The Open University

Innovation
Knowledge
Development

SCHUMACHER MEETS SCHUMPETER: APPROPRIATE TECHNOLOGY BELOW THE RADAR

IKD Working Paper No. *54*

December 2009

Raphael Kaplinsky

Contacts for correspondence:
Raphael Kaplinsky, Development Policy and Practice, The Open University
R.Kaplinsky@open.ac.uk

Acknowledgements:
I am grateful to David Kaplan and Rhys Jenkins for comments on an earlier draft.

www.open.ac.uk/ikd/publications/working-papers

ABSTRACT

Innovation and technological change play an important role in poverty reduction through their contribution to growth, their use of factors of production, their environmental spillovers, the social relations associated with production and the characteristics of the products which they produce. It was only after the 1960s that these linkages were identified, with the recognition that much of global technological progress was directed to meet the needs of the global rich, and was best-suited to operation in high-income environments. The development and diffusion of “appropriate technologies” was an agenda largely pursued by the not-for-profit Appropriate Technology movement. However, with the global diffusion of innovative capabilities, and the rapid rise of incomes of the very poor = the “second bottom billion” – innovation for the poor and innovation appropriate for production in low-wage and poor-infrastructure environments has increasingly become an arena for profitable production. The very large size of China and India, coupled with their growing technological capabilities and the rapid growth of low-incomes, makes it likely that they will become the dominant sources of innovation for the poor.

Keywords and key phrases
“Fortune at the bottom of the pyramid”
Induced technological change
Appropriate technology
Reverse innovation
China, India, Asian Drivers

1. Introduction

Roughly-speaking, in 2007 (before the global crisis of 2008-9), around nine hundred million of the world's population of 5.4 billion was living below the internationally-agreed poverty line of $1 per day, with an additional 1.7 billion living at more than $1, and less than $2 per day (both income levels adjusted for purchasing power). Respectively, these two groups of the global poor accounted for 19 and 50 percent of the global population. Progress has been made in reducing absolute poverty since 1981 (when the respective poverty-incidences were 29 and 66 percent), but the poor remain with us, and in very large numbers (all numbers from Chen and Ravallion, 2008).[1] Since the financial crisis in 2008, the numbers living in absolute poverty have risen by between 55m and 90m, reversing many of the gains achieved over the previous decade.[2] It is not surprising therefore that a reduction in the levels of absolute poverty is the primary MDG target.

The poverty-reduction agenda raises issues of both growth and distribution. In turn, both the growth and distribution imperatives raise issues of technology and innovation. Technological progress and innovation determine productivity, and hence the rate of growth. By combining income-yielding factors (notably land, labour and capital) in different proportions, and by producing goods and services which address the needs of particular sets of consumers, technology also has an impact on distribution. Moreover, technology has derived implications for infrastructure, whose quality and availability is unevenly spread. The infrastructural requirements of a given technology will determine access to its use, and hence further affect both growth and distribution. Finally, technologies also have environmental impacts, and these, too, may have major implications for both growth and distribution.[3]

In much of the growth literature, the distributional consequences of technological progress and innovation are ignored (Cozzens and Kaplinsky, 2009). On the other hand, concern with distribution and technological appropriateness often explicitly turns its back on the growth imperative, regulating it to a distant and subsidiary objective after factor, social and environmental appropriateness (as in many of the critiques of genetically modified crops). In an ideal normative world, therefore, the challenge is to align these two developmental objectives, with technological progress and

---

1 These data refer to the absolutely poor. However, many development concerns arise with regard to the relatively poor, where the incidence of inequality has risen in most economies since the early 1980s.

2 http://www.un.org/millenniumgoals/pdf/MDG_Report_2009_ENG.pdf, accessed 19th October 2009.

3 Of course, technological progress is not exogenous to production systems and is consequently not "neutral", in other words, distribution also feeds into technological progress. Technology reflects patterns of power and social relations, generally reinforcing or strengthening the power of dominant social actors. This paper will not however consider these issues of bi-causality in the pattern of technological progress, but see Dickson, 1974; Clark, 1985 and Cozzens and Kaplinsky, 2009.

innovation simultaneously promoting growth and more equitable distribution, with very limited trade-offs between these two objectives.

Over the past two or three centuries, the dominant source of technological change and innovation has been in Europe and North America, joined in recent decades by a clutch of predominantly north-East Asian middle- and high-income economies (notably Japan, Korea and Taiwan), increasingly integrated into large-volume global markets. Not surprisingly, this context for innovation and growth has led to an innovation trajectory in recent decades which increasingly favours the use of labour-saving technological progress, assumes high-quality and pervasive infrastructure, and produces products for high-income consumers at a large scale. Increasingly, however, the global division of innovative effort is shifting to China and India, the new emerging Asian Driver economies (www.asiandrivers.open.ac.uk). In this paper we address the possibility – indeed the likelihood – that this shift in the geography of technological progress and innovation will have significant implications for the direction of technological progress, and hence for growth and the alleviation of global poverty. However, this ongoing transition is largely unrecognised – it is, so to speak, below the radar.

In addressing this agenda, the paper takes the following form. The discussion begins in Section 2 by charting the origins of the appropriate technology (AT) movement, with a particular focus on the low income developing world. Section 3 highlights developments in best-practise innovation in high-income economies which are relevant to the discussion in this paper. Section 4 briefly summarises the changing global distribution of capabilities in recent years, and this is followed in Section 5 by a discussion of induced technical change. Section 6 contrasts the theoretical frameworks of Schumacher and Schumpeter, arguing that ATs are no longer the province of non-for-profit NGOs, but are the bread and butter of capitalist accumulation. Section 7 draws out the major research and policy implications

2. The Sussex Manifesto and the Rise of the Appropriate Technology Movement

In neoclassical economics, there is no trade-off between technological choice, growth and distribution.[4] This is because it makes a number of assumptions which allow for a full range of technological choice, encompassing access to technologies, infinite variations of labour and capital (sometimes, also land), factor prices for land, labour and capital which represent their opportunity cost accurately,[5] no economies of scale, and the absence of environmental spillovers. It also assumes a high degree of homogeneity in the quality of

[4] For an elaboration on the discussion on the choice of technology, see Clark (1985). Sen's classical elaboration of the economics of technical choice identifies a trade-off between employment- and investment-maximisation (Sen, 1969).

[5] For a non-economist audience, this means that the prices of these factors reflect the value they would add in their alternative use. Thus, for example, if the marginal product of labour in agriculture was very low, then unskilled labour drawn from the agricultural to the industrial sector would be priced at this low cost.

each of these factors. In these circumstances, the pattern of technological choice will be determined by relative factor prices, and thus labour-intensive techniques would be chosen in low-income economies, and capital-intensive techniques in high-income economies.

During the 1950s and 1960s, a number of important objections were raised to the neo-classical framework. First, technological change had been assumed as an exogenous *deus ex machina* process, that is, it was a given coming from outside the production system. This assumption was challenged by a Solow's investigation into the factors contributing to US manufacturing growth over the period 1911-56 (Solow, 1957). He concluded that only around 12.5% of the observed growth of labour productivity over this period could be explained by increments in the stock of capital, the remaining 87.5% being a "residual" accounted for by "technological change". This insight problematised the processes underlying the generation of new technologies, and hence challenged the orthodoxy which rather than focusing on the determinants of and the rate of increase of technological progress, was instead primarily concerned with the optimality of choice and allocative efficiency – that is how to get the most production out of a given bundle of technology and resources.

Second, at about the same time, a seminal paper contested the core neoclassical assumption that there was an infinite range of efficient technologies available to produce a given good or service, combining factors of production in different combinations (Eckaus, 1955). Instead, argued Eckaus, at any one time there was a limited range of "efficient" technologies available. By "efficient", he referred to "economic efficiency" (making the most productive use of a given set of resources) rather than with technological efficiency (for example, the most efficient transformation of material inputs), environmental efficiency (for example, minimising pollution) or "social efficiency" (that is, reflecting social norms in production processes). Moreover, Eckaus (1987) and others (for example, Stewart, 1979; Emmanuel 1982), argued that since the inputs into improving technologies were heavily concentrated in Europe and North America where wages were relatively high, the single or the limited range of efficient techniques were overwhelmingly those which were most capital intensive, and which operated at high levels of scale. In other words and in extreme form, the only economically efficient techniques available are the capital intensive techniques. Other more labour intensive techniques would use both more capital and labour per unit of output, and would thus be economically inefficient, thus creating economic costs (ie a reduction in output and growth) for low income countries if they chose to use the labour intensive options.

Third, one of the core assumptions of the neo-classical framework was that all of the production techniques (as we have seen, assumed to be accessible, and available in infinite combinations of factors) produced identical products. Instead, it was argued, different production techniques produced differentiated, although largely substitutable products. Lancaster challenged this characterisation of product choice in a directly analogous manner to Eckaus' critique of the neo-classical framework for examining the choice of techniques (Lancaster, 1966). He argued that the assumption of an infinite range of products providing an identical range of utility was a myth. At any one time there was a limited range of products which met all consumer requirements more effectively than their inefficient alternatives and that these efficient products were, relatively speaking, biased in meeting the needs of high income consumers in which environments these products had been developed.[6]

A fourth and related development in the critique of the neo-classical framework was the link that was drawn between these developments in process and product technologies. It was increasingly recognised that there was a fixity between process and product technologies. Given processes (for example capital intensive techniques) were associated with given products (for example, those biased in favour of high income consumers) (Lancaster 1966; Stewart, 1979). Moreover, both process and product techniques were generally "owned", that is they could not be freely drawn-down from the shelf of available techniques, so that in many low income countries, this fixity between product and process also involved a fixity of entrepreneurship (often transnational corporations selling branded products) (Langdon, 1981; Emmanuel, 1983).

In the context of a great north-south divide in global living standards, there were two particularly prominent policy-related reactions to these patently unrealistic assumptions in neo-classical economics. The first was the Sussex Manifesto (SM), written as an advisory note to the UN Commission on The Second Development Decade in 1969 (Sussex Manifesto, 1970). Although not accepted by its UN sponsors (who did not approve of the SM's targets for redirecting Science and Technology to meet the needs of low income countries), it became increasingly influential in framing thinking about development and technological change. The second critical policy response to the neo-classical framework lay in the promotion of appropriate technology (AT)

2.1. The Sussex Manifesto

The SM challenged the neo-classical framework in three ways. First, it addressed the need to endogenise technological progress, that it, it arose directly from purposeful actions rooted within the political-socio-economic system. In bringing technological generation to the centre of the development discussion, the SM identified the importance of science and technology (hereafter S&T) in raising economy-wide productivity and output. Second, the SM also recognised that a key problem was the geographical concentration of inventive inputs in high income economies. This meant that most new technologies were induced by factor and operating conditions in high income economies. Third, it addressed the institutional context for R&D and argued that the underinvestment of S&T in low income economies was exacerbated by the "external brain-drain" of skills to high income economies. There was also an "internal brain-drain" as domestic S&T systems, largely publicly-

[6] For example, detergent (a product pioneered in high income countries) may be both cheaper and wash clothes more effectively than the soap traditionally produced in low income countries.

financed, were modelled on advanced country institutions. As a result high-level human and capital resources were wastefully built-up with little impact on local economic systems. Thus - a theme running through the Manifesto - the consequence of these characteristics of the global S&T system was that much of it was wastefully expended, and that technological progress was biased in meeting the needs of rich consumers by generating large scale and capital intensive technologies.

2.2. Schumacher and the AT Movement

The key contribution in the growth of the AT movement was that of Schumacher (Schumacher, 1973). Schumacher's early account of AT objectives was founded on the distinction between "man-as-producer" and "man-as-consumer" - “There is no escape from this confusion as long as the land and the creatures upon it are looked upon as nothing but ‘factors of production’. The consequences of this mis-specification of priorities is that agriculture has been treated as if it were an industry, rather than a biological process and that the earth's resources have been depleted and damaged ” (p 97). Schumacher regarded the idea that a civilisation could sustain itself on the basis of such a transgression as an “ethical, spiritual, and metaphysical monstrosity. It means conducting the economic affairs of man as if people really did not matter at all” (p 135). The environmentally destroying and capital intensive techniques which resulted from innovative efforts were antipathetic to the interests of humankind as a whole. But, moreover, since they emanated from high-income countries, they were also particularly inappropriate for low income countries since they were highly capital-intensive and operated at a large-scale. In response to this, Schumacher called for the development of “intermediate technologies” (£100 rather than £1 or £1,000 per job created) operating at smaller scales - “Small-scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large-scale ones, simply because their individual force is small in relation to the recuperative forces of nature” (p 31).

Schumacher co-founded the Intermediate Technology Development Group (ITDG) in 1964 (subsequently transformed itself into Practical Action, www.PracticalAction.org). ITDG rapidly developed alliances with similar initiatives promoting small scale labour intensive innovations in a variety of low income countries, and particularly in India where the Ghandian tradition had foreshadowed the rise of the AT movement in the north. The ideas spread rapidly and widely, especially but not exclusively to the NGO movement. For example, shortly after Schumacher's book was published, the United Nations Environment Programme (UNEP) was formed. As part of its process of targeting ATs, UNEP provided a set of criteria by which appropriateness could be judged, notably a preference “for energy-production technologies based on renewable, rather than depletable, energy resources, .. for technologies which produce goods that can be recycled and re-used,...and that are designed for durability, rather than quick obsolescence, .. for production technologies based on raw materials which are replenishable ... rather than exhaustible, .. for technologies of production and consumption which inherently minimise noxious or dangerous emissions and wastes, rather than those which require 'fixes' to curb their intrinsically polluting tendencies, .. for technologies of production and consumption which incorporate waste minimisation and utilisation procedures as integral components, .. for technologies which blend into natural ecosystems by causing them minimal disturbance, rather than those which threaten the biosphere with major perturbations, and .. for technologies based on the rational sustained use rather than indiscriminate rapid devastation, of the environment" Reddy (1979 p. 178).

2.3. Did the SM and the AT movement have a lasting impact?

The SM spoke to an audience of specialised S&T professionals and large corporations. Its call for increased inputs of science and technology resonated with the aspirations and skill-sets of these large and almost exclusively formal-sector actors. It also accorded with the objectives of governments in many low-income countries which targeted the growth of scientific and technological capabilities in order to spur industrial development. In the subsequent decades since the SM was written, this focus on R&D has been reflected in increasing R&D investments by low income economy governments (Section 4.2 below).

By contrast, Schumacher's call for the development of AT influenced only a small audience, predominantly comprising of NGOs and some bilateral aid agencies. Reflecting Schumacher's own concerns ("as long as the land and the creatures upon it are looked upon as nothing but 'factors of production'.") It was essentially an ethical response to the prevalence of poverty rather than being driven by the pursuit of growth through the development (and use) of more profitable choices of technology. In some cases the response to the AT movement was actively hostile, particularly in low income countries where the scientific and professional elite saw the AT movement as an attempt to consign poor countries to a state of perpetual underdevelopment, locked into the use of low productivity, undynamic and inefficient techniques (Emmanuel, 1982; Eckaus, 1987).

Thus, the development and diffusion of appropriate technologies – understood here as technologies which are appropriate for low income countries in that they are labour-intensive, simple to operate and repair, producing products for low income consumers at small scales and with a minimally-harmful impact on the environment – may have been at the centre of the development community's concerns. But they were at the fringes of the attention of the key actors allocating resources. Their diffusion was largely an "act of charity" rather than the result of the pursuit of profit.

3. The Changing Paradigm of Innovation

By the end of the 1970s, the debate about technology and development had largely matured, Most of the key issues had been set on the table, and concerns with technological choice and the generation of technology were muted as low income countries grappled with Structural Adjustment agendas and integration into the globalising economy, often seeking to replicate the successful experience of the East Asian newly industrialising economies. *De facto*, for many low income countries, technological progress remained an exogenous process located largely in the north, providing a supply of increasingly efficient, but capital-intensive and large-scale technologies depending on high-quality infrastructure, and owned predominantly by actors in the north.

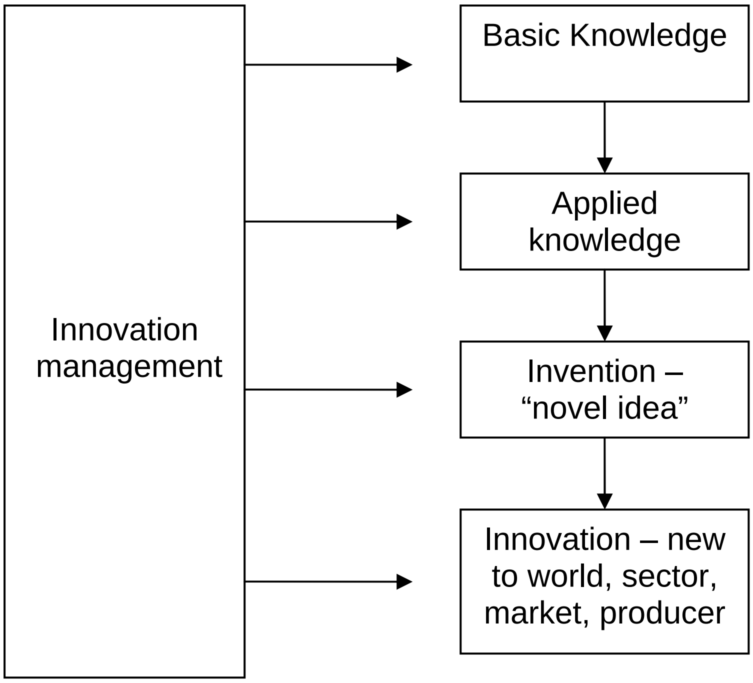
Since then, the innovation systems in the industrially advanced countries have experienced a series of profound changes and at the same time our understanding of the characteristics and determinants of the innovation cycle has deepened. In this Section we will briefly describe those changes which are germane to our discussion in Section 5 on the growth of capabilities in the south and the emergence of profit-oriented AT which is of relevance to low income countries. We begin with a discussion of the development of extended innovation cycles, then observe the centrality of firms in the innovation cycle, the growing importance of users in the development of technologies and the impact which these (and other) changes have had on archetypal “best practice” in northern innovation cycles.

3.1.The innovation cycle

The SM was concerned with S&T, its derived emphasis on R&D and the relevance of the outputs of the S&T system for low income countries. It made no attempt to open up the processes leading to usable outputs from the S&T system, and although it recognised that there were problems with the productivity of some S&T systems (notably through the “internal brain drain”). Its understanding of the range of activities involved in successful innovation was weak. It assumed, by default, some level of automaticity in the conversion of S&T inputs into implemented innovations. To use a culinary metaphor, the SM produced a single indigestible offering rather than a five-course meal. In this it was not out of kilter with the times, and the seamless identification of R&D with the extended cycle of applying knowledge successfully to production characterised much of the early thinking on the endogenisation of technological change in production systems.

In the half century since Solow’s challenge to economic orthodoxy, the conception of the innovation cycle has become much more holistic, and it is now widely accepted to incorporate a series of generally sequential stages (Figure 1). The first of these is the production of *basic knowledge*, followed by its refinement into *specific knowledge* – together, these are often described as Research and Development. If successful, these R&D activities (the Science and Technology in the SM) result in *inventions*, novel applications of knowledge (although inventions may also arise as a result of less formal activities than institutionalised R&D). When these inventions are applied to the delivery of goods and services, this results in *innovations*, which may be new to the world, new to the sector (ie being applied from other sectors), new to the country, or new to the producer and consumer. It was only from the mid-1990s that the *management of innovation* was recognised as playing a key, but crucial, role in the various components of this innovation cycle (Tidd, Bessant and Pavitt, 2005), addressing the capacity to search systematically from the shelf of available techniques and to introduce routines (Nelson and Winter, 1982) to ensure that innovations were timeously applied to realise practical outcomes in final markets at low cost.

Figure 1: The Innovation Cycle



3.2. The firm as the key actor in the innovation cycle

Different types of institutions play different roles at different stages in the innovation cycle, and this varies by sector and by the innovation challenge. The ensemble of institutional actors supporting this cycle of innovation make up the National Systems of Innovation (Lundvall, 1992; Nelson, 1993) which comprises a mix of producing firms, tertiary educational institutions (universities), research and technology organisations (RTOs), service providers (such as producer associations), and consumers and consumer associations.

To a greater or lesser extent, this ensemble comprises a mix of profit and not-for-profit institutions. Where the innovation cycle addresses goods and services provided by the public sector, not-for-profit institutions such as universities and NGOs may play a lead role. Where the knowledge and technology involved is complex, there may be a relatively greater role played by tertiary educational institutions and RTOs. But, as a general rule, in the contemporary global economy where innovation is driven by the search for profit, the key innovation actors are profit-maximising firms.

Consequently, an understanding of the true drivers of innovation needs to be rooted in the sociology of the firm (Penrose, 1959; Bell, 2007). The effectiveness and nature of innovations will reflect the firm's ownership, its particular competences, its routines, its trajectory and the particular signals it responds to in the development of new processes and products, a series of determinants captured in evolutionary economics (Nelson and Winter, 1982; Ruttan, 2001).

Abstracting from the sociological character of the firm for the moment, it is possible to distinguish three broad sets of characteristics exhibited by many firms in the contemporary innovation cycle. The first are those changes which involve relatively big leaps, and which draw on the inputs of specialised knowledge. As technologies were becoming more complex in the in post-war period, the archetypal "small inventor with a good idea" was eclipsed by teams of researchers working in the R&D departments of large, global transnational corporations (TNCs) (Freeman, Clarke and Soete, 1982). Indeed, this is the picture most widely conjured up when we think of firm-level innovation. But, and this is the second firm-characteristic of innovation, in reality much if not most improvements in product and process arise out of a series of incremental changes occurring during production and which are not formally recognised as "R&D". Although the significance of these small incremental changes had been recognised in some empirically-based analyses of technical change (notably Hollander, 1965, and Katz, 1987), the importance of these incremental changes grew significantly after the mid-1980s as Toyota and follower Japanese firms restructured their labour processes to endogenise contributions to technological change as part of the job description of all of the labour force. Toyota and its followers were able to show that the cumulative effect of a myriad of small changes within the production and design process added up to rapid and significant changes (Imai, 1987; Monden, 1983). The critical distinguishing features of kaizen was its incremental nature, its frequency and, crucially in contra-distinction to the SM paradigm, the fact that they overwhelming emanated from shop floor workers rather than from the firm's R&D department. And, thirdly, firms have begun to realise that investments to generate good ideas offer little reward if the absence of structured routines designed to ensure rapid and effective deployment, that is, that the innovation process is managed (Tidd, Bessant and Pavitt, 2005).

The development of kaizen practices and the explicit addressing of innovation management in corporate structures can be traced to economy-wide structural changes and the evolution of the post-war production paradigm. Towards the end of the 1960s, as Europe, North America and Japan had completed the basics of post-war construction, supply-constraints became less binding and markets more competitive. Consumers with growing incomes wanted more differentiated products, introduced more rapidly and with higher quality, but without the cost premium hitherto associated with customised markets. This ushered in a "second industrial divide", one of "flexible specialisation" (Piore and Sabel, 1984), involving differentiated products targeted at fragmented niche markets and a much higher clockspeed of innovation (Stalk and Hout, 1990). The combination of differentiation with scale marked a transition from mass production techniques to those of mass customisation (Pine, 1993). The production system which evolved was ideally suited to meeting the needs of high-income consumers, prepared to trade-off price for higher quality and enhanced differentiation. A good contemporary example of this model is that of the apparel retailing chain Zara which changes its product offering on a weekly basis.

3.3. User-driven induced innovation

The producer-user interaction is an essential characteristic of the relationship between the suppliers of capital and intermediate goods and their downstream user industries, and has been long-recognised (including in Pavitt's taxonomy of innovation, Pavitt, 1984). But, more recently, or perhaps more recently recognised, is the role which *final consumers* play in innovation processes. Effective final use often requires considerable learning, and as von Hippel has pointed out, the knowledge so produced is asymmetrical; that is, the user often knows much more about the product and its characteristics than does the producer. Moreover, much of this knowledge is path-dependent and context-specific – "In the specific case of product development, this means that users as a class will tend to develop innovations that draw heavily on their own information about need and context of use" (von Hippel, 2005: 70).

Thus, in an increasing number of sectors, users are purposively incorporated in the innovation cycle. "Beta-vintages" are released at a deliberately premature stage of product development to lead-users, aided by the growing sophistication of real and virtual model-making technologies (such as CNC-controlled profilers). Firms "… sell platform products intentionally designed for post-sale modification by users" (von Hippel, 2005: 128). Lead users then refine the product, ironing out weaknesses, and attuning the product to specific market-niches, before suppliers proceed to large-scale production. Examples of user-led innovation classically include beta-releases of software, and Microsoft is famous (or perhaps infamous) for the retro-fixing of software based on user experience. Von Hippel provides other examples of final-user led innovation in products based on the sophisticated knowledge of high-income and technically-educated consumers.

3.4. Mode 1 and Mode 2 ideal types

The combination of these factors – growing product differentiation produced by firm-centred innovation systems increasingly involving active interaction with users – has led to a change in the organisation and visioning of the innovation process. This has been characterised as a transition from Mode 1 to Mode 2 innovation (Gibbons et. al, 1994). Ever since the publication of the Rothschild report on UK science policy in 1971 which introduced the notion of the "customer-contractor" relationship into government R&D expenditure policy, (Rothschild, 1971) there had been an implicit realisation that bureaucratic separation of "science" from "economic production" was an inefficient way of managing resources. By the 1990s a series of institutional changes had been introduced designed to tie public investment in "science" to stated welfare objectives.[7] Common to all of these “institutional innovations” was the realisation that the search for and validation of knowledge needed to involve a much wider body of stakeholder interests and capacities than had been the conventional case.

The concept of *Mode 2* innovation was developed to characterise and theorise this transition in innovation paradigm, and to contrast this against the inherited *Mode 1* model implicit in the S&T-R&D science-push approach championed by the SM. The essential characteristics of *Mode 2* knowledge include the following characteristics which are relevant to the discussion in this paper (Nowotny et al, 2003). First, It is generated within the context of application and not solely through scientific experiment. Second, it is developed within and across widely different organisational forms, and finally, it is “reflexive” in the sense that it is not reducible to an objective investigation of “natural law” but is rather a dialogue between research actors and subjects

Thus a series of changing practices in innovation systems have come to dominate the innovation process in high-income economies. They involve systemic efficiency, a combination of big-jumps (“kaikaku”) and small improvements (“kaizen”), reflexive interaction between innovators and supporting institutions and customers, and is largely driven by the firm, particularly large TNCs operating on a global scale. Sadly, little of this innovation-best-practice has filtered through to the bulk of low income economies, who predominantly continue to see innovation as a process of big-pushes, driven forward by R&D in the S&T system (Chataway. 2009). The development of a powerful pharmaceutical industry in India is a classic example (Chataway, Kale and Wield, 2008). It has done much to provide cheap generic drugs to the world, but historically embedded in a *Mode 1* framework, it has done little to address the needs of the poor in India. Thus, investment in R&D for new drug development in India is heavily oriented to the needs of rich consumers in the West, much as it is in large Western based MNCs. This bias extends to India’s S&T-based innovation system as a whole, which largely fails to invest science in relation of needs of the poor.

4. The Changing Geography of Production, Capabilities and Consumption

To summarise the discussion above, roughly-speaking we can divide the second half of the twentieth century into two periods with regard to the character of dominant industrial and innovation paradigms. Until the early 1970s, a period when supply was constrained in major markets, the production system was supply-driven, producing relatively standardised products for predominantly undifferentiated markets. The innovation system was essentially sequential in nature, characterised by an image of knowledge-intensive inventions generated in specialised R&D institutions and in R&D

[7] Good examples of this were the creation of the UK Biotechnology Directorate in 1980, the UK Dept. of Trade and industry’s Link scheme of the 1990s and the establishment of Foresight Exercises in many countries during the 1980s and 1990s.

Departments within large firms. As consumer incomes rose in these high income countries, markets became more volatile and fragmented and new structures of innovation emerged, involving greater interaction between the constituent institutions in the system of innovation, greater intercourse with users, and new labour processes which built on the creativity of the labour force. What did not change in these five decades was the direction of technological progress, with most new products targeted at high income consumers, including not just those in high income economies, but also the elite in low income economies. What also did not change was the bias in innovations in process technology, with technical change increasingly capital intensive, aiming to reap scale economies through large volume production and increasingly being reliant on sophisticated infrastructure.

But some things did change, with significant implications for the nature of technical progress in the 21st Century. Three related changes have been particularly important – the development and extension of global value chains, the diffusion of capabilities to low income economies, and the very rapid growth of low income consumers.

4.1. The development and extension of global value chains

The early 1970s is widely seen as having marked a turning point in the structural characteristics of production in high income countries (Piore and Sabel, 1984; Ruttan, 2001). As competition changed from maximising the supply of relatively undifferentiated products to meetings the needs of consumers in increasingly differentiated markets, so flexibility became of growing importance in production. This flexibility was achieved through changes on a number of fronts – in automation technologies (Kaplinsky, 1984), through changes in work organisation and intra-firm organisation (Best, 1990), and in the outsourcing of activities which were not seen as lying in the core competences of the firm (Hamel and Prahalad, 1994). This latter phenomenon, allied to the demands of global buyers for large volumes of low-cost products (Hamilton and Feenstra, 2005), led to a rapid expansion of global value chains. These chains involved the increasing decomposition of production, with lead-firms focusing on the core competences and outsourcing non-core components of production (Gereffi, 1994; Kaplinsky and Morris, 2001). Where these outsourced activities involved relatively low skills, and/or were labour intensive, the outsourcng increasingly went to low-income economies.

The globalisation of production saw a dramatic expansion in global value chains and provided the basis for export-oriented industrialisation in many low income economies, but particularly in Asia. The first tier of low-income global suppliers were the Asian Tigers (Hong Kong, Korea, Singapore and Taiwan), but this rapidly spread to other regions in Asia, and in Central and Latin America and North Africa. Most recently, the largest and most dynamic economies benefiting from the extensions of these global value chains has been China in manufacturing, and India in IT services. Much of this outsourcing was of low value added activities, so-called “processing trade” in China (Fu, 2003). The rapidity of growth of outsourcing in manufacturing to

China in particular is evidenced by the historically significant change in market shares in global manufacturing value added (MVA) (Table 1). In a relatively short period of two decades (bear in mind how long it took Germany to catch up with the UK and then the US to catch up with Europe), South and East Asia's share of global MVA grew from 4.1 percent to 19.7 percent, and much of this (but not all) was accounted for by China. Significantly, Africa's share was miniscule and has fallen, whilst that of Latin America showed little change. Outsourcing of thin value added activities was not confined to China in manufacturing or India in services, but was widespread, including in Central America and even (to a more limited extent) in sub-Sahara's clothing sector (Kaplinsky and Morris, 2008).

Table 1. Global distribution of manufacturing value added (MVA)

	Share of the World			Share of developing countries		
By Income	**1985**	**1995**	**2005**	**1985**	**1995**	**2005**
S. and E. Asia	4.1	12.9	19.7	29.2	59.5	69.4
Of which: China	1.4	5.1	9.8	10.2	23.6	34.7
Latin America	6.7	6.9	6.4	46.9	31.5	22.6
Sub-Saharan Africa	1.0	0.3	0.3	7.1	1.3	1.0

Source: Data provided by Statistics Office, UNIDO, June 2008.

4.2. The global diffusion of capabilities

This global diffusion of MVA has been associated with a pervasive increase in capabilities in many low-income economies. These capabilities have been built on a number of strands of activity. The first has been the relatively passive processes of learning-by-doing, described by Ruttan as "the learning that takes place after a technical innovation has been adopted. It may involve 'doing more' or 'doing it longer' and learning-by-using, or some combination of the two. It involves acquisition of new skills, process technology inventions, and improvements in the organization of production" (Ruttan, 2001: 90). Sub-contracted production in global value chains provided valuable experience for many producers in low income economies

Second, closely related to this process of learning-by-doing are the more active processes of "learning by adaptation" and "learning by capacity expansion" (Bell, 2007). These essentially firm-level activities – generally associated with efforts to make maximum use of purchased, and often imported technologies – arise out of incremental changes undertaken by people involved in the operation of the equipment such as plant engineers, line-managers, quality-control departments, and logistics and marketing departments. They do not qualify as "Research and Development" in the formal sense.

R&D is the third type of activity underlying the diffusion of capabilities to low income economies. Bell (drawing on the OECD Frascati Manuals definition used to measure R&D) characterises it as involving: ***"creative work*** that is undertaken on ***a systematic basis***, in order to ***increase the stock of knowledge***, and ***use*** this stock of knowledge to ***devise new applications"*** (Bell, 2007: 122, emphasis in original). Here there has been a significant global dispersion of activities in the past four decades. The Sussex Manifesto (Section 3.1 above) estimated that at the end of the 1960s, only approximately two percent of global R&D occurred in the developing economies. Two decades later, this ratio had risen to 10 percent, and by 2000, more than one-fifth of global R&D was located in the developing world.[8]

Table 1. Developing countries in Global R&D

	c1970	1990	2000
Share of global R&D ($PPP) (%)	2.0	10.2	21.0
R&D as % GDP	NA	0.7	0.9
Coverage	Excluding centrally planned	Including centrally planned and NIC economies	

Source: 1970 - Sussex Manifesto, 1970; 1990 and 2000 - UIS Bulletin on Science and Technology Statistics, Issue No 1, 2004, cited in M. Bell, 2007

An increasing share of this dispersed R&D occurs within the corporate sector, particularly in China and India

> "In a rather sudden shift, the number of MNE [Multinational Enterprises]) R&D centers in China rose more than tenfold to around 1,100 (representing 920 MNEs by the end of 2008) and to 780 (670 MNEs) in India ... The *internal* MNE R&D offshoring growth took place in parallel to the learning processes of Indian and Chinese vendors and CROs [Contract Research Organisations], leading to a similar expansion of *R&D offshore outsourcing*. Most surveys point to a continuation of this trend as companies report plans to move future R&D expansion to these two countries" (Bruche, 2009, 1-2).

Bruche observes that although much of this outsourced R&D is relatively routine in nature, there are emerging poles of higher-level innovation in a number of middle income economies (for example, Brazil).

8 To some extent this strong performance overestimated real achievements, since in 1970 the centrally planned economies were excluded from these calculations, and in later decades much of the growth in developing economy R&D was located in the Asian Tigers.

4.3. The rapid growth of consumption in low income economies

A remarkable and increasingly recognised feature of global growth has been the stellar performance of China and India. With annual rates of growth of more than nine percent stretching back for almost 30 years in China and of more than six percent for nearly 20 years in India. This compares with average growth rates of around three percent in the northern economies in the same period. Assuming that these relative growth rates are sustained for the next two decades, the sheer size of China and India means that there will be a substantial shift in global purchasing power from the current high income economies to the current low income economies.

Table 3 shows the impact of these relative growth rates. It focuses on the locus of consumption by the global consuming class ("the Middle Class"), defined as those consumers with annual incomes of between $10 and $100 per day in 2009 (in 2005 PPP $) (Kharas, 2009). Projecting forward to 2030 on the basis of growth rates in the past two decades, the centre of gravity of global consumption shifts decisively. The share of Europe and US falls from 64 percent in 2009 to 30 percent in 2030, whilst that of the south in general and Asia in particular rises. The share of Asia and the Pacific in the global consuming class is projected to rise from 23 percent in 2009 to 59 percent in 2030.[9]

Table 3. Spending by the Global Middle , 2009 to 2030, Percent of global (millions of 2005 PPP dollars)

	2009	2030
N. America	26	10
Europe	38	20
C. and S. America	7	6
Asia Pacific	23	59
SSA	1	1
M. East, N. Africa	4	4

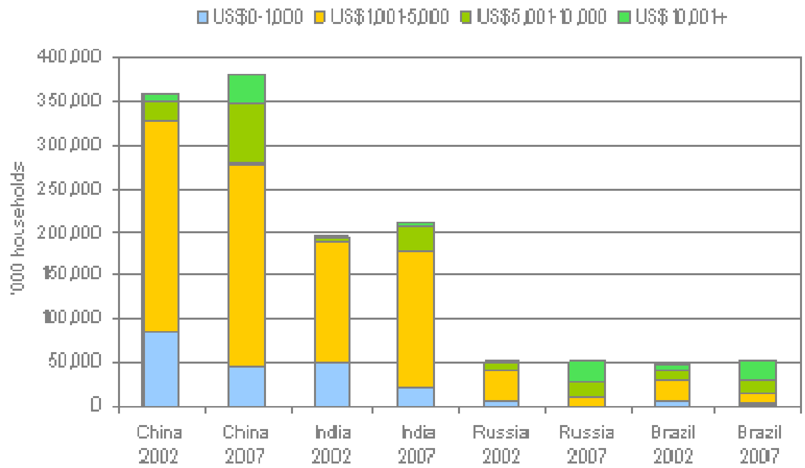
Source: Selected from Table 3, Kharas, 2009,

In calculating these rough numbers, Kharas takes account of intra-country income distributions. However, the elastic definition of the "global middle class" - ranging from $10 to $100 per capita per day – does not highlight the growth rates of consumption by different income ranges within this $10-100 range, particularly in China and India, the very large and rapidly-growing economies which dominate these estimates. By contrast, Figure 2 decomposes income groups in these two economies, and Brazil and Russia.

9 As with all long-term projections based on historical experience, changes in relative growth rates will have a major impact on the outcomes. For example, should the current financial crisis lead to a major slowdown in large northern economies, and should China and India be able to sustain high growth rates on the basis of sustained national and regional expansion, the shift of global consumption to the south will be even greater than that suggested in Table 3.

(It uses current dollars, and focuses on the number of households, rather than using PPP dollars and focusing on consumption by individual consumption). It shows that, at least by number, the dominant category of consumers in these rapidly-growing low income economies are in the $1,000-$5,000 per annum group. Crucially, and with considerable significance for the future direction of technical change as we will argue below, this category of consumers is very different from that which drove global consumption in the north until the end of the twentieth century. Even the next biggest group of households which earns between $5,000 and $10,000 p.a has a much lower standard of living than median of incomes in the high income economies which have driven technical change over the past decades.

Figure 3. Households according to disposable income bracket in China, India, Brazil and Russia: 2002/2007 '000 households



Source: Euromonitor International from national statistics, cited in Media Eghbal (2008),

5. Induced Technical Change and Innovation Rents

Following this detour into the changing paradigm of innovation in the high income economies (Section 3 above) and the changing geography of global production (Section 4), we can now return to the determinants of technical change and their relevance to meeting the needs of the global poor. We begin by addressing two sets of economic literature which have a bearing on our understanding of technical change and innovation. The first concerns the inducements to technical change, and the second focuses on the pursuit of innovation rents and the role which innovation plays in this.

5.1. Induced technical change

It is possible to distinguish between both demand and supply inducements to innovation. Curiously, the role which demand plays in stimulating innovation is almost certainly under-recognised in economic theory. Ruttan's classic textbook *Technology, Growth and Development* identifies three divers of induced technical change. The first is that of demand, but this is treated only cursorily, meriting less than a single page in a text of more than 600 pages. Ruttan observes its general role – "..changes in demand represent a powerful inducement for the allocation of research resources" (Ruttan, 2001: 102) - but there is no elaboration either of the relative importance of demand as an inducement to innovation, nor of biases in the interaction between particular patterns of demand and particular paths of technical change. Even Lancaster, who as we saw in Section 2, provided an analytic framework for examining the bias in product characteristics, was largely silent on the interaction between the character of markets and the direction of technical change.

Nevertheless, despite its virtual exclusion in the economics of technical change, it is abundantly clear that demand plays a crucial role. For one, it stimulates the pace of innovation. Rapid market growth, particularly where markets are large, characteristically draws forth new products and also affects the rate of change in process technology.[10] For another, markets are also clearly an important determinant of the direction of technical change. High income markets place an emphasis on quality and differentiation, and can be tolerant of high acquisition costs. In contrast, low income markets characteristically are prepared to sacrifice product quality and variety for low relative price and low acquisition costs.

The second inducing factor to the direction of technical change indentified by Ruttan is relative factor price. The classic text is by Hicks, who observed the persistent bias towards labour-saving technologies in the 1930s – "The real reason for the predominance of labor saving inventions is surely that … a change in the relative price of the factors of production is itself a spur to innovation and to inventions of a particular kind – directed at economising the use of a factor which has become relatively expensive" (Hicks, 1932: 125-5, cited in Ruttan, 2001: 102). Fellner elaborated this by observing that *expectations* of changing prices, played an important inducing role in biases in technical change (Fellner, 1961).

Ruttan's third factor inducing patterns of technical change relates to the trajectories of innovating firms. Characteristically, firms will have imperfect information and will scan their known contacts and data-sources in the search for improvements in process and products. They will, as evolutionary economics has shown, also do so in the context of the routines which they have developed to master their past operations. These firms, thus have their own path-dependencies and trajectories (Dosi, 1984).

These factors inducing technical change provide important insights allowing us to understand the limited historic role which technical change in general has played in meeting the needs of poor consumers and the operating conditions in low income economies. Given that product technology is characterised by inflexibilities (Lancaster's elaboration of Eckaus), the major markets have historically been comprised of high income consumers. Hence the development of autos which, even at the bottom end of the scale, cost more than $15,000. These generally have central-locking, air-bags and air-conditioning, and meet emission standards in Europe and North America. They are different in character to the new rudimentary cars costing around $2,000 which are now being introduced in India. Similarly, it is understandable that technical change has tried to economise on labour when wage

10 "Verdoorn's Law" addresses the manner in which rising demand allows firms achieve economies of scale, and to move down the cost curve, thereby increasing labour productivity.

costs can exceed $50 per hour. In 2006, a typical car in the US cost $28, 450 of which the labour cost (direct and indirect) was only 8.4 percent (http://www.uaw.org/barg/07fact/fact02.php, accessed 20th October 2009). The theory of induced technical change also explains why firms have historically sold their wares across geographical environments in the same packaging in order to maintain brand name, and to use proprietary packaging technologies, even though the acquisition costs of this standard packaging put the product outside of the consuming power of poor people.[11]

5.2. Innovation rents and innovation

As we have seen, it was only after the 1960s that theories of technical change began to problematise the processes whereby new processes and products were developed and commercialised. Until then, technical change had been seen as a "given", coming from outside of the production system. A key early distinction made in the unravelling of these social processes was that made by Schumpeter. He distinguished inventions (a new and original idea, which could include new forms of organisation) from innovation (the successful application of that idea in the delivery of a new product or a new process of production in meeting user needs) (Schumpeter, 1939). Schumpeter characterised the act of entrepreneurship as involving the innovation of inventions. For him, this was the key characteristic of capitalism, and helped to explain both small business cycles and much larger waves of innovation involving considerable "creative destruction" as innovation-laggards were swept away by competition from radical new technologies.

Schumpeter provided an analytical framework to show how innovation was endogenous to, and central to capitalism. Given the quest for profit, and in the absence of permanent monopolies, entrepreneurs search for new inventions which they could apply as innovations and thus earn super-normal profits. These new inventions might be protected by property rights, but more generally by proprietary knowledge and first-mover status. But over time they would be copied ("diffusion"), competition would increase as the innovation was copied, and the super-normal profits would thus eroded. The cycle would then be repeated as the original entrepreneur or a new entrepreneur applied a new and superior invention, in turn passing into the 'land of super-normal profits'.

Schumpeter was aware that inventions did not necessarily translate into innovations. They might stand on the shelf for many years, and perhaps for ever. But more typically, it is in this search for super-normal profits that technical change and the dynamism of capitalism is to be understood. Without new products, processes or forms of productive organisation, economies would grow at a much slower rate (at the extensive, rather than the intensive margin). In the Schumpeterian schema, technical change thus lies at the heart of the capitalist system. Indeed, one of the primary reasons for the withering

---

11 This latter case refers to the celebrated example highlighted by Prahalad and Hammond. They show how when Unilever's Indian subsidiary became aware of this it repackaged its detergents in very small sachets, opening up a vast and rapidly growing market segment amongst the poor (Prahalad and Hammond, 2002).

away of the command economies in Eastern Europe was precisely because technical change was muted – they lacked a "Schumpeterian motor".

6. Schumacher meets Schumpeter

Schumacher had a "good idea". Indeed, from the development perspective we can say that he had "the right idea". Clearly, growth, poverty-reduction and distribution in low income economies would be considerably enhanced if producers had access to technologies which were labour-intensive and small in scale, and if they produced products which were low in cost and accessible for low income consumers. But there were three problems which made his good idea fanciful. First, there was a shortage of entrepreneurship in low income countries. We refer here to entrepreneurship in the Schumpeterian sense of a group of innovation-actors who systematically applied new ideas to production rather than producing by acquiring the technology form others (particularly from northern equipment suppliers). Second, the capabilities required to develop new ideas for innovation were thinly spread globally, overwhelmingly concentrated in high income countries. Schumacher's third problem was the absence of effective demand in low income countries in general, and by poor consumers in particular. These consumers clearly had unfilled needs, but they lacked the incomes to satisfy these unmet needs.

As we have seen in Section 5 above, all three of these underlying weaknesses in the Schumacher framework have been subject to significant change over the past two decades, particularly in China and India. Capitalism has become rampart, even if it is different in character to the "classic" Anglo-Saxon model of free-market entrepreneurs operating in perfectly competitive markets. It often takes the form of state-owned firms, particularly in China, but crucially, these firms are engaged in the dedicated pursuit of profit. Capabilities are now widespread, not just in formal R&D activities, but across the spectrum of skills utilised across the value chain. And the incomes of the poor are growing rapidly. In fact, as we have seen in Figure 3, the most dynamic group of consumers are those households with incomes of less than $5,000 per year.

If we then think about these changes in the context of the factors inducing technical change (Section 5.1 above), we can anticipate a number of important changes which are likely to have considerable developmental impacts in other low income economies. Consider the first two of Ruttan's inducing factors. The first is demand, even though he treats this lightly. When high-income consumers induce product innovation, this results in the choice of highly-differentiated "positional" products, that is goods which confer a status on the consumer (a Gucci bag, for example). The emphasis will be on quality rather than price, and acquisition costs (a large box of detergent) may be high. By contrast, and we are talking of a spectrum here, low income consumers need function, rather than "position", they are prepared to settle for low quality (for example, basic mobile phones), and they want (as Hindustan Lever has found with its detergents – Prahalad, 2005) low acquisition costs. The driving of consumption by low income households earning less than $5,000 will undoubtedly induce a different set of products compared to the bankers and other high-income earners in northern economies.[12]

The second determinant inducing technical change affects process technologies. Wages in countries such as China and India are a fraction of those in the north. It is highly likely, therefore that new techniques produced in these environments will be more labour intensive. They also occur in the context of weak infrastructure, particularly in relation to its quality and reliability. For this and other reasons, innovations in low income economies are more likely to be robust, and less likely to be sensitive to high-quality infrastructure. Further, low income consumers are not as fussed with the environmental and labour standards involved in the production of goods which they consume. Hence production systems in these environments are less likely to require adherence to International Standards Organisation (ISO) and other global standards. To the extent that technical change arises from the innovations by small scale indigenous firms (see below), it is also likely that they will be less reliant on very large volume production. Aimed at small scale emerging firms, they are also likely to involve lower acquisition costs, and to facilitate decentralised production. Therefore, in most of these senses (particularly with regard to the economic rather than social or environmental appropriateness), these induced technical changes in processes are likely to meet many of the requirements of appropriateness set out by Schumacher, Practical Action, and other bodies who have historically promoted the diffusion of AT. But they will do so in a way which allows for profit-maximising investment rather than through sponsorship by NGOs and aid agencies.

There is more uncertainty about change with regard to Ruttan's third inducing factor, that is, firm-trajectories. It was Prahalad, an Indian-origin business theorist working in the US and the UK who was one of the first to spot the potential which the growth which these low income markets offered for profitable production. He drew attention to the market potential of this new class of consumers (Prahalad and Hammond, 2002), pointing out that there was something in the region of 4 billion people living at per capita incomes below £2,000 p.a.. He argued that there was a "fortune at the bottom of the pyramid". But crucially, and perhaps not surprisingly given that he worked in northern business schools, Prahalad believed that this provided a market opportunity for transnational corporations (TNCs) rather than for the small-scale and locally-owned firms long identified in the appropriate technology and informal sector literature as being key providers for low income consumers. He argued that "[b]y stimulating commerce and development at the bottom of the economic pyramid, [northern-based] MNCs could radically improve the lives of billions of people… Achieving this goal does not require multinationals to spearhead global social development initiatives for charitable purposes. They need only act in their own self interest, for there are enormous business benefits to be gained by entering developing markets" (Prahalad and Hammond, 2002: 4).

12 "More of the income change [in the US between 1966 and 2001] accrued to the top one percent than the entire lower 50 percent, and more accrued to the top 1/100 percent than to the top 20 percent" (Dew-Becker and Gordon, 2005: 36).

But this belief that northern TNCs would be able to grasp this market is an untested assertion. It is contestable for two reasons. First, as Christenson's widely-cited work has pointed out, large firms which dominate industries are often extremely good at hearing the demands of their existing customers, but very poor at hearing those of new customers. His argument is essentially that these weakness flows directly from their core strengths which is that they invested considerable resources in acutely understanding the needs of their core customers. Thus when a new technology arrives which fails to address these known needs effectively, the major innovating firms are dismissive. For example, IBM neglected the arrival of the $5^1/_4$ floppy disc since it was hopelessly inadequate for the needs of its corporate customers who required vast quantities of data-storage. Its problem was that it knew its existing customer base too well, but had no feel for a new generation of much less demanding customers. As Christenson observed the previously dominant industry leaders "…..were as well-run as one could expect a firm managed by mortals to be – but that there is something about the way decisions get made in successful organisations what sows the seeds of eventual failure". They failed precisely because they listened to their customers so well – "the logical, competent decisions of management that are critical to the success of their companies are also why they lose their positions of leadership"(Christenson, 1997: xiii).

So in many cases the potential offered by these rapidly growing markets of poor consumers is below the radar of the globally dominant firms (Chataway et al, 2009). But this is not true of all firms, notably in recent years the operations of Unilever's Indian subsidiary. Whilst the idea is rapidly catching on, for example in GE's strategy of "reverse innovation" propounded by its CEO (Immelt, et. al., 2009), it is an open question whether the gold-plating trajectories and the existing customer-base of these large TNCs will enable them to participate effectively in these markets. Consider, for example, the problems posed to TNCs with a high brand-presence in the north is their operations in low income countries do not meet the labour and environmental standards of their northern customers. Ongoing research on timber in Africa and cassava in Thailand shows that when markets shift from the traditional northern customers to those in China, standards in value chains tend to be non-existent or of very marginal importance (Kaplinsky et. al, 2010, forthcoming). This is the second caveat to Prahalad's assertion that TNCs will dominate these low income consumer markets in the south. Following this logic, however, it is possible to see the rise of southern-based TNCs as being better able to serve the needs of producers in low-income economies and low income consumers. This echoes the observations made in a different time-period and context by both Wells (Wells, 1983, and Lall (Lall, 1984).

7. Conclusions

Much of the discussion in previous sections is conjecture. There are very good reasons to assume that technical change originating in the south will become a major driver of innovation in the 21st century. There are also good reasons to assume that because of the context of this innovation, the technical changes which are being induced will be more appropriate to the needs of low income consumers and low income producers than those which have hitherto emanated from the north. There is more uncertainty as to which firms will come to dominate these markets producing techniques appropriate for low income countries and poor consumers.

The discussion in previous sections also collapses important sub-trends in the task of identifying a distinct new family of innovations which are particularly appropriate for low-income operating environments and low-income consumers. Many of the products arising from innovation processes in the north have also filtered down into low-cost goods for the poor (for example, a wrist-watches). There is also clearly a substantial innovation trajectory in China and India and other low income economies which targets both mass production and high income consumers (Zeng and Williamson, 2007). Nevertheless, with respect to the first of these caveats, it remains the case that the needs of the very poor consumers have not been met effectively – witness the increasing rush of large TNCs seeking to penetrate these markets. There is also plenty of evidence of the persistent capital intensity of production techniques utilised in low-income economies despite high levels of unemployment and low wages. With regard to the second of these caveats, there is no reason why we cannot envisage a world in which innovation in the Asian Driver economies simultaneously reflects the activities of large globally-focused and high=tech firms and small, predominantly small low-tech-firms.

However, there is little evidence to substantiate these outcomes, other than the casual empiricism which many researchers observe in their work in low income countries. For example, this author has interviewed a South African trader who specialises in providing African firms with cardboard box packaging equipment. Historically he sourced these machines from Germany and Switzerland. He now sources exclusively from China, where he can purchase three machines for the price of the European variants, and the machines are more robust for African operating conditions. In Uganda, a prominent industrialist reports that “Most of the newly installed, and especially small and medium polyethylene sealing machines for industries now in East Africa are made in China. This is even more rampant in the small operator and domestic scale units that is used by the market vendors packaging of food. All the new (400+) small and (10) medium size rice plants are made in China. This includes the small diesel engines(10-25 HP) to run the small mill. The new grinding mills for maize and water pumps are also from China. The Chinese engines are even better modelled, lower in fuel consumption, smaller in size and much cheaper than the Indian models. The new big and modern maize and wheat flour mills, carpentry machines, generator sets are all coming from China. Of course there are disappointment with some varieties but there is also satisfaction in many others in the market” (Idro, 20-09; personal communication).

Clearly, therefore, there is an important research agenda to pursue. But, to the extent that we are witnessing a transition in innovation processes with significant implications for growth, poverty-reduction and distribution in the south, important policy agendas are also raised. First, how can southern producers gain access to these new innovations, particularly those occurring below-the-radar in China, India and other low income countries? Second, what mechanisms of technology transfer are likely to emerge, or might be fashioned through purposive policy interventions? Can the mistakes in historic processes of technology transfer – which have inhibited learning and raised the costs of acquisition – be avoided? Third, what actions can governments and aid agencies take to maximise the rate at which these new vintages of innovation take place in many low income countries, rather than just in a few particularly dynamic economies such as China, India and Brazil? And, fourth, what are the implications for agencies such as Practical Action and other NGOs associated with the development and diffusion of ATs when the primary driver of innovation moves from the non-for-profit "good works" of Schumacher to the "naked greed" of Schumpeter?

References

Bell, R. M. (2007), "Technological learning and the development of productive and innovative capacities in the industry and infrastructure sectors of the Least Developed Countries: What's roles for ODA?", Paper prepared for UNCTAD Division for Africa, Least Developed Countries Specialised Programme, Brighton, Science Policy research.

Best Michael H. (1990), The New Competition, Oxford: Polity Press.

Bruche, G. (2009), "'A new geography of innovation - China and India rising"', Columbia FDI Perspectives, No. 4, April 29, 2009

Chataway, J., Kale D. and Wield, D. (eds) (2007), "The Indian Pharmaceutical Industry before and after TRIPs", Technology Analysis and Strategic Management. Vol. 19, Issue 5

Chataway, J. N. Clark, R. Kaplinsky, D. Kale, P. Robbins and R. Hanlin (2009), "Below the Radar: What Does Innovation in the Asian Driver Economies Have to Offer Other Low Income Economies? IKD Working Paper No. 41, Milton Keynes: Open University

Chen, S. and M. Ravallion 2008), "The Developing World Is Poorer Than We Thought, But No Less Successful in the Fight against Poverty", Policy Research Working Paper 4703, Washington, D.C: The World Bank Development Research Group.

Christenson, C. (1997), The Innovator's Dilemma, Cambridge, Mass: Harvard Business School Press.

Clark, N. G (1985), The Political Economy of Science and Technology, Oxford: Blackwell.

Cozzens, S. E, and R. Kaplinsky (2009), "Innovation, Poverty and Inequality: Cause, Coincidence, or Co-evolution?", in Lundvall, B-A; J K Joseph, C. Chaminade and J. Vang (Eds.), Handbook of Innovation Systems and Developing Countries. Building Domestic Capabilities in a Global Context, Cheltenham: Edward Elgar.

Dew-Becker, I. and R. J. Gordon (2005), "Where did the Productivity Growth Go? Inflation Dynamics and the Distribution of Income", Working Paper, 11842, Cambridge, Mass: National Bureau of Economic Research http://www.nber.org/papers/w11842.

Dickson D, (1974), Alternative Technology and the Politics of Technical Change, London, Fontana.

Dosi, G. (1982). "Technological Paradigms and Technological Trajectories", Research Policy, Vol. 11, No. 3,

Eckaus R S, (1955), "The Factor Proportions Problem in Underdeveloped Areas", American Economic Review, Vol. 45, No. 4, pp. 539-565.

Eckaus R S, (1987), "Appropriate technology: The Movement Has Only A Few Clothes On", Issues in Science and Technology, Winter, pp 62-71

Emmanuel, A. (1982), Appropriate Technology and Underdevelopment, Chichester: J. Wiley.

Feenstra, R. C. and G. G. Hamilton, (2005), Emergent Economies, Divergent Paths: Economic Organization and International Trade in South Korea and Taiwan, New York: Cambridge University Press.

Fellner, W. (1961), “Two Propositions in the Theory of Induced Innovation”, Economic Journal, 71: 305-308.

Freeman, C., J. Clark and L. Soete (1982), Unemployment and Technical Innovation: A Study of Long Waves and Economic Development, London, Frances Pinter.

Fu, X., (2003), Exports, Foreign Direct Investment and Economic Development in China, London and New York: Palgrave Macmillan.

Gibbons, M, C. Limoges, H. Nowotny; S. Schwartzman, P. Scott, P and M. Trow (1994), The new production of knowledge: The dynamics of science and research in contemporary societies, London: Sage.

Gereffi, G. (1994), “The Organization of Buyer-Driven Global Commodity Chains: How U. S. Retailers Shape Overseas Production Networks”, in G. Gereffi and M. Korzeniewicz (eds.), Commodity Chains and Global Capitalism, London: Praeger.

Hamel, G. and C. K. Prahalad (1994), Competing for the Future, Cambridge: Harvard Business School Press.

Feenstra, R. C. and G. G. Hamilton, (2005), Emergent Economies, Divergent Paths: Economic Organization and International Trade in South Korea and Taiwan, New York: Cambridge University Press.

Hicks, J. (1932), The Theory of Wages, London: Macmillan, (Reprinted 1963).

Hollander, S. (1965), The Sources of Increased Efficiency: A Study of Dupont Rayon Plants, Cambridge, Mass.: MIT Press.

Kharas, H. (2009), “The Emerging Middle Class in Developing Countries”, Working Paper, OECD Development Centre, Paris.

Imai M (1986), Kaizen: The Key to Japan's Competitive Success, New York, McGraw-Hill.

Immelt, J., V. Govindarajan and C. Trimble (2009), “How GE is Disrupting Itself”, Harvard Business Review, October, pp. 56-65.

Kaplinsky R (1984), Automation; The Technology and Society, Harmondsworth, Longmans.

Kaplinsky R (1990), The Economies of Small: Appropriate Technology in a Changing World, London: Intermediate Technology Press.

Kaplinsky, R. and M. Morris (2001), A Handbook for Value Chain Research, http://asiandrivers.open.ac.uk/documents/Value_chain_Handbook_RKMM_Nov_2001.pdf

Kaplinsky, R. and M. Morris (2008), “Do the Asian Drivers Undermine Export-Oriented Industrialisation in SSA”, World Development Special Issue on Asian Drivers and their Impact on Developing Countries, Vol. 36, No. 2, pp. 254-273.

Kaplinsky, R., M. Z. Farooki, A. Terheggen and J. P. Tijaja (2010), "What happens in global value chains when the market shifts from the north to the south?", Paper prepared for World Bank project on Global Crisis and Value Chain Governance, Development Policy and Practice, Milton Keynes: The Open University.

Katz, J. (1982). "Technology and Economic Development: An Overview of Research Findings," in M.Syrquin and S. Teitel (eds), Trade, Stability, Technology and Equity in Latin America, New York: Academic Press.

Lall, S. (1984). The New Multinationals. New York, Wiley

Lancaster K. J. (1966), "Change and Innovation in the Technology of Consumption", American Economic Review, Vol. 56, No. 1/2, pp. 14-23.

Langdon, S. (1981), Multinational Corporations in the Political Economy of Kenya, London, Macmillan.

Lundvall, B. A, (1992), National Systems of Innovation, London: Frances Pinter.

Media Eghbal (2008), "BRIC economies withstand global financial crisis", 5 Nov http://www.euromonitor.com/BRIC_economies_withstand_global_financial_crisis

Monden Y. (1983), Toyota Production System: Practical Approach to Production Management, Atlanta: Industrial Engineering and Management Press,

Nelson R. R. (1993), National Innovation Systems: A Comparative Analysis, New York: Oxford University Press.

Nowotny H., P. Scott, P and M. Gibbons (2003), "Introduction: 'Mark 2 Revisited: The New Production of Knowledge", Minerva, 41, pp. 179-194.

Penrose, E. (1959), The Theory of the Growth of the Firm, New York: John Wiley and Sons.

Pine, J. B. (1993), Mass Customization: The New Frontier in Business Competition, Cambridge, Mass: Harvard Business School Press.

Piore M. J. and C. Sabel (1984), The Second Industrial Divide: Possibilities for Prosperity, N. York: Basic Books.

Prahalad, C. K., and A. Hammond (2002, "Serving the World's Poor Profitably", Harvard Business Review, September, pp. 4-11.

Prahalad, C. K. (2005), The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits, Upper Saddle River, NJ: Pearson Education/Wharton School Publishing.

Reddy, A. (1979) in A. Bhalla (ed) (1979), Towards Global Action for Appropriate Technology, Geneva, ILO.

Rothschild, Lord (1971) "The Organisation and Management of Government R&D", Framework for Government Research and Development, (London; HMSO, Cmnd. 4814).

Ruttan, V. W. (2001), Technology, growth and development: An induced innovation perspective, N. York: Oxford University Press.

Schumpeter J. A. (1934), The Theory of Economic Development, Cambridge, Mass: Harvard University Press.

Schumacher, F. (1973), Small is Beautiful, London, Blond and Briggs.

Sen A. K. (1968), The Choice of Techniques, Oxford: Blackwell, 3rd Edition.

Solow R (1957), "Technical Change and the Aggregate production Function", Review of Economics and Statistics, Vol 39, pp 312-320.

Stalk G (Jnr) and Hout T.M. (1990), Competing Against Time: How Time-Based Competition is Reshaping Global Markets, New York, The Free Press.

Stewart, F. (1979), Technology and Underdevelopment, London, Macmillan, 2nd edition.

Singer, H., C. Cooper, R. C. Desai, C. Freeman, O. Gish, S. Hall and G. Oldham (1970), The Sussex Manifesto: Science and Technology for Developing Countries during the Second Development Decade, IDS Reprints No. 101, Brighton: Institute of Development Studies.

Terheggen, A. (2010, forthcoming), “The New Kid in the Forest: The Impact of China’s Resource Demand on the Gabonese Timber Value Chain” PhD Dissertation, Development Policy and Practice, Milton Keynes: The Open University.

Tijaja, J. P. (2010, forthcoming), “The Role of Exogenous Factors and Domestic Agency in Changing Market Conditions: Lessons from the Thai Cassava Value Chains”, PhD Dissertation, Development Policy and Practice, Milton Keynes: The Open University.

Tidd, J., J. Bessant and K. Pavitt (2005), Managing Innovation: Integrating Technological, Market and Organizational Change, Chichester: John Wiley and Sons Ltd (3rd Edition).

Von Hippel, E. (1994), Technological Innovations, N. York: Oxford University Press.

Wells (1983). Third World Multinationals: The Role of Foreign Direct Investment from Developing Countries, Cambridge MA, MIT Press.

Zeng, M. and P. J. Williamson (2007), Dragons at Your Door, Boston: Harvard Business School Press.