation appears now unique with respect to its application. Re-use and re-combinations of sometimes routine, sometimes novel pieces of knowledge are likely to be of particular importance, but their successful application might ultimately well involve engineering expertise, design capabilities even research.

a) Innovation from the "tip" to the "bottom" of the income pyramid

A feature of industrial R&D and the underlying model of technological progress which has not received that much attention in the development literature is the focus of industrial research on continuous quality improvements of existing and new consumer goods, enlarging at the same time continuously the demand for such quality improved or new consumer goods. A growth model emerged over the post-war period in the US, Europe and Japan which appeared to generate its own infinite demand for more material consumer goods: a continuous growth path of rising income with increasing consumer goods' production *and* consumption (Pasinetti, 1981). As if consumer goods - contrary to food - would remain totally unaffected by Engel's law.

The continuously rising industrial R&D efforts in high income countries appeared in other words to match perfectly the continuously rising incomes of the citizens of those countries leading to a continuous enlargement of their consumption basket with new, better designed or better performing products. The actual initial demand for such quality improvements often arose from extreme professional, sometimes military use circumstances, but thanks to the media – which typically would emphasize the prestige image of such professional use using symbol figures such as sport athletes or movie actors – the average, non-professional consumer could easily become convinced that he or she was also in need of new goods with such technologically sophisticated professional quality characteristics even though those characteristics might ultimately add only marginally to one's utility. In a certain way the highest income groups in society, the "***tip***" of the income pyramid, acted often as first, try-out group in society, contributing happily to the innovation monopoly rents of the innovating firm. So a continuous circle of research was set in motion centring on the search for new qualitative features[5] to be added to existing goods.

This "*professional-use driven*" innovation circle has been the main source for extracting innovation rents out of consumer goods – ranging from consumer electronics, sport goods, shoe wear, household equipment, computers, mobile telephony, medical diagnostics, sleeping comfort, and so on – with a "too long" *physical* life time.

But the worldwide risks of this relatively straightforward professional-use driven innovation strategy for the existing global multinational corporations have increased significantly, not in the least because of globalization. While the world market for new innovative goods appears at first sight gigantic and without any doubt sufficient to recoup investments relatively quickly, the huge research, development, prototype and global marketing costs, coupled with ever-increasing numbers of competing international players means that the length of time that a company can enjoy its innovation rents is diminishing very rapidly. Hence, despite the growing high income classes in the large

[5] One may think of audio and sound, vision and clarity, miniaturization and mobility, weight and shock/water resistance, feeling and ergonomiticity, etc.

emerging BRIC economies, the new generation of goods being sold to the emerging high income classes in those countries will be insufficient in actual earning opportunities to fund both the shift towards mass production and the development of the next technology generation of the good in question. Having developed incredibly sophisticated technological new goods, many firms are encountering major global sales problems over a much contracted product life cycle with increased competition and rapidly over-saturated markets.

b) Innovation at the bottom of the income pyramid: a new form of "appropriate innovation"?

The need for a shift in research on innovation in private businesses has been popularized by CK Prahalad in his by now famous book: The Fortune at the Bottom of the Pyramid (2004) with the provocative subtitle "*Eradicating Poverty Through Profits.*" One of the best-known Prahalad examples of a Bottom of the Pyramid (BoP) innovation is the multiple-fuel stove innovation developed for the rural poor, in which cow dung and biomass (sticks and grass) can be used as cooking fuels. Traditionally these fuels are used in an extremely inefficient way and are dangerous to use due to the smoke inhaled from indoor fires. With the so-called "combination stove" that costs less than $20, the user can now switch relatively easily from biomass to natural gas, according to his/her needs. "If it succeeds in India…" Prahalad notes, "…it will be rolled out across multiple geographies, with potentially immense impact on the quality of life of people throughout the developing world." Drawing on this example, Prahalad observes that "the process of designing these breakthrough innovations started with the identification of the following four conditions:… 1. The innovation must result in a product or service of world-class quality. 2. The innovation must achieve a significant price reduction — at least 90 percent off the cost of a comparable product or service in the West. 3. The innovation must be scalable: It must be able to be produced, marketed, and used in many locales and circumstances. 4. The innovation must be affordable at the bottom of the economic pyramid, reaching people with the lowest levels of income in any given society." (CK Prahalad, *The Innovation Sandbox*). Since the book of Prahalad, there has been a flood of similar examples of BoP innovations being primarily introduced by foreign, large multinational corporations from developed countries in developing countries, sometimes in poor rural villages, sometimes in urban slums[6].

At first sight these BoP examples seem to contradict Lall's earlier observations about the limited effectiveness of technology transfer through FDI. As Lall noted, back in 1992: "With few exceptions, the developing country affiliate receives the result of innovation, not the innovative process itself: it is not efficient for the enterprise concerned to invest in the skill and linkage creation in a new location." (Lall, 1992, p.179). This is where BoP innovation takes on, in my view, a totally new meaning.

First of all the likely and most successful location of the innovative process activities, the BoP learning lab, will have to be close to *BoP users* contexts. Given the crucial role of

[6] For some of those examples in the sanitation area, see Ramani (2008). For an overview of the BoP literature see Weehuizen (2008).

users in the innovation process as argued above, this will imply that BoP laboratories will have to be embedded in users' environments and not be part of the traditional high- tech R&D centres and enclaves whether in the developed or developing country. In this sense the notion of "**grassroots innovation**" developed by Anil Gupta can be considered as the endogenous, intrinsic version of Prahalad's external, top down version of BoP innovation. To be successful though, such version will have to pay particular attention to all the elements and features emphasized by Lall back in the early 90's: the local context, the vertical linkages, the avoidance of innovation "truncation" (Lall, 1980, 1992) by which I mean following Lall, the isolation of the innovation process from the host country's technological and production infrastructure. All this brings now to the forefront for successful BoP innovation, the need for a local business model that also fully embodies local behavioural responses to innovation. Hence, the increasingly recognized need in BoP innovation for strategic alliances between large MNCs and local NGOs.

Second, in line with the shift in research paradigm described in the first sections of this paper, the innovation process itself is now also likely to be reversed, starting with the design phase which will be confronted most directly with any attempt at finding functional solutions to some of the particular BoP users' framework conditions. This will involve not just the need to bring the product on the market at a substantially lower price than existing goods, as Prahalad emphasized, but also, and more in line with Sanjaya Lall's observations, a clear adaptation to the sometimes poor local infrastructure facilities with respect to energy delivery systems, water access, transport infrastructure, digital access, etc. ***Autonomy*** is the key word here. It is no surprise that the most rapidly spreading technology in developing countries has been mobile communication with currently more than 3 billion users worldwide. Autonomy from high quality energy, water, broadband network availability is undoubtedly one of the most pervasive drivers for BoP innovation. Another one might well be "cradle to cradle" sustainable innovation. The lack of high quality logistic infrastructure facilities in rural development settings might well imply that once goods are sold, the repair and/or central recollection of obsolete goods or their parts will be expensive. By contrast local re-use along the principles of cradle-to-cradle might well be a new form of sustainable grassroots innovation. It is in this sense that one might talk about "***appropriate innovation***" and that there seems to be some analytical similarity with the old notion of "appropriate technology"[7].

Third, the feedback from BoP users and from design developers upstream towards more applied research assistance, even fundamental research in some of the core research labs of Western firms might well become one of the most interesting examples of reverse transfer of technology (from the South to the North), re-invigorating and motivating the research community in the highly developed world increasingly "in search of relevance."[8] Not surprisingly, the main focus within the developed world at the moment is on BoP innovations in the health area, a sector where applied medical research is increasingly

[7] The notion of appropriate technology was of course much more formalized in terms of a rational set of economically determined "choices of technique" (Sen, 1968), depending very much on capital-labour substitution possibilities. The term "appropriate innovation" by contrast is much more open.
[8] See Soete (2008), Knowledge on the move, The Hague

dominated by access to new technologically sophisticated equipment and much less by more down to earth research questions about, and the list is non-exhaustive: anti-biotic resistance, infectious diseases or resistant tuberculosis. Not surprisingly, health is the sector most in need for what could be called a bottom of the pyramid research re-prioritization.

Conclusions

Underlying the shifts described here, there is of course, the dramatic shift in the globalization of science and technology as it has accelerated over the last ten to fifteen years. For most countries in the world, the contribution of domestic S&T to the global stock of knowledge is today relatively small; the contribution to domestic productivity growth equally small. There is little doubt that the largest part of world wide productivity growth over the last ten years has been associated with an acceleration in the diffusion of technological change and with global access to codified knowledge. The role of information and communication technologies has been instrumental here, as has been, as Sanjaya Lall has been at pains to emphasize, that of more capital and organisational embedded forms of technology transfer.

While there remains a huge world-wide concentration of research investments in a relatively small number of rich countries/regions, it is important to realize that such activities, whether privately or publicly funded are increasingly becoming global in focus. The shifts in global demand underlying the process of globalisation taking place today, affect in other words increasingly also the allocation of private resources to the sort of research, knowledge creation and diffusion, and innovation being carried out in research laboratories, wherever located. From this perspective it is important to realize that the new, much more global, international business community is becoming concerned, also from its internal research strategy perspective, about the sustainability of its long term growth based on the demand of high income groups rising in absolute terms at a much slower rate than lower income groups.

Up to a point this trend is similar to what happened in the US at the beginning of the 20^{th} Century period - also a period of rapid growth and rising income inequality - when Henry Ford introduced the **Ford Model T.** His “putting America on wheels” strategy centred on assembly line production and on paying workers wages so as to create a lasting market for the car. How to create a similar global mass market for consumer goods, represents in the context of the 21^{st} Century of course a much more complex, global challenge, but the similarity and the timing of such business concerns is striking. It is in a certain sense the ultimate paradox of inequality: the business community itself is becoming concerned over too much inequality limiting its own long future output growth potential.

It is in this sense that the vision of innovation for development outlined here, appears both new, yet also very familiar: very familiar to all those familiar with Sanjaya Lall’s research who will undoubtedly recognize many of his views and visions in some of the concepts and notions discussed here on how to develop successful innovation-for-development strategies.

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