RESPONSIBLE GOVERNANCE IN SCIENCE AND TECHNOLOGY POLICY: REFLECTIONS FROM EUROPE, CHINA AND INDIA

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ABSTRACT

This Issues and Opinions Essay provides insights on developments and challenges related to responsible governance in the field of science and technology (S&T) across Europe, China and India. The Essay presents an overview of policy debates and some key public policy documents in these three geopolitical areas, exploring how responsibility is viewed and outlined in the policy domain. Considerations on the range of processes and actors affecting the relationship between science and society in China and India are also presented. Finally, the Essay introduces 'responsiveness' as a possible area for

comparative research work on responsibility in S&T and relevant policy collaboration amongst the three regions.

1. Introduction[1]

The notion of responsibility, and the growing imperative to manage science and technology (S&T) responsibly, has gained considerable traction over the last few decades. The necessity to govern modern S&T responsibly originated a few decades ago in diverse fields like ethics [2] and technology assessment [3-5]. It is however in the last decade that responsibility has begun to be recognized within S&T policy-making, notably in policy and funding programmes. It has also started to be a subject of the recommendations of influential scientific and advisory boards and the content of policy and strategic documents produced in fields such as synthetic biology [6], geoengineering [7] and nanotechnology [8-11]. This emphasis on responsibility in S&T is a product of emerging approaches that are looking at the points at which science, technology and society meet. Technology assessment [12, 13], ethics of technology [12, 14], ethical, legal and social aspects of emerging technologies [15], anticipatory governance [16] and socio-technical integration [17] are all examples of this.

Current discussions on the responsible governance of S&T place particular importance issues deriving from the social implications of S&T. Moreover, the responsible approach to S&T governance includes the 'upstream movement' that views participation as a crucial instrument for incorporating societal views in policies and decisions about S&T [18, 19]. Current debate and scientific literature on the responsible governance of S&T are largely limited to experiences and approaches advanced in Europe and North America. This Issues and Opinions Essay is an attempt to explore responsible governance of S&T beyond these boundaries and to include Asia in the picture. While it does not present the results of a specific research project, the Essay introduces some reflections of S&T policy experts in the European Union (EU), China and India with the aim of initiating a debate on the scope, and possibilities, of further comparative work on how responsible governance of S&T is perceived and can develop internationally. China and India have both emerged as significant players in the production of S&T, new ideas and global knowledge. The EU, India and China are at different stages of economic and social development, but all face challenges with regard to the relationship between science and society.

1The idea of this paper originated from a workshop entitled 'Responsible Governance of Science and Technology: perspectives from Europe, China and India' held at the European Parliament in Brussels, Belgium on March 2014, to which all the Authors participated. The event was organised by the Science and Technology Options Assessment (STOA) Panel. The STOA Panel is the European Parliament's in-house source of independent, balanced analysis of public policy issues related to S&T. Its aim is to inform parliamentary debate and keep the Members of the European Parliament up-to-date with current and emerging S&T issues and their policy implications. [1]

As far as S&T policy is concerned, the EU has agreed internally on the common understanding that responsible governance should include social and ethical considerations in strategy and policy formulation, encompassing both expert and public opinion and utilising a widened process of consultation. The current concept of Responsible Research and Innovation (RRI) has been developed from these ideas [20-23]. Although this concept of RRI is not included explicitly in official Indian and Chinese S&T policy, comparable ideas about conducting such responsible governance are being debated and elements have even started to appear in policy documents. For example, in the national plan of science and technology in China, scientific development is still seen as the unquestioned driver of the country's economic performance. A reference is made, however, to responsible management and the right of society to take part in the discussions and decision making processes in S&T [24]. Similarly in India, the 'Science, Technology and Innovation Policy 2013' document of the Indian Department of Science and Technology (DST) suggested that S&T could be targeted at improving the quality of life: "…science technology and innovation for the people is the new paradigm of the Indian science, technology and innovation policy" [25].

These official commitments are accompanied, and partially caused, by the vocal action of civil society, aiming to shape (and contest) technology policies and developments in these countries. As in the EU, recent public controversies in areas such as scientific misconduct, food safety and public health in China and India, have proven to be a catalyst for S&T debates. They have highlighted limitations in governance and have also begun eroding public trust in science [26, 27]. This is particularly evident in debates on genetically modified crops whereby public debates initiated by civil society organisations in India and China were not only very similar in content and intensity to those in Europe but have also led to similar policy initiatives in GM food regulations. More importantly, they have initiated the development of new decision making processes that highlight the need for more accountability and responsibility in governance [28]. Overall, views on the social implications of S&T are increasingly being incorporated in the standard approaches to analysing advantages and disadvantages of new technologies, and systems of wider consultation have gained, or are gaining, policy acceptance throughout the EU, China and India. Despite having such views in common, a closer look at the respective geographical context of each region is needed to define concepts and strategies that can effectively explore this interest in responsibility.

The first section will provide background information on the scientific, technologic and economic contexts shaping the S&T developments in the three regions. The second

section will discuss the concept of responsible governance of S&T, with a view of the current debate on RRI in the EU as it represents the main point of reference in the discourse surrounding the incorporation of responsibility in public policy. The third and fourth sections will present some considerations on the debate concerning responsible S&T governance in China and India, along with the main challenges to its uptake. The final section will discuss the possible implications of the current trend for further research and policy collaboration between the three regions.

2. Science, technology and the economy

This Essay does not provide a comprehensive analysis of China, India and the EU. Data are presented, drawn from different scientific, technological and economic contexts, and are used to illustrate the differences between the debates and policies relating to responsible S&T governance in these regions.

2.1 European Union

The EU originated with economic integration between countries in Europe, which aimed to end the devastating wars between them. Both economic and political integration have since deepened, with expansion from the six countries that founded the EU's predecessor in 1950, the European Coal and Steel Community, to the current twenty-eight Member States. In 1979, citizens were given the right to elect Members of the European Parliament directly.

In 1986 the European single market was introduced, following the signing of the Single European Act, and formed the basis of the free flow of trade across the borders of EU Member States. Alongside this, the growth of political ties between Member States, formally recognised as the 'European Economic Community', was renamed as the 'European Community'. This later became the European Union, indicative of closer links between members enshrined in the Maastricht Treaty of 1993 and the Treaty of Amsterdam in 1999. In 2002, a new single currency, the Euro, was introduced in many Member States. Ten new countries joined the EU in 2004. 2009 saw the entry into force of the Treaty of Lisbon, intended to provide the EU with modern institutions and more efficient working methods. In recent years, the economic downturn has severely hurt Europe. In 2009, gross domestic product (GDP) fell in all EU Member States (with the exception of Poland) with a mean decrease of 4.5% (Figure 1) [29].

FIGURE 1 APPROXIMATELY HERE

Unemployment rates increased substantially from 7.2% in 2007 to 10.6% in January 2014, with even over a quarter of the active population unemployed in Spain and Greece. In parallel with the financial crisis, public confidence in the EU has fallen to low levels in the last years. The EU is the biggest trading partner in the world, followed by the United States and China [29]. The EU currently spends about 2% of GDP on R&D, which represents an annual expenditure of about EUR 245 billion (Figure 2) [32].

FIGURE 2 APPROXIMATELY HERE

The EU has adopted an ambitious strategy for S&T that aims to make the region the world leader in both output quality and R&D expenditure. Investing 3% of the EU's GDP in R&D, reducing the rates of early school leaving to below 10%, and ensuring that at least 40% of 30-34–year-olds complete third level education are all objectives of the Europe 2020 strategy, the EU's growth strategy for the decade [33].

2.2 China

In China, before reforms and opening up started in 1978, the state-led S&T system was very hierarchical. R&D expenditure was concentrated in government institutions with few links to the market. Universities had almost no role in technological development or commercialization. By the late 1970s, the government recognised the low level of effectiveness of such a system and initiated a series of reforms to close the gap between China and Western countries. Reform of the economic system included the introduction of market pressures, rationalisation of the government-led economy, creation of spin-off high-technology companies and the import of technology (foreign firms were granted access to the domestic market in return for technology transfer) [34]. Nowadays, globalisation links Chinese companies to foreign customers, technology suppliers, and strategic partners. Economic openness has increased competition, forcing China to innovate and raise productivity. Notwithstanding these changes, China remains largely under central, top-down control.

China has seen tremendous development over the past two decades, with an average GDP growth of nearly 10% per year (Figure 1). In 2005 the Chinese economy was half the size of the American economy. In 2011 it was 87%. Considering China's 24% economic growth from 2011 to 2014 compared to the American figure of 7.6%, the Chinese economy is likely to overtake the United States economy this year [35,36]. China is the leading supplier of goods for the EU (17%) and the second market for European goods [29]. This pace of development is mirrored in the S&T sector: China now has the third largest R&D investment budget in the world. According to the Scimago World Report 2013 (based on the period 2007–2011) the Chinese Academy of Sciences is the second ranked institution in the world for the number of scientific articles produced [37]. China is a world leader in many high-tech areas, such as biotechnologies and nanotechnology. However, the pace of change has created a host of social problems not unlike those seen in more advanced economies. The new-found ability to create economic wealth through S&T developments has produced a general euphoria about S&T but little discussion of its implications for everyday life. The management system of S&T, characterised both by centralised bureaucracy in the public sector and deregulation in the private sector, creates additional barriers to an effective system of regulation [38]. Socio-economic inequalities produced by rapid economic development are another hindrance for S&T.

2.3 India

Before the economy was opened in 1991, central planning, extensive regulatory controls, and widespread restrictions on foreign investment were the defining characteristics of the Indian economy [34]. The socialist vision of Nehru (prime minister from 1947 to 1964) gave way to an era of accelerated foreign direct investment, and economic and technical progress. India has emerged as one of the strongest developing economies in the world. The rate of GDP growth reached nearly 6% and stayed at this level for two decades. If the EU is not counted as a single unit, the Indian economy will become the third largest economy in the world before 2020 [39]. The EU and India are major trading partners. India is the EU's eighth largest export market [40]. According to the Economic Survey 2012-13, following the slowdown induced by the global financial crisis in 2008-09, the Indian economy responded strongly and achieved a growth rate of 8.6% and 9.3% respectively in 2009-10 and 2010-11, though the growth slowed down to 5.0% in 2012-13 [41]. India's hi-tech exports increased from US$ 10 billion in 2009 to US$

12.4 billion in 2012 [42]. Thus, it is very clear that S&T is and will be playing a major role in the economic growth, particularly in the realm of international trade.
R&D spending in India is low compared to Europe or China (Table 1).

TABLE 1 APPROXIMATELY HERE

The 12th Five-Year Plan for the period 2012-2017 proposes to increase R&D expenditure to 2% of GDP. It also intends to increase the number of full-time researchers/scientists from the current level of 154,000 to 250,000; boost the volume of publication outputs in basic research from a global share of 3% to 5%; improve the global publication ranking from 9th to 6th by the end of the 12th Plan; and focus on doubling the number of patents and increasing the commercialization of patent portfolio to 5–6% from the current level of less than 2% [43]. In addition, India's R&D spending as a percentage of GDP has increased from 0.81% in 2005 to 0.87% in 2010; India's share in global research publications increased from 2.2% in 2000 to 3.5% in 2010 as per the SCI (Science Citation Index) database [44]. However, these achievements mask severe problems. For example, inequality continues to be of considerable importance, with a quarter of India's population living below the poverty line [39,45]. The country remains largely an agrarian economy, with roughly 50% of the work force employed in the agricultural sector. India has about 250 million adults who cannot read or write, literacy is declining slowly, and the percentage in higher education is low (Table 1). There are also problems in the S&T sector; the Indian Institutes of Technology produce elite engineering graduates, but a large proportion of traditional universities are inadequate, with lack of autonomy and financial resources and a paucity of research output [46].

3. Responsible governance in the European Union

Over the past two decades, a series of events progressively undermined the legitimacy of EU S&T governance, raising concerns over the social uptake of scientific-technological innovations [47]. Food crises in the 1990s, such as bovine spongiform encephalopathy ('mad cow disease') and the dioxin contamination scandal (with dioxin detected in animal food products, mainly eggs and chickens), undermined public confidence in regulatory procedures and expert-based policy-making [48]. A significant part of the European public considers GMOs to be the uncritical development of a potentially dangerous technology, whose risks were under-analysed [49]. These experiences forced

European policy-makers to demonstrate to the public that the social and ethical principles behind publicly funded R&D investments were adequately considered. In 'Science, society and the citizen in Europe', the EC argued that the relationships between S&T and society "have to change because of the impact of science and research [...] on the quality of life in Europe" [50].

Philippe Busquin, European Commissioner for R&D from 1999 to 2004, and later STOA Chair, stated that "democratic governance must ensure that social and economic issues are taken into consideration in research activities" [51]. In the execution of the European Commission's 'Science and Society Action Plan' which was launched in December 2001 [52], the European Commission (EC) appointed a high-level expert group to develop guidelines on genetic testing. The results of their work was published in a report entitled, '25 Recommendations on the ethical, legal and social implications of genetic testing' [53]. Within the Seventh Framework Programme for Research of the European Union (FP7) running from 2007 to 2013, the EC published guidelines on responsible research and research ethics, and on the ethical reviews procedures for EU-funded research projects [54].

Following on from the emerging broader international trends discussed in the introduction to this essay [6-9], the EC has now gone further than simply publishing guidelines and has begun to institutionalise the responsible governance of S&T in its sector policies. Notably, the EC action plan on nanotechnology outlined a responsible strategy to integrate health, safety and environmental aspects and which takes into account public opinion [10]. As part of this strategy, the EC issued a 'Code of Conduct for Responsible Nanosciences and Nanotechnologies' in 2008 [11], designed to be an overarching responsibility framework for research and technology developments. Recent debates have also considered the future of nanotechnology [55, 56] and sought the development of a new governance paradigm, anticipating resultant societal reaction [16].

This attention to responsible governance was not restricted to the European institutions, but it was also prominent in some of the EU Member States. For instance, the UK Royal Society addressed the scientific and technical aspects of geo-engineering and advocated an adequate research governance framework to "guide the sustainable and responsible development of research activity", including the development of scientific codes of practice [7]. The UK Engineering and Physical Sciences Research Council has also

developed a framework of responsible innovation in its funding scheme to incorporate concerns about ethical acceptability and social needs in its research processes [57]. Also in the Netherlands, the Dutch Organization for Scientific Research (NWO) started a funding programme for responsible innovation in 2009. This programme encourages research where the ethical and social aspects of new technology are considered from the design phase onwards. This prevents adjustments having to be made in retrospect if society rejects the new technology [58].

3.1 Responsible Research and Innovation (RRI): conceptual development and incorporation in the EU public policy

The integration of responsible development into technological and scientific fields such as nanotechnology has, over the years, run parallel to the establishment of responsibility as a feature of EU S&T policy. Areas of work that were previously referred to as 'science in society' in the EC are instead being renamed to 'responsible research and innovation' (RRI) [59]. RRI and its 'sister notion' of Responsible Innovation, have been defined in different ways [20-23]. Nevertheless, some common characteristics are discernible. These can be summarised in four features, following closely the definition proposed by Owen [22] and Owen et al. [23]:

- First, RRI is anticipatory, which means it should analyse potential impacts - both intended and unintended - including economic, social, and environmental aspects.
- Second, it is reflective, examining the underlying purposes, motivations and assumptions of research, and considering uncertainties and risks.
- Third, RRI should be deliberative, which means it should open these issues and debates to broad deliberation and inclusive engagement.
- Finally, RRI should be responsive by using deliberation to influence the direction and pace of innovation.

As a "collective and continuous commitment" organised around these four aspects (anticipation, reflection, deliberation and responsiveness) RRI steers innovation by incorporating considerations of ethical acceptability and social needs [21]. RRI has the potential to take into account risk and precaution, as an answer to the policy and regulatory dilemmas arising from techno-scientific fields whose impacts are poorly characterised or highly uncertain. In doing so, it takes a more proactive stance that seeks to answer the question: "what sort of future do we collectively want innovation to create for Europe?" [22]. As part of a broader movement towards better public

engagement in S&T, RRI has appropriated public participation and deliberation as the main instruments by which it can ensure that care and responsiveness, two relevant dimensions of responsibility, primarily involved in RRI, are in place [23]. The dimensions of care implies having the will and capacity to commit, in the present, to safeguard societal needs in the future, therefore incorporating this into RRI helps to orientate future research and innovation towards helping us to realise a vision of the future we want to live in. The dimensions of responsiveness implies an openness to respond to the diverse views and knowledge present in society, "both in terms of defining the targets for innovation and how its trajectory then evolves" [23, 35]. Responsiveness is accompanied by deliberation, a "widely configured" process, that "seeks not simply to understand views on the purposes and intended products of science and innovation and their acceptability, but that such engagement pro-actively helps establish and shape new agendas which set the direction of science and innovation themselves" [23, 35].

3.2 Incorporation of RRI into policy-making processes

Produced in the European environment of policy and academia, the concept of RRI has seen a remarkable degree of institutionalisation in the EU's S&T policies. Horizon 2020, the most important EU programme for R&D, is clearly focused on achieving the balance of supporting research and innovation and at the same time ensuring that the values and needs of society are taken into account. With the aim of expanding the relationship between science and society and reinforcing public confidence in science, "Horizon 2020 should foster the informed engagement of citizens and civil society in research and innovation matters by promoting science education, by making scientific knowledge more accessible, by developing responsible research and innovation agendas that meet citizens' and civil society's concerns" [60]. Horizon 2020 applies the RRI goal of orientating innovation towards social needs by establishing a 'challenge-based approach', whose ambition is to gather resources and knowledge from across different fields, technologies and disciplines to answer major EU policy priorities and social concerns (e.g. health, food security, clean energy, green transport, social inclusion, freedom and security).

RRI is one of the main cross-cutting issues of Horizon 2020, with an impact on all pillars and work programmes. The mainstreaming of RRI in Horizon 2020 is complemented by a

dedicated programme called 'Science with and for Society'. This has the specific task to "develop the governance for the advancement of RRI by all stakeholders". Such a contribution will be targeted at the following key issues: i) engage society more broadly in research and innovation activities, ii) increase the access to scientific results, iii) ensure gender equality in both research programming and research content, iv) take account of the ethics dimension, and v) promote science education [61]. Several collaborative projects on RRI started under FP7 responding to Science in Society calls, such as Gest, Epinet, EST-Frame and Res-AgorA [62-65]. In this context, the private sector has also started to reflect on RRI; private funding agencies are an important part of a recently-started collaborative project on this subject covering 30 European countries [66].

In a complementary way to this broader EU push towards RRI, public national initiatives started to appear or have continued to function. For instance, the NWO's Responsible Innovation funding programme, which was one of the first cross-sector programmes on RRI, is on-going [58]. In the UK, a joint digital economy initiative by the national Research Councils has led to the appointment of a Responsible Innovation Advisory Panel. This explores the resources the digital economy and ICT research communities require to address RRI [67]. This is also the case for ethics advisory boards at the national and the European level, such as the European Group on Ethics in Science and Technology, appointed by the President of the EC, and the Committee on Bioethics, an intergovernmental body of the Council of Europe [68]. TA bodies are attached to national parliaments in ten EU Member States to advise parliaments on the possible social, economic and environmental impact of new science and technologies, while STOA fulfils the same role at the European Parliament [69]. Their roles and remit, particularly in relation to inclusive deliberation, mean that they are valuable in assisting the mainstreaming of RRI in the EU and ensuring its uptake in S&T decision-making processes.

4. Responsible Governance in China

RRI is not a commonly used concept in Chinese S&T governance. However, similar ideas, such as 'responsible research', 'ethics of science and technology', and 'science, technology and society' have for a long time been hot topics in both academic and social discussions [70, 71]. Similar to Europe and other parts of the world, there is now a trend to emphasise more responsible research and innovation in China.

The background to responsible S&T governance in China can be summarised through three different concepts. The first concept relates to what in Chinese is called 'Developmentalism', which refers to the primacy of economic development for S&T. Since reform and opening up in the late 1970s, promoting economic development has become the main priority, as indicated by the former Chinese leader Deng Xiaoping, "Development is the absolute principle" [38]. The principle of developmentalism significantly influenced the distribution of S&T resources and the mode of S&T development.

'Scientism' is the second most commonly used, and descriptive, concept. S&T has been considered the driving force of economic and social development. The Chinese government has frequently emphasised the important role of S&T in promoting social and economic development since reform and opening up. In 2012 the government declared the "innovation-driven development strategy", putting S&T in the key position of the transformation of the economic development mode. Meanwhile, public attitudes towards S&T have been positive in China. For instance, in a 2010 survey, 89% of the public agreed that "S&T makes our lives healthier, easier and more comfortable" [72], whilst only 66% of the European public agreed with that statement [73].

The third and final concept is the top-down management system. The traditional governmental policy-making system in China could be summarised as a typical top-down system where the government plays a dominant role in decision-making. Society is very weak compared to the strong state. As a result, public participation in S&T policy-making has been rare.

The responsibility of S&T has been limited to promoting China's economic growth, wealth and power. For many years, the social responsibility of S&T has been neglected. However, great social changes have taken place in the last years that have increased concerns for scientific research and innovation and new arenas for the discussion of responsible S&T have emerged.

4.1 Responsible governance at public, scientific and governmental levels

Facing increasing problems around environmental pollution, resource shortages, social injustice and rising public calls for improved livelihoods and better social services, the Chinese government has acknowledged the limits of developmentalism and is actively changing the purely economic-oriented development mode into a more sustainable and inclusive one. Over the past decade, the Communist Party Central Committee and the

State Council have put forward new concepts advocating a scientific outlook on development and improving society. In 2012, the Ministries of Science and Technology and of Finance launched the 'Science and Technology Program for Public Wellbeing', whose aim is to ensure that more people benefit from S&T innovation [74].

Chinese policy-makers have also realised the limits of the top-down governmental management mode. Promoting innovation and involving all parties in social governance has become one of the major tasks of the current government. This has also been reflected in S&T governance that has incorporated various modes of responsible S&T governance as it is understood in Europe. For instance, when starting the compilation of the 'Outline of the National Program for Long-and-Medium-Term Scientific and Technological Development' in 2003, the government introduced multiple forms of public participation. As a result the Ministry of Science and Technology opened a new channel about the outline on its official website to keep the public informed of progress, and launched a public participation forum with 19 topics that the public could visit to make comments and share views on the compilation of the outline. In 2008, in order to promote public participation in the governance of GM food technology, the Chinese Academy of Science and the Xicheng district government in Beijing organised a consensus conference that provided a platform of open dialogue between the public and experts [75]. As part of the 'National Technology Foresight Report (2013-2014)' the Chinese Academy of Science and Technology is conducting an online public survey to collect data on the public's needs and their suggestions for future technology development in China.

Besides governmental strategies and policies, there are two additional and important levels at which the responsible governance debate has developed in China: the public and scientists. For the public, the rapid economic growth of the last thirty years has greatly improved living standards. As people's living conditions and level of education have rapidly increased, public awareness of rights and perception of risks have risen accordingly. As a result, the Chinese public has become more and more concerned about ethical issues in S&T. For instance, in 2007 citizens in Xiamen, a city in south-eastern China, gathered to protest the plan to establish a p-xylene plant in a suburb because they feared it would pollute the environment. Despite the assurances of industry and local government, the citizens refused to accept the factory. Eventually, the local government gave up the plan and moved the plant to another city [76]. Similar protests have happened in recent years in other Chinese cities. In 2011, a senior researcher for a tobacco research institute was elected to the Chinese Academy of

Engineering (CAE) for his achievement in providing technology to reduce tar content in tobacco. This election soon caused public debate. It was argued that technology to reduce tobacco tar was unethical as it might persuade more people to smoke, with the scientist seen as being in the service of the tobacco industry. Therefore, the CAE was asked to deprive the scientist of the title of academician [77]. Although the CAE did not remove him, it took measures to ensure that no more members of the tobacco industry would be admitted [78]. Concern about responsible governance of S&T has also been demonstrated in public opinion research. The Chinese Academy of Science and Technology for Development conducted two rounds of surveys of citizens in five Chinese cities in 2007 and 2010. When asked "should scientists be responsible for the misuse of their research products?" 36% responded affirmatively in 2007. In 2010, this percentage increased to 46%. The rising public perception of risk and concern for ethical issues in S&T has led to higher requirements for responsible governance in China [79].

In the past, discussions amongst Chinese scientists focused on the responsibility of scientists as members of the scientific community. As the Chinese capacity for scientific research grew rapidly, the morality and integrity of science faced increasing challenges as the scope and impact of scientific misconduct increased. In a 2008 national survey of 30,000 S&T personnel, nearly half thought scientific misconduct was common in China, and more than half of respondents stated that they knew researchers around them who had committed scientific misconduct [80]. The scientific community in China has taken various measures to fight misconduct. For example, in 2007, the Chinese Association of Science and Technology formally issued 'The Norms of Scientific Ethics of Science and Technology Personnel' defining the principles of scientific morality, the scope of scientific misconduct, and the process to monitor scientific misconduct [81]. Increasingly, researchers have also become aware that their studies have social and ethical implications. In a survey on science ethics of researchers in China conducted in 2012, only 19% of respondents thought that no ethical issues were involved in their research [82].

5. Responsible Governance of S&T: an Indian perspective

In the Indian context the state plays the leading role in deciding priorities in research, funding and the application of S&T for development. In India, S&T has been identified in the policy agenda since the 1950s as a key means to achieve national prosperity, both in terms of economic growth and social development. The Scientific Policy Resolution of

1958 clearly stated that "the key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital" [83]. The subsequent S&T policies, namely the Technology Policy Statement of 1983, the Science and Technology Policy of 2003 and the most recent Science, Technology and Innovation Policy (STIP) of 2013, have reiterated the broad vision of 1958 while expanding and enriching it further [25,84,85]. The latest STIP 2013 categorically states that "science, technology and innovation (STI) have emerged as the major drivers of national development globally. As India aspires for faster, sustainable and inclusive growth, the Indian STI system, with the advantages of a large demographic dividend and the huge talent pool, will need to play a defining role in achieving these national goals. The national STI enterprise must become central to national development" [25]. The on-going national 12th Five-Year Plan (2012-17) also recognises that the objective of development is a broad-based improvement in the economic and social conditions of the people [43].

The Government on the other hand has been active in promoting the role of S&T in national and social development. The Ministry of Science and Technology has launched a programme, Science for Equity Empowerment and Development (SEED). This aims to provide chances for scientists to run action-oriented and location-specific projects that use S&T to improve the socio-economic situation of the poor and disadvantaged, particularly in rural areas [86].

5.1 The role of public policy and civil society in responsible S&T policy in India

It has rightly been suggested by Mashelkar [87] that the four pillars underlying India's S&T goals can be recognised as techno-nationalism, inclusive growth, techno-globalism and global leadership. Of particular relevance for responsible governance is the idea of inclusive growth, well established in Indian S&T policies. The latest Science, Technology and Innovation Policy 2013 mentions "a strong and visible Science, Research and Innovation System for High-Technology-led path for India as the goal of the new STI Policy" and 'science, technology and innovation for the people' as the new paradigm of the Indian STI enterprise. It exhorts that the national STI system must, therefore,

recognise the Indian society as its major stakeholder: "Innovation for inclusive growth implies ensuring access, availability and affordability of solutions to as large a population as possible" [25]. Thus, it can also be observed that the evolution of S&T policies in India since the 1950s also reflects the change in the nature and mode of advancing new dimensions in the notion of 'responsible governance' of S&T in India. This changed from the top-down approach in the early years, where the government on its own took responsibility for S&T development and direction, to the inclusive approach, where the involvement of the 'entire Indian people' is aspired to, in terms of coordination at all levels with any sector of economic, scientific and technological activity.

Although it is not clear how the inclusive approach will be fully translated into action, there are some promising examples. One case is the discovery, development, and delivery of drugs and vaccines that are affordable, and accessible to the poor [88,89]. The Open Source Drug Discovery project is a similar initiative, started in 2007 by the Indian Council of Scientific and Industrial Research to develop drugs for tuberculosis using an open source approach. This project involves the participation of students, experts and researchers from both the public and private sectors, whereby data is collected and shared [90].

Another encouraging example is the evolution of Indian policies aimed at regulating genetically engineered agriculture. Through stakeholder debates it became clear that in India agrifood innovation could not be divorced from broader socioeconomic impacts (effects on small farmer communities, the environment, labour costs, traditional agriculture, etc.) while food security is a major preoccupation for policymakers. Food policy has been influenced by various interest groups and trade bodies for which socioeconomic issues are key value considerations. This appears to have produced a number of highly pragmatic policy choices aiming to sustain and develop organic agriculture while at the same time making room for the long-term implementation of biotechnology innovations. Whereas initial regulations emphasised human health and environmental impacts due to being so heavily based upon OECD data sources; India first expanded biosafety to address the economic security of farmers, only later increasing citizen participation and consultation [28].

Civil society has also been able to play a role in steering S&T governance, however the process could be further democratised by increasing the number of farmers, using genetically engineered cotton crops, in a debate currently being conducted on their behalf [91]. As in China, spontaneous public protests have proven a catalyst for the S&T

debates taking place inside the country. For example, huge public protests were mounted against the establishment of nuclear power plants in various parts of India. Villagers, farmers and activists opposed the plants on the grounds of loss of livelihood, health and environment hazards, and increased vulnerability to earthquakes. In the case of the proposed plant at Mithivirdi in Gujarat state, environmental experts and activists also alleged that there were serious flaws in the Environment Impact Assessment carried out by the government body, Engineers India Limited [92].

6. Dimensions of responsible governance

The previous sections of this Essay have illustrated similarities with China, India and the EU. They have identified a common trend towards use of responsible S&T governance through alignment of social needs and goals with science and innovation. Similarly, they have illustrated the (often conflicting) interactions between the science policy system and the public, an interaction that is nevertheless stimulating and creative. In an attempt to find a common denominator with all of these developments, we find the concept of 'responsiveness' to be the term that best describes the similarities between the three regions. Responsiveness refers to the capacity, commitment and practice of responding to societal demands within, and by, the science system and policy making. It signifies the process of incorporating lay values and opinions in societal debates and official decision making. In the following section, three dimensions that are relevant to responsiveness are introduced. These can serve as a guide for comparing responsible S&T governance in these three different cultural and institutional settings.

6.1 Public participation

In the RRI literature, responsiveness is inextricably linked to deliberation and public participation [23]. While it would be inexact to affirm that the RRI literature reduces public participation to those forms that are institutionalised in policy making, especially in its public-sponsored form, the institutional environment in which RRI is developing (EU policy and, especially, its main research funding instrument Horizon 2020) frames public participation mostly within the broader framework of publicly sponsored projects and initiatives. As we have seen above, China and India share an interest in, and are moving towards, institutionalised forms of public engagement. An important element in building responsiveness into the science system is the spontaneous and less institutionalised action of citizens, be they organised in civil society organisations or local movements which who are more vocally pushing societal views, needs and

demands, up the political and scientific agenda. This plurality of public participation suggests it is necessary to take a broader view in order to identify these many configurations of participation in diverse cultural and institutional contexts (see e.g. [93] on the varieties of public participation).

Scientific literacy poses a significant challenge to promotion of public participation in S&T governance. China, for example, is confronted by the fact that the number of people with a basic level of scientific literacy is only just over 3% of the Chinese population [72]. The level of economic development and education varies greatly among social classes, regions and ethnic groups. In such a large and diverse country, promoting public participation in S&T governance will be a difficult task. India is also aware of the problems created by such low levels of scientific literacy. Not accounting for science literacy in India, the overall literacy rate of India is only about 74% [94]. There is therefore an urgent need for concerted efforts to be made to increase literacy rates amongst citizens as well as overall scientific understanding. This is one of the objectives of the Indian government's Science and Technology strategy of 2003, stating that "one was to ensure that the message of science reaches every citizen of India" [85]. However, this effort of science communication and popularisation by government agencies, such as the Department of Science and Technology and the Council of Scientific and Industrial Research (CSIR), relies mainly on a one-way communication approach. Citizens are expected to learn, appreciate and understand developments in science, and the policies of the government, in a way that closely resembles the deficit model of public understanding of science.

6.2 Encouraging responsibility (responsibilisation) of the scientific community

Responsiveness implies also a degree of active involvement in, and commitment of, the actors involved in scientific research or an innovation process, including, the scientific community itself. We use the term 'responsibilisation' to describe this active commitment of social actors [95]. In this respect, the scientific community China and India has been pushed to the forefront of society. The push by scientific associations to adopt a Code of ethics for Chinese scientists, as well as the widespread awareness that scientific research and technology development entails ethical and social issues, points to the issue of responsibilisation, and suggests some reasons for optimism. In India, programs such as the Science for Equity Empowerment and Development (SEED) have created a framework in which scientists can link their research activities closely to the achievement of societal goals. In the European Union, the 'Horizon 2020 Science, With

And For Society' programme aims to create a forum for scientists to engage with wider society and encourage its active role in building RRI.

6.3 Intermediary bodies in directing science policy

Both the evolution of the national research systems [96] and the diverse and multi-layered configuration of the EU result in the proliferation of intermediary bodies and organisations which acquire an essential role in directing European science policy. Ethics committees, technology assessment, foresight bodies and science councils are all part of this dense network which plays an important role in the promotion and development of responsible S&T governance across Europe. As part of the science advisory system, they contribute to the inclusion of societal considerations in science and technology policy. Furthermore, the gradual engagement of stakeholders, especially in technology assessment, creates important opportunities for broadening public participation. This thick layer of intermediary organisations is almost non-existent in India and China but there is a strong will to develop them along the same lines as in Europe.

7. Conclusions

Responsibility in S&T governance via Responsiveness is an urgent undertaking in all three regions. While innovation still dominates discourse in Chinese society, many policy-makers and scientists worry that emphasising the responsibility of research and innovation may impede China's S&T development [97]. Promoting responsible S&T governance will not only require a reform of the existing S&T governance system but also fundamental reforms of China's economic development and social governance system, such as changing the mode of economic-focused development and including more public participation in the social governance system. Similarly, India is struggling to strike a balance between promoting innovation and ensuring that it is inclusive. Policy-makers in the Ministry of S&T believe that the various aspects of inclusiveness can have adverse effects on science, technology and innovation potential. Proponents argue that it is high time that the various stakeholders who would be impacted by such science, technology and innovation exercises be informed and involved from the outset, to bridge the gap between science and society. In the European Union, to realise the expectations expressed in Horizon 2020, a concerted effort will be needed to increase RRI diffusion and effectiveness. The EC recently convened an Expert Group on the State

of Art in Europe on RRI to assess alternative policy options for fostering RRI policies in Europe [21]. The Group report clearly identified the need to coordinate efforts in the EU as a crucial issue, concerning RRI mainstreaming in research and policy as well as for its effective implementation through, for example, ad hoc funding or the adoption of RRI-related criteria for existing programmes. This is even more important in the context of EU governance, which is diverse and multi-layered.

This Issues and Opinions Essay has briefly presented some key aspects of public S&T policy and has highlighted several themes working towards the development of responsible S&T governance in China, India and the EU. The goal was not to outline a fully-fledged comparative analysis, but rather to propose some topics for further academic and policy debate. Responsiveness (i.e. the capacity, commitment and practice of responding to societal demands in and by the science system and policy making) has been chosen as an umbrella term to make sense of these interactions and as a guiding concept in the selection and presentation of these topics. This is because it is at the heart of the alignment of science practice and policy with societal demands and goals that is proposed by taking the RRI approach. Supporting a plurality of public participation, encouraging responsibilisation within the scientific community, and strengthening intermediary organisations in the Science Advisory Systems, is identified as possible elements for responsibility. Around these elements, comparison and collaboration can be organised. Although globalisation connects S&T developments together around the world, we are aware that responsible governance needs to be individually developed within each cultural, and needs-based, context.

Overall, responsible governance represents a strong force for international change. The direction and form of change will depend on local norms and needs. Further in-depth research on the existing application of responsible governance in the EU, China and India is needed in order to reach a level of shared understanding that might foster the establishment of common research programmes in S&T governance. The conceptual and procedural aspects of change in practices and policies of responsible governance will require further international collaboration that would run in parallel to the S&T collaboration that is currently taking place within the EU, China and India.

We hope this Essay can contribute towards fostering a robust scientific debate on this issue which, in turn, can help to promote international collaboration in the field of responsible S&T governance.

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Table 1

Selected demographic and economic data for the EU, China and India, 2011-2014

	EU	China	India
People			
Population (million)	505.6[a]	1,334.1[b]	1,241.5[b]
Population under 15 (%)	15.6[a]	18.0[b]	29.4[b]
Life expectancy at birth (years)	80.5[a]	73[b]	65[b]
Under-five mortality rate (per 1000 live births)	4[c]	15[c]	61[c]
Tertiary Education (%)	36.8[a]	26.7[b]	23.3[b]
Economy			
GDP/capita (US$)	32,817.332[a]	9,083.2[b]	3,869.7[b]
Agricultural employment (%)	5[a]	35[b]	47[b]
Military spending (% GDP)	1.55[a]	2.0[b]	2.4[b]
Starting a business (days)	13[b]	33[b]	27[b]
High-technology export (% of manufactured exports)	15[c*]	26[c]	7[c]
Energy use/capita (kg oil equiv.)	3,322.8[c*]	2,029[b]	614[b]
Individuals using the Internet (%)	73.4[c*]	38.3[c]	10.1[c]
R&D			
Expenditure for R&D (%)	2.06[a]	1.84[b]	0.81[d]
Researchers in R&D (per million people)	2,924[b]	963[b]	160[d]

*Source a: [29]; b:[30]; c:[42]; d:[31]; *:Euro Area.*

Figure 1. GDP of the EU, China and India 2004-2014 (billions US $)
Source: [29, 30].

Figure 2. R&D as percentage of GDP of the EU, China and India, 2003-2011
Source: [30, 31].