COMMENTARY

Science and innovation in the 21st century: new paradigms and challenges for policy design

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Responsible innovation, entrepreneurial university, translation gap, valley of death, sustainability, risk, regulation and governance broadly encompass the oeuvre of innovation studies, and are becoming ubiquitous concepts in the debate on science, technology and innovation (STI). Close reading of the literature shows distinct strands of research within this domain; lack of convergence in terms of conceptual framework leading to articulation of different models for conduct and governance of science and technology (S&T). The persistent selective framing of innovation is leading to considerable bias in the way we theorize and define innovation, resulting in articulation of weak policy frameworks. This note draws attention to two dominant strands of scholarship within innovation studies, one influenced by economic thinking and the other STS (science–technology–society studies) to make the above claim. Keeping this as the basis of argument, the note posits that this divergence is creating impediments in developing successful models for translation of S&T for socio-economic benefits. Thus it calls for exploring and exploiting models that can build convergence between the different strands of innovation research. In this context, it draws attention to the promising possibilities of the 'post-normal science' thesis to show this as one of the useful analytical frameworks in the contemporary context.

Divergent strands within innovation studies

Science is increasingly being seen as an object for exploitation and wealth creation in innovation studies influenced by the economics school of thought. Strong evidence from empirical studies shows knowledge-intensive activities as a critical factor in making a company/region globally competitive, thus providing support to this theoretical research strand. 'Turning science into business' is an underlying thesis of this school of thought. Keeping it as a dominant concept, innovation scholars devote attention to mechanisms that can create tradable knowledge (commodity) and successful models of translation/technology transfer[1,2]. Emergence of the so called 'science-based-technologies' has led to the dispersion of scientific activities across different locations and articulation of a 'third university mission', that of engagement with societal needs and market. This has also influenced new technology-transfer models bringing innovation, entrepreneurship and translational research within the mode and practice of science. These are being operationalized through creation of novel institutions such as science parks, incubators, start-ups and accelerators. These new institutional structures highlight the distinctive shift in innovation perspective influencing policy; from earlier one-dimensional directed science push[3]/demand pull linear models towards looking at innovation as a coupling and matching process that inescapably intertwines technological and economic dimensions[4]. Evolutionary models that emphasize diversity within the system and its ability to selectively exploit trajectories and transition from one technology to another, thus brought in the evolutionary perspective in understanding the process of innovation[5].

New models that underscore S&T institutional interactions draw attention to innovation as a systemic phenomenon. The systemic approach to innovation, the system of innovation (SI) approach complements the 'market failure' rationale for government intervention by an 'institutional failure' rationale[6]. The central thesis of this approach is that firms do not innovate in isolation, but depend on interactive learning between actors and institutions. Unlike neoclassical theory, it also addresses to some extent the uncertainties inherent in innovation. The National Innovation System framework which has been extended to regional and sectoral innovation systems has become an influential model in policy formulation globally[7]. Its influence can also be seen in other models, such as Ekzkowitz and Leydesdorff[8] rethinking innovation as taking place in a hybrid space of a 'triple helix' of university–industry–government interactions.

The other dominant strand of research in innovation studies is seen influenced by STS. STI as a social phenomenon is the underlying thesis of STS. Social constructivist approach has emerged as a useful analytical framework in STS. A central tenet of this framework is that technological artifacts are socially constructed and are open to sociological analysis. Similarly, scientific knowledge claims are examined in a wider political and social context. One of the roots of any scientific controversy is that scientific findings are open to more than one interpretations (interpretive flexibility), and its closure requires social mechanism. The developmental process of technological artifact is described as an alternation of variation and selection resulting in a 'multidirectional' model[9]. Actor-network thesis is another important analytical framework within STS. Actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to refine and transform what it is made of. We observe that the concept of social capital in SI borrows from this school of thought of 'structural embeddedness', which emphasizes that individuals, i.e. actors are able to acquire capabilities through social networks.

The changing context of science

Science is seen as a key determinant in addressing global challenges of health, water and climate change, and also as a driver for competitiveness and economic growth. On the other hand, the infallibility of science is being questioned. We increasingly find in the debate on climate change, pollution, genetic engineering, exposure and toxicity among others, that new models are required to address these contemporary challenges. Accelerating technology change and increasing competitive pressure is plausibly the reason behind introduction of new products in the market without the extensive testing required. The recent example of battery bursting of mobile phones shows how big companies are pushing their new products in the market without proper safeguards. Many influential technologies/technological interventions that have been cited as successful innovations are being questioned because of adverse socio-economic impacts that were later observed. Chlorofluorocarbons (CFCs) as a ubiquitous cooling agent became a global concern as increasing scientific evidence showed them to be the major contributor to ozone-layer depletion. The contentious replacement of this cooling agent with huge technology transfer cost for developing countries is another story[10]. The high socio-economic impact of the green revolution in India had led to overlooking the adverse consequences that emerged from it. It is now widely accepted that caution should have been exercised before its widespread introduction.

These pressing issues are calling for the need to go beyond the 'predictability model of science', as emerging technologies are exhibiting unknown risk environments and uncertainty which have no precedence. Thus, established forms of risk assessment may not be applicable to new technologies. There is a growing demand for public participation in scientific and technical decision-making and policy formulation. The overall view is that 'science becomes more and more necessary, but at the same time less and less sufficient for the socially binding definition of truth'. This calls for governance of S&T to go beyond the narrow framing of STI, for example, ethical–legal–social aspects (ELSI) intervention at the early stage in identifying impact of S&T to avoid future social, environmental and health problems. Funtowicz and Ravetz[11] define science in this contemporary perspective as 'post-normal', where facts are uncertain, values in dispute, stakes high and decision urgent; 'to indicate that the puzzle-solving exercises of normal science (in the Kuhnian sense) which were so successfully extended from the laboratories to the conquest of nature, are no longer appropriate for the resolution of policy issues of risk and environment'. They claim that in assessing the health risks of chemicals, or tracking the movement of an environmental contaminant, or predicting effects of human activities on global temperature or the ozone layer, one has to move beyond the statistical inference values and models. The activity of science now has to encompass the management of irreducible uncertainties in knowledge and in ethics, and the recognition of different legitimate perspectives and ways of knowing.

This thesis accommodates to some extent the contemporary thinking by influential scholars. Ulrich Beck[12], for example, characterizes modern society as a 'risk society', 'which is increasingly occupied with debating, preventing and managing risks that it itself has produced'. Giddens[13] introduces the concept of 'manufactured risk', which he defines as hitherto risk environments which have no precedence; and hence we have very little previous experience of how to deal with the threats posed by such risks. Wynne[14] argues that reflexivity is excluded from the social and political interactions between experts and social groups over modern risks; the systematic assumption of realism in science is also underscored by this thesis.

Final remarks

New technologies have far reaching socio-economic impact. Genetic engineering not only has the potential to control and regulate the functions of genes, but also to modify an organism. Modification of life forms through genetic engineering and their patenting has led to contentious debates. Nanotechnology, on the other hand, is the control of matter at the nano scale, wherein new radical properties emerge due to size. Uncertain facts emerge at the nano scale, still a lot science does not know. Contestable knowledge and resolving disputes within science is becoming difficult in new technologies. A more radical shift is seen in recent years with increasing maturity and convergence between digital, physical and biological technologies.

To some extent we see emergence of new approaches to address risk, uncertainties and values that are at stake. We see, for example, ELSI, real-time technology assessment (integration of social science and policy research with science and engineering research from the outset)[15], constructive technology assessment (social impacts of S&T being anticipated and accommodated within S&T development itself) in STI policy discourse and implementation strategy[16]. These different approaches are being integrated within the broad framework of 'responsible innovation'. The roots of this framework can be seen in the post-normal thesis[17,18].

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