From Science and Technology to Innovation for Development

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Abstract

Science and Technology (S&T) for development is often associated with radical technological change that offers new opportunities for human development. In affluent, highly developed countries, the use of material saving and energy efficient technologies promises to gradually eliminate unsustainable consumption patterns; while in developing countries, S&T are expected to eradicate world poverty, diseases and underdevelopment. Despite the many warnings raised by development and S&T economists that sustainable technological change depends on corresponding institutional change, there has been a tendency to take the economic sustainability of new technologies for granted. Humanity, waiting so to say, for such "technology manna" and technology transfer from North to South to become implemented.

In this paper, I will not enter the global sustainability policy challenges, which have been discussed at greater length elsewhere (see Kemp, Soete and Weehuizen, 2005 and 2011), but focus on the shift from S&T to *Innovation for Development*, which has occurred over the last ten to twenty years. This shift fully recognizes the "endogenous" nature of innovation as opposed to the old, neo-classical exogenous view of technological change and technology transfer, as it was popular in the 70's and 80's.

1. Introduction

Many S&T scholars that contributed to endogenous growth literature found that the process of innovation is actually much more complex and challenging in a developing country context. Aghion and Howitt (2005) have questioned the sustainability of S&T even in the high income country context and argued that the future innovation policy challenge will need to address the double meaning of "non-sustainability" resulting from technological "progress". Next to the ecological unsustainability of particular technological "progress" trajectories such as fossil fuel energy dependency, there is also the unsustainability of the "creative destruction" process within environments that give increasingly premiums to insiders, to security and risk aversiveness in favour of maintain rather than creating income and wealth. It is in this sense that as argued below, a high income environment is increasingly "inappropriate" for innovation that goes beyond incremental improvements.

In an emerging, developing country context, by contrast, it has been argued by a number of development economists such as Martin Bell (1985), Carl Dahlman and Larry Westphal (1983) Sanyaya Lall (1992), Howard Pack (1981), that industrial science and technology policies appear first and foremost more directed towards "backing winners". The central innovation policy question in these countries is how to further broaden an emerging national technological expertise in the direction of international competitiveness and specialisation. Such S&T policy broadening will have to involve a strong recognition on the part of policy makers of the importance of engineering and design skills, of accumulating "experience" rather than just Research and Development (R&D) investments and of enabling innovative entrepreneurship based on a multitude of talent and creativity across the board driven by the need to find solutions for the manifold problems of development. In short, the natural environment for innovation is likely to flourish in developing countries.. It is also in this environment that innovation takes on its full meaning: not just limited to technological innovation but including social and organisational innovation. As Lina Sonne (2011) has argued: "the need for increased ability to innovate should not be confused with the fixation on new state-of-the-art technology (Juma and Yee-Cheong, 2005). Instead a paradigm shift is needed away from these, often labour saving, innovative activities on the international innovation frontier, to mature or platform technologies. These less complex technologies are more useful for smaller scale and local solutions needed in terms of technology upgrading in developing countries (Juma and Yee-Cheong, 2005). Whilst frontier technologies are considered 'exciting' or 'sexy' it is the smaller and simpler innovation process which provides solutions that are more easily adapted to fit with the needs of countries where labour is generally abundant and cheap" .

2. Technology and the emergence of formalized industrial research activities

The strong focus on S&T, and industrial Research and Development (R&D) in particular, as the central factor behind economic development is actually of relatively recent origin. Up to the late 50's, R&D was barely recognised by growth 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 many industries, mostly in ordinary workshops. As Chris Freeman and myself noted in the Economics of Industrial Innovation: *"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 he 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).

What became distinctive about modern, industrial R&D in the late 19th and early 20th Century 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. 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.

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

As increasingly acknowledged by innovation studies scholars ranging from economists such as Paul David and Dominique Foray to S&T 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 occurred over the last twenty years. It is interesting to note that both the more economically embedded innovation research community as well as the more STS embedded research community converge on this issue: in each case the perception of the nature of the innovation process appears to have changed significantly.

Thus for innovation economist such as David and Foray innovation capability is today seen less in terms of the ability to discover radically new technological principles, but much more in terms of the ability to exploit effects produced by new combinations – one is reminded of Schumpeter's already old notion of "neue Kombinationen" – and use of pieces from the existing stock of knowledge (David and Foray, 2002). This alternative view, also closely associated with the emergence of numerous knowledge "service" innovations, 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 also referred to as "innovation without research". This shift in the nature of the innovation process implies actually a more complex structure of knowledge production activities, involving a much greater diversity of organizations having as explicit goal the production of knowledge. The previous industrial system was based on a relatively simple dichotomy between knowledge generation and deliberate learning in R&D laboratories on the one hand, and production and consumption activities on the other hand where the motivation for acting was not to acquire new knowledge but rather to produce or use effective outputs. As David and Foray have argued: "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". These places are no longer readily observable from national R&D statistics, yet they appear essential to sustain innovative activities, locally and even globally.

In short, most of our notions of traditional R&D-based technological progress are still dominant in many industrial sectors ranging from chemicals and pharmaceuticals to motor vehicles, semiconductors and electronic consumer goods. These sectors are characterized by the S&T system's ability to organise technological improvements along clearly agreed-upon criteria and ability to evaluate the progress continuously (Freeman and Soete, 2009). At the same time, a crucial part of the engineering research consisted, as Richard Nelson put it, "of the ability to hold in place" meaning to replicate and subsequently upscale experiments previously 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. Many of the detailed historical descriptions by Vernan Ruttan, Nathan Rosenberg and Giovanni Dosi of the emergence of the agricultural, chemical, electrical and electronic engineering research fields provide ample illustrations of such continuous learning processes.

The process of learning is very different in the alternative mode of technological progress described above. Since there is no procedure-related protocol in place yet, the development process is more based on flexibility and confronted with many intrinsic difficulties in replication. Learning from previous experiences or from other sectors is more difficult or can even be misleading. Evaluation is also difficult because of changing external circumstances over time, among sectors, across locations. It will often be impossible to separate out specific context variables from real causes and effects. In view of the frequent lack of availability of "hard" data that can be scientifically analysed and interpreted, technological "progress" will be much more based on trial and error . As a result, technological change is 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.

4. Implications for development

The new mode of technological progress brings 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 to be 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 the old industrial R&D and the underlying model of technological progress which has not received much attention in the development literature is the focus of industrial R&D 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. The mass consumption growth model which emerged over the post-war period in the US, Europe and Japan 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 of decreasing marginal utilityAgain I do not elaborate here on the challenges this growth model raises for achieving a pattern of sustainable development at the global level.

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 use circumstances, but thanks to the advertising campaigns in the media portraying popular symbolic figures in sports and entertainment presenting the new products to emphasize the prestige image of such professional use – the average, non-professional consumer could easily become convinced of the personal need of such new goods even though those additional quality characteristics might ultimately add only marginally to individual 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 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 – often with an extended *physical* life time. However, 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 size of the world market appears at first sight gigantic for new innovative goods and often without any doubt sufficient to recoup investments relatively quickly, the huge research, development, 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 large emerging BRIC economies, the new generation of goods being sold to these newly affluent people will not generate sufficient earnings to fund both the costs of mass production and the development of the next technology generation of the respective good. Having developed technologically incredibly sophisticated new goods, many firms are encountering major global sales problems in view of 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 the late CK The

Prahalad in his 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 impacts on the people's quality of life 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 lower than 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.

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 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 (1997) 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 refers to the isolation of the innovation process from the host country's technological and production infrastructure. All this brings now to the forefront 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 (e.g Hybrid Value Chains).

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 must also be more in line with Sanjaya Lall's observations. He refers to the need of a robust and dependable adaptation to potentially poor and shaky 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 innovation in a developing country context. Another one might well be "cradle to cradle" sustainable innovation (Braungart and McDonough 2002). 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".

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), reinvigorating and motivating the research community in the highly developed world increasingly "in search of relevance." 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 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 reprioritization (Crisp, 2010).

5. Conclusions

The dramatic acceleration of the globalization of science and technology (S&T) over the last ten to fifteen years largely helps explain the transformation of the process of innovation described in this paper. 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 is equally small. It is instead the increasing speed of diffusion of technological change and with it global access to codified knowledge that explains the largest part of world wide productivity growth over the last ten years.. The role of information and communication technologies has been instrumental here, as has been that of more capital and organisation- 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, increasingly affect 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, with 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 20th 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 in the context of the 21st Century represents 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 maybe novel, yet also very familiar: familiar to the many development economists dealing with technology accumulation and learning 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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