BELOW THE RADAR: WHAT DOES INNOVATION IN THE ASIAN DRIVER ECONOMIES HAVE TO OFFER OTHER LOW INCOME ECONOMIES?

THIS PAPER REFLECTS DISCUSSIONS IN THE DEVELOPMENT POLICY AND PRACTICE GROUP AT THE OPEN UNIVERSITY. PARTICIPATING MEMBERS ARE JOANNA CHATAWAY, NORMAN CLARK, REBECCA HANLIN, DINAR KALE, RAPHAEL KAPLINSKY AND PETER ROBBINS.

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"We often assume that these frontiers of science will benefit only the richer nations of the world, …[But] [i]n fact resource-poor settings can actually drive innovation, demanding ingenious product designs that are less expensive, and easier to use, and require less infrastructure. It is also easier to disrupt the technological status quo in the absence of entrenched commercial interests organised around existing products" (Elias, 2006: 540)

"By and large, disruptive technology is initially embraced by the least profitable customers in a market" (Christenson, 1990: xvii)

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1. Introduction

However pressing the distributional concerns of redressing inequality and overcoming poverty are in the short-run, in the long run meeting the development needs of humankind requires economic growth. This much is indisputable, although the composition of this growth - the weight given to different social and environmental parameters - is of course subject to contestation. Growth can arise from one or a combination of two different sources – an increase in the *amount* of investment applied to production ("extensive growth"), and an improvement in the *quality* of this investment ("intensive growth"). Most rapidly-growing economies draw on both the extensive and intensive margins. But, increasingly through the last three centuries, and inevitably even more so in the coming centuries as global resources are depleted, the focus of attention has been, and will be, placed on the intensive margin. And as we now have also realised, innovation and technological change lie at the centre of investment quality and therefore at the root of growth and development agendas. It was not always so. In the early part of the 20th century as far as most analysts were concerned, the capacity of economic systems to produce more over time simply took place. And if it was determined by anything it was by the rate of investment i.e. by the rate of addition to the stock of capital within the economic system under consideration.

This tradition was placed in question by a remarkable study carried out in 1956. Using conventional comparative static techniques, Robert Solow (1957) attempted to provide a statistical explanation of the causes of US manufacturing growth over the period 1911-56. He concluded that only around 12.5% of the observed growth of labour productivity (output per worker) over this period could be 'explained' by increments in the stock of capital, the remaining 87.5% being a 'residual' or an unexplained 'technological change' or 'improvement in productivity'. What was significant about this study was that a major economic magnitude (the rate of economic growth) could not apparently be explained by the established causal variable. It was not so much the rate of investment that was important but rather the *productivity* of investment – and that remained unexplained. From that point on the growth agenda became one of identifying what these causal factors might be and clearly an important one was investment in science and technology.[1] In turn of course issues of science policy then became strategic since science was concerned above all with the creation of new knowledge much of this presumably economically useful.

The link with the agenda for underdevelopment was just as significant since underlying all international poverty and inequality were poor economic conditions. It was this above all that gave rise to the drafting of the Sussex Manifesto by a group of policy-oriented social scientists at the Science Policy Research Unit and the Institute of Development Studies at Sussex University (Singer et. al., 1970). The Sussex Manifesto (hereafter, SM) reflected best-practice thinking at the time, and has continued to frame (or perhaps reflect) the dominant mode of thinking about, and the patterns of organising science policy in, and for, low income economies. It is a model which overwhelmingly focuses on science and technology as the primary source of technological change and the historically high-income northern economies as the primary locus of new technology and innovation. It has also tended statistically to conflate S&T with R&D expenditure.

[1] S&T was not the only one. Authors such as Denison (1962) investigated others such as entrepreneurship, education and scale factors.

However, in recent years there have been major structural changes in processes of innovation, and in thinking about innovation processes. Little of this has filtered through to the development community which continues to run on old tramlines. In this paper we briefly review the old model (Section 2) and then focus on the new currents of thinking and practice about innovation, so-called *Mode 2* innovation (Section 3). This is followed in Section 4 by a discussion of a series of emerging and outlier trends in innovation in various global settings. These trends offer the possibility for developing economies of disrupting dominant power relations in innovation, and also of better meeting the needs of the poor. This leads us in Section 5 to identify the potentially key role played by an innovation surge in the Asian Driver economies, and its potential relevance to meeting developmental needs in other low income economies. In this final section we also note however some outstanding science policy questions and the importance of keeping these questions alive in policy debates.

2. Running On Tram-Lines: Best Practice In Development-Centred Innovation

In bringing innovation 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 – "The underlying problem arises from the international division of labour in science and technology and the present massive orientation of world scientific effort to the problems and objectives of interest principally to the advanced countries" (SM, p 1). The Manifesto argued that inherent weaknesses of low income economies with regard to S&T were exacerbated by the external brain-drain of skill migration to high income economies. There was also an "internal brain-drain" as domestic S&T systems, largely public 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.

A number of solutions were proposed to meet these problems – developing countries should raise their R&D expenditure to 0.5 percent of GDP; the advanced countries should support R&D in low income economies, including by providing aid, and orienting at least five percent of their own R&D to meeting the needs of developing countries; a technology transfer bank should be established to widen the shelf of existing technologies available to producers in low income economies. All of this, argued the SM, should be accompanied by appropriate institutional change within and outside the S&T system in developing economies. In offering this analysis of the shortfall in the nature and extent of technology development for low income economies, the SM closely reflected a new type of thinking about technology development in the advanced countries although the point about "institutional change" was never really taken on board. Thus the SM concentrated on R&D in research and technology organisations (RTOs) as the *major* source of innovation. Most of these RTOs, and the accompanying R&D, were in the public sector.

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 and the international community to meet the needs of low income countries. Table 1 shows the extent of investment in R&D in such economies. The SM had 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. In aggregate, at 0.9%

of GDP in 2000, the commitment by developing economies to R&D expenditure was almost double the SM target. 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. Nevertheless, there can be little doubt that in many developing economies – including, but not limited to large economies such as China, India, Brazil, Mexico and South Africa - investments in R&D have grown significantly over the past four decades.

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

These internal commitments to R&D expansion in developing countries were complemented by significant progress in the level of resources devoted by the international community to S&T directed at low income economy needs. In addition to widespread support for the expansion of tertiary education in the developing world, the most notable investments in global RTOs focused on the developing world occurred within the framework of the CGIAR family of research centres with particular relevance to agriculture. Despite problems in the architecture of these institutions, they did have some major early successes, most notably in the case of the green revolution. However, whilst the original CG centres did well in selected mandated crops they did so under particular conditions and contexts. Since the early 1980s they do not seem to have achieved similar levels of success, and they are now under some threat (Hall et al, 2003).

Despite this increase in commitments to R&D, the development of innovation capacity in many low income economies has been poor. Many developing countries do not seem to have been able to avoid the very problem that the SM was trying to avoid – the waste of resources arising from what the SM referred to as “the internal brain drain”. Technology development continues to rely on inputs from the industrially advanced economies and is often inappropriate to the needs of low income consumers and operating environments with poor infrastructure. The shortfall of these innovation processes with respect to meeting the health problems concentrated in developing economies (Malaria, HIV-positivity, TB) is increasingly widely-recognised, and being confronted (with varying degrees of success) within the context of the Global Fund, the Gates Foundation and other initiatives (Chataway et al, 2007, Moran, 2005). In agriculture there are still too many examples of local agribusiness bypassing local S&T systems and relying on foreign sources of technology to provide up-to-date innovation responses (Keskin et al, 2008)

An important divergence from the SM-inspired orthodoxy during the 1970s and 1980s was the appropriate technology (AT) movement. Schumacher’s original concerns with inappropriateness in process (and particularly with the capital-intensity of innovation) built on the observed limited range of efficient production techniques (Schumacher, 1973; Eckaus, 1955; Stewart, 1979; Clark, 1985). Subsequently the recognition of the limited range of efficient process technologies was complemented by a focus on the limited range of efficient product technologies (Lancaster, 1966), and the fixity between process and product technologies (Langdon, 1981). For some years the AT movement flourished (Jequier, 1976; Carr, 1985; Kaplinsky, 1990), but essentially it remained a by-water of dissent and limited change, rather than a full-blooded counter-response to the hegemony of an R&D based innovative drive centred in the high income economies. Nevertheless, despite this recognition of the inadequacy of innovation proposed by the SM, in some important respects the AT was a victim itself of the same weakness. It tended to emphasise "hard technologies" as the solution, a technology-fix not dissimilar to the supply-based R&D agendas of the SM model.[2]

In the light of these problems, and given the persistent levels of poverty that continue to exist we believe there is a need to give urgent policy attention to processes of innovation which are efficient and appropriate for low income developing economies. There is still a large body of opinion that would simply increase the levels of expenditure on R&D targeted at, and in, countries with low per capita incomes[3]. However, since the SM was written, much has changed in the structure of best-practice innovation in the industrialised countries, suggesting that business-as-we-know-it/running-along-the-same-tramlines may no longer be appropriate. Yet in many respects perspectives on innovation and R&D in many developing country contexts still faithfully reflect the worldview of the SM (Bell, 2005, 2006 & 2007; Hall 2005; Clark, 2002, 2009). New ways of thinking about innovation appear so far to have had little impact.

We believe that these changes are so significant that it forces us to think about developing country innovation in very different ways. But before considering these policy implications, in Sections 3 and 4 we highlight some of the major changes which have been, and continue to take place in the environment in which innovation occurs, and consequently in the architecture of innovation practices.

3. *Mode 2* Innovation: New Currents In The Innovation Stream

(i) New Industrial Paradigm

A key development in the structure of innovation processes can be traced back to the transformation in industrialised country markets during the late 1960s and early 1970s. Until then, the focus on economic growth had been on enhancing the supply response following WW2 and then the Korean War. This was essentially an environment of constrained supply in an era in which per capita incomes were not much different to those in current middle-income economies. It was a world characterised by relatively limited product diversity, thus allowing for economies in scale in production utilising

[2] Although more recently there have been moves to place the AT debate within an innovation systems analysis. See Hall et al (2007)

[3] Good examples of this can be found in Lipton (1988) and Pardey et al (1997). In the latter the authors provide a detailed account of the decline in African agricultural research spending but there is virtually no analysis of why this has happened. Consequently the final conclusion focusing on the need to increase finance is unconvincing. The Lipton paper goes further in linking declining research expenditures to falling economic rates of return but the analysis virtually ignores institutional questions, concentrating instead on poor policy frameworks, below optimum size of research stations and product relevance.

inflexible dedicated equipment and hierarchical labour processes. This production paradigm has variously been referred to as mass production or Fordism and was extensively chronicled by Piore and Sabel, Best and others (Piore and Sabel, 1984; Best, 1990).

Two trends eroded the efficacy of this system of mass production (Kaplinsky, 1994). First, in a context of rising per capita incomes, consumers who were offered the choice were no longer satisfied by homogenous consumption goods. A premium was paid for variety and quality, and markets became increasingly segmented and volatile as producers developed the capacity to develop and exploit new niches. Second, hierarchical labour processes with sharp divides between skilled and unskilled labour, working in large scale production environments, became increasingly alienated. Strikes grew in importance throughout the high income economies, absenteeism was high and quality and attention to detail in machine-paced assembly was low. Wastage was high, and the costs of inventories and logistics in "just-in-case" production systems characterised by large inventories were burdensome (Feigenbaum, 1991),

It is in this context that the new production paradigm's efficiency is to be seen. Piore and Sabel 1984) recount two alternative forms of new production system – the flexible craft-based systems prevalent in the industrial districts of Italy, and the just-in-time and flexible production systems developed in Japan.[4] It was the latter development which has come to play the dominant role in the emergence of a new innovation paradigm. Initially developed in Toyota (Monden, 1983; Cusumano, 1985) and then rapidly spreading to other sectors in Japan and globally (Womack and Jones,1996) – including to developing countries, Kaplinsky, 1994) – this new post-florist/flexible specialisation/lean production paradigm rapidly asserted its competitiveness.

This supremacy was evident in a number of respects. It provided for increased flexibility and diversity, exemplified currently by the Zara clothing retail chain which changes its product offering every week. By reducing defects and wastage, and especially by thinning inventory lines and producing to order rather than to forecast, it was also significantly cost-saving – Dell's make-to-order offering is now widely replicated across industries. Crucially it also led to fundamental changes in the nature of work and the organisation of firms and value chains. If a single phrase were to sum up the innovation challenge provided by this new production paradigm, it is one of enhanced clock-speed (Stalk and Hout, 1990).

Toyota's advance to supremacy in the global auto sector reflects its mastery of lean production. It achieves high levels of quality, and couples this with rapid product innovation, excellent price-quality trade-offs, and thin-inventories. It is widely-copied across industries. Critically, the new production paradigm is not confined to manufacturing – global agricultural-to-retail value chains, coordinated by retail giants such as Walmart and Tesco illustrate the generic nature of the competitiveness of this new system of innovation and production (Womack and Jones, 1996) and the new paradigm has even been implemented in hospital design (Kaplinsky, 1995).

A number of features of this production paradigm reflected a sharp divergence from the model implicit in the SM. In the first place, Toyota distinguished between big changes

[4] Piore and Sabel's particular "take" on the new production paradigm was to characterise it as a system of flexible specialisation, highlighting the combination of segmented markets and rapid product differentiation

("kaikaku") and small incremental changes ("kaizen") (Womack and Jones, 1996). The R&D and S&T approach to technology development was very much in the mould of kaikaku. But in reality, 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.[5] These changes are referred to as "kaizen", continuous improvement, and result from active participation by the labour force in making suggestions for improvement in process and product (Imai, 1987). The numbers of these suggestions from the labour force – requiring, by the way, a shift from the single-tasking and single skilling Taylorist division of labour in mass production – were staggering. In the early 1990s, Nissan garnered more than six million suggestions from its labour force annually, around 77 from each worker per year (Kaplinsky, 1994). The critical distinguishing features of kaizen were their incremental nature, their frequency and, crucially in contra-distinction to the SM paradigm, the fact that they overwhelming emanated from shop floor workers. Scientists, R&D and S&T – the backbone of the inherited model – were conspicuous by their absence. This is not, of course to say that Toyota makes no attempt at kaikaku innovations. It is at the forefront of hybrid autos, electrically-powered cars and sophisticated R&D intensive engine management systems. But it integrates these within an institutional context that is quite different from the traditional one.

A second distinguishing feature of innovation in the lean production paradigm is its interdisciplinarity and in-parallel nature. This is exemplified by the ability which Toyota and other Japanese automakers have developed to reduce the design cycle for a new car from more than eight years to less than 18 months. This was achieved by the introduction of cross-functional design teams – a mix of disciplines and functions – and having them work in parallel, rather than in sequence. This is referred to as "concurrent engineering". In the previous paradigm, there was a strict sequence of specialisation and temporal separation in the design and development cycle, with each function working on its task only when the previous function had completed and passed on its work. An important component of these concurrent engineering teams is that the end-actors in the production chain – marketing and sales – are included in these teams to ensure that the products are pulled by customer demand, rather than pushed by the imperatives of supply.[6]

The third distinguishing feature of the lean production paradigm led on directly from this. Concurrent engineering practices were extended from the different functions within the firm to the different links within the value chain. Systemic efficiency thus required close interaction across the spectrum of firms involved in the chain. Crucially, governance by lead firms was required to coordinate this innovation cycle which increasingly involved high-trust relations between firms without the cement of internalisation through dominant equity holdings (Sako, 1992).

As described, this new paradigm involved close interaction between innovation and production. There was no clear separation of the innovation process as an "S&T" activity driven by R&D by highly skilled scientists and technologists. This of course is not to say

[5] The importance of incremental technical change had, at the micro level, been demonstrated for some time in the industrially advanced countries (Hollander, 1965), as well as in developing economies (Katz, 1987). But the significance of this micro-level of change had been little noticed, either in innovation theory or in institutional design.

[6] Similar principles were reflected in the transition from just-in-case inventory push systems in mass production to just-in-time pull systems in lean production (Womack and Jones, 1996; Kaplinsky, 1995)

that there was no S&T or R&D content, but rather that these were often subsumed in, and integrated with the design and production and marketing functions within and between firms. This point has recently been emphasised in Bell's recent report to UNCTAD (2007) on overseas development assistance. Based upon of detailed empirical analysis over the last 50 years or so he argues that successful technology development is largely enterprise-based and relies on "public sector science" only to a limited extent. R&D is important of course but it is not where innovation mainly takes place and it is innovation, not R&D that really drives possibilities for poverty reduction.

Take for example industrial activity. It really does not matter whether you are considering a cassava processing plant in Ghana or a deep water petroleum facility off the coast of Angola. In either case the investment activities associated with any new venture will follow roughly the same rules. The firm will determine the macroeconomic and government regulatory context, specify the process and product design, the ancillary facilities such as power and water supply, the necessary financial and due diligence components, and associated contracting and sub-contracting arrangements for its engineering. Management of the package is a highly skill-intensive process and one that takes time. It will of course hopefully embed the latest knowledge as a necessary condition but in practice every project is a new project and it is in this process of "getting it right" that much of the necessary learning and innovation takes place. Bell also shows that in general the resources needed here are many multiples of basic and applied "research rich countries costs." It is in the *doing of it* that knowledge is expanded. And this is where the private sector is so successful. No enterprise would tolerate the levels of economic inefficiency routinely exhibited by public sector science. It could not afford to.[7]

(ii) From Mode 1 to Mode 2

A second factor that has begun to influence the innovation debate is the concept of *Mode 2* science introduced by Gibbons and his colleagues in a book published in 1994[8]. Ever since the publication of the Rothschild report on UK science policy in 1971[9] which introduced the notion of the "customer-contractor" relationship into government R&D expenditure policy,[10] there had been an implicit realisation that bureaucratic separation of "science" from "economic production" was an inefficient way of managing resources. Indeed this view probably goes back even further to the famous Reith lecture of C P Snow in the late 1950s[11]. By the 1990s there had arisen a whole series of institutional changes designed to tie public investment in "science" to stated welfare objectives. Good examples of this were the creation of the UK *Biotechnology Directorate* in 1980, the UK DTI Link scheme of the 1990s and the establishment of *Foresight Exercises* in many countries during the 1980s and 1990s. 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. Not only had R&D expenditures become merely a part of the story but also the funding activities of research councils and other donors were struggling to give this operational meaning in practice.

[7] See also Bell (2005)
[8] See Gibbons et al (1994)
[9] See Rothschild (1971)
[10] Similar developments began in other high income economies but we have used the UK for illustrative purposes
[11] See Snow (1963)

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 implicit in the SM (Gibbons et. al., 1994). In the words of Nowotny et al (2003) its broad thesis was that

> “the old paradigm of scientific discovery (*Mode 1*) characterised by the hegemony of disciplinary science, with its strong sense of an internal hierarchy between the disciplines and driven by the autonomy of scientists and their host institutions, the universities, was being superseded – although not replaced - by a new paradigm (*Mode 2*) which was socially distributed, application-oriented, trans-disciplinary and subject to multiple accountabilities”.[12]

The argument is both positive (this is what is actually taking place) and normative (it represents an opportunity to improve best practice) and has caused considerable debate within scientific and related communities. The essential characteristics of *Mode 2* knowledge may be summarised as follows:

- It is generated within the context of application and not solely through scientific experiment
- It is essentially trans-disciplinary and not solely reducible to the outputs of single disciplines
- It is developed within and across widely different organisational forms
- 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
- Quality is controlled not only by scientific peer review but also by other actors including research “clients”
- Issues of policy, commercialisation (including intellectual property rights) and accountability are now very much to fore in corresponding science management

What this adds up to is that the framing context in which knowledge generation/validation takes place has changed. Even where S&T and R&D intensity is necessitated by the knowledge-intensive nature of technologies, the capacity of technology suppliers to determine the innovation agenda has been curbed. Instead, research efforts are steered by demanding providers of finance, by important intermediary bodies like banks and NGOs and by the needs of users. Researchers are increasingly accountable to a progressively more complex array of stakeholder groups and operate in a context of deepening globalisation. At the same time, and reflecting the reigning-in of the pursuit of knowledge for knowledge’s sake, there has been an increasing tendency for knowledge generation to be privately appropriated rather than being seen as a public good

In this context, *Mode 2* innovation has different characteristics. First, the emphasis on usefulness and application has meant that knowledge is developed in the context of use rather than as a process detached from production and consumption. Firms, and groups of firms, become a primary locus of innovation (Bell, 2007). Secondly, the innovation agenda is increasingly trans-disciplinary and much of the requisite knowledge is tacit, and held in teams and routines rather than stored as abstract and codified information.

[12] See Nowotny et al (2003), p 15

Third, many more players are incorporated in the innovation cycle – for example, workers, NGOs, banks, firms in a value chain and users, as well as the “usual suspect” research and technology organisations (RTOs) and universities. And, finally, the innovation process is much more reflexive, involving an interaction (often in a number of iterations) between knowledge-producers and knowledge-users.

It is this changing practice in innovation systems, involving systemic efficiency, in parallel-activities and a combination of big-jumps (“kaikaku” and small improvements (“kaizen”) which has come to dominate the innovation process in high-income economies. Sadly, little of this innovation-best-practice has filtered through to low income economies, who predominantly continue to see innovation as a process of big-pushes, driven by R&D in the S&T system. This leads to major anomalies in a number of contexts. The development of a powerful pharmaceutical industry in India is a landmark in the history industrial development (Chataway, Kale and Wield, 2008) and had done much to provide cheap generic drugs to the world but has done little to address the needs of the poor in India. Moreover, there is still the problem of how to invest science in relation of needs of the poor. The investment in R&D for new drug development in India is heavily oriented to the needs of rich consumers in West mush as it is in large Western based MNCs.
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So, clearly, much can be offered to speed up and make more relevant innovation systems in low-income economies. *Mode 2* principles need to be applied but Mode 2 principles are unlikely to entirely resolve the problem..

4. Beyond *Mode 2*: New Consumers, Disruption And New Entrants

If *Mode 2* innovation systems offer significant benefits in low-income economy environments, to what extent does this meet the challenge of promoting development in these economies? The problem is that this wider diffusion of innovation systems will, at best, only help to arrest the growth in the innovation-divide between high- and low-income economies. It does little to redress the global balance in innovation hegemony or to effectively meet the needs of very low income consumers, the “bottom billion” (Collier, 2007). We have, therefore, to think beyond the *Mode 1 - Mode 2* innovation divide, and to move into an arena which we term “below the radar innovation”.[13] This builds on *Mode 2* practices, but goes beyond them to encompass new and disruptive forms of innovation which simultaneously meet the needs of a very different group of consumers, and potentially change the pecking-order currently governing global corporate and national hierarchies.

In sketching-out this emerging pattern of below-the-radar-innovation (hereafter BRI) we begin by drawing on strands of new behaviour which are either relatively new, or whose significance has, hitherto, been under-recognised. We refer to this ensemble of developments as being “below the radar” since the *collective significance* of these new currents is only poorly recognised at present, not just by policy makers, but also by many of the core innovation systems which continue to plough an innovation path confident in their long-term supremacy as innovation leaders. We begin with a review of some relatively neglected concepts in the innovation systems literature (focusing on architectural systems and global value chains rather than on the national and regional innovation systems addressed in much of the innovation systems literature). We then

[13] We are grateful to John Bessant for suggesting this terminology to us.

consider the emergence of new forms of demand-led innovation, before turning to the opportunities opened for profitable production by the rapid growth of low-income consumers in the global economy.

4.1. Innovation systems

Initially put forward by economists such as Nelson and Freeman in the 1980s to explain the rapid economic growth of the so-called “newly industrialising countries” (NICs) over the latter part of the 20th century[14] the use of innovation systems has been extended and developed widely over the past decades.[15] Originally the concept was developed to deal with the inability of conventional economic variables (such as capital investment and R&D expenditures) to explain differential rates of economic performance and to locate the role of knowledge among a much wider range of stakeholder groups than had previously been the case. The concept is now used as a kind of shorthand for the network of inter-organisational linkages that apparently successful countries have built up as a support system for economic production across the board. In this sense it has been explicitly recognised that economic creativity is actually about the quality of "technology linkages" and "knowledge flows" amongst and between a wide spectrum of economic agents. At least is has in relation to technology development in the high income economies. We shall return to rather different scenario for low income economies below. There are however two additional dimensions of innovation systems which are particularly relevant to BRI. The first of these is the distinction between component and architectural innovation, first highlighted in the early 1990s by Henderson and Clark. The components refer to the core modules of knowledge and capability. The architecture refers to the systemic way in which these components are combined.

Henderson and Clark make the important point that core capabilities in particular components of capability involve routines – structures of governance, of information flow and of organisation (Henderson and Clark, 1990). They engender forms of path-dependency (Dosi, 1982; Nelson, 1993) which may blind firms which possess valuable and complex competences in components from radically different ways of integrating these components - “[a]rchitectural innovation presents established firms with a more subtle challenge. Recognizing what is useful and what is not, and acquiring and applying new knowledge when necessary, may be quite difficult for an established firm because of the way knowledge – particularly architectural knowledge – is organized and managed” (Henderson and Clark, 1990: 404). This path dependency is not limited to the routines developed by individual links with competences in key core components. It applies equally to the design of the architectural system. The system itself, involving often long-lived relations of trust between key players in the chain, is also characterised by sticky and repeated forms of intra-system interaction, and their associated routines.

A second important strand in systems-thinking which is relevant to BRI is that provided by global value chain analysis (Gereffi et al, 2005; Kaplinsky and Morris, 2001; http://www.globalvaluechains.org/). “The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use”

[14] See Freeman (1987) and Nelson (1993) for example. NICs refer to the “newly industrialising countries”.
[15] See, for example, Oyeyinka (2005)

(Kaplinsky and Morris, 2001: 4). There are a number of distinctive features to this value chain approach. One is that the chain typically has deep routes into its supply base, and extended foliage in its links with varied tiers of intermediary processors and final consumers. Chain coordination is thus a key component of successful chain performance. Second, and related, the value chain framework is not just a heuristic taxonomy for recording flows of products, people and knowledge. The coordination which chains require involves power – the power of inclusion/exclusion, the setting and monitoring of chain performance standards, and the allocation of the division of labour in chain roles. Third, in the context of deepening globalisation, value chains are increasingly global, drawing not just on global suppliers, but targeting a global pool of global consumers.

How might these two components of systems thinking influence the significance of a new genre of BRI? The point is that global value chains involve a consortium of firms and related organisations that are brought together in particular business configurations, targeting global markets in the search for economies of scale. The individual links in these chains represent the core competences of Henderson and Clark; the chain represents their architecture. Given that value chains are trust-intensive, these increasingly global system architectures are subject to path dependency, drawing on and incorporating a range of changing competences and players. The governance of these chains is largely in the hands of a relatively small number of TNCs who target global markets with global brands (Toyota, Loreal) and established delivery systems (MacDonalds). They invest vast sums in the sophisticated learning of the needs of their customer base and in aligning the business strategy of their chain organisation to meeting these needs. Although they differentiate their final offerings to meet the needs of culturally specific markets, as a general rule these differentiations are minor variations on a theme. For example, even within France, Nestle markets different blends between northern and southern regions. What they know much less about are the needs of different consumers, very different operating environments, and of the chain configurations which are best suited to meeting these new needs and operating conditions. The neglected needs which are most evident are those of very low income consumers in developing countries characterised by insecurity, volatility, and poor infrastructure.

4.2. Demand-led innovation

Mode 1 innovation systems and their associated production structures are essentially supply-pushed systems. Producers make guesses (sometimes more informed than others) on what they think their final users will value. *Mode 2* innovation systems, as we have seen, are more reflexive, drawing consumers into processes determining the prioritisation of research agendas. In some cases, by exercising financial muscle and using contract supply procedures, users pull required innovation from production systems; in other cases, producers proactively interact with users and other linked bodies in the development of suitable products and processes.

This 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 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).

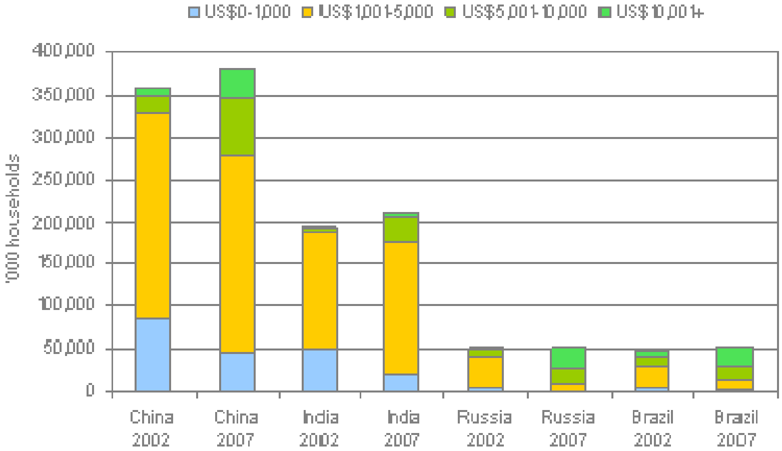
Thus, in an increasing number of sectors, “beta-vintages” are released at a deliberately premature stage of product development to lead-users, aided by the growing sophistication of real and virtual model-making technologies (such as CNC-controlled profilers). Firms “… sell platform products intentionally 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. There are few documented cases of final-user innovation involving low income consumers, or indeed of user-led innovations in systems (as opposed to core components of systems) as in health-delivery value chains.

4.3. The bottom of the pyramid

One of the characteristics of the deepening globalisation which unfolded in the last few decades of the 20th century was that it was characterised by growing inequality. There are clear analytical explanations for this divergence in income streams – for those with rents (including, increasingly innovation rents), returns can be realised over large global markets; for those without rents, competition is increasingly intense and global in nature (Kaplinsky, 2005). The pursuit of these global rents has largely been driven by the core innovators in the high-income economies, producing differentiated versions of core products to cope with the characteristics of specific market. But, essentially these differentiated products are variants of a single core technology. The dominant innovators know, and exploit, their markets – middle and high-income consumers, not just in high-income economies but also (as a consequence of growing inequality) in many low-income economies as well.

Yet, although it is true that as a global phenomenon, income inequality has worsened within and between countries, there has been a single major countervailing factor which has meant that, arguably at least, the population-weighted distribution of global income has not worsened (Milanovic, 2003). This has been a consequence of the very rapid and sustained growth in China, such that despite growing internal inequality, the rapid absolute income growth in a country with one-fifth of global population is such that it affects the global numbers living in particular income groups. China’s rapid and sustained growth is extensively documented, and India, too, has grown very rapidly since the early 1990s. Together these two countries account for almost 40 percent of the global population. Both countries have witnessed the very rapid growth of a new and very large class of consumers – often misnamed “the middle class” despite earning incomes which by high-income country standards would be classified as the “poor” – has been rapid and dramatic. As Figure 1 shows, in both China and India there has been a very rapid growth in the number of households with a collective annual income of more than $1,000 and less than $5,000, the primary community of “bottom of the pyramid cash-consumers. (Below $1,000 per household, disposable cash incomes are too low for significant consumption). China has begun to also see significant growth in the number of households with an income of between $5,000 and $10,000.

Figure 1. Households according to disposable income bracket in BRIC countries: 2002/2007 '000 households



Source: Euromonitor International from national statistics, cited in Media Eghbal (2008), "BRIC economies withstand global financial crisis", 5 Nov 2008, http://www.euromonitor.com/BRIC_economies_withstand_global_financial_crisis

Prahalad and Hammond 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.. Together with Hammond, and in his subsequent book (Prahalad, 2005) Prahalad makes three key points which lead him to characterise this market as being "the fortune at the bottom of the pyramid". First, although incomes are low, many of these people are active consumers of purchased goods and services. But their consumption is often much more socialised than that of higher income consumers. For example, cellular phone handsets in rural areas are shared amongst many users, rather than being individually owned. Second, many of the products which the poor consume make intensive use of radical new technologies, a departure from products classically highlighted in the appropriate technology literature. And third, and perhaps most radically, these poor consumers represent a market of growing significance and provide the potential for highly profitable production. Crucially, Prahalad sees this as providing a market opportunity for TNCs rather than for the SMEs and locally-owned firms long identified in the appropriate technology and informal sector literature as being key providers for low income consumers.

5. Below The Radar Innovation: Prospects For The Future?

The original Sussex Manifesto was written in 1970 as an advisory document for UN policy during the "Second Development Decade". In many ways it was ahead of its time and sought to raise issues that were not part of conventional policy discourse. Regrettably the SM did not really make the impact it deserved and time has gone on. Now 40 years ahead it is clear that the international context has changed considerably raising important questions about the role of S/T in the new globalised 21st century. We have argued that until the late 20th century, the dominant mode of thinking about innovation was to characterise this as a challenge involving the application of science and technology (measured through R&D expenditures) to economic production. Organisationally this gave primacy to scientific and technological inquiry in institutions of higher learning, in RTOs and in the research laboratories of large firms. Conceptually this involved a linear conveyor-belt, loosely characterised as science ➔ invention ➔ technology ➔ production, beginning in the national system of innovation with very high level and disciplinary-specialised skills, and subsequently spreading to the productive sector where innovations were implemented by much lower level skills. In the innovations systems literature this was referred to as *Mode 1* innovation.

This *Mode 1* innovation system began to run out of steam for a variety of reasons outlined in Section 3. It has begun to be supplanted - at least in many high-income economies – by *Mode 2* forms of organisation, involving greater enterprise-based technology development, a heavy input of low-level incremental change, greater interaction between the invention-development-production components of the innovation-cycle, the undermining of specialised disciplinary silos, and a transition from a supply-pushed innovative system to a user-pulled funding process. "Best-practice" thinking about innovation and development is thus increasingly geared towards the promotion of the *Mode 2* framework. There is clearly considerable scope for gains to be realised through the promotion of increased enterprise- and farm-based innovative efforts, and the reflexive interaction among producing units, NGOs, RTOs and higher educational institutions. This policy agenda is increasingly widely recognised (albeit not widely implemented) – it is, to open the radar-metaphor, on the strategic radar screens of many private sector decisions-makers and policy makers in low income economies.

However, at best, the rapid adoption of *Mode 2* only offers the possibility of allowing innovation systems in low-income countries to arrest the growing innovation gap with high-income economies. It does little to challenge the hegemony of established hierarchies in global innovation processes. It does not address the challenge of meeting the needs of very low income consumers. In some cases this means ignoring the demands of consumers who are happy with much lower levels of quality than the products produced for global markets (albeit with variation) by TNCs, and who often consume (collectively on occasions) in distinctively different patterns from the prevailing markets in the high-income countries and the high-income communities within low-income economies. Nor does the *Mode 2* model respond centrally to the need to develop and diffuse forms of production and service delivery which are appropriate to low income economies with poor and unreliable infrastructure and fragmented and seasonal markets. And nor does it meet the needs in many sectors (such as health, agriculture and education) of developing different distributional systems for the delivery of the products and services which they require.

Finally, in key areas such as areas of life sciences, Mode 2 approaches may not resolve science policy challenges of redirecting investment in basic science to meet the challenges of the poor. For example, it is clear that after more than 10 years of investment in highly creative Mode 2 experiments in HIV vaccine research in organisations such as the International AIDS Vaccine Initiative, new approaches to basic science need to be explored. While product and clinical trials based approaches were positive in many respects they did not resolve the quandary of how to steer basic science, such as in cutting-edge systems biology, in such a way as to be relevant to needs to the poor. The current debate over how to evaluate the work of the CGIAR centres and scientists is an indication of the same problem. Should CGIAR scientists and centres be evaluated through the quantitative metrics relating to citations and publication in world leading discipline journals or by their contribution to alleviating poverty and linking to MDGs?

Given this we anticipate the development and diffusion of a new pattern of innovation in and for low income economies which we characterise as BRI. A BRI approach might take the following forms

- In terms of *capabilities*, it is premised on the reality of growing science and technological capabilities in low income economies in general, and in China and India (the two core Asian Driver economies) in particular. This follows many decades of investment in education and skill development, the growth of large and dynamic capital goods sectors, and growing expertise in innovation in business systems, though in poorer regions such as Africa and many parts of Latin America such capabilities largely remain to be built.

- In terms of *markets*, rapid growth provides enormous incentives for innovation and for the reaping of economies of scale and scope (Verdoorn's Law, McCombie, 1986). However, distinctively this is a market of very low-income consumers, with associated trade-offs between price and product quality and variety. Since many of these consumers are also closely linked to the agricultural sector, incomes often vary seasonally. Large households and dense living also provide scope for less individualised and more shared and collective forms of consumption

- In terms of *production parameters*, low labour costs provide the potential for less mechanised forms of production. Infrastructure is typically poor and unreliable, labour relations are distinctive, and in many cases skills amongst the labour force are also low.

Many of these market and production characteristics are long-lived and underpin the long-term commitment towards appropriate technology; the new elements are the dynamic market conditions and the very substantial accretion of production, skill and

Figure 2: Capabilities, markets and production structures underlying BRI

Capabilities	• Science, technology and project management skills • Capital goods • Business systems • Systemic technology development
Markets	• Rapid growth • Particularly rapid growth in low-income market segments • Collective consumption • Seasonal markets
Production parameters	• Low wages • Unreliable and poor infrastructure • Low skill levels

technological capabilities in low-income economies. As we observed above, a key feature of BRI is the *collective significance* of these various developments underlying innovation as a process.

The likelihood, therefore, is for the development of new products in China and India aimed at these low-income markets. The product-process linkage inherent in many sectors – again, observed in the appropriate technology literature – leads to a clustering of production technologies which are similarly reflective of operating conditions in these low-income markets. This is not a development which is confined to goods (for example one child per laptop and wind-up computers), but also to services (for example, the provision of low cost rural health delivery incorporating a mix of western and traditional healers, and innovation in long-distance learning. Similarly, this interactive nexus of low-income products and production technologies is not confined to the core component technologies identified by Henderson and Clark, but equally to the value chains within which they are embedded.

Thus, we anticipate a new generation in innovation systems, with the core development of low-income economy specific products and processes being located in low-income economies, particularly China and India. Because of the context of their development, they are particularly appropriate for other low-income economies. We can already observe this in Africa, for example. Many of the professional elites examining the entry of China into the continent are dismissive of the very poor quality of many Chinese products. However, from the perspective of very poor consumers, a wireless costing $2 may look and sound tinny, and may have a relatively limited lifespan. But it is cheap, and it is appropriate. Similarly on health, some generically produced drugs (such as those treating TB and malaria) may not have the same level of therapeutic benefit as the newest variants of treatment, but they are low-cost and will often minimise the worse aspects of a morbidity inducing condition such as chronic high blood pressure.

But to what extent is this disruptive of established innovation hierarchies? Here it is helpful to turn to the ideas of Christenson whose writings on disruptive innovation have been so influential (Christenson;1997). Christenson addresses the failure of well-performing companies to exploit the development of new technologies. 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). Christenson goes on to observe that "[b]y and large, disruptive technology is initially embraced by the least profitable customers in a market" (op. cit: xvii)

We are anticipating a similar process with regard to the new families of low-income goods and services associated with Asian-Driver based innovation. The disruption in this case is not the arrival of new technologies which drive the search for new markets, but the disruption provided by distinctively new types of consumers, based in low income countries. These markets induce innovation. But in the same way that IBM was oblivious to the significance of what subsequently came to represent an enormous market of distributed computing and memory-storage, so too the existing innovation leaders are unable to either recognise or exploit these dynamic new market opportunities. Their trajectories and market antennae inhibit them from fully recognising these new opportunities which are “below the radar”. Their cost structures – not just with regard to their core component technologies, but also the structure of their value chains - makes it difficult to address these markets, even if they are recognised. And their trajectories and routines place severe obstacles in their dynamic response to these new opportunities.

In this critical disruptive sense, BRI flies in the face of Prahalad’s assertions that northern MNCs can effectively grasp the market opportunities which he correctly identified as arising from the growth of low income consumers in the Asian Driver economies. 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).

Of course there are parallels with the idea of BRI and the appropriate technology movement. In a sense BRI is the maturation of many of the ideas of the AT movement, including the idea of blending simple technologies with advanced technologies such as electronics and nanotechnology (Bhalla, 1984). What is different is that BRI involves the movement of appropriate innovation from the fringes of the growth process and from the purview of the NGO movement to the centre of the globally-dynamic segments of the global economy, the core of profit generation and appropriation in the corporate sector and the heart of social provision by the state in low income markets. Crucially, it is a process predominantly driven in low income economies, by low income economy firms and in some areas by the inclusion of (social and natural) scientists and technologists based in low income countries.

To the extent that such a change in emphasis takes place it will be crucially necessary to incorporate appropriate institutional change within the publicly-financed knowledge system itself. For research institutes and higher education bodies in many low income economies are still largely operating as Mode 1 organisations. As such their impact on development is much less than it could be. For example, new entrepreneurs are often forced to rely on foreign technical inputs even in areas like simple food processing where local expertise should be available (Keskin et al; 2009). Similarly universities produce graduates for whom there are not only no jobs but also whose training is well below international standards. The best graduates then join the external brain drain and are effectively lost to the local economy.[16] Possibilities for capacity building are also

[16] In a recent Panorama TV programme looking at what happens to UK tax payers money as overseas aid one component asked soon-to-be graduates in Uganda where they wanted to work. The vast majority stated they wished to work for an international donor. We are grateful to Ian Maudlin and Andy Frost for drawing our attention to this point

diminished considerably. Hence while there has been a gradual movement towards Mode 2 patterns of institutional behaviour in the high income economies this has not really taken place in many of the poorest low income economies, especially in relation to their universities and agricultural development. Similar criticisms have been levelled at the use and abuse of international aid funding which appears to prop up research organisations (located in both rich and poor countries) and linked NGOs but with little obvious impact on ultimate users. And as mentioned above, even CGIAR institutes established with a specific developmental mandate are now under serious criticism for their apparent lack of impact.

6. Conclusions

In this paper we have tried to show that modern analyses of innovation policy for low income economies are still unduly focused on traditional (and in our view outdated) assumptions about the interactivity of science and economic production. .At the same time there has been little appreciation of the potential for change shown by economic systems in East and South Asia. The policy agenda must now shift towards understanding in much more detail the underlying dynamics of technology developments currently taking place in countries we have labelled the *Asian Drivers* where new patterns of institutional change and capacity building are evolving under the radar, so to speak. We also need to understand how this context of innovation may or may not make the resulting products and services, and the value chains in which they are delivered, appropriate to other low income economies. Some of the results of this understanding will undoubtedly make for uncomfortable reading since they will call in question many of our deeply held assumptions about the structure and functioning of established knowledge systems. Nevertheless the challenges are exciting since they hold out possibilities for a genuine breakthrough in international development. In this way perhaps poverty might indeed “become history.”

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