What sort of knowledge systems do we need in the age of sustainable development?

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What age are we in?

It feels like every conference I attend these days is about industry 4.0. For those of you who have been living under a stone for the last few years, industry 4.0 is predicted as the next industrial revolution, characterised by the deployment of cyber-physical systems, the internet of things and such like. According to the industry 4.0 aficionados, three industrial revolutions have punctuated the past 250 years, each with emblematic technologies. Industry 1.0: Water and steam power. Industry 2.0: Mass production and electricity: Industry 3.0: Computing and automation. It's a neat heuristic, and it's been hugely powerful in getting people talking about imagined technological futures.

The idea that the history of the world can be described by dominant technologies is not new. We all know about the stone age, (which apparently didn't come to an end because we ran out of stones), the bronze age, the iron age, and so on, in phases of ever more technological sophistication. When I was growing up we were told it was the space age, with advanced rocket technology, moon landings, ballistic missiles and Star Trek. My parents where brought up in the atomic and jet age – nuclear technology for bombs and energy and jet engines for fighter planes and cheap holidays abroad. My grandparents grew up in the age of electrical and chemical engineering: Light bulbs and aniline synthetic dyes for textiles, also handy for blowing things up in the First World War. And my great grandparents grew up in the great age of steam power that, among other things, gave them unpleasant and short lives in the coal mining industry.

From technology histories to Knowledge systems

The problem with explaining the past and the future through a purely technology lens is that it doesn't give any sense of the broader purpose to which technological advance is being pursued. Without a sense of the goals and ambitions society trying is to achieve, it is difficult to discuss the science and

innovation capabilities needed to achieve these ambitions through technological change.

For some time now, scholars studying technical change have understood this and explained that innovation is as much a social and political process as it a technological one. In other words, innovation doesn't just involve the hardware of scientific research and technology development. It also involves the software of social interaction, networks sharing and adapting ideas and knowledge. It involves new technological competencies in business and homes. It involves regulation and incentives from governments (and markets) to encourage or discourage the production and use of certain ideas in different ways. And it involves political choices and this in turn means that the direction that innovation takes is always vulnerable to the influence of those with the loudest and most powerful voice. And that's not always in everybody's best interest.

By the same line of argument, technology isn't intrinsically "good" or "bad". Its value relates to the purpose for which it is deployed and ways in which its use is regulated and controlled. For example, the same technology that produced pesticide resistant (roundup ready) soybean could be used to produce drought tolerant millets for Africa. It's a choice that reflects incentives, power and politics.

An emerging way of thinking about how to connect societies' aspirations with science, technology and innovation planning and capacity building is the idea of a knowledge system. At its simplest, the concept is a way of mapping and framing the development of the capability needed to produce and use knowledge for different purposes. Although at a formative stage, the knowledge system concept could, among other things, provide an analytical lens to look at the adequacy of knowledge resources, the functionality, performance and governance of knowledge related capacity, all in relation to a stated purpose (see box 1). Similarly, it has the potential to frame new investment options to build knowledge system capability

Box 1. Elements of a knowledge system.

Knowledge system actors and resources

- All sources of knowledge, formal and informal, public and private and the capabilities to produce and use this knowledge.
- The financial and other resources needed to produce, transmit and use knowledge.

Knowledge system functionality

- The relationships and networks (formal and informal) through which knowledge is transmitted and combined and used for innovation.
- The institutional arrangements, governance arrangements, policy settings and that enable and direct the use of knowledge for innovation
- The policy-making and entrepreneurial capabilities to design and implement innovation policy and manage technological change across enterprise to system scales.

Knowledge systems performance.

- Metrics and evidence of knowledge systems outcomes in relation to national and

other development plans and targets.
- Alignment of knowledge systems performance metrics with national development priorities.

Knowledge system political economy distortions, lock-ins and contextual factors

- The agency of different groups to act within & influence knowledge systems & the power relations of the incumbent system that constrain and enabled this.
- Capacity of systems to learn and adapt, creating new configurations of knowledge, organisations and policies and institutional arrangements.
- The unique historical patterns of institutional and capacity development and cultural and political setting of a particular country.

Exploring knowledge systems in East Africa.

A research team from the African Centre for Technology Studies in Kenya, the UK Universities of Sussex, Greenwich and University College, London, along with the Commonwealth Scientific and Industrial Research Organisation of Australia have recently started to elaborate the use of the knowledge system concept in East Africa in a project funded by the UK's Department for International Development through the East Africa Research Hub. The project known as Knowledge Systems Innovation (KSI), focuses on Kenya, Tanzania and Rwanda. It is exploring how to develop the knowledge system concept to guide investments to create a range of configurations of capability appropriate for different development aspirations in target countries. A key departure from previous analytical and policy practice is the emphasis the concept gives to "*directionality and diversity*". Directionality in the sense of the purposeful steps – governance arrangements, policies, common practices and norms – that ensure that innovation action is aligned to sustainable development agendas. Diversity in the sense of the diversity of sources of knowledge that are deployed to address issues of inclusion, sustainability and economic growth. But also diversity in the sense of an adequate set of different ways of organising knowledge use and innovation to achieve these ends.

The project recognises that as a way of defining directionality the notion of sustainable development is a fairly blunt instrument and that national development agendas are always more nuanced. For example, part of Kenya's knowledge system aspiration is to help socially relevant ICT innovation processes that have emerged informally to better link into the mainstream research system. Flagging the sustainable development agenda is never-the-less a useful way of highlighting that innovation has both a pace **and** a direction and that economic growth is only one performance criteria when considering investments in knowledge-related capability.

The way the project team is developing the knowledge systems concept is not just to apply it as purely diagnostic tools – although this is clearly one important function. Rather the project team views the knowledge systems approach as one that generates and champions a dialogue process (fuelled by evidence from different types of analysis) about (a) the purpose of the knowledge system in terms of development aspirations (b) the sorts of capacities and investments needed to achieve that purpose.

It is early days for this sort of approach. The shift implied by this thinking is likely to be a long-term process that that, over time, changes the science, technology and innovation conversation to one concerned with new forms of capacity and governance that deliver on current development promises. Identifying new forms of investment, assessing their performance and socialising this with policy stakeholders will be a critical part of creating this new conversation.

Why do we need different sorts of knowledge system?

The argument that many countries need to reconfigure knowledge systems might seem puzzling. Surely there is a fairly well worn path on how to do this with experiences of successful economies being a blue print of how to proceed? Well…., actually, no.

One of the challenges relates back to the technology ages that we started with. In this view of the world, the knowledge system that a country needs is one that has science and technology capability related to the vintage of technology that is dominant at the time. So in the industry 3.0 revolution, countries should have built computing and automation science and technology capability and should now be thinking about cyber-physical systems capability. Unfortunately, this line of argument has two important flaws.

Firstly, the most common form of investment in science and technology is developing research capability and systems. In emerging economies this is usually in public sector research systems. The problem is that while research systems are necessary for innovation, they don't guarantee it (remember the social software of innovation mentioned earlier). Other forms of investment are also required.

The second, is that, as already mentioned, the critical question is not about how much research and other capability is need, but more importantly what it is needed for. To make this argument differently, science and technology capability – actually the whole of innovation capability -- is not only framed by the frontier technology of the moment. It is framed by the purposes to which society wishes to deploy that capability. Or at least it should be.

Development epochs and their knowledge systems

To illustrate this, the table below takes a stylised look at the nature of different knowledge systems ages over time. This helps highlight major differences in each development epoch and the reasons why knowledge systems need to be adapted to these.

Knowledge system epoch	**The age of the Western economic revolution 1.0** 1700 -- 1900	**The age of global conflict 2.0** 1900 -1980	**The age of global reconstruction and de-colonisation 3.0** 1945 -- 1980	**The age of (neo)liberailsation . 4.0** 1980 -- onwards	**The age of sustainable development . 5.0** Now
Defining	Industrialisatio	Maintaining	Rebuilding or	Rolling back the	Tackling

feature of the development epoch	n and securing access to natural resources through colonisation	existing world order through a military technology race.	creating new economic capability, establishing new technology based industries.	state and creating public value through the market.	planetary boundaries and rebalancing social and environmental performance of economic systems
Defining feature of Knowledge systems in each	Learned societies pursuing scientific discovery. Entrepreneurial engineer inventors driving industrialisation Public investment in natural resource commodity research to boost supply from the colonies	Massive expansion in public research in military technology and related civil applications. The emergence and prospering of R&D intensive companies	Heavy investment in public good research capability and research and education.	Increasing reliance on market forces to determine research priorities and innovation directions. Reductions in the size public good research capability	Context relevant patterns of knowledge system capability appropriate for different societal aspiration

Its easy to pick holes in this stylised view of different ages of knowledge systems: the different ages were never sharply demarked; some of the knowledge systems capacities of earlier ages are still relevant to the current age of sustainable development; knowledge system are always tin catch up mode, chasing the aspirations of new and ever-changing epochs. The message however is that if we are serious about driving the sustainable development agenda through innovation, we need to think seriously about the type of knowledge system capability that is going to be needed and how to adapt the capabilities developed in the 20th century for the altogether more challenging 21st century. Maybe the next conference I go to will be on knowledge systems 5.0 ☺

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