*Changing Social Relations between Science and Society: Contemporary Challenges**

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Social history of modern science, particularly the way it acquired social legitimacy, clearly depicts the science and society relationships emerging from the time of Galileo. The social institution of science has evolved as one of the most powerful, highly influential and sought out institutions. Knowledge as public good; peer review of science; prominence attached to open publications; and premium placed on professional recognition and scientific autonomy remained the hall mark of science for the last three centuries. Based on this ethos of science, the social institution of science evolved a unique social contract between science and society in the last six decades. As we enter the second decade of twenty-first century, the social institution of science is undergoing a major change. Three societal forces are responsible for the change: (i) globalisation; (ii) industrial and post-industrial society; and (iii) climate change. What is at stake? Is there a significant change? Is it transforming the very social institution of science? And what implications this has for our contemporary and future society? These are some of the important issues, which will be addressed in this article.

The epistemological roots of science, in all its ramifications, can be traced to Asia, Mesopotamia, Egypt, through Greeks, Judeo-Christian, Arab and scholastic traditions. From Bachelard's notion of 'epistemological break' or Kuhnian notion of paradigmatic shift for modern science began the renaissance and reformation (fourteenth to sixteenth centuries), which gave birth to historic figures such as Galileo Galilei and Leonardo da Vinci. Another enveloping but a complimentary era followed this development. Science as a body of systematic knowledge

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about nature and of universe from the time of the Copernicus Revolution and the age of Enlightenment (sixteenth and seventeenth centuries) culminated into what historians of science termed as the seventeenth century Scientific Revolution. This era for the first time witnessed institutionalisation of modern sciences in various professional societies and the bodies such as Academia dei Lincei, Rome (1603); Leopoldina, Germany (1652); Royal Society, London (1660) French Academy of Sciences (1666) rechristened as Royal Academy of Sciences, France (1699); Russian Academy of Sciences (1724) Dublin Academy of Science (1735); and Asiatic Society of Bengal (1784), among others.[1] It may be pointed out that precursor to these bodies is 'Solomon's House' of Bacon. Francis Bacon in his utopia *New Atlantis* (1627) painted the picture of future university and science organisation featuring knowledge as cumulative process by community and experimentally testable organisation.

However, as influential writings of Ben-David (1971), among others,[2] draw our attention to the fact that it was not until eighteenth and nineteenth centuries that science and its activities pursued by professionals and begun to acquire the status of a profession. Scientists began to have the career with regular emoluments, employment in research institutions, professional bodies and universities. Creation of university chairs, Ph.D. training programmes, establishment of science societies, launching of professional journals and research laboratories as well as the advancement of systematic knowledge emerged and developed by mid-nineteenth and early twentieth centuries. This process is an integral part of the professionalisation of science. This process began in the developing world of Asia, Africa and Latin America from the middle and later parts of twentieth century (see Gaillard et al., 1997; Waast, 1996).

The social history of modern science, particularly the way in which it acquired social legitimacy and utilitarian values clearly depicts the science and society relationships fully emerging from the time of Galileo Galilei.[3] In twentieth century, this relationship between science and society reflects in large measure, Comtian positivism in its third stage. In a way it,

> characterized the story of science from remote antiquity, but especially from the Renaissance and the Scientific Revolution of the Seventeenth Century, as one of steady accomplishment, a march of the intellect, achieving victories over myth and superstition by a lengthy process of observation, trial, error and eventually the codification of laws and theories. (Mac-Leod, 1977, p. 152)

Science, over a period of time, acquired social legitimacy and in the process came in conflict with the Church and the religion. This is well documented in the case of Galileo who upheld and advocated Copernican astronomy. Underlying the processes of science gaining social legitimacy is the web of social relations among science, its practitioners, the knowledge it generated and the society. The element of rationality, truth and what has come to be known as objective knowledge was widely accepted and upheld by the society at large. Over a period of time, it has come to be recognised as part of the culture, a perspective, an ideology and a viewpoint of society.

As one Indian historian argues, 'science as culture and as part of the social formation of society … is more wide-angled and takes in many facets involving interactions and osmosis'. The 'knowledge emerges from the combination of an indigenous genesis together with transmission from other coexisting cultures, a transmission which can involve some contestation and some negotiation. This process takes the form of cultural transactions, within a culture and between cultures. Knowledge, viewed either as a body of information or as theories of explanation, is part of this transaction' (Thapar, 1999, pp. 16–18).

Science as culture can be understood in two ways and forms, both the integral parts of society. 'First in its own evolution and secondly in its accommodation by culture' (Gillispie, 1962, p. 89). In the intellectual debates of history and sociology of science these two forms of science are seen as 'internal' and 'external' for quite some time now. As Thomas Kuhn (1968, p. 76) pointed out, internal form of science is 'concerned with the substance of science as knowledge' and external form relates to 'the activity of scientists as a social group within a larger culture'.[4] Another influential sociologist who laid the foundations since mid-twentieth century to explore and analyse science and society relations is Robert K. Merton. Extending the cultural foundations of science from a number of empirical studies of scientists in the seventeenth century, England and particularly the Royal Society, Merton may be credited to have also laid the foundations of science as a social institution:

> Science is deceptively inclusive word which refers to a variety of distinct though interrelated items. It is commonly used to denote a set of characteristic methods by means of which knowledge is certified; a stock of accumulated knowledge stemming from the application of these methods; a set of cultural values and mores governing the activities termed scientific or any combination of the foregoing. We are here concerned in a preliminary fashion with the cultural structure of science, that is with one limited aspect of science as an institution. (Merton, 1972, p. 66)

This insight and perspective of science as culture and science as integral part of a wider culture or as a sub-system of society (among other sub-systems such as social, political, economic and market) is seen as basic to our exploration of the changing social relations between science and society in this essay. The concern here is not just the science, science community and science as social institution but also the impact of science on society and vice versa. In other words, our concern will be on ways in which this institution of science has changed as a result of various forces acting and influencing it. The term science is being used here in a rather broader sense of understanding of science as social system and its influence on society by its application.[5]

As we have briefly sketched what is otherwise well known, the social institution of science has evolved as one of the most powerful, highly influential and sought out institutions by the governments, private and corporate business enterprises and society at large. It is needless to elaborate here that the institution of modern science as it evolved over a period of more than five centuries is intimately associated with the material wealth, prosperity and in improving the health, longevity and living standards and comforts of our daily life-worlds. At the same time, we cannot ignore the fact that it is in some way or other associated with certain dangerous consequences and dysfunctional impacts on society.

The era of unbound optimism over science, progress and development has come under recurrent scrutiny since the 1970s. Whether it was Rachel Carson's (1962) *Silent Spring*; Club of Rome Report (1972) on *Limits to Growth*; or the critiques coming from scholars such as Ashis Nandy through his controversial volume on *Science, Hegemony and Violence—A Requiem for Modernity* (1988)—clearly reflected the changing mood over science and society relations. This critique progressed in the 1990s and has come into sharp focus in the last decade, particularly with the impact of globalisation. The enthusiasm and euphoria of globalisation did not last long. Within a decade and a half of globalisation, Joseph Stiglitz cautioned us with his most influential work on *Globalization and its Discontents* (2002) and followed it up by another new insight, *The Price of Inequality: How Today's Society Endangers Our Future* (2012).[6] America, which was seen as the most powerful and wealthiest among the industrially advanced countries, is now characterised by Stiglitz as the country with 'most inequality, and the least equality of opportunity, among the advanced countries. While market forces play a role in this stark picture, politics has shaped those market forces.' It is quite obvious that science as social institution cannot remain oblivious of the social reality of this changing world painted by the Nobel Laureate. This disenchantment with globalisation is in fact wide spread out in the developing world (see Bardhan, 2010; Drez and Sen, 2013). While these intellectual discourses set out a warning on the extent of crises unfolding upon our lives, one source of influential reports in the last decade has further jolted our imagination and earlier enthusiasm over optimism of science in addressing societal problems confronting us. Series of reports from the Intergovernmental Panel on Climate Change (IPCC) on the problems of climate change, in a large measure, drew attention to how hyper industrialisation and modernisation drives by all countries led to this alarming situation that we are confronting today.

As we move into the second decade of twenty-first century, the very fact that the main theme of this essay is on changing relations between science and society raises several issues: What is at stake? Is there a significant change? If so, what has really changed? Is it transforming the very social institution of science? What are the forces acting upon this historic and most powerful social institution? And what implications this has for our contemporary and future society? These are some of the main questions which will be addressed in this article. In doing so, it will be pertinent to delimit the exploration here so as to make it manageable given the limitations of space and time. In the light of what has been briefly discussed in the preceding sections, we can see that there are three major societal forces impacting the social institution of science: (i) the forces of globalisation; (ii) industrial and post-industrial forces and (iii) the impact of climate change and sustainability. These are seen to be responsible for the changing relations between science and society. Let us begin with globalisation and its impact on science–society relations.

Globalisation and the Changing Social Contract between Science and Society

Globalisation

There are scholarly writings that support as well as oppose globalisation. There are other scholars in the past who have not considered it as a form of social force as only small parts of economy or segments of the population, both in the developed and developing worlds, were touched and impacted upon by globalisation in the 1990s. Notwithstanding this stance, the fact remains that the world economy, markets flows and creative industries including science and technology are much more integrated today than ever before in history. The impact of globalisation, understood in terms of Thomas Friedman's *The World is Flat* (2005) or in terms of the increasing interdependence of nation states, is so pervasive that it is difficult to deny or ignore its impact. Even though the concepts of nation state, sovereignty, national economy and even a sense of nationalism are quite strong and manifest themselves in varying forms in our lives, there is an overarching impact of globalisation that is difficult to ignore.

The impact of globalisation is not confined to mere social (world as global village via the information and communications technology revolution) or economic (role of Transnational Corporations and the movement of global capital flows) or political spheres of our lives (global and UN regimes in security, international trade, environment, etc., binding on countries). Globalisation has penetrated deep into the very institution of science and technology since the last couple of decades and has in fact already begun to transform this very social institution of science that has evolved over the last 300–400 years. The major point that is being advanced here in this section is that the social contract between science and society that has evolved in the post-war period, embedded in the ethos of science as social institution, is undergoing a major transformation. Before we get down to explore the features of transformation that is under way, it is pertinent here to spell what is meant by the social contract.[7]

Social Contract between Science and Society—Post-war Experience

Social contract[8] is a tacit understanding between actors and it is a trust reposed on a body or an institution for the service it renders in the interest of general public and society at large. Social contract in terms of trust evolves over a period of time and is not a sudden development. It may be manifested in different forms and contexts. It may remain in a specific context, country or region or might spread across countries and cultures. Indeed it may be seen as a social principle that is legitimised as it finds acceptance. It may become binding and socially acceptable though it may not have a legal sanction. That being the case, the social institution of science evolved certain norms and ethos of science, which provided a philosophical and moral underpinning to the social contract that has evolved in the post-war period.

As pointed out earlier, Merton's (1972) pioneering research on science as social institution, so far, remains one of the most important but an idealistic explanation of social contract between science and society based on certain ethos of *universalism, communalism, disinterestedness* and *organised scepticism*.

Universalism exemplifies impersonal character of science for the acceptance or rejection does not depend on the social or personal attributes. Careers in science are open to talents based on the professional recognition. *Communalism* ethos is antithetical to secrecy and property rights. 'Intellectual property' is limited to that of professional recognition and esteem that the community of science as social institution bestows upon individuals and groups. 'The institutional conception of science as part of public domain is linked with the imperative for communication of findings. The pressure for diffusion of results is reinforced by the institutional goal of advancing the boundaries of knowledge and by the incentive of recognition which is, of course, contingent upon publication' (Merton, 1972, p. 74). *Disinterestedness* draws attention to passion for knowledge, idle curiosity and altruistic concern for the benefit to humanity and society at large. Competition and recognition for contribution to the advancement of knowledge is very much part of the norm of disinterestedness. Scientists expect nothing else but recognition from the institution of science. *Organised scepticism* signifies the very notion of doubt or a scientific temper as it is seen both a methodological and an institutional mandate. Scientists are expected to suspend judgement or details about their research till the facts are at hand. They need to scrutinise beliefs about scientific facts in terms of empirical and logical criteria. 'In modern totalitarian society, anti-rationalism and the centralization of institutional control both serve to limit the scope provided for scientific activity' (Merton, 1972, p. 78). As he goes on to explain:

> The ethos of science is that effectively toned complex of values and norms which is held to be binding on the man of science. The norms are expressed in the form of prescriptions, proscriptions, preferences and permissions. They are legitimized in terms of institutional values. These imperatives, transmitted by precept and example and reinforced by sanctions are in varying degrees internalized by the scientist, thus fashioning his scientific conscience or, if one prefers a latter-day phrase, his superego. Although the ethos of science has not been codified, it can be inferred from the moral consensus of scientists expressed in use and wont, in countless writings on the scientific spirit and in moral indignation directed toward contraventions of the ethos. (Merton, [1942]1972, pp. 66–67)

From a Mertonian perspective, the ethos of science, that is, institutional imperatives, is derived from the goal of science and the methods, which is the systematic production of knowledge that we call science.[9] 'The mores of science possess a methodologic rational but they are binding, not only because they are procedurally efficient, but because they believed to be right and good. They are moral as well as technical prescriptions' (Merton, 1972, p. 68). In a somewhat similar vein, Michael Polanyi (1962) argued for freedom and autonomy of science institution in his influential work *Republic of Science*. Community of scientists is organised and works according to the same principles that is found in economic production,[10] the 'free cooperation of independent scientists' and is a 'special case of coordination by mutual adjustment'. As pointed out by Guston (1992, p. 4), for Polanyi the freedom and success of science ultimately hinge on this social contract. 'The Republic of Science realizes the ideal of Rousseau, of a community in which each is equal partner in a General Will.' As the citizens in Rousseau's explanation of Will, scientists are subjected to a General Will represented by scientific opinion. The submission leaves, each free but each is also obliged and devoted to the ideals of scientific work (Polanyi, 1964, p. 64).[11] In a Weberian sense the social institution of science drawn by Merton and Polanyi exemplifies an ideal institution of science and the way in which scientific knowledge is constituted and produced. Underlying the social institution of science is considerable autonomy assigned to science. However, one should note that the perspective of science as social institution governed by ethos with considerable autonomy guaranteed by governments is not without ideological moorings and political orientations.[12]

This contract acquired legitimacy in the organisation of science encompassing universities, public and private research laboratories, science councils and science academies. Actors in these institutions produced systematic knowledge and advanced the state of scientific knowledge yielding societal benefits. They would also train scientists and engineers, doctors and a range of professionals needed by the society and industry. It is for this reason that the state and governments in the public interest funded scientific research but did not normally interfere with research autonomy. Scientific knowledge production was by and large regulated by a peer system, which is controlled by the institution of science.

As Gibbons (1999) noted, industrial and business enterprises would normally produce science as well as take basic scientific knowledge produced in various institutional segments and applies it to make products and innovations. They would in the process, of course, make profit for the investments made in converting this knowledge. Governments will continue to fund scientific research from public purse to fill the gap between the public good of science and the private good of industry and business enterprises. They would do this as they have the responsibility for defence, national security, public health, safety, creating infrastructure, etc. Wherever there are market failures governments would step in to fund science in the public interest. These features together with the ideals of Merton and Polanyi remained as the cornerstone of the scientific enterprise in the post-war era. As pointed out earlier, these ideals and ethos of science manifested in varying forms and contexts of scientific research organisations around the world. In sum, they represent and define the social contract between science and society. Drawing upon historical experience of science and society relations, Ben Martin (2003) draws attention to some important guiding posts, which have cemented the social contract of science in the post-war era.

At the conclusion of Second World War, Vannevar Bush[13] was given the charge to produce a report to plan post-war organisation of science and technology in the United States of America. As it turned out, this report became an historic document called *Science: The Endless Frontier* (1945), often referred to as *Vannevar Bush Social Contract* for science in USA. What we know as 'science-push' or linear model of innovation[14] that guided scientific research in the post-war era was set out in the Bush report. As Ben Martin (2003, p. 9) points out, 'the clear implication of the model was that if, government put money into the basic research end of the chain, out from the other end of the chain would eventually come benefits in terms of wealth, health and national security, although what form those benefits would take and when they would materialize was unpredictable'. As he further went on to specify, Bush's social contract laid down various principles of science organisation: (i) high level of autonomy for science; (ii) decision on which areas of science should be funded be left to scientists; (iii) peer review to allocate resources for research and (iv) basic research best suited to be carried out in universities.

In substance, the essential features of social contract between science and society that we have seen above manifested in other institutions in Europe and Asia. For instance, the *Humboldt model* of organising modern universities, which combined teaching and research functions in the same institutional sphere for the first time, is referred to as *The Humboldt Social Contract* (Ben Martin, 2003). This model spread all over Germany and to other countries. Here also the government assumed the main responsibility to fund university-based research with considerable autonomy.

In France, even though *Grandes Ecoles* and universities to some extent concentrated on teaching, the full-time basic research was delegated to specialised science organisations such as National Centre for Scientific Research (CNRS). In essence, the principles of social contract were widely prevalent and flourished throughout post-war era until mid-1990s. For instance, Aubert Guy (1995) the Director—General of CNRS in 1995, remarked 'until recently we have lived with the dogma that it was necessary to support the development of knowledge'. It was only after 1990s that transformations began to occur in France (see Vavakova, 1998).

In Britain the social contract was upheld by the *Haldane Principle*, which advocated that the government would fund scientific research but scientists will be left with considerable autonomy as to how to spend their research money on fields of research. The decisions on research were left to the scientific community and research councils. Funding research universities were left with considerable autonomy until about 1970s and 1980s when *Rothschild's Report* begun to have some impact on science.[15] Similar situation prevailed in large science organisations in Australia, Canada, New Zealand, India and South Africa.

Changing Social Contract between Science and Society—Post-1990s

With the onset of contemporary phase of globalisation from the 1990s, a definite cleavage emerged in the social institution of science. The social contract that emerged immediately after the Second World War, which legitimised autonomy of science and considerable public funding for research for almost five decades, begun to weaken. Ethos and norms of science such as public good of knowledge; peer evaluation and peer review of science from groups within the discipline-based scientific elite; social control of science exercised by the social institution of science; prominence attached to open science which was conducive to the advancement of knowledge; premium placed on professional recognition and rewards and various other values which remained the hall mark of science begun to transform under the impact of globalisation.

In 1994, six science policy experts led by Michael Gibbon from the Sussex university's Science policy Research Unit put forward a thesis to argue that the academic science and the ethos of science as social institution characterised as Mode-1 knowledge is undergoing a transformation to post-academic science system they called Mode-2.[16] As well-known physicist and science policy analyst John Ziman (1996, p. 752) remarked, 'academic science is undergoing a cultural revolution. It is giving way to "post-academic" science which may be so different sociologically and philosophically that will produce a different type of knowledge.' There are several other influential scholars[17] who shared the view that the contract between science and society is changing fast. In the light of this brief review on social transformation of science and society relations, let us see what is at stake? What is actually changing or transformed over the last two decades or so?

Public Good to Market Good

Historically speaking, public good in science, which entails making scientific discoveries and scientific facts known and disseminated in the interest of public and welfare of the society at large, played an important part. Public good *versus* market good are based on two different opposing logics: that of open disclosure of research and thus enabling free circulation of knowledge; and that of suppressing information from reaching the public for making a profit or regulating research based on market criteria and steer it towards commercialisation of research. The 1990s witnessed the beginning of the new tension between these two logics in the organisation and administration of scientific research the world over. The tensions increased with the globalisation and the rise of Transnational Corporations worldwide. Operating mechanisms of market driven commercial interests were applied to regulate research in most public science organisations from 1990s.

R.A. Mashelkar, Director General of India's largest science organisation, Council of Scientific and Industrial Research (CSIR) in January 1996 articulated new research policies called *CSIR 2001: Vision and Strategy.*[18] These policies, in effect, opened a new 'paradigm' signalling a break with the past. This new policy became a road map and a strategy for future of CSIR functioning well into the present times. Mashelkar considered himself as the 'CEO of CSIR' and defined a *new product* and *process* for CSIR. 'The new product was research as a business. The new process was doing research in a business like manner,' which in all its ramifications enthused the industry, corporate and business world through creating a global R&D platform (Krishna, 2007).

The Director General of French CNRS and the Chief of Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) expressed similar changes in the goal direction of research. For instance, Guy Aubert, the chief of CNRS in 1995 said,

> it is necessary to reinforce our partnership with business firms and the external world generally …. Researchers should recognize that in the present crisis it cannot be taken for granted that there will always be more money to develop knowledge or research… Until recently we have lived with the dogma that it was necessary to support the development of knowledge.[19]

In the case of Germany, the fall of Soviet Union and unification of Germany after 1989 also signalled the end of the post-war social contract between science and society. As Weingart and Maasen (2007, pp. 75–76) observe,

> one of the latter's central elements had been the institutionalized trust in the self-regulating mechanisms of science assuring the prudent use of public funds and the ultimate utility for the common good of their expenditure. The erosion of this leading principle gave way to a 'new deal' between science and society, basically resting on the idea of universities becoming both efficient and organizational actors, largely governed by a managerial regime.

In Australia, CSIRO's National Research Flagships initiative was launched in 2003 by constituting six national multidisciplinary programmers. For the first time CSIRO hired top professionals from the US Business Schools to design a new trajectory of commercialisation in scientific research. Research at CSIRO by 2002 was reorganised in terms of national 'flagships'. A Deputy CEO of CSIRO stressed that while 'flagships are about doing excellent science, they are also very much about delivery, about ensuring that the technology or outcome of the research is taken up and used' (Krishna, 2007).

Advancing Knowledge to Creation of Wealth

Scientific communities and large science organisations have begun to give less and less importance to the advancement of knowledge. They are reoriented towards 'creation of wealth'—an important ideological shift that has happened in the last couple of decades. There has been a corresponding shift of emphasis from basic research to technological innovation and commercialisation. There is nothing wrong in the creation of wealth from knowledge. Scientific organisations in the post-war era under the *existing* social contract have been involved in this process via a linear model of innovation. But the problem under the *emerging* social contract is that the operating principles of science organisations are undergoing a transformation to mimic corporate R&D whose structure of relevance is with market and commercialisation of products. Value addition, profit and creation of wealth have become a primary goal, whilst the advancement of knowledge has taken a back seat. Manifestation of this ideological change can be observed in science organisations.

During twelve years between 1984 and 1996 CNRS increased its contracts with firms almost tenfold, from 350 to more than 3,200. Assisted by a series of tax incentives and the focus of the National Agency for Valorisation of Research (ANVAR) on SMEs, CNRS partnerships with industry received a good boost in the 1990s. In the last decade there have been recurrent drives towards reorganisation and evaluation of the French CNRS and universities that led to massive protests since 2008. National Research and Innovation Strategy was launched in 2009. In varying forms these are attempts to drive research more towards innovation and market end of the R&D spectrum for the creation of wealth. The National Agency for Research created in 2005 to fund research on the competitive basis and the Competitiveness Cluster Policy came into operation in 2008. The same year witnessed the reform of French universities. For the first time in history the governance of public research in universities was changed to allow firms to get representation in the Board of Directors. There is a clear sign of shift away from the advancement of knowledge towards commercial interests not only in CNRS, but also in major science agencies in Germany, Australia, UK, Japan and India. This is not only going to have serious implications for the generation of new knowledge, but also will impede the very progress of science.

There are serious distortions in priorities of scientific research taking place. For instance, UK's Economic and Social Research Council's (ESRC) programme in science in society observes that 'Global Forum for Health Research has concluded that 90% of the world's health research is spent on research into problems that only effect 10% of the world's people' (see ESRC, 2003). Monsanto's 'Terminator Gene' is another example of how scientific research is being directed to maximise profit and increased market access for products. This has been happening since quite a long time in corporate research. The radical change that has come about is in the large public research organisations and universities, which are now partnering corporate R&D in a big way.

The two changes, namely market good and creation of wealth that are well-entrenched in the institution of science have begun to have very serious implications for a number of developing countries. For instance, the initial processes of institutionalisation and professionalisation of science that is going on in several African countries is disrupted in the face of radical changes that are taking place in the social institution of science.

Open Science to Secrecy and Intellectual Property Rights (IPR)

ICSU (2005)[20] expressed serious concerns with regard to equity, access and challenges of universality (ICSU, 2005, p. 12). Its report noted that

> end of Cold War has not brought, as some had hoped, an end to concerns about the mobility of scientists and the free flow of science. Rather, traditional threat to mobility and Principle of Universality continue in many areas of the world in the form of state discrimination against scientists and repression of research and communication. (ICSU, 2005, p. 12)

There are some other serious developments, which indicate how open science is sacrificed. There is a big move towards IPR, secrecy and patenting in science, which has already taken deep roots in the science system. Some notable developments are as follows:

1. On 8 February 2004, a body called Union of Concerned Scientists (UCS) in the USA submitted a petition to President George Bush to restore scientific integrity in policy making. Among sixty prominent scientists in UCS there were twenty Nobel Laureates. They charged the US government for appointing experts on various science committees who did not have professional competence and had conflicts of interests. UCS has asked the US Environment Protection Agency to stop the suppression of data relating to public health and honour disclosure of science information (ICSU, 2005, p. 12).
2. Indian traditional system of knowledge, Yoga that is considered as an open source method for a healthy life, is seriously threatened. According to information sources,[21] the US Patent and Trademark Office has issued 150 yoga related copyrights, 134 patents on yoga accessories and 2,035 yoga trademarks. Not surprisingly even Yoga mat is patented.
3. Remedies based on traditional knowledge of *turmeric* and *neem* are patented by the US and European Patent Offices—but got revoked by Indian science organisations and civil society groups. There are other cases such basmati rice, Darjeeling tea, etc., and various natural and geographic foods and beverages are threatened from their synthetic biosimilars.
4. Indian science agencies have established multidisciplinary teams to work on digitally cataloguing 1,500 Yoga poses recorded in ancient texts written in Sanskrit, Urdu and Persian. India will use the catalogue to block anyone from obtaining patents on the 5,000-year-old open knowledge on stretching, breathing and meditating. Digital codification of traditional knowledge by CSIR is now a big research programme to tackle biopiracy from corporate research agencies. Biodiversity registers which catalogue important facts in the indigenous systems of knowledge in medicine, environment, etc., are being documented in all districts of India.

5. Movement towards open source knowledge (pharma and software) and scientific commons is growing but the pace is very slow as big corporations are blocking these efforts in various ways.
6. IPR are designed to encourage innovation and protect invention. In doing so they block public domain of science curbing scientific progress and spread of science.

From Peer Evaluation to Regulation by Clients, Markets and Public at Large

For a long time now, legitimation of scientific facts and certification of systematic knowledge (social control in science) was carried out by scientific peers and the science institution. The scientific autonomy was preserved and sustained by the institution of science in a number of ways. Governments and public money though allocated research funds did not interfere with research autonomy. With the onset of globalisation, much of the peer evaluation and social control in science is now being shifted to what sociologist Helga Nowotny has called 'AGORA' or 'civil space'. Under the new social contract emerging, scientific results in biotechnology, biomedical science, pharmaceutical, etc., are no more legitimised and approved by laboratory or scientific community alone but also by different stakeholders in science, particularly the corporate firms. This is a major shift-taking place in science institution.

1. Novartis in 1998 struck a deal with the Department of Plant and Microbial Genetics at the University of California, Berkeley, USA for US$ 25 billion. Under the agreement, Novartis gets rights to negotiate and direct 33 per cent of Department's discoveries for several years and overseeing also how the money is utilised. Ignacio Chapela and David Quist vocally opposed the Novartis agreement from the Department. This initially led to Chapela being denied tenure appointment by the university raising concern about academic and scientific freedom and the Principle of Universality (ICSU, 2005, p. 14).
2. Corporates determine the content and direction of research at the MIT, USA via Whitehead Institute of Biological Sciences since the 1990s. This is located on MIT campus.
3. Clear signs are visible in France with the firms being represented in the advisory bodies of Universities under the new reforms introduced.

Academic Science to Entrepreneurial Universities

Historically the academic science and universities have gone through two revolutions. First was when the process of teaching was institutionalised sometime around the thirteenth to fifteenth centuries (first academic revolution). The second was when the Humboldtian model of combining teaching and research was introduced for the first time in the Berlin University and later spread to

Germany and across Europe and North America from the early nineteenth century (second academic revolution). We are now witnessing a third academic revolution of 'Triple Helix' or university–industry–government partnerships. Innovation and commercialisation of academic research has now become an integral part of the university governance and academic policy along with teaching and research. Before 1990s, there was nothing like 'entrepreneurial university' but as Etzkowitz (2002) predicted, the concept spread like a 'wild fire'. There are various structural changes that have come about, towards entrepreneurial university and science.

1. Science parks and innovation parks are now integral part of traditional universities. Begbroke Science park at Oxford University; St. Johns Innovation Centre and Incubator at Cambridge University; Science Park (Tuspark) at Tsinghua University, Beijing and Science Park at IIT Madras are some examples.
2. With the introduction of Bayh-Dole Act in 1980, Technology Transfer Offices (TTOs) and incubation units have been established in all major universities in the USA. TTOs are now seen as a major source of revenue in the US universities.
3. Trans National Corporations and universities used to maintain some distance in the past. This is now fast eroding as most TNCs have joint projects and programmes with universities for commercialisation and market exploitation of products coming out of science research. Novartis case pointed out above at the University of California is not an isolated case. Herbert W. Boyer and Stanley Cohen's scientific research which led to recombinant DNA technology and eventually led to formation of biotech company Genentech (1976) is a 'block bluster' venture on the US stock exchange. Universities entering into stock exchange in one form or other are a big change that has come about in the last decade and a half.

Challenge of Industrial and Post-industrial Societies

The second major factor considered here responsible for changing social relations between science and society is the challenge of industrial and post-industrial societies. In a way these are two sides of the same coin. Science and technology remain the main driving forces behind industrial and post-industrial societies. Rapid industrialisation and modernisation, in a large measure, meant to generate wealth from industrial and post-industrial policies. Maximize profit and generate economic value from the application of science has been the motive behind government policies and corporate business enterprises alike. There are several changes that have come about in the science and society relations under heavy industrialisation and post-industrial policies involving science and technology strategies. We will touch upon two recent developments.

Rise of Regulatory Science and Citizen Science

The last three decades beginning with the Bhopal Gas Tragedy in India in 1984[22] and the *Mad Cow Disease* in UK in the late 1980s and early 1990s witnessed a new phase in the relations between science and society to deal with hazards, risk and regulation of science and technology. It was no accident that Ulrich Beck titled his book *Risk Society: Towards a New Modernity* (1992). For more than 25 years, Beck tried to diagnose the question: how can social and political thought and action in the face of radical global change be intertwined with modernity? Curiously, this was also the phase of growing information and communication technology revolution, publication of results from the Human Genome Project and the rise of biomedical sciences and GM technologies.

In the post-war era, how to deal with risk and uncertainty in new science and technologies became a major issue of concern both for governments and public at large. In 2003, the British government had to confront a widespread public distrust of science of genetically modified (GM) crops and foods. The evaluation of what is good and bad for health was no more confined to science institution but also depended on AGORA—the civil society groups and citizens. In fact the Royal Society of London, for the first time in 2000 recognised that public approval is an important factor. The same was the case in France, Germany and many parts of Europe and Asia. These developments have given rise to two modes of science and society relations, namely 'regulatory science' and 'citizen science'.

Whereas in regulatory science the government bodies and political decision makers take a proactive stand to directly intervene and take decisions, in citizen science, representatives of civil society groups assume this role to take a final call on decisions. With the history of strong environmental movements in Europe and Asia, *green politics* have come to assume an important role in science and society relations, particularly in regulatory science. For instance, in late 1990s five governments in Europe including France had green parties, which played a significant role in regulating science, particularly in the aftermath of mad cow disease in the case of GMOs.

When big science institutions such as European Organisation for Nuclear Research (CERN) come out with mega scientific experiments and discover 'God Particle' (that is Higgs boson particle), there is hardly any controversy and the world accepted it as one of the important discoveries. This is very much part of big science and advancement of knowledge. It is not the same with embryonic stem cells research and biomedical scientific research regulation. About 8 weeks and younger embryonic stem cells have the potential to produce any cell type in the body. Different governments and cultures in Europe, North America and Asia define and regulate science here to take a decision for allowing research on stem cell. The ways in which decisions are made about scientific research on stem cells depend profoundly on political cultures, religious beliefs and what government accepts on the basis of public mood. Traditional structures or the social contract of science of the post-war era has broken down in Europe, as elsewhere, by the late 1990s for new technosciences.[23]

In Germany the moment conception takes place life comes into being and hence scientists are not allowed to do research on stem cells. They can however import embryonic stem cells for research. In UK the concept of 14-day *conceptus* (gap between fertilisation and birth of embryo, foetus) before conspicuous cell differentiation appears was devised to allow research on up to 14 days embryonic stem cells. The USA under Bush administration completely banned public funding for stem cell research on religious grounds. Decisions on safety standards on food additives, for automobile exhaust emissions, radiation by telecommunication towers and power plants, lead levels and pollution levels in the atmosphere, etc., are taken not necessarily based on any consensual scientific opinion but by politically driven technical regimes concerned with science and technology regulation. Biotechnology has emerged as the most contested research terrain, which has led us to institutionalize regulatory science in the interest of society at large. Leading scholars like Francis Fukuyama has given a loud call for regulating biotechnology:

> What should we do in response to biotechnology that, in the future, will mix great potential benefits with threats that are either physical and obvious or spiritual and subtle? The answer is obvious: We should use the power of the state to regulate it. And if that proves to be beyond the power of any individual nation-state, biotechnology needs to be regulated on an international basis. We need to start thinking concretely-now-about how to build institutions that can discriminate between good and bad uses of biotechnology, and that can effectively enforce those rules both nationally and internationally. (Francis Fukuyama, *The Chronicle of Higher Education* 22 March 2002)

Citizen science may be defined in several ways but it is being used here to point out a new democratic locus or a pole of decision making in science on matters concerning the impact of science and technology on our daily lives. In contradistinction to public science, academic science and industrial research, citizen science is the knowledge and analyses of science, technology and society relationship advocated by the civil society groups, NGOs, environmental groups and by people science movements (Krishna, 1997). The term, however, gained momentum after Alan Irwin's (1995) book, *Citizen Science: A Study of People, Expertise and Sustainable Development*. Alan rightly argued against the view that people are ignorant and that the knowledge of people is very significant even if it crosses scientific disciplinary lines and is based on personal and practical understanding. As argued elsewhere (Krishna, 1997), people science movements and civil society groups in India in the last three decades have played a significant part in tendering knowledge and analyses on the relations between science and society. These efforts have influenced the decision making in science and technology on environment, big dams, science education, energy and GMOs.[24] The success of citizen science in India in placing temporary moratorium on the release of BT Brinjal in 2012 is another important example that is relevant here.[25] Public understanding of science (PUS) as it emerged is no more concerned with merely popularisation of science and science communication. It has gone beyond this phase to become another important actor effectively intervening into national science and technology systems and decision making in science.

Inclusive Innovation—Science and Society at the 'Bottom of the Pyramid'

The rise of Asia propelled by the markets and growth rates of China and India in the last two decades generated a good deal of wealth in these countries. This is not unrelated to science, technology and innovation policies in establishing industrial and post-industrial societies in these countries. These policies have led to increase in income for a section of population. What is also true is the fact that growth processes have also increased inequality between 1990s and 2010 for a vast majority of the population in these countries.

The euphoria surrounding globalisation, industrialisation and unprecedented economic growth has dampened in a large measure in the face of increasing evidence of growing, inequity and worsening social indicators in the last 5 years. Kaplinsky (2007) in his influential volume *Globalization, Poverty and Inequality*, drew attention to the impact of innovation under globalisation with the metaphor of 'glass as half empty'. Innovation led to growth and prosperity but at the same time reduced the incomes of people and increased inequality among lower sections of society. About 3 years later, Pranab Bardhan (2010), while assessing the economic rise of China and India, titled his influential volume as *Awakening Giants—Feet of Clay*—again drawing attention to inequality under globalisation. More recently, Drez and Sen (2013) have painstakingly provided evidence to question the story of euphoria of globalisation in their volume, *An Uncertain Glory*, in the Indian context. There is some evidence in these writings in the case of India to argue that globalisation has marginally improved the income of vast majority of poor people during 1990 and 2010. However, the statistics do not reveal the social reality of poor people in distress for the lack of sanitation, access to health, housing and nutritious food. The official figures of poverty line in India are so low that it hardly helps vast majority of poor to improve their livelihood in any significant manner.[26]

In the specific case of India more than 85 per cent of the labour force nearly 500 million people are in the informal sector (informal employment in Asia is 65 per cent; 48 per cent in North Africa; 51 per cent in Latin America; 72 per cent in sub-Saharan Africa and 15 per cent in developed countries).[27] Some 500 million people in India and China will migrate to urban areas in the coming two decades.[28] One can characterise this as a 'Great Transition' in Asia.

It is not just an issue of creating sustainable mega urban cities, but the problem for India and China is how can we create employment and sustainable livelihoods for over three-quarter billion people living in non-urban regions? Can we arrest urban flow? High technology and 'big science' projects that are talked about in India and China are unlikely to have immediate or medium term solutions to these parts of Asia for people in the informal economy. Whilst the fruits of these high technology and big science need to be extended or even down scaled to link up to these regions, one is looking towards new perspective or a paradigm of sustainable development and inclusive innovation to address the problem of rural–urban migration and informal economy.

The new paradigm that is emerging is known as inclusive innovation. It refers to different types and forms of innovation activities or performance by which we can get more for lesser cost and which could cater and meet the needs and demands of more people. Local knowledge systems are blended with science and technology and are deployed to scale up their use in manufacturing and designing a variety of needs for people at the bottom of the pyramid. Inclusive innovation may or may not be R&D-based and need not always mean technological innovation. Inclusive innovation also means institutional, individual, social, business and organisational innovation manifested in microenterprises. In all its ramifications, inclusive innovation has led to an alternative science and society relations anchored at the 'bottom of the pyramid'. There are now successful models and institutional operating mechanisms at the ground level. Jaipur foot and hand; Barefoot College, Arvind Eye Clinic, Narayana Hrudalaya, National Innovation Foundation and Honeybee Network, among others, are good examples of what the future holds for a vast majority of people in India in the informal sector. There is indeed a big movement of actors, agencies and institutional initiatives in India, China and various other developing countries to bridge a different kind of 'divide'.

Inclusive innovation and science and society relations at the bottom of the pyramid have given a big boost to scientific and technological pluralism. A new perspective to bring together traditional and modern science in agriculture, health, manufacturing and a number of other activities has demonstrated the potential for sustaining livelihoods of people.

Climate Change and the Challenge of Energy Research

Climate change and rising CO_2 levels is the third major social force that is posing different type of challenges to science and society relations. Much of the problem in finding solutions to climate change issues seems to fall beyond mere science and technology factors into science and society relations. These encompass complex sets of relations between industrially developed Northern versus developing South countries; between emerging BRICS versus North[29]; between BRICS versus rest of the developing world; and between small developing and very vulnerable countries such as in the Pacific[30] and Indian Ocean versus neighbouring large countries. This is quite apparent from the outcome of Bali Action Plan, Kyoto Protocol and the three UN Framework Convention on Climate Change meetings at Copenhagen, Cancun and Durban. There are four major challenges that are crucial and which have come into sharp focus:

1. There is a clear realisation now than ever before that our mode and pace of hyper industrialisation and modernisation process is unlikely to be sustainable from the perspective of climate change issues. In a number of ways this reminds us of the 'Club of Rome' report on *Limits to Growth*;
2. One of the most contested issues that have come to surface since the Bali Action Plan between developed North and developing countries of South is the framework on 'Common But Differentiated Responsibilities' (CBDR). Differentiated responsibility is based upon the historical responsibility of States and differing capacities of States or countries to address climate change. Hence the distinction made between Annex 1 countries (most of the North countries) and non-Annex 1 countries, in the South. Different capacities that command science and technology factors are at the core of this issue. Industrialised nations have the scientific and technological capacity to address climate change both through mitigation and adaptation. Developing South countries do not have the same command and capacity. Historically speaking who has contributed to the carbon build up in the atmosphere and who benefited from it most? Much of the responsibility and onus lies on these countries is an issue which is being contested;
3. Closely related to this is the contested issue of economic calculations of carbon emissions in the atmosphere based on per capita basis rather than country-based calculations. Countries with large populations such as China, India, Indonesia, Pakistan, among others, are negotiating this issue which is not acceptable to Northern developed countries as it will tilt the balance of CBRD in favour of developing world;
4. The fourth issue is related to technology transfer from North to South. Leaving emerging economies such as BRICS, which have considerable science and technology capacity, the main issue of technology transfer involves the bulk of developing world in Africa, Latin America, Caribbean, Asia and Pacific, etc. Some initiatives such as Clean Development Mechanism (CDM), which involves Annex 1 countries to invest in projects leading to emission reduction in non-Annex 1 countries, did not lead to any technology transfer. Given scientific and technical capacity of North to tackle climate change problems, the issue of relevant technology transfer to small and poor South and developing countries is the most important factor in addressing the problem. A new paradigm of climate change cooperation in technology transfer for these countries seems an important avenue.

However, to limit our discussion from this large climate change canvass, let us consider two examples from energy-related problems. These are specifically chosen to throw light on how science and society relations in energy-related issue have the prospect of opening up a window for addressing the issue, though in a small way.

Need for Scientific Commons

Building national capacities in low carbon innovation in energy technologies is emerging as one of the major solutions to address the problem of CO_2 emissions. Nuclear energy is capital intensive and demands a high level of local and national technological capability to manage it. For a number of reasons only a small number of countries have evolved the capacity to harness this technology. However, it was considered as appropriate to address climate change problems before Fukushima disaster. In any case, the entry barriers and political hurdles are so high that it is difficult to be adopted by several developing countries.

Much of the 'know-how' and 'know-why' in renewable and clean technologies (photo voltaic and thin films, wind power technologies, advance biofuel, hybrid technology for automobiles, battery operated cars, among others) is located in the industrially advanced countries of Europe, North America and Japan. Here intellectual property rights (IPRs), patents and international technology transfer regimes play a very significant part in the deployment of renewable and clean technologies to small and poor developing countries. In the present circumstances, renewable energy technologies in wind, solar, bioconversion, etc., seems quite relevant. However, Table 1 shows, more than 95 per cent of the relevant patents in renewable energy technologies, indicating innovation potential, are concentrated in Europe, North America and Japan.

Aftermath of 2008 financial crises, almost all developed countries is banking on evolving global competitiveness in renewable energy and green technologies. It is unlikely that they would give away or transfer energy efficiency technologies (for example such as LED) to developing countries. Reeling under recession, developed countries like Japan have identified green technologies as new sources to improve their economies. As Nelson (2004) at length argued, international agencies responsible for climate change governance must find suitable institutional mechanisms for administering 'scientific commons'. In this specific case, a number of crucial patents and know-how could be obtained from the market by a UN regime on climate change and place it in the pool of 'scientific commons'. The developing and poor countries can access these technologies. BRICS may

Table 1
Patent Holding of Renewable Energy Technologies in the World 2007

Renewable Energy Patents	*Wind Power Patents (numbers)*	*Auto Pollution Control Patents (%)*	*Photo Voltaic Patents*
EU: 36%	EU 162	Japan 38	Japan 38%
USA: 20%	USA 29	EU 48.9	EU 30%
Japan: 19.8%	India 2	USA 8	USA 35%
BRICS: 6.5%	China 2	BRICS 0.7	BRICS 5%
N = 1,068	N = 196		N = 2,000

Source: Collected from various sources of United States Patents Office Documents 2005, 2006 and 2007.

not qualify for this category but it will help a vast majority of nations in Africa, Asia, Pacific and Latin America.

Climate Innovation Centres

Whereas OECD countries invest around 2.5 per cent average of GDP on R&D, emerging economies (BRICS) spend around 1–1.5 per cent of GDP. Vast majority of more than sixty-five developing countries spend 0.1–0.5 per cent of GDP. Given the low level of scientific and technological capacity in general and climate-related energy and innovation in particular, a novel idea emerges for establishing climate innovation centres (CICs) based on cooperation among a group of countries to focus on certain critical themes and problem areas.[31] For instance, Kenya has already taken a lead to establish CIC. As pointed out by its Prime Minister, CICs are meant 'specifically to achieve the essential technological advancement and innovative technology among SMEs' (Krishna, 1997, p. 9). Neighbouring countries could benefit by joining in such CIC on cooperative basis to optimise scarce resources for establishing technological capacities. Without establishing technological capacities in some crucial sectors of renewable and clean energy, including energy efficient technologies, it will become difficult to even absorb technologies under international technology transfer. Crossing this hurdle remains the main problem in several developing countries in Africa, Asia and Latin America.

For instance, there are potential cases of science cooperation via CICs on problem or themes. In the case of China, India, Indonesia and Australia coal will play a significant part (over 50 per cent of total energy needs) in the coming 40 years. The idea of cooperative CIC in coal efficiency technologies (such as carbon capture and storage—CCS, Integrated gasification combined cycle, etc.) will be of paramount importance. For example, a mere demonstration for a CCS plant would cost more than 1 billion USD that is unlikely to be met by any single country. Technological cooperation among South countries, outside global climate platforms and regimes (such as the meetings of Copenhagen, Cancun and Durban), seems more promising.

There are various regional groupings such as ASEAN, SAARC in Asia; and Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Southern African Development Community (SADC), etc., in Africa. With the exception of SAARC university in New Delhi, (combined effort of South Asian countries) no other country grouping seems to have established any joint research and innovation centres for addressing nationally and internationally challenging problems such as climate change. There is a good case for these groupings to promote cooperative CICs.

Concluding Remarks

The social contract between science and society, in the last couple of decades, has undergone such a dramatic transformation that it is difficult to find a parallel in the recent post-war history. Since the end of Cold War the pace of scientific research and science-based innovation has advanced quite rapidly. At the same time, socio-economic and political context of scientific research and science organisation has undergone a radical change. The very foundation of science as social institution, that has evolved over the years is undergoing a transformation. The change is no less than a 'cultural revolution'. As explored above, three societal forces are responsible for the changing relations between science and society: globalisation; industrial and post-industrial policies and climate change. Given the limitations of time and space, our exploration was limited to analyse some important features of change by selectively drawing upon countries, organisations, actors and agencies from different parts of the world. Following points emerge as a way of concluding remarks.

1. The impact of globalisation is not something confined to mere political, economic and social institutions. These economic and market bound forces have penetrated deep into the social institution of science and transformed it so radically that we can now clearly distinguish the existing social contract and the emerging social contract between science and society as shown in Table 2.
2. Globalisation has become a reality of society, economy and our daily life-worlds. How can we rescue science institution from completely being overtaken by economic and market oriented forces of globalisation? As Amartya Sen observed from an economic perspective, we need to evolve mechanisms for maintaining a 'level playing field' between public good and market good. We need to evolve institutional mechanisms and policy instruments for 'making globalization work for every one' and not for few.[32]

Table 2
Changing Social Contract between Science and Society

Elements of Existing Social Contract	*Elements of Emerging Social Contract*
Science as part of culture and public good	Science is becoming a part of commerce and market good
Primary objective of science being advancement of knowledge	Generating wealth has become much more important
Peer evaluation and social control of scientific knowledge regulated by science institution	External clients, market institutions interfere and influence the goal direction of science
Scientific criteria/merit as the basis of evaluation	Social and economic interests play a role
Autonomy of science institution sustained	determining priorities in research Autonomy of science institution infringed
Open knowledge as public good conducive for the advancement of knowledge and technical progress	Secrecy is now institutionalised and accepted by scientific community in the form IPR and patents Patents impede progress of science

Source: Author's conceptualisation.

3. Public good as overarching principle in organising and funding research in several countries like India played a very significant part in enhancing endogenous scientific and technological capabilities in the post-war era. This needs to be maintained and particularly strengthened in the context of developing and poor countries. Any dilution will have serious implications for the underprivileged sections of society in the developing countries. In industrially advanced countries, public good in science research serves an important function of tackling societal challenges such as climate change and risk in new technologies. Developing countries lack resources to devote too much emphasis on these problems.
4. Our experience in the past has shown that open knowledge has its own merits as it helps in solving many important practical problems and at the same time feeds in to advancing newer knowledge thresholds and paradigms. Some institutional safeguards and various exceptions in the clauses governing patents have to be put in place in academic and research organisations so as not to impede further progress of science. 'To privatize basic knowledge is a danger both for the advancement of science, and for the advance of technology' (Nelson, 2004, p. 356).
5. Industrial and post-industrial policies have not only increased technological risks of various kinds and intensities, but also it has created considerable measure of public mistrust of science and fear of technology in the society. This is particularly true after the mad cow disease and GMOs oriented research. Fukushima disaster has led to different kind of fear and perception of risk. There is no doubt that these problems relating to risk and hazards in science and technology have to be dealt with by systematic regulatory mechanisms. At the same time, curbing scientific research by magnifying 'risk' factors or bringing in irrational and non-science issues will be dangerous for the progress of science. This has to be dealt with scientifically and here comes the role of public understanding of science (PUS), which should be expanded and institutionalised at different levels of science organisation along with other institutional measures.
6. Regulatory science and citizen science have emerged as important actors in the democratisation of science and society relationships. Representatives of civil society should be given more space in the governance of science and technology. There is a need for a new dialogue between professional bodies, scientific societies and academies of science and citizen science groups.
7. Science and technology policies in the last two decades, has increased income and wealth for a section of the people. This is quite evident in countries such as India and others. Inclusive innovation is emerging as a new response to address the neglected domain of science and society relations at the 'bottom of the pyramid'. There are several successful models in the case of India, China and other developing countries. But the challenge lies in finding institutional and other avenues to replicate and diffuse these success models.

8. Inclusive innovation should not be seen as merely ‘local’ and ‘indigenous’ traditional knowledge resources and skills that require improvements. Policies should aim at building intermediary institutional mechanisms to connect local and indigenous knowledge traditions with formal and modern science and technology institutions.
9. Exploring problems underlying climate change with reference to renewable energy issues has revealed a window of opportunity for developing countries in the form of new concepts such as ‘scientific commons’ and CIC. However, solutions to various climate change problems seem to be beyond scientific and technological issues in the domain of international cooperation and an attitude of conciliation and negotiation between North and South. One is reminded of Gandhi’s philosophical observation, that ‘earth provides enough to satisfy every man’s need but not for every man’s greed’.

NOTES

1. Students of Galileo founded the Accademia del Cimento (Academy of Experiment) in Florence in1657. Colbert founded the French Academy in 1666. In contrast to Royal Society, this academy was funded by the government.
2. There is a plethora of writings but two sources are sociologically interesting. See Barnes (1972) and Mac-Leod (1977).
3. As it is well known in history of science, Galileo came in conflict with Catholic Church for his advocacy of Copernican astronomy of heliocentric system. Roman Inquisition tried Galileo in 1633 and found him suspect of heresy and sentenced him to imprisonment. However, it was converted to house arrest in which he remained for the rest of his life.
4. It is not the intention here to further explore internal and external spheres of science, which is rather interesting for deeper social history of science. Kuhn’s passing reference is being used here to bring home the point that the subject matter of science and its social relations are integral parts of society and culture as one of the sub-systems.
5. It is rather pertinent here to point out that the concern in exploring the changing relations between science and society is not just science per se but is seen in broader meaning and relevance context of technology and innovation. There are several ways by which scientific research and systematic knowledge impacts society and this is also part of the concern here.
6. Similar crises are now gripping parts of European countries such as Greece, Spain, Portugal and others. Unemployment rates among youth are high in many parts of Europe. There is indeed a growing perception of how globalisation phase has led to the present crises.
7. The concept of social contract between science and society has become quite popular in the science policy writings. See Gibbons (1999), Guston (1992), Lubchenco (1998), UNESCO (1998), Arie Rip (2007) and Forrester et al. (2002).
8. It may be pointed out that I am not the first to use this notion of social contract between science and society. One can find a small number of very influential writings in science and public policy that has employed this term of social contract between science and society. For instance, see Ben Martin (2003), Guston (1992) and Gibbons (1999).
9. In 1957, in another influential article on scientific priority struggles in science Merton mentioned about two more norms: of *originality* and counter balancing norm of *scientific humility.*
10. See Guston (1992) who discusses the social contract of science invoking Robert Merton and Michael Polanyi.
11. Actually quoting from Guston (1992) for one finds no better way of expression than he does.
12. In a way, Robert Merton, Michael Polanyi and various other scholars such as Karl Popper, who wrote an influential book, *Open Society and Its Enemies*, were clearly aware of the way in which

institution of science progressed under Nazi Germany and scientific research governed and directed by Soviet Marxism under Stalin in the Soviet Union.

13. Vannevar Bush in 1941 became advisor to American President Roosevelt as he was appointed as the Director of the Office of Scientific Research and Development (OSRD) that played a significant role in the Second World War via Manhattan Project.
14. The social contract of Vennevar Bush guided the US post-war scientific research with a focus on basic research. This should not be taken to suggest purely fundamental research. On the other hand, military oriented, weapons oriented and all types of long-term and short-term basic research was promoted in the US within the overarching Bush doctrine. The linear model of innovation that this doctrine advocated became popular in one form or other all over Europe and in Asia in countries like India.
15. This report advocated the 'customer-contract' principle which raised accountability and at the same attempted to reorient the then existing pattern of funding scientific research in the UK.
16. Mode-1 is characterised as academic science pursued in universities and science organisations; disciplinary; homogeneity; autonomy and traditional quality control (peer review). Whereas Mode-2 is characterised as emerging from context of application; transdisciplinary, heterogeneity; reflexivity and subject to accountability and controlled by novelty quality control.
17. See Ben Martin (2003). It may also be pointed out that various scholars questioned Gibbons et al. Mode-1 and Mode-2 formulations. See Godin and Yves (2000), Pestre (2003) and Shinn (2003).
18. CSIR set up a committee to examine the new context for the re-organisation of CSIR under the Chairmanship of R.A. Mashelkar, the then Director of the National Chemical Laboratory, one of India's leading laboratories in chemical and pharmaceutical research. The Committee's report, 'Creating an Enabling Environment for Commercialization of CSIR Knowledge-base', was submitted in 1993. The main recommendations were quite radical and clearly argued for re-organising the functioning of CSIR research on a commercial and corporate basis by creating marketing groups in each laboratory; investing in equity and allowing scientists to serve on corporate bodies and creating specific institutional channels and mechanisms to foster commercialisation of research.
19. Guy Aubert's interview in *Les Echoes*, 13 March 1995 as quoted in Vavakova (1998). Actually the change began in CNRS since the 1980s from President Mitterrand's time.
20. International Council of Scientific Unions (ICSU) a body operating within UNESCO.
21. See http://1degreebio.org/blog/?bid=120
22. In the recent history we have witnessed one of the major industrial disasters in the case of Bhopal Gas Tragedy in India, which took away more than 4,000 lives in 1984. While India was grappling with the industrial disaster to articulate policies for risk and hazards, Europe and North America was gearing up for a transition into the post-industrial society.
23. 'In Europe, traditional structures and procedures for deciding which technological innovations to encourage, which to forbid, and which to restrict broke down in the late 1990s under the weight of issues such as mad cow disease and biotechnology. Today, a fascinating set of institutional experiments in policymaking is underway in the United Kingdom and the EU, especially in relation to green and red biotechnologies. An entire generation of novel institutions, such as the European Food Safety Authority, its counterparts in the 25 EU member states, the UK Human Genetics Commission, the Commission de Génie Biomoléculaire in France, and the Gentechnikkommission in Austria, have been established. The United States, on the other hand, is trying to maintain its institutional status quo.' See the review of *Designs on Nature: Science and Democracy in Europe and the United States* by Sheila Jasanoff. Princeton, NJ: Princeton University Press, 2005 by Erik Millstone http://www.issues.org/22.3/br_millstone.html
24. The large people science movement led by Kerala Shastra Sahitya Parishad (KSSP) in 1980s stalled the construction of a big dam in the rainforest regions of Kerala.
25. It is pertinent to point out that one is not taking an anti-science stand. In the 1980s Sunderlal Bahuguna's movement on Chipko Andolan in the foot hills of the Himalaya region in northern India led to a moratorium on felling of trees for 15 years. This policy still prevails currently in different form.

26. For instance, according to the Planning Commission rural poverty reduced from 42 to 33.8 per cent in rural areas; and 25.5 to 20.9 per cent in urban areas between 2005 and 2010 respectively. But these estimates are based on the controversial Tendulkar methodology, which fixes poverty line of rural people at ₹ 22.42 per person and ₹ 28.65 in urban areas. Given the inflation rates of about 8 to 9 per cent per annum during this period, it is difficult to imagine how people are coming out of poverty whilst the income of middle and rich classes have witnessed considerable increase during the same period.
27. Based on ILO and World Bank reports.
28. According to some current estimates and reports from the UN Population Division of the Department of Social and Economic Affairs.
29. When we speak in North versus South terms, we include developed countries such as Australia in the North group.
30. One is referring to countries such as Palau, Marshall Islands, Federated States of Micronesia, Nauru, etc. in the Pacific and small countries like Mauritius and Maldives in the Indian Ocean.
31. The idea of CICs was mooted by India before Copenhagen conference. Later the idea gained importance in the Intergovernmental Panel on Climate Change (IPCC), the World Bank, UK Department for International Development (DFID) and other international agencies involved in climate change. See also *Climate Innovation Centers—A New Way to Foster Climate Change Technologies in the Developing World*, An InfoDev publication in collaboration with UNIDO and DFID, 2010, IBRD and World Bank (hereafter referred to as CIC report). It may be noted that this report does not mention about a group of countries coming together to form CIC. It mentions standalone CICs by countries. Group of countries coming together is the proposal being mooted in this essay.
32. Comments of Professor Amartya Sen in a debate with Joseph Stiglitz and Dr Manmohan Singh at FICCI seminar, New Delhi around 2003 at the launching of J. Stiglitz, book *Globalization and Its Discontents* (2002).

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