Research Policy 38 (2009) 571–582

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Editorial

Emerging challenges for science, technology and innovation policy research: A reflexive overview

ABSTRACT

This opening article in the special issue provides a reflexive overview of the nature and purpose of science, technology and innovation (STI) policy research at present, and makes a case for a collective and critical reflection on the means and ends of our research. The complex interaction between the past, present and future in the STI policy research field is one of the key themes of this article and of the special issue more generally. We first attempt to problematise what current STI policy research is, and then expand on the goals of the special issue. Besides summarising each article, we also discuss how these articles, individually and collectively, provide an overview of a number of epistemic, normative and practical challenges that confront us, articulating the main features of each of these. We end with a call for a sustained, critical and extensive 'conversation' among researchers in our field about the nature and purpose of STI policy research and the challenges we face.

> "Tomorrow is not something that necessarily will happen, nor is it a pure repetition of today with its face superficially touched up so it can continue to be the same . . . Men and women make the history that is possible, not the history that they would like to make or the history that sometimes they are told should be made." Paulo Freire (1988, p. xxviii)

1. Introduction

The past, present and future are linked in complex ways. While it is certainly true that 'history matters', today and tomorrow are not (and indeed should not be) merely a repetition of yesterday, nor even something that is uniquely determined by history. Following Freire, we can think about the future as a set of possibilities; exactly which one we will get, while undoubtedly constrained by the past, also depends on the actions we take today. This complex interaction between the past, present and future in the science, technology and innovation (STI) policy research field is one of the key themes of this article and of the special issue more generally. As we shall see, the past shapes and informs the present and the future, while those active in the present interpret the past, constructing a specific version of history, and in so doing they also help to shape the future. As a consequence (and to further complicate matters), things do not stay the same; people, and the society and the wider environment in which they operate, are always changing.[1]

As suggested by the title chosen for this special issue, in what follows we present an overview of the current status of STI policy research field in order to take stock of what has been achieved and what remains to be done, inviting the reader to reflect on a number of challenges that currently confront the field. This opening article and the rest of the special issue represent an attempt to stimulate a critical and collective 'conversation' on the nature and purpose of our field and on the emerging issues that merit discussion. Debate is the very lifeblood of academic life, ranging from more low-level arguments about concepts, theory, methodology, analysis and interpretation up to the occasional outbreak of more fundamental 'paradigm wars'. Yet paradoxically, one characteristic of the academic community is that "we seldom talk to one another or understand one another" (Czarniawska, as paraphrased in Weick, 1999, p. 803). Far too infrequently do we reflect systematically on our own practices of policy research for STI and engage in discussions about our field and its evolving research agenda. This special issue is an invitation, or perhaps even a provocation, to start doing exactly this.

We decided that a good way to launch this process was to critically examine what we currently do in our research when we say that we are carrying out policy research on science, technology and innovation. The opportunity to pursue this was presented to us in our roles as co-organisers of the SPRU[2] 40th Conference, which we saw as providing an ideal occasion to reflect on where our field has got to and what it needs to do next. Out of the nearly 200 papers presented at the conference, we identified a number that, besides providing high quality individual contributions on key topics in our field, together would provide an overview of our field and a starting point for identifying and analysing the key issues that lie before us.

[1] As Heraclitus observed 2500 years ago, "No man ever steps in the same river twice, for it's not the same river and he's not the same man."

[2] SPRU (Science and Technology Policy Research) is based at the University of Sussex, UK. Details of the SPRU 40th Conference are available at: http://www.sussex.ac.uk/Units/spru/events/ocs/index.php.

0048-7333/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.respol.2009.01.021

From this and other evidence, it is apparent that policy research on science, technology and innovation continues to be a somewhat heterogeneous set of activities undertaken by a community of diverse actors, each with rather different roles and aims. A central goal of this research community is to serve the ends of society, helping to construct more effective policies for science, technology and innovation, which in turn will yield greater benefits for society. We are – or should be – concerned not only with the means to reach those ends but also, when necessary, with questioning both the means and indeed the ends of society. Our particular focus here is on those STI policy researchers who, working in academia, concentrate more on making intellectual contributions, providing independent and critical work on policy problems and policy-making. In the current academic and policy context in which we operate, there has been a trend towards more instrumental and entrepreneurial activities, both at the individual and organisational level, but this needs to be balanced with a substantial element of critical and independent scholarship. Achieving an optimum balance requires reflexivity on our own practices as individuals and collectively – on what do we do as academic STI policy researchers.

The structure of this article is that we first set the scene with regard to the STI policy research field and expand on the goals of the special issue. Next, we introduce and briefly summarise each article that follows in the special issue. We then discuss how these articles, individually and collectively, provide an overview of the epistemic, normative and practical challenges that confront us. We end with a call for a sustained, critical and extensive debate in our research community about the nature and purpose of STI policy research.

2. What is STI policy research? And policy for whom and for what?

STI policy research can be defined relatively simply as the application of social science (whether economics, sociology, political science, organisational science, business and management science, or psychology)[3] to the study of policy for science, technology and innovation. Rather than being theory-driven or paradigm-driven, it is primarily a problem-oriented field that focuses on practical issues to do with specific policies for science, technology and innovation, taking account of the central role of firms in the evolution of technology and innovation.[4] As such, much of it is empirically oriented and motivated; where there is theorising, this is mostly inductive, reflecting on what the empirical record appears to show. This differentiates it from social science disciplines where theory comes first and the empirical work is largely to test the theory.[5] Drawing on a wide range of disciplines, it is generally viewed as an intrinsically interdisciplinary research area.[6]

The STI policy field is not the only one, however, where social scientists are involved in studying science, technology and innovation. It is easy to identify at least two other, related and partially overlapping research communities – science and technology studies (STS), and technology and innovation management (TIM). The former consists primarily of sociologists of science and technology, along with philosophers and historians of science,[7] while the latter is composed mainly of researchers from management, business, administration and organisation science. All three communities are thus composed of various epistemic sub-communities that both divide the three communities but also provide multiple and diverse bridges between them (e.g. in the form of membership of common networks).

There is a certain specialisation and division of labour among these three fields, partially reflecting the rather different disciplinary origins of the fields. One aspect of this is a preference for different units and levels of analysis as well as different target audiences and publication outlets. At some risk of oversimplification, we can say that STI originated initially from economics and to a lesser extent sociology, political science, history of technology, management science, and organisational science. It exhibits a preference for firm, industrial and national levels of analysis, viewing the Market and the State (in the shape of Government or policy-makers, with their role in regulating or facilitating market interactions and collective processes among business firms and other organisations) as the main interlocutors.[8] In contrast, sociology is the main discipline that has shaped STS, with other important contributions coming from the history and philosophy of science (and occasionally from science itself). Many of its practitioners share a focus on the processes connected to scientific and technical knowledge production, the notion of 'social construction', and in some cases a reformist or activist interest to make science and technology accountable to public interests and to society more broadly (e.g. Sismondo, 2007). Finally, TIM was shaped primarily by business and management studies, with major contributions from economics and industrial organisation. It focuses more on research, development and innovative activities within firms at the individual level and (to a lesser extent) collectively (e.g. at the level of industries or sectors), and how best to manage these.

Since the early years, the relationship of STI policy research to the policy-making process for science, technology and innovation has had an instrumental as well as a critical function (Blume, 1970). STI policy research originated at the crossroads of discussions among natural scientists, philosophers and social scientists about the social relations of science and technology, and about the growing policy needs of government for data or other evidence that could inform its decisions on the organisation and finance of science and technology (and, later, of innovation). Intellectual debates and theorising in academia about the functioning and structure of science constituted some of the background to STI policy research. The production of statistics and instruments for the measurement of science, technology and innovation – such as R&D expenditures, personnel statistics, patent statistics, and bibliometric (i.e. publication and citation) indicators – influenced and gradually became more important inputs to policy making. These were produced by a number of actors within the policy research community, including international organisations such as OECD and UNESCO and later the European Commission, research consultancy organisations like the RAND Corporation and CHI Research,[9] in-house research groups within government agencies (such as NSF), and academic research centres like SPRU.

Over time, the instrumental and critical functions of STI policy research have co-evolved. If one adopts the approach of Ball

[3] There have also been significant contributions by historians of innovation and technology.

[4] The definitional approach adopted here is a pragmatic one, i.e. STI policy research is what STI policy researchers do (as compared to what they should or ought to do, or what they perhaps did in the past).

[5] We are grateful to Richard Nelson for some of the observations here.

[6] Whether it is yet coming close to developing its own 'paradigm' (in the strict Kuhnian sense) is more debateable (see the discussion in Martin, 2009). However, it has certainly come to depend heavily on a shared body of work associated with such pioneers as Chris Freeman, Richard Nelson, Keith Pavitt and Nathan Rosenberg. Indeed, Dosi and colleagues have (somewhat provocatively) termed this 'the Stanford-Yale-Sussex synthesis' (Dosi et al., 2006a,b), although that rather downplays other important streams of work.

[7] Some historians of technology might also classify themselves as more part of the STS than the STI policy research community.

[8] We are grateful to Ed Steinmueller for his observations on this and other issues covered in the introduction.

[9] Originally known as Computer Horizons Incorporated, the firm subsequently adopted the acronym CHI Research. It was set up and led for over 30 years by Dr. Francis Narin, a pioneer of S&T indicators and of 'evaluative bibliometrics'.

(1995),[10] one might perhaps try to categorise it today in terms of four interacting components – STI policy science, STI policy engineering, STI policy entrepreneurship and STI policy scholarship. The 'policy engineer' can be viewed as an actor who uses a "set of procedures which enables one to determine the technically best course of action to adopt in order to implement a decision or achieve a goal" (quoted in Ball, 1995, p. 258). The 'policy scientist', in contrast, "is one who seeks the most technically correct answer to political problems in terms of available social scientific knowledge" (Ball, 1995, p. 259), while the 'policy entrepreneur' "is committed to the application of certain technical solutions or organizations and contexts" (Ball, 1995, p. 265), and actively searches for opportunities to apply his or her favoured solutions. Ball (1995) argues that particularly in the case of policy engineering and policy entrepreneurship, "policy is both de-politicised and thoroughly technicised" (Ball, 1995, p. 259). It is merely "problem-solving technicism" – a form of technical rationality that "rests upon an uncritical acceptance of moral and political consensus", in which "debates and conflicts which link policies to values and morals are displaced by bland rationalist empiricism" (Ball, 1995, p. 259). Policy research is sometimes claimed to be de-politicised; policy making is viewed as an exercise of planning, and "the function of the social sciences is to provide the theoretical foundation that makes this planning possible" (Fay, as quoted in Ball, 1995, p. 259). These instrumental and utilitarian components of STI policy research need to be counterbalanced by the one of STI 'policy scholarship'. However, (at least in the view of those engaged in policy engineering or entrepreneurship) the nature and the purpose of STI policy scholarship is rather more ambiguous and less well defined, not least because its adherents often deny that there is one technically correct course for social action.

The notion that the role of policy scientists in society, like that of other social scientists, is merely to provide specialised, impartial, objective knowledge and that what society then does with that knowledge is someone else's problem has been openly criticised. Some scholars argue that policy scholarship should, over time, influence how people think about problems, recognising that today's problems are often influenced by yesterday's ideas (e.g. Birnbaum, 2000). The purpose of policy scholarship is to shape ways of thinking and learning about society's problems, and to understand how key actors in the policy process come to understand those problems. Theory can be regarded as one of the ways to help people in "thinking otherwise" (Mahon, 1992, as quoted in Ball, 1995, p. 266). Furthermore, some scholars have started to focus on the political aspect of policy making and policy research, arguing that there is a 'new policy research':

> Moving from the modest claims of ideas-based empiricism, the new policy analysis makes claims about the primacy of ideas and the indeterminacy of knowledge. Rather than rational actors following their interests, it is the interplay of values and norms and different forms of knowledge which characterise the policy process. (John, 1998, p. 157, quoted in Hughes, 2003)

Thus, critical and independent policy scholarship on the fundamental problems of policy-making may be viewed as a process of critical reflection on the core assumptions and values, both explicit and implicit, on which policy-making is based, providing an improved theoretical understanding and thereby influencing the policy debate and policy-making. This type of policy scholarship can flourish in academia, but only under the right conditions that nurture the balance and synergy with the other three components of policy research outlined above.

Sometimes, three or even all four components of STI policy research[11] can be identified in single or overall contributions of individual researchers or in the collaborative efforts of groups of researchers. The interaction between these components may vary across the various individuals, institutions and subfields making up STI policy research, and over time. Although playing a role in some of these components may be relatively easier than in others, integrating these four components is ultimately a collective responsibility. The key question is whether or not there is some sort of 'invisible hand' operating here to ensure an optimum interaction between the various components, so that collectively we are discharging our responsibility towards society as effectively as possible. Becoming aware that today's ideas will shape tomorrow's problems is one part of this. However, we do need to reflect periodically on whether STI policy research field is addressing all four components adequately, and whether in the field there is balance between them that is appropriate for the needs of society. It is hoped that this special issue, amongst other things, will initiate a discussion and perhaps even a debate on this crucial matter. In order to do this, we first need to problematise our own practices in carrying out STI policy research, something that entails engaging in a certain amount of critical reflexivity. It means questioning our roles in STI policy research and our interactions with other actors in the STI policy community, along with the assumptions, motives, values, tools and theories that drive our work.

Critical reflexivity at the individual level is often facilitated by processes of reflection that occur at the level of the field. It is probably no coincidence that other fields in social sciences have been engaging in these types of debates about the praxis and the role of academic work in society.[12] (For similar discussions in the two interdisciplinary fields that are related to and partially overlap with the STI policy field, STS and technology and management studies (TIM), see for example the ongoing debate on the need for STS scholars to become public intellectuals triggered by Bijker's (2003) article on 'The need for public intellectuals', and the book by Breen and Hamel (2008) on the future of management.) The STI field has certainly engaged on a few previous occasions in critical reflexivity on its own practices, as we shall see in the next section.

2.1. Past exemplars of critical reflexivity in STI policy research

Let us examine two previous examples of critical reflexivity on STI policy research practices provided by scholars in our own field, examples that may not be well known by some of those now working in the field. Earlier, we argued that talking to each other – in the form of 'conversations' triggered by (and that further stimulate) critical reflexivity – is vital to the health of a research field. Sometimes, parallel and disconnected discussions, debates, silences or what gets forgotten in our profession are equally important to examine if we are to understand a research field. The cases examined here are the discussions that occurred first in the early 1970s concerning the 'limits to growth' thesis and computer world models, and secondly around a critical essay by Richard

[10] The ideas for this part of the discussion come from the re-elaboration and extension of Fay (1975)'s work by Ball (1995).

[11] The academic STI policy research field is perhaps somewhat unusual in having a fairly even spread of activities spanning the four categories, at least compared with STS, which is more concentrated towards the 'policy scholarship' end of the spectrum, and with TIM, which is more heavily concentrated towards the 'policy engineering/entrepreneurship' end of the spectrum.

[12] For instance, for these debates in social sciences in general see Flyvbjerg (2001); in sociology see Burawoy (2005); in political science see Schram and Caterino (2006); see Shapiro et al. (2007) (and the earlier references cited therein) for the various reflections in management research on the relationship between research and practice; also see Pfeffer and Fang (2001) and Mintzberg and Gosling (2002) on the role of business schools and management education.

Nelson published a few years later (in 1977) on three approaches to policy analysis.

2.1.1. The Limits to Growth and the debate about computer world models (1970–1974)

At the start of the 1970s, the MIT systems scientist, Jay Forrester, extended the application of his systems dynamics approach to model the future of the world economy, population and the environment, publishing his results in a 1971 book, *World Dynamics*. With the sponsorship of the Club of Rome, this work was extended and popularised by Meadows et al. (1972) in their 1972 bestseller book, *The Limits to Growth*. In this, they put forward a general computer model of the future of the world, a model that brought together forecasts of population growth, resource depletion, food supply, capital investment and pollution. In particular, they examined the effects of continued economic and demographic growth in a world of finite resources, and derived various policy implications, such as the need for birth control to limit population growth.

Their computer simulation models were enthusiastically greeted by many because they encouraged "serious considerations of what was previously thought unthinkable: that industrialised societies may have 'overshot' their appropriate levels and they may now have to not just decelerate or stop growth, but reduce their technology and material consumption levels" (Streatfeild, 1973, p. 4). The work generated a variety of responses, being discussed and criticised by a number of social scientists. Prominent among these were economists such as Robert Solow (who in earlier years had analysed the contribution of technical change to economic growth), who complained about the weak base of the data on which the predictions were made, and a group of science policy scholars based at SPRU at the University of Sussex, who engaged in an in-depth analysis of *The Limits to Growth* book and related publications by the MIT group, resulting in a sustained debate between the MIT and SPRU groups.

The SPRU group published their analysis first in a special issue of the journal *Futures*, and then in a 1973 book, *Thinking About the Future: A Critique of the Limits to Growth*. Their clear conclusion was that "although system dynamics is a useful step towards the important exercise of world modelling, it should in no sense be used now as a basis for policy making" (Streatfeild, 1973, p. 4). The SPRU response centred partly on the feasibility and desirability of continued economic growth, and on the composition and distribution of growth.[13] Although the SPRU group, like other scholars, agreed with the MIT researchers on the urgency of various social and political problems, such as population growth rates, pollution and resource depletion, they heavily criticised the use of computerised model-building in the social sciences. In particular, they focused their critique around the assumptions built into the model, including the relative lack of emphasis on political and social limits compared with physical limits, the reliability of the empirical data used in the model (e.g. the statistics on known reserves and rates of depletion), and the apparent under-estimation of the potential of continuous technical developments.

The MIT group produced a forceful and critical response to the SPRU analysis of their work, which was published in the same special issue of *Futures* (Meadows et al., 1973). They pointed out that "the Sussex authors have not put forward an alternative theory of growth to support their views, nor have they described in precise terms the process of social change and technological advance that they believe will accommodate current growth processes". They labelled the SPRU response as "technological optimism" that, although containing a number of important contributions to economics and forecasting, made several technical mistakes, especially in relation to system dynamics, ecology and control theory.

The exchange between the two groups shows some elements of a 'paradigm war', where ideologies, intellectual frameworks and assumptions about the nature of the world shape preferences for the design and use of means to study the world. However, the debates around the limits to growth and the use of computerised world models for policy-making in the early 1970s stimulated a worldwide general interest in dynamic computer simulation models, in particular on world 'issues' models as complementary means to other existing tools for forecasting, such as the Delphi method and scenario analysis, to study and help solve social problems. It contributed to establishing world modelling as a research approach (Cole, 1974) and opened up the possibility for many subsequent computer-based models for policy-making such as microworlds (Morecroft, 1988) and agent modelling.

2.1.2. The Moon and the Ghetto (1977)

In 1977, Richard Nelson published a critical essay in the form of a short book entitled *The Moon and the Ghetto: An Essay on Public Policy Analysis*. In this, he examined three intellectual traditions that had influenced policy analysis from the 1950s to the 1970s – the 'classical economics' perspective based on rational choice analysis, the organisational perspective, and the research and development perspective. This richly contextual and critical analysis of the origins and evolution of each policy analysis perspective provides an insight into their role in shaping policy-making in many countries around the world up to the present. Overall, it is one of the few comprehensive and accessible studies of the nature and purpose of policy analysis in that period.

Nelson's essay is an exemplar of critical reflexivity in our field because of its clarity in establishing what should be the nature and purpose of policy, and in making a case for the role of policy analysis (or policy research) in the policy-making process. In particular, Nelson highlights the need for persuasive and powerful analysis that provides a normative structure (on where to go) and a positive or scientific structure (i.e. the 'map' showing how to get there). In Nelson's view, our ability to solve a particular social problem – including specifying what the problem is, as well as what might offer a solution – also requires a theory of the genesis of policy problems. In addition, he pointed to the need to consider the conflicts that arise when we attempt to decide what values, and whose values, we should include in the policy analysis and policy making. In short, both the means and the ends of policy should constitute the domain of policy research.

It is somewhat puzzling how these two cases of critical reflexivity were relatively quickly forgotten and had largely sunk into professional oblivion by early 1980s, but we leave it to the reader to offer possible explanations as to why this occurred. Few people now in our field seem to be aware of and refer to the ideas underpinning the debate about the limits to growth and computer world models, and the reflections contained in Nelson's (1977) essay.[14] But fast forward some 30 years, and in our academic discourse we are still focussing on growth and its sustainability, and we are

[13] "In our view the Growth versus no Growth debate has become a rather sterile one of the Tweedledum/Tweedledee variety, because it tends to ignore the really important issues of the composition of growth in output, and the distribution of the fruits of growth. Some types of growth are quite consistent not merely with conservation of the environment, but with its enhancement. The problem, in our view, is a socio-political one of stimulating this type of growth and of more equitable distribution, both between countries and within them." (Freeman, 1973, p. 10).

[14] In the ISI Web of Knowledge Citation Index, *The Moon and the Ghetto* (1977) has only 81 citations and the article by Freeman on 'Malthus with the computer' (1973) has just 2 citations. This compares with other work by Nelson, such as *An Evolutionary Theory of Technical Change* (with Winter, 1982) which has 4350 citations, and by Chris Freeman, such as *The Economics of Industrial Innovation*, which has 1060 citations (as accessed on 4 December 2008).

once more thinking seriously (and with some concern) about the future. Maybe we are now more comfortable in talking openly about sustainability rather than unfettered economic progress, and 'sustainable development' seems like a good idea (even if we lack a rigorous definition for it). Yet we still do not have a very satisfactory theory of social change. Our ability to improve social problems remains rather limited, and we do not know why we appear to have achieved only modest gains in relation to many societal problems, a failing aptly summarised by Nelson (1977) with the simple but troubling question, "If we can land a man on the moon, why can't we solve the problems of the ghetto?" Since then, there have been further developments in space exploration, such as landing a robot on Mars, but in many parts of the world (including some cities in developed countries) there are still millions of people with low levels of literacy and suffering from malnourishment and ill-health.

While one can debate exactly how much progress has been made in the intervening decades, it is clearly vital to take stock of what has been achieved and what remains to be done, defining what our main challenges are and thinking systematically about the future. Research fields, like people and organisations, may go through a life cycle or career. Birthdays for organisations, as for people, are moments not just for celebration, but also for taking stock of what one has achieved in life and for reflecting on future directions. We felt that SPRU, one of the oldest organisations in the field of STI policy research, reaching the age of 40 was an apposite moment for initiating a critical and collective evaluation of the past and present, and for a reflection about the future of our field.

3. The special issue: selection process and critical commentaries on individual papers

In this section we will describe how the papers for this special issue were selected, summarise their content and analyse them collectively as exemplars of STI policy research.

3.1. The selection process

The original call for papers for the SPRU 40th Conference invited participants "to engage in a critical evaluation of the present and future research agenda of the Science, Technology and Innovation (STI) field ... [and] to explore empirical, theoretical and applied policy approaches that can enable us to conceptualise the contradictory nature of modern science and technology and innovation, and thus provide practical policy guidance." The papers that were thus attracted amply demonstrate that STI policy research is still very much an interdisciplinary field composed of various communities of research practice that, like the people involved in them, are at different stages in their respective 'careers', with evident consequences for how research priorities are set, for which topics attract most attention, for which perspectives are considered relevant and which methodologies most productive, and for the relationships that exist between academic researchers and non-academics in the STI policy community.

From the 190 presentations at the conference, we selected a set of papers that seemed to be representative of the current status of the STI policy field and of what STI policy researchers actually do. In arriving at this, we sampled along a number of dimensions, with a strong emphasis on covering a full range of topics in the broad field of STI policy research, on methodological pluralism, and on diversity in the affiliation of researchers to different communities of research practice.

If we look at our field from an historical perspective, we observe that, broadly speaking, 'science' (or 'research'), then 'technology' and later 'innovation' were concepts and corresponding areas of work that were gradually introduced in sequence from the 1960s onwards, each overlaying what had gone before (see Godin, 2005 about this).[15] We were therefore particularly interested in papers about science, technology and innovation and their intersections. At the same time, we needed to pay attention to the topics and societal issues that are currently attracting most attention. As noted earlier, the STI policy research field overlaps with the two 'neighbouring' fields of STS and TIM, and has co-evolved with these, so we tried to include papers produced at or near the intersections with these fields. Besides sampling for methodological variety, we also attempted to incorporate papers reflecting a different balance between the four components of the STI policy research (policy science, engineering, entrepreneurship and critical scholarship) discussed earlier. We have taken papers from the various epistemic communities that constitute the STI policy field, focusing on the evolution of different concepts, perspectives, tools and discourses. Last, but certainly not least, we selected papers that reflected upon our own practice as researchers and that could be viewed as artefacts of professional memory, as indicated for example by their sensitivity to the historical genesis and genealogy, institutional context of use and evaluation of ideas, concepts and frameworks.

Based on this sampling approach, a number of authors were invited to submit their papers for the special issue. We subjected them to a first round of review by us as guest editors of the special issue. The revised papers that remained then underwent a thorough peer-review process, using a mixture of referees from within the set of contributing authors and from outside, with most papers being revised once more and a few being revised twice before being finally accepted.

3.2. Summary of individual contributions[16]

The paper 'Developing science, technology and innovation indicators: what we can learn from the past' by Freeman and Soete offers a critical historical overview of the development and use of science, technology and innovation indicators. The authors map the dramatic growth over the last 40 years of STI indicators, setting this in its rapidly evolving institutional context and providing an engaging description and explanation of the genesis and changes in the various categories (such as novelty, research, industrial R&D, professional R&D systems, technology, open innovation and collaboration) and their meanings. They are keen to point out that the collective dimension of the innovative work on indicators was very much a joint initiative in which many participated, although only a few are named directly. The authors demonstrate that the science–technology–innovation system that these changing indicators have tried to measure has itself been subject to continuous and rapid evolution. The authors' cautionary and sometimes critical comments on the use, abuse and problems of indicators are made on the basis of a combined total of 80 years of indicators work by the two authors. Their paper should be read as a comprehensive, critical and accessible introduction to the evolution of STI indicators and their changing policy implications.

In their paper 'Gender-specific patterns in patenting and publishing', Frietsch et al. (2009) use many sources to measure and investigate differences in the output of men and women in science and technology in 14 countries around the world. The aim of their analysis is to provide an explanation for a set of phenomena related to women in science and technology revealed by other statistics,

[15] There is a possible analogy here with the 'triune' brain model and its evolution over history, beginning with the reptilian brain, which was later overlain with the primitive mammalian brain, and later still with the neo-cortex.

[16] The sequence finally chosen for the papers was only one of several possibilities. It is a combination of categorising papers in terms of whether they are most related to science, technology or innovation, while the first and last papers are about STI policy as a whole and encapsulate a more retrospective or prospective approach.

such as those pointing to a 'leaky pipeline' (in other words, the proportion of women tends to decrease as they approach higher rungs of the career ladder), the lower productivity in terms of publishing by women compared to men, and differences between countries and disciplines with regard to the outputs produced by women. The authors critically examine previous studies on the topic, with their fragmented and in some cases contradictory results, and provide a useful background to understand the contribution of this paper. By analysing different databases that have been patiently and painstakingly brought together from previously unconnected sources, they arrive at a number of important and policy-relevant findings. The data problems in this area of research are considerable, due to a lack of consistency and to the variety of sources that need to be used. The paper, by combining some of these sources in a more rigorous way, opens the door for further research on a set of issues that needs to be considered in future policy discussions of gender issues in science and technology.

Yegorov's paper 'Post-Soviet science: difficulties in the transformation of the R&D systems in Russia and Ukraine' uses descriptive statistics and other sources of data to analyse and evaluate science policy during the transitions of two countries – Russia and Ukraine – after the collapse of the Soviet Union in the late 1980s. It is an insightful paper for a number of reasons. First of all, it provides access to a number of data that are normally not available to non-Russian speakers. Second, the insider view of the author validates and in some cases challenges the outsider view of scholars who have studied the two national systems discussed in this paper, Russia and Ukraine. Finally, the paper offers a comparative perspective to discussions of research policies in other contexts outside Western Europe and the US. The paper is a case-study of what happens to a STI system when resources available to policy makers are extremely constrained, as in the case of Ukraine, or when STI policy is viewed as instrumental and strategic in gaining geopolitical influence, as in the case of Russia. Moreover, it shows how concepts and tools developed in a specific context can be misleading or problematic when applied in a different context (e.g. the use of output indicators such as patents and publications to measure the productivity of research work). The author's view of a highly uncertain and maybe rather gloomy future is set in the context of a clear description of the past and an identification of the current challenges for the R&D systems described.

The article 'Organizational and institutional influences on creativity in scientific research' by Heinze et al. (2009) focuses on creativity in scientific research with the aim of understanding "whether there is a predominant contextual pattern for creative events in scientific research". The analytical framework that supports their empirical investigation is founded on a detailed examination of the existing literature on factors that influence how research groups conduct their work and their successful accomplishments. The methodology is clearly described and is based on a mixed-methods case-study research strategy that combines surveys, interviews, archival sources and bibliometric data. The empirical cases focus on two areas of natural sciences, human genetics and nanotechnology, and were carried out in research organisations in the US and in Europe. This article makes an important contribution to our understanding of the factors underpinning creative achievements in scientific research today. It confirms some of the findings of previous studies about the importance for creativity in scientific research of factors such as research autonomy, communication within and across organisations, leadership and flexible research funding, but sets these factors in the current scientific context. The authors open up an agenda for future studies on a number of core issues, such as the implications for the future of current funding agencies' behaviour, of funding arrangements based on peer review, and of the widespread use of performance indicators and measures that focus on productivity and recognition instead of funding based on "trust that scientists will do their work". The authors invite the reader to critically examine the overall direction of our innovation system and its implications for our future capacity to continue to be creative in science.

Millstone's paper 'Science, risk and governance: radical rhetorics and the realities of reform in food safety governance' provides a longitudinal overview of the evolution of the science policy-making process with respect to food safety in the UK and certain other European countries, at the European level, and in the US. The article describes the diversity of policy-making processes in different countries at the same point in time and over time, their different evolutionary trajectories through three main models of science-based policy making, where change is not only in one direction but can go backwards as well as forwards, and the reasons behind this diversity. The level of empirical detail based on a set of primary and secondary sources, including the author's own experience and insider's view of the events described, is noteworthy. The paper provides convincing evidence of a substantial gap between the theory and practice of policy-making processes, the former associated with policy scholars or analysts and the latter with policy makers. In Millstone's account, the strategic behaviour and rhetoric of the actors involved in the policy-making processes – for example, the failure of policy makers to take responsibility for controversial and contested issues, and their preference for outsourcing decisions (and any subsequent blame) to expert advisory committees – is critically examined to provide a discussion of the normative implications.

In 'Regulatory policy as innovation: constructing rules of engagement for a technological zone of tissue engineering in the European Union', Faulkner (2009) challenges the conventional view in science, technology and innovation studies on regulation that can be briefly summarised as 'regulation lags behind innovation'. By focusing on regulatory work at European level in the emergent technological field of tissue engineering, the author specifies the innovative and constructive aspects of regulatory work. The paper draws on a set of concepts derived from sociology and from science and technology studies. The idea of a 'technological zone' is given a central place, but the author makes an effort to justify the choice of zone and to contrast its explanatory power with that of other concepts such as the sector, the techno-scientific innovation network and the inter-organisational field. The extensive empirical and analytical work is based on a deep understanding of the technology under study and its political and economic context at the European level. It is conducted through a mixed-method case-study based on an interpretative approach. The paper provides an innovative contribution in terms of extending our vocabulary and conceptual analysis of innovative technological fields, and it is convincing in its argument that regulatory work can be innovative. It reminds us of the importance of the material aspect of technologies, of discourses about them because "what turns a piece of stuff into a social object is its embedment in a narrative construction" (Harré, 2002, quoted in Faulkner, this issue), and (like Millstone's article) what we can learn about policy-making processes by analysing the discourse of the actors involved in them.

In 'Accounting for change in national systems of innovation: a friendly critique based on the US case', Hart provides a critical review of the National Innovation System approach by demonstrating the shortcomings of this framework in accounting for three major changes or shocks in the US innovation system (the Internet boom and bust of the late 1990s and early 2000s, the response to the terrorist attacks of 11 September 2001, and the acceleration of productivity growth since the mid-1990s). However, he also suggests ways to overcome these shortcomings through further elaboration of the innovation system approach. In the opening sentence of the paper, Hart claims that the history of our field can be viewed as a series of empirical problems and analytical responses, and invites the research community to respond to the empirical

challenges described later on. The paper provides a critical appraisal of the epistemic community responsible for the innovation system approach, its diversity and the knowledge accumulated so far. The author integrates certain ideas from comparative political economics and historical sociology into the systems of innovation approach, showing how ideas can cross over from one academic field to another with fruitful results. From the evidence provided in the paper, Hart concludes that culture and institutions are crucially important, which leads him to highlight the challenge posed by the need to renew our intellectual technologies in an ever changing world.

As we saw earlier, studies of the future have an important place in the history of STI policy field. In 'Prospective analysis of technological innovation systems: identifying technological and organisational development options for biogas in Switzerland', Markard et al. (2009) relate to this area of studies but with a more modern proposal that takes into account the challenges of viewing innovation processes and systems as non-linear, co-dynamic and highly uncertain. This paper, although it builds on previous work on foresight and scenario methods, is clearly related to recent work on socio-technical regimes and innovation systems, developing a methodology to assess the future development of technological innovation systems behind novel technologies. It proposes an approach to analysing the evolution of technological innovation systems and presents an empirical application of this approach in the case of the biogas innovation system in Switzerland, which helps the reader to understand the potential of the methodology proposed. The discussion is framed in terms of vocabulary and concepts that belong to, and have specific meanings within, the epistemic community that the authors inhabit, but which can sometimes prove challenging to the outsider reader. However, this should not prevent us from appreciating the instrumental and analytical value provided by the methodology described in the paper.

Nill and Kemp's (2009) paper 'Evolutionary approaches for sustainable innovation policies: from niche to paradigm?' is a challenging effort to evaluate three approaches to innovation policies inspired by systems and evolutionary thinking. The authors have been involved in designing and applying these approaches with other researchers in a number of technological areas, and this makes their insights particularly valuable. The aim of their exercise is to make a contribution to the process of integration of these approaches to create an evolutionary framework (or even a 'paradigm', as implied by the title for this paper) to sustainable innovation policy. Their evaluation framework for the three approaches is grounded in economic policy language and provides an accessible introduction to the strengths, weaknesses and complementarities of the three approaches. The paper aims to set an agenda for future research and discussion on evolutionary approaches to STI policies. The authors identify four issues that deserve special attention: the normative basis for innovation policy; the need to develop sharper criteria for the design of policies and instruments to implement those policies; the importance of considering and developing a better understanding of the co-evolution of techno-economic and political systems; and the need for further studies of the international dimension of innovation policies.

The paper 'Science, technology and innovation for economic growth: linking policy research and practice in 'STIG systems'' by Aghion et al. (2009) closes this special issue. It is a complex and intriguing paper that takes on directly the challenge we originally posed in the call for papers of the SPRU 40th Conference to discuss the evolving links between policy research and practice. Using an economic 'lens', the authors reflect on systems approaches and their relevance for policy issues of science, technology and innovation. They articulate a series of problems connected to economic growth, and sketch some preliminary ideas on how complex systems ideas could be put to use in order to deal with the economy when viewed as a complex system. The main contribution of the paper is the cautionary but realistic message regarding the ambition of policy researchers and policy makers to use systems, evolutionary and complexity ideas for policy intervention. This view has some similarities with the synthesis of analysis given over 35 years ago by the SPRU group of the MIT world models and the thesis about 'limits to growth' – in other words, systems dynamics is a useful step towards modelling, but it should not be used as a basis for policy making. Whether complex systems ideas are useful and ready now for use in STI policy could be an important discussion to start.

As is implicit in the selection of the papers to form the special issue, these articles are noteworthy not only for their individual contributions, but also because they can be analysed collectively in order to attempt an answer to the general question that we posed at the beginning of this article about what do researchers do when they say that they do STI policy research.

4. Commentary on the set of articles: common themes and features

Let us now examine whether there are common themes or features underlying the rather heterogeneous field of STI policy research and, if so, what these themes or features might be. Becoming aware of what these common features are may provide entry points into the evolving research agenda of our field. We will then attempt in the following section to elaborate some epistemic, normative and practical challenges that our field needs to address.

As the papers in this special issue well illustrate, the field of science, technology and innovation policy research is a heterogeneous one. It is not easy to define exactly what the key issues are, nor the core research problems that bind our field together, faced as we are with long lists of different key words, topics, methodologies and references. A comparative analysis of the set of papers assembled here may provide some possible answers.

Although the diversity remains significant, the articles share much more than their differences. There are numerous direct and indirect links that can be identified among them. The articles share a degree of commonality around topics (e.g. the organisation of research work is the focus of the three papers by Yegorov, Heinze and colleagues, and Frietsch and colleagues), approaches (systemic approaches are apparent in almost all the papers of this issue), and levels of analysis (e.g. supra-national entities such as those discussed by Aghion and colleagues (science–technology–innovation–growth systems), Freeman and Soete (the STI system) and Faulkner (Europe)). Yet a qualitative analysis of the references cited in these papers shows a limited overlap for the papers within the clusters noted above and even less so across the entire set of papers. A discourse analysis of the papers shows wider semantic diversity beyond the use of common key words such as science, technology and innovation. Overall, the set of articles would seem to reflect a high level of specialisation among the research communities of practice, engaged in separate discussions and debates that do not extend to the overall field (which consequently comes across as rather fragmented).

Nevertheless, this specialisation and fragmentation coexists with a tendency to unity and a search for a shared paradigm, achieved either through synthesis and integration or through identifying new possibilities. In each period in the history of the field, a specific framework or perhaps even a proto-paradigm seems to have prevailed (e.g. systems of innovation in the 1990s as in Hart, and evolutionary and systemic paradigms more recently as in Nill and Kemp, and in Aghion and colleagues). That framework attracts support because of its apparent ability to deal with a specific set of societal problems that are seen as needing to be solved at that particular time (e.g. slow industrialisation in the 1960s, the energy

crisis of the mid-1970s and again today, competitiveness in the 1980s and 1990s, and the environmental impact of our activities and the search for green alternatives at the present time). Moreover, a set of ideas has come to be widely accepted at the level of the field over time, sometimes coexisting with but often challenging, or even overthrowing, previous conventional wisdom. These include the following: that the relationships between science, technology and innovation are interactive rather than linear; that the process of technological development and innovation is more one of evolution than the 'spontaneous' creation of new technologies and innovations; that the innovative capacity of a nation depends not only on the strength of individual 'players' (firms, universities, government research laboratories) but perhaps more importantly on the links between those actors; that regulation can stimulate as well as constrain innovation; that firms carry out R&D not only to generate new technologies but also to absorb and exploit the results of R&D carried out by others; that firms are perhaps better viewed from a resource-based perspective than from the viewpoint of transactional economics; and that economic growth and sustainability are not necessarily mutually incompatible.

Searching for common themes and features within the STI policy research field, we should remind ourselves of the role of people as carriers of ideas, intellectual frameworks, concepts, traditions, methods, and research priorities (Abbott, 2001) and that research problems, like researchers, have 'careers', so they 'rise and fall' (Hilgartner and Bosk, 1988). We recognise that success in the world of research generally entails 'standing on the shoulders of giants' and selectively borrowing (with due acknowledgement), developing and recombining existing ideas but framing them in a way that provides a fruitful sense of novelty. Contextual conditions influence research practices, but conflicts between inter-generational cohorts also play an important role: new generations of researchers often seek to challenge the ideas of those who came before them, before becoming the 'old guard' for the next generation to take on. Moreover, there are many situations in society that have the potential to be framed as social problems and which deserve societal attention, but only a few at each moment in time come to be collectively defined as such. So they enter and subsequently exit the public agenda and our own research agenda in STI policy, often for a number of different or even conflicting reasons.[17]

4.1. Pluralism in STI intellectual technologies

The articles in this special issue share a strong attention to the design, use and evaluation of 'intellectual technologies' (Bell, 1973) – conceptual categories and specialised languages but also tools, frameworks, methodologies and theories – that belong to our field. The intellectual technologies employed in this set of papers vary quite widely, illustrating the conceptual, theoretical and methodological pluralism of the field. In many cases, these intellectual technologies have been created by importing conceptual categories, theories and tools from other fields, and synthesising and adapting them to our field through extensive innovative work (see, for instance, Freeman and Soete's discussion of innovative work on STI indicators, or Nill and Kemp's discussion of evolutionary approaches to innovation policy). New conceptual categories that are imported from other academic fields to extend and enrich the vocabulary for analysing science, technology and innovation[18] are used as metaphors or analogies to help understand empirical phenomena (e.g. the evolutionary metaphor imported from biological sciences to social sciences to understand cultural evolution, for example). They may then be assembled in conceptual or analytical frameworks or in middle-range theories[19] to guide policy analysis. Disciplinary theories and general-purpose theories (often of a higher level type, such as complexity theory) are sometimes imported from other areas in an effort to create indigenous, 'middle range'[20] and interdisciplinary theories. The same applies to generic tools such as computer simulation based on agent modelling or social network analysis, which are now regularly used in our field.

These intellectual technologies appear to be rather different from those adopted by researchers in the STI policy field a few decades ago. New intellectual technologies derived from various systems, evolutionary and complexity perspectives developed in other fields now occupy the space that in the 1970s was occupied by approaches such as linear programming, risk analysis, and stochastic models derived from operations research and decision analysis.

4.2. Relationship between policy practice and policy research

All the papers directly or indirectly touch upon the relationship between STI policy practice and STI policy research, although they provide rather different takes on this. In some cases, the relation between academics and practitioners is viewed through the metaphor of the Red Queen of *Alice in Wonderland*, with academic policy researchers "trying to stay ahead of policy abuse" (see Freeman and Soete, 2009). Alternatively, it is argued that scientists sitting on expert advisory committee and professors of science policy need to be aware of the strategic behaviour and rhetoric of politicians and policy makers, who would often like to avoid responsibility for taking decisions on controversial issues and instead outsource decisions (and any subsequent blame) to them (see Millstone, 2009). In other cases, policy makers are viewed as reflexive practitioners who may in some respects be ahead of academics in terms of embracing evolutionary and systemic policy frameworks, although the latter seem well on their way to catching up (Nill and Kemp, 2009).

The relationship between STI policy research and practice has direct consequences for the evolutionary nature and purpose of STI policy research and whether we are discharging our responsibility to society in terms of the instrumental and critical purposes of our research. We need to question whether we are suitably balancing the four components of STI policy research previously described, and whether we are providing, besides tools and methodologies, ways of 'thinking otherwise', and challenging taken-for-granted assumptions and values. In short, are we still STI policy 'scholars' or are we in danger of becoming merely STI policy 'technologists'?

5. Epistemic, normative and practical challenges for the field of science, technology and innovation policy research

From the previous discussion, we can identify three main types of challenges that confront the field. Although these are highly interdependent, for the sake of clarity of the discussion, we consider them separately.

[17] For example, genetic engineering and GM food have been viewed by certain governments, major corporations, parts of the scientific community and some in the media as a source of benefits for society, whereas they are viewed as 'problems' by many activists, other scientists and even some governments.

[18] For instance, the biological concept of a 'niche' has been appropriated both by the transition management/socio-technical transitions community of research practice in STI, and by population ecology in organisational studies, although with rather different meanings.

[19] See Wyatt and Balmer (2007) on middle-range theories in the STS field.

[20] Merton's concept of 'middle-range' theory was originally intended for sociology, but it has been extended to others fields such as archaeology and nursing. Middle-range theories 'seek to establish scientific laws about the impact of particular social features on particular activities and avoid making comprehensive statements about society' (Menzies, 1982, p. 123).

5.1. Epistemic challenges

As we have noted, the STI policy field is an intrinsically interdisciplinary, problem-oriented and pluralistic field, and certain epistemic challenges follow from this. First of all, synthesising, combining and integrating words, ideas, concepts, theories, frameworks and existing knowledge (or even just tinkering with them) is always going to be a challenging activity. For instance, when development and sustainability are linked together in a new concept like sustainable development, the compatibility among the goals or the mechanisms to create a positive-sum game for humankind and the planet are assumed, but not argued or demonstrated with evidence (Johnston, 2003), with the result that we can quickly find ourselves on shaky grounds. Furthermore, translational and interactional work is required to operate across disciplinary boundaries, and life in the interaction zones is never easy, as scholars in science and technology studies and particularly the sociology of science have noted (e.g. Galison, 1997; Collins, 2004).

The combination of various systems-based, complexity and evolutionary theories to provide the underpinnings for our conceptual frameworks, requires first explaining what specific theories we are referring to, how they can be adapted to the social systems that we are focusing on, and how they can be integrated to produce new social theories that explain phenomena in complex and evolutionary social systems. For instance, since the 1970s we can identify a shift to a more systemic way of thinking in our policy research, a framework which offers a set of powerful conceptual tools – such as system, element, relationship, input, transformation, output, environment, feedback, control and hierarchy – that can be used to analyse different empirical phenomena and problems that fall within the STI policy research domain. Systems thinking, since the early developments with systems dynamics within the fields of operational research and engineering, has gone through many subsequent developments. However, it has thus far failed to produce a 'general system theory' that describes the behaviour of all systems, whatever their type, and that at the same time is empirically relevant (Jackson, 2001). It is now a portfolio of different approaches, methodologies and supporting toolboxes, which includes systems dynamics, systems analysis, soft systems thinking, and critical systems thinking (Forrester, 1961; Churchman, 1971; Checkland, 1981; Lane, 1999). These approaches, methodologies and supporting 'toolboxes' can be used to tackle complexity in a variety of social systems. However, it should be noted that different approaches to systems thinking may embody implicit theories such as the feedback approach in system dynamics (Forrester, 1961), even though these implicit theories are not social theories. Specific systems approaches may also incorporate certain social assumptions (Lane, 1999). In general, the specific systems approaches adopted should be clearly identified, and their implicit assumptions and social theories need to be made explicit. The same need for clear identification and transparency of assumptions and theories applies when we draw upon complexity or evolutionary theories to design our intellectual technologies.[21] Furthermore, if we adopt, say, a systemic, complex and evolutionary lens[22] as a new intellectual meta-perspective on which to build frameworks that are useful in analysing social problems and devising solutions, we immediately run into another related epistemic problem: the need to reshape our learning tools to educate not only ourselves but also policy makers, citizens, and others about the sea-change in thinking that is required in order to successfully employ a complex and evolutionary systems perspective in our activities (Goldstone, 2006).

Second, our theories, models and frameworks can be viewed as 'maps' that help us navigate the policy community in the process of solving or ameliorating societal problems. At the same time, we must bear in mind that 'the map is not the territory' (Korzybski, 1931); maps or models are simplified representations of something more complex, but not the thing in itself. Sometimes we disagree on the level of simplification or the mode of representation that we judge appropriate in social sciences,[23] i.e. on what constitutes a legitimate and useful model. Moreover, there is a belief among some scholars that in certain circumstances good outcomes can come from 'bad maps' or poor models. They argue that bad maps can be useful in some circumstances (Weick, 1995; Rip, 2006, cited in Shove and Walker, 2007; Nelson, 2008). For example, Weick (1995) recounts a story told by the Hungarian Nobel Laureate, Albert Szent-Gyorti, about a small Hungarian detachment that, after becoming lost in the snow in the Swiss Alps, managed to survive and to return to the main camp using and putting their faith (and lives), without realising it, in the wrong map (in this case, a map of the Pyrenees!). This story suggests that when we are lost, any old map will do and good outcomes can come even from bad or wrong maps because they do at least allow us to begin to act, generating outcomes in a particular social context and making sense of those outcomes (Weick, 1995, pp. 54–55).[24] Along the same lines, Shove and Walker (2007) stress the "value, productivity, and everyday necessity of an 'illusion of agency'", picking up the argument of Rip that "illusions are productive because they motivate action and repair work, and thus something (whatever) is achieved" (Rip, 2006, p. 94, cited in Shove and Walker, 2007). The history of medicine likewise shows that 'incorrect' theories about the causes of some diseases can sometimes lead to the unintended and unrelated discovery of a successful treatment (Thagard, 1999; Nelson, 2008).[25]

However, a word of caution as to how we deal with theories and models of our field is necessary here. Our intellectual technologies and the actions that they cause have consequences, including some that are unintended and generally unpredictable due to the complex and evolutionary features of the social systems in which we operate. Some of the consequences can be positive and may lead to beneficial outcomes. Yet we need to consider carefully the potential risks involved when a particular theory or model acquires momentum and visibility in the academic or policy domain through citations and other mechanisms associated with our current academic knowledge production system. This is particularly true when that theory or model becomes taken for granted, 'the only alternative in town', and comes to dominate decisions on the investment of resources to solve specific problems. In social sciences and other areas of knowledge that deal with complex phenomena like medicine, theories and models can become taken for granted without any direct correlation with the real value they provide to our understanding and to our capacity to solve the problems that first triggered their development. As with bad maps, when we are lost or when we do not have any alternatives, good outcomes can sometimes come from them, but not always. In certain situations, ill-informed actions can have dire consequences, and

[21] See, for example, the discussions of evolutionary theories in social sciences compared to biology at http://etss.net/ and in particular of evolutionary theories in technological change in the book edited by Ziman (2000).

[22] We focus here on the complex systems lens, but the same observations on learning apply to other new intellectual technologies such as evolutionary, co-evolutionary and ecological perspectives.

[23] Many of our 'models' in social sciences are little more than boxes and arrows arranged in a two-dimensional space.

[24] Perhaps there is an analogy here with the well known 'placebo effect' in medicine.

[25] See Nelson (2008) for a discussion of how theories do not need to be causally valid to be useful in guiding action and "how the practical value of a theory that is not connected with the actual causal forces at work can be very context specific" (p. 2).

not doing anything, at least until we can figure out better alternatives or better models, may in certain circumstances offer the better option.

Third, the process by which certain developments in society become first social problems, then policy problems and finally policy research problems is important but not at all well understood. It deserves further study, especially in our field. As Becker (2003) succinctly put it, "many different people have ideas about what in society needs fixing." Some scholars have argued that social problems are collectively defined, and they rise and fall on the public agenda depending on a range of factors, many of which are not directly related to objective conditions (Hilgartner and Bosk, 1988). The genesis of policy problems and research problems is a critical process in STI policy, just as much as deciding how those problems can be addressed, yet we do not have any satisfactory theory for this (Nelson, 1977). The current emphasis on the problems of the environment in many public and academic arenas at the expense of virtually everything else is an example of the competition among social problems and the dynamics and social forces that underpin our current 'social problems industry' (Hilgartner and Bosk, 1988).

Finally, we face a number of epistemic challenges that we share with other academic interdisciplinary fields. Specialisation and division of labour in academic fields are well known and well studied phenomena (e.g. Becher and Trowler, 2001; Abbott, 2001). Less attention, however, has been paid to processes of agenda-setting in social sciences and in particular in interdisciplinary contexts (Shove, 2006). We also need a better understanding of how we theorise, what constitutes theory and reliable knowledge, and how reliable knowledge is different from useful knowledge and its representations (see e.g. *Academy of Management Review*, 1999 special issue in Vol. 24, issue 4). Even the previously unchallenged assumption that the right to research is available only to trained and professional specialists has started to come under question and action research is invoked as the way forward by some researchers in our field (Appadurai, 2006).

5.2. Normative challenges

Thinking, learning and producing knowledge are all forms of action. As academics, we think, learn and produce knowledge, so we act. Doing research and disseminating knowledge thorough talking (e.g. speeches, presentations, lectures) and writing (publications) are our traditional forms of intervention. The language that we use is not value-free but imbued with politics (Bauman, 1991). Whether categorising, labelling, framing or measuring, or developing an analytical framework for understanding certain phenomena, our intellectual technologies are all forms of intervention and means to certain ends, and as such they have intended but also unintended consequences. We need to think for whom these consequences may be beneficial or detrimental, by what measure and across what space and scale (Shove and Walker, 2007).

Furthermore, let us ask ourselves two simple questions: Are our means in danger of becoming our ends? Should we indeed be concerned with the ends of society or only with means to achieve those ends (cf. Burawoy, 2005)? Nelson (1977) gives a positive answer to the latter and one that we would like to endorse: our task as policy scholars is not only to provide persuasive analysis that points to problems, their interpretation and possible solutions, but also to critically examine what values (and whose values) should be taken into account in doing this. As Parsons (1937) and Simon (1947) among others have argued, in every society at specific times certain ultimate ends (e.g. prosperity, happiness and peace) and values (e.g. freedom and democracy) result in normative rules that shape but do not determine specific actions. Actors, through their actions, pursue more immediate ends, and guidance to action is provided by these normative rules and perhaps by a theory or a point of view regarding the key things or means-ends chains that, it is hoped, will lead to the desired ultimate ends. In short, our framework for policy analysis requires "both a normative structure, which helps to illuminate where one wants to go and provides criteria for choosing good routes, and a positive or scientific structure, which provides a map." (Nelson, 1977).

A similar view has been put forward recently by Woodhouse and Sarewitz (2007), who argue that it is part of our duty as policy researchers to establish whether, with our chosen forms of intervention, we actually solved the problems that we intended to solve, or whether we created new problems or made the existing problems worse. They invite us to reconsider and challenge in STI policy research such things as the conventional wisdom of scientific progress and the idea that research translates more or less automatically into benefits for all:

> scholars of science and technology studies have documented the manifold ways that science and technology are political in the sense of encoding some values and perspectives more than others . . . every scientist, . . . every other participant in science policy making pursues not *the* public interest but their own syntheses of public and private objectives. Nobody takes account of every plausible perspective; everyone champions some interests and ignores or actually acts against others. (Woodhouse and Sarewitz, 2007, p. 139; original emphasis)

Or put more succinctly, "people in and out of [social] science are morally obligated to re-examine who gets what from science and technology" (Woodhouse and Sarewitz, 2007, p. 148).

5.3. Practical challenges

In addition to the epistemic and normative challenges discussed above, academic STI policy research is carried out in a context within and outside academia that is rapidly changing and seems to becoming ever more complicated, with consequences for the nature and purpose of STI policy research and its relationship with STI policy practice. STI policy practice depends in part on evidence and research skills produced by STI policy research both within and outside academia to analyse and solve problems. Evidence is viewed by many policy practitioners as legitimate and useful when it is the result of knowledge production that is 'scientific', i.e. a systematised, specialised mode of enquiry that results in seemingly objective and value-free knowledge. Yet sometimes, the perception is that policy research is useful only when it legitimises solutions that have already been reached without analysis – when it provides 'policy-based evidence' rather than 'evidence-based policy' (Marmot, 2004). Universities do policy research but they are also expected to train researchers in 'social research technology', i.e. the routine application of techniques to problem-solving and the provision of a set of tools for investigation, enabling them to become skilled in "pragmatically driven conceptual empiricism" (Williams, 2000).

STI policy research is not immune to current debates about the changing role and purpose of the university in the 21st century and the emerging reconfiguration of knowledge production (e.g. Slaughter and Leslie, 1997; Nowotny et al., 2001; Delanty, 2001). Like other academics, STI policy researchers are asked to come up with concrete, relevant and easily quantifiable outcomes of their work (e.g. publications), to be on top of the exponential growth of media and the associated new technologies like the Internet that transform their social roles and functions, and to respond to wake-up calls claiming that academics who thought that the status of intellectuals was the natural entitlement of university employment were mistaken (Fuller, 2005). These debates indicate a strong need

for individual and collective critical reflection on what it means to be an academic and in particular an academic in STI policy research.

Critically reflecting and re-imagining academic work is necessary not only at the individual level but also at the organisational and institutional levels. Surrounding these is a continuously changing environment, in which the production of knowledge is reconfigured in the light of the proliferation of different kinds of knowledge and the emergence of other producers of knowledge who have begun to occupy the spaces previously dominated by academics (Binks et al., 2006). The pressures that are driving these changes also have organisational and financial implications for academic STI policy researchers and for the existing institutional forms in which academic STI policy work is organised (for instance, research centres, programmes, disciplines, departments and universities), as well as for the outputs of their research work. It has been suggested that the

> restructuring in the mode of knowledge implies not the end of the university but its reconfiguration. The great significance of the institution of the university today is that it can be the most important site of interconnectivity in what is now a knowledge society. . . . The university cannot re-establish the broken unity of knowledge but it can open up avenues of communication between these different kinds of knowledge, in particular knowledge as science and knowledge as culture. (Binks et al., 2006, p. 8)

If we take this line of reasoning, there are opportunities for academic institutions, including those engaged in STI policy research, as "knowledge arbiter and broker in a more complex and differentiated knowledge production process" (Binks et al., 2006).

Other scholars argue that academics should view themselves as more than just arbiters and brokers, and should also engage in processes to envisage wide-ranging alternatives (Johnston and Goodman, 2006), putting forward a convincing case for the increased use of research imagination (Appadurai, 2000; Boden and Epstein, 2006). What is needed from academics is a willingness to take risks and a passion for social engagement[26] – in other words, not just studying the world but helping to change it through different forms of intervention (Bijker, 2003). Said (1994), amongst others, has argued that defining the situation and discerning possibilities for active intervention whether we perform them ourselves or acknowledge them in others, providing a critique of 'what is' as opposed to the many different visions of 'what ought to be', all these provide academics with some hope for re-establishing their role in society.

To conclude, we are aware that the above discussion of the epistemic, normative and practical issues that we need to confront as researchers in the STI policy field might appear rather overwhelming. Reflecting in a critical manner on the present, and thinking, imagining and shaping the future is never easy. However, in line with the quotation from Freire at the start of this article, we see the unfolding evolution of our field as an ongoing search among a set of possibilities, and the critical and reflexive analysis of what we do today should be a source of inspiration and a way of thinking otherwise about possible futures. Challenges can be confronted or just ignored, but either choice has consequences. We contend that a critical and collective conversation in our field, at this stage in its development, is needed and that this can help equip us in responding to the challenges outlined in this introductory article.

[26] What we mean here is somewhat different from the idea of 'engaged scholarship' put forward recently by Van de Ven (2007). Lack of space, however, prevents us from elaborating the idea further here.

6. Conclusions

In this article, we have set out the goals and structure of this special issue. As we have emphasised, it offers at the same time a reflexive overview of the nature and purpose of science, technology and innovation policy research at present, and an invitation to begin a discussion in our field on our evolving research agenda and on a number of emerging issues elaborated and illustrated by the set of articles included here. Besides summarising what each article is about, we have also highlighted those features that are connected to the broader challenges currently confronting us in the STI policy research field. We have distinguished three main types challenge – epistemic, normative and practical – identifying and discussing some of the main features of each. We hope that the reader will find the following individual papers of interest, but will also see the articles in this special issue collectively as an illustration of emerging challenges. Perhaps some will then join us in a productive conversation about the past, present and the future of our field.

Acknowledgements

This special issue is only possible thanks to the efforts of all the contributing authors, who were subject to not one but two separate forms of review, the first by the two editors, and the second by selected referees. We would therefore like to thank Philippe Aghion, Paul David, Alex Faulkner, Dominique Foray, Christopher Freeman, Rainer Frietsch, Hariolf Grupp, Inna Haller, David Hart, Thomas Heinze, René Kemp, Jochen Markard, Erik Millstone, Jan Nill, Juan Rogers, Jacqueline Senker, Philip Shapira, Luc Soete, Martin Stadelmann, Bernhard Truffer, Melanie Vrohlings and Igor Yegorov form their efforts in preparing the articles that make up this special issue. Many of these authors also contributed as reviewers of other papers in the collection. In this task, they were aided by John Abraham, Philip Auerswwald, Andrew Barry, Frans Berkhout, Julia Black, Kjersten Whittington Bunker, Gustavo Crespi, Paola Criscuolo, Waverly Ding, Felicia Fai, Frank Gault, Elisa Giuliani, Benoit Godin, Sven Hemlin, Rogers Hollingsworth, Annamaria Inzelt, Bjorn Jindra, Calestous Juma, Michael Khan, Marku Lehtonen, Werner Meske, David Mowery, Richard Nelson, Pari Patel, Martha Prevezer, Slavo Radosevic, Matias Ramirez, Jerry Ravetz, Henry Rothstein, Bhaven Sampat, Dean Simonton, Sigrid Stagl and Ivo Zander.

Lastly, we are very grateful to John Abraham, Ruud Kempener, Richard Nelson, Edward Steinmueller, and Catherine Will for their insightful and helpful comments on an earlier version of this overview paper.

References

Abbott, A., 2001. Chaos of Disciplines. University of Chicago Press, Chicago.
Aghion, P., David, P.A., Foray, D., 2009. Science, technology and innovation for economic growth: linking policy research and practice in 'STIG systems'. Research Policy 38, this issue.
Appadurai, A., 2000. Grassroots globalization and the research imagination. Public Culture 12, 1–19.
Appadurai, A., 2006. The right to research. Globalization, Societies and Education 4, 167–177.
Ball, S., 1995. Intellectuals or technicians? The urgent role of theory in educational studies. British Journal of Educational Studies 43, 255–271.
Bauman, Z., 1991. Modernity and Ambivalence. Cornell University Press, Ithaca, NY.
Becher, T., Trowler, P.R., 2001. Academic Tribes and Territories: Intellectual Enquiry and the Culture of Disciplines. The Society for Research Into Higher Education and Open University Press, Buckingham.
Becker, H., 2003. Making sociology relevant to society, paper given at the meeting of the European Sociological Association in Murcia, Spain 2003 (unpaginated version retrieved from http://home.earthlink.net/~hsbecker/relevant.html on 4 December 2007).
Bell, D., 1973. The Coming of Post-Industrial Society: A Venture in Social Forecasting. Basic Books, New York.
Bijker, W., 2003. The need for public intellectuals: a space for STS. Science, Technology & Human Values 28, 443–450.
Binks, M., Starkey, K., Mahon, C.L., 2006. Entrepreneurship education and the business school. Technology Analysis & Strategic Management 18, 1–18.

Birnbaum, R., 2000. Policy scholars are from Venus; policy makers are from Mars. The Review of Higher Education 23, 119–132.
Blume, S., 1970. Science policy and science policy research. Nature 228, 215–218.
Boden, R., Epstein, D., 2006. Managing the research imagination? Globalization and Research in Higher Education 4, 223–236.
Breen, B., Hamel, G., 2008. The Future of Management. Harvard Business School Press, Boston.
Burawoy, M., 2005. For public sociology. American Sociological Review 70, 4–28.
Checkland, P.B., 1981. Systems Thinking, Systems Practice. Wiley, Chichester.
Churchman, C.W., 1971. The Design of Inquiring Systems. Basic Books, New York.
Cole, S., 1974. World models, their progress and applicability. Futures 6, 201–218.
Collins, H.M., 2004. Interactional expertise as a third kind of knowledge. Phenomenology and the Cognitive Sciences 3, 125–143.
Delanty, G., 2001. Challenging Knowledge: The University in the Knowledge Society. The Society for Research Into Higher Education and Open University Press, Buckingham.
Dosi, G., Llerena, P., Labini, M.S., 2006a. The relationships between science, technologies and their industrial exploitation: an illustration through the myths and realities of the so-called 'European Paradox'. Research Policy 35, 1450–1464.
Dosi, G., Malerba, F., Ramello, G.B., Silva, F., 2006b. Information, appropriability, and the generation of innovative knowledge four decades after Arrow and Nelson: an introduction. Industrial and Corporate Change 15, 891–901.
Faulkner, A., 2009. Regulatory policy as innovation: constructing rules of engagement for a technological zone of tissue engineering in the European Union. Research Policy 38, 571–582.
Fay, B., 1975. Social Theory and Political Practice. Allen and Unwin, London.
Flyvbjerg, B., 2001. Making Social Science Matter. Cambridge University Press, Cambridge.
Forrester, J.W., 1961. Industrial Dynamics. MIT Press, Cambridge, MA.
Forrester, J.W., 1971. World Dynamics. MIT Press, Cambridge, MA.
Freeman, C., 1973. Malthus with a computer. Futures 5, 5–13.
Freeman, C., Soete, L., 2009. Developing science, technology and innovation indicators: what we can learn from the past. Research Policy 38, this issue.
Frietsch, R., Haller, I., Vrohlings, M., Grupp, H., 2009. Gender-specific patterns in patenting and publishing. Research Policy 38, this issue.
Fuller, S., 2005. The Intellectual: The Positive Power of Negative Thinking. Icon Books, London.
Freire, P., 1988. Editor's introduction. In: Giroux, H.A. (Ed.), Teachers as Intellectuals: Toward a Critical Pedagogy of Learning (Critical Studies in Education Series). Bergin & Garvey, Westport, pp. xxvii–xxviii.
Galison, P., 1997. Image and Logic: A Material Culture of Microphysics. University of Chicago, Chicago.
Godin, B., 2005. The linear model of innovation: the historical construction of an analytical framework. Science, Technology, and Human Values 31, 639–667.
Goldstone, R.L., 2006. The complex systems sea-change in education. The Journal of Learning Sciences 15, 35–43.
Hart, D., 2009. Accounting for change in national systems of innovation: a friendly critique based on the US case. Research Policy 38, this issue.
Heinze, T., Shapira, P., Rogers, J.D., Senker, J.M., 2009. Organizational and institutional influences on creativity in scientific research. Research Policy 38, this issue.
Hilgartner, S., Bosk, C., 1988. The rise and fall of social problems: a public arenas model. American Journal of Sociology 94, 53–78.
Hughes, O.E., 2003. Public Management and Administration. An Introduction. Palgrave, Basingstoke.
Jackson, M.C., 2001. Critical systems thinking and practice. European Journal of Operations Research 18, 233–244.
Johnston, J., 2003. Who cares about the commons? Capitalism, Nature, Socialism 14 (4), 1–41.
Johnston, J., Goodman, J., 2006. Hope and activism in the ivory tower: Freirean lessons for critical globalization research. Globalization 3, 9–30.
Korzybski, A., 1931. A non-Aristotelian system and its necessity for rigour in mathematics and physics, Paper presented before the American Mathematical Society at the New Orleans, Louisiana, meeting of the American Association for the Advancement of Science December 28, 1931. Reprinted in Science and Sanity, 1933, 747–761.
Lane, D., 1999. Social theory and system dynamics practice. European Journal of Operational Research 113, 501–527.
Markard, J., Stadelmann, M., Truffer, B., 2009. Prospective analysis of technological innovation systems: identifying technological and organizational development options for biogas in Switzerland. Research Policy 38, this issue.
Marmot, M.G., 2004. Evidence based policy or policy based evidence? British Medical Journal 328, 906–907.
Martin, B.R., 2009. The evolution of science policy and innovation studies, TIK Working papers on Innovation Studies, No. 20080828, University of Oslo (downloadable from http://www.tik.uio.no/InnoWP/2008%20Ben%20Martin-Evolution%20of%20SPIS.pdf).
Meadows, D.H., Meadows, D.L., Randers, J., Behrens, W.W., 1972. The Limits to Growth. Universe Books, New York.
Meadows, D.H., Meadows, D.L., Randers, J., Behrens, W.W., 1973. A response to Sussex. Futures 5, 135–152.
Menzies, K., 1982. Sociological Theory in Use. Routledge & Kegan Paul, London.
Millstone, E., 2009. Science, risk and governance: radical rhetorics and the realities of reform in food safety governance. Research Policy 38, this issue.
Mintzberg, H., Gosling, J., 2002. Educating managers beyond borders. Academy of Management Learning and Education 1, 64–76.
Morecroft, J.D.W., 1988. System dynamics and microworlds for policy makers. European Journal of Operational Research 35, 301–320.
Nelson, R.R., 1977. The Moon and the Ghetto: An Essay on Public Policy Analysis. WW Norton & Company, New York.
Nelson, R.R., 2008. Bounded rationality, cognitive maps, and trial and error learning. Journal of Economic Behaviour & Organization 67 (1), 78–89.
Nill, J., Kemp, R., 2009. Evolutionary approaches for sustainable innovation policies: from niche to paradigm? Research Policy 38, this issue.
Nowotny, H., Scott, P., Gibbons, M., 2001. Rethinking Science: Knowledge and the Public in the Age of Uncertainty. Polity Press, Cambridge.
Parsons, T., 1937. The Structure of Social Action. Free Press, New York.
Pfeffer, J., Fang, C.T., 2001. The end of the business school? Less success that meets the eye. Academy of Management Learning and Education 1, 78–95.
Said, E., 1994. Representations of the Intellectual (Reith Lectures). Pantheon Books, New York.
Schram, S.F., Caterino, B., 2006. Making Political Science Matter: Debating Knowledge, Research and Method. New York University Press, New York.
Shapiro, D.L., Kirkman, B.L., Courtney, H.G., 2007. Perceived causes and solutions of the translation problem in management research. Academy of Management Journal 50, 249–266.
Shove, E., 2006. Interactive Agenda Setting in Social Sciences, summary report of a series of six workshops, http://www.lancs.ac.uk/fass/projects/iass/files/iass_summary.pdf (downloaded from http://www.lancs.ac.uk/fass/projects/iass/ on 4 December 2008).
Shove, E., Walker, G., 2007. Caution! Transition ahead: politics, practice and sustainable transition management. Environment and Planning A 39, 763–770.
Simon, H., 1947. Administrative Behavior. Macmillan, New York.
Sismondo, S., 2007. Science and technology studies and an engaged program. In: Hackett, E., Amsterdamska, O., Lynch, M., Wajcman, J. (Eds.), The Handbook of Science and Technology Studies. MIT Press, Cambridge, MA.
Slaughter, S., Leslie, L.L., 1997. Academic Capitalism, Politics, Policies and the Entrepreneurial University. Johns Hopkins University Press, Baltimore, MD.
Streatfeild, G., 1973. World dynamics challenged. Futures 5, 4.
Thagard, P., 1999. How Scientists Explain Disease. Princeton University Press, Princeton.
Van de Ven, A.H., 2007. Engaged Scholarship. Oxford University Press, Oxford.
Weick, K., 1999. Theory construction as disciplined reflexivity: tradeoffs in the 90s. Academy of Management Review 24, 797–806.
Williams, M., 2000. Social research – the emergence of a discipline? International Journal of Social Research Methodology 3, 157–166.
Woodhouse, E., Sarewitz, D., 2007. Science policies for reducing societal inequities. Science and Public Policy 34, 139–150.
Wyatt, S., Balmer, B., 2007. What and where is the middle in science and technology studies? Science, Technology and Human Values 32, 619–626.
Yegorov, I., 2009. Post-Soviet science: difficulties in the transformation of the R&D systems in Russia and Ukraine. Research Policy 38, this issue.
Ziman, J., 2000. Technological Innovation as an Evolutionary Process. Cambridge University Press, Cambridge.

Piera Morlacchi*
Ben R. Martin
SPRU, University of Sussex, Brighton BN1 9QE, UK

* Corresponding author. Tel.: +44 1273 877974.
E-mail address: P.Morlacchi@sussex.ac.uk (P. Morlacchi)

Available online 9 March 2009