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Innovation studies in the 21st century: Questions from a user's perspective

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Abstract

Science-based innovations have played an important role in our society for centuries. In this paper, after a discussion of the concept of innovation, changes in three major developments in the context of innovation processes are analysed: structural changes in our economy, the broadening of decision-making processes and the emergence of the network society, and changes in the knowledge infrastructure. On the basis of this analysis, questions and challenges confronting the players involved in innovation processes and the management of them are identified and topics for a research agenda for innovation researchers that take into account the needs of these players are formulated. The focus is on the macro and meso level, and the broadening of decision-making on innovation processes acts as an important guiding principle. Three lines of research are distinguished on the research agenda: (1) empirical studies of innovation processes and systems, (2) critical reflection on innovation theory, and (3) analysis and support of decision-making processes. With regard to the first line, case studies of innovation in services, life sciences, the relationship between ICT and sustainability and the identification of (intangible) throughput and output indicators are on the agenda. The reflection on theory (line 2) focuses primarily on innovation in chains and clusters, the role of (knowledge intensive) intermediaries and the interaction between processes and systems. Furthermore, innovation studies should also try to contribute towards endogenisation of innovation in other scientific disciplines. With regard to the analysis and support of decision-making processes (line 3), strategic intelligence providing insight into the potential, application and implementation of new technologies and the development of instruments to support players in innovation processes are addressed. An important basic assumption of this paper is that innovation studies should not only strive to deepen the insight into innovation processes and systems, but also to contribute to the development of insights, concepts, methods, techniques and instruments to support various players involved in innovation processes. The

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major conclusion of this paper is that shifts in the context of innovation processes, more particularly the emergence of the 'porous society', will lead to a radical transformation of innovation systems in which (knowledge intensive) intermediaries and the quality of the interface between users and producers play an increasingly important role.

Keywords: Innovation studies; Innovation management; Innovation policy; Innovation systems; Coevolution; Technology assessment

1. On modern things and ancient times

1.1. Introduction

> As the century closed, the world became smaller. The public rapidly gained access to new and dramatically faster communications technologies. Entrepreneurs, able to draw on unprecedented scale economies, built vast empires. Great fortunes were made. The government demanded that these powerful new monopolists be held accountable under antitrust law. Everyday brought forth new technological advances to which the old business models seemed no longer to apply. Yet, somehow, the basic laws of economics asserted themselves. Those who mastered these laws survived in the new environment. Those who did not, failed.

This quotation, dating from the end of the 19th century, was used by Shapiro and Varian to introduce their book 'Information Rules: A Strategic Guide to the Network Economy' [1]. One of the main themes discussed in this book is that while science and technology have led to major changes in our society for many centuries, this has not always resulted in everything being turned upside down. Shapiro and Varian feel that the insights embedded in the foundations of the economic sciences remain valid to a large extent. If we succeed in placing these existing insights into the new context, then it will become apparent that we have a great deal more to say about the way in which science and technology are shaped in our society than we might think. However, the opportunities new scientific insights offer us, and the world in which we are able to make them reality, changes so rapidly that to actually do something with them costs us a great deal of effort. This often leads to defensive reactions. Shapiro and Varian argue that these defensive reactions are more likely to be hazardous than beneficial, and give three examples as an illustration. Early in the 19th century, booksellers feared that the travelling libraries of the day would undermine their wares. Quite the opposite was true: more people learned to appreciate the value of books (Shapiro and Varian refer to these as experience goods) and book sales increased explosively. The same mechanism was seen in the 1970s when another experience good was introduced: video. Hollywood raised a huge hue and cry, but the sale of films on videotape ultimately became one of the most important cash cows of Hollywood today. The third example is that of MIT Press. While many people fear the risk of illegal copies in this case as well, MIT Press has apparently doubled its sales of hard copies since its first appearance on the Internet.

Although by no means all economists agree with Shapiro and Hall, I still feel that these two authors made a salient point. Despite all the commotion associated with the development of new knowledge, on the whole they still believe in continuity. This is based not only on the robustness of economic laws, but rather on the increasing understanding that it is we ourselves that to a large extent determine—if we really want to—whether and how science and technology is given shape and form in our society. The historic studies conducted by scientists such as Hughes, Pieterson, Lintsen et al. and Schot et al. support this theory, [2–5]. The idea was simply not *bon ton* for many years. During the Renaissance and for many years thereafter, scientific and technological developments were regarded as autonomous processes to which man should subordinate himself. Even in the 1930s, Chicago chose as the slogan for the World Expo: Science finds, industry applies and man conforms. The essence of my argument is that the—often intangible—development of science and technology is not something that simply happens. In common with the development of economic and social systems, the development of science and technology is the work of man, and therefore, by definition, can be influenced.

1.2. The main theme

The basic assumption underlying this paper is that science and technology is the work of man, and that we ourselves determine to a large extent how it is given shape and form in our society. In doing so we learn a great deal about the past. That past also makes it clear that 'to make science and technology work', to innovate, is not easy. A number of problematic cases that may illustrate this point are set out in Box 1.

Box 1
Innovation is not easy

Complex ethical debates on neonatology
Nuclear energy, which fails to meets its promises and leads to major problems
Societal objections to genetically engineered food, cloning and genetic screening
Computers that do not really help to raise the quality of education
DDT, a substance that fails to free the world of famine, but results in a major environmental problem
The many unsuccessful attempts to introduce road pricing
The small and medium-sized enterprises that continue to find it difficult to transform knowledge into successful products and services
The high number of promising new high-tech firms in the fields of life sciences and new media that are still unsuccessful

If we take a closer look at these examples, two more observations can be made. First, sometimes innovations look successful on the short run, but appear far from that in the

longer term. Main reasons for this are the often not so realistic expectations on the future development of technologies and a lack of insight in unexpected impacts. A second observation is that scientific or technological problems are the main barriers in only a few cases. It generally involves ethical, social, management, organisational and institutional problems. This is also evident from the early 1980s when, in response to the economic recession as well as for the purpose of promoting innovation, the OECD nations substantially increased their investment in research. While this did lead to a major growth in scientific and technological knowledge, it still failed to lead to many innovations, let alone to the anticipated increase in productivity. This phenomenon is known among economists and innovation scientists as the 'Solow Paradox' or the 'Productivity Puzzle' [6]. In the European context, the term generally used is the 'European Disease': Europe is proficient in the production of excellent scientific knowledge, but weak in transforming inventions into successful products, services and solutions for societal problems [7]. The solution to this problem has been the main theme of innovation policy for almost two decades in most OECD countries. Although a certain amount of progress has been achieved, it is evidently a very persistent problem and numerous questions remain unanswered. This observation brings me to the main subject of this paper:

> How can innovation studies make a better contribution towards the support of public and private players involved in innovation processes?

The outline of this paper is as follows. After defining the term 'innovation' in Section 2, I will move on to discuss three major changes that have taken place over the past few decades in the complex interaction between innovation processes and the context within which they occur. In Section 3, these changes are described and the consequences for innovation studies are identified. In Section 4, this analysis is translated into elements of a research agenda that takes into account the needs of the players involved. To wind up, the major results will be summarised in Section 5.

2. Invention and innovation

2.1. The importance of innovation

There is no lack of bombastic prose on the increasing importance of science and technology in our society. However, it is by no means an easy matter to come up with real objective evidence to show that this influence is greater than it was, say, a hundred years ago. After all, we tend to see today's developments as being far more preponderant than the developments of the past. Nevertheless, this does not alter the fact that new knowledge plays a crucial role in societal and economic developments, even in our day and age. Knowledge-intensive products and services are taking on an increasingly significant role in the economy. Over the last 20 years, exports of these products and services from the United States and Japan have increased by 500% to 600% [8]. And while the European Union lags

behind in this respect (showing a growth of 300%), knowledge-intensive goods are also highly significant for this economic bloc as well. Illustrative of the increasing knowledge content of our economy is the observation that the weight of 1 dollar in American export has been cut by half over the past 10 years.

Knowledge is of paramount importance for society in the broader sense too. The role of information technology in education, of biotechnology for health care and our food, and the significance of new materials for clothing and consumer products and the high level of penetration of high-tech equipment into our homes [9] are only a few examples.

2.2. Invention versus innovation

It will be clear from the foregoing that new scientific and technological knowledge often fails to lead as a matter of course to successful products, services and solutions to problems in society. In other words: new knowledge, the invention, should certainly be seen as a potential that can be drawn upon, but that more is required to actually transform it into successful applications. It is against this background that I define innovation as follows:

> . . .a successful combination of hardware, software and orgware, viewed from a societal and/or economic point of view.

Hardware relates to the material equipment (mostly) involved and software concerns the knowledge in terms of manuals, software, digital content, tacit knowledge involved in the innovation. Orgware refers to the organisational and institutional conditions that influence the development of an invention into an innovation and the actual functioning of an innovation.

2.3. Not individually but together: coevolution

While this definition of innovation has its limitations, it also has several advantages. It is a simple definition, stressing that new knowledge does not automatically lead to more prosperity and a higher level of welfare, and making it quite clear that an innovation is more than iron, steel and plastic. In short: things that hurt your toes if you drop them out of your hands. This also applies with regard to what at first sight are purely hardware innovations, such as the conveyor belt. Without the extremely radical social, financial and economic innovations that were part and parcel of the First and Second Industrial Revolutions, such as the concept of the factory and Taylorism, they would have been inconceivable.

However, we must not allow ourselves to be confused by the apparent simplicity of this definition. Innovation is a complex process that takes place at the level of specific products, businesses and sectors, as well as at the level of our national and international communities. It involves technological artifacts such as the petrol engine, technological systems such as the motor car, in which the petrol engine becomes a useful attribute, and the techno-social system of roads, petrol stations, mobility behaviour and mobility policy

that the car needs if it is to function properly, but which at the same time the car itself helps to shape.

A second comment relates to the suggestion that innovations are the causal result of inventions. While this is sometimes true, in many cases it is not. The steam engine is a good example of a technical invention that could only be developed further thanks to the emergence of social and economic innovations, such as the emergence of capitalism and the entrepreneur. It is the emergence of the factory, which gave rise to the need for a central source of power, that prompted the further evolution of the steam engine—which up to then had been a low-performance machine used for pumping water out of mine shafts. Johnson gives a convincing description of how, in Japan in the 1980s, societal innovations and innovations involving the organisation of work were the driving force behind new, extremely successful production systems [10].

Innovation processes are neither linear nor causal and are better regarded as interactive processes in which there is a large extent of coevolution of scientific, technological and societal systems. The cause and effect are often difficult to distinguish. Hughes speaks in this connection of a seamless web [1]. Schwarz and Thompson speak of a technology culture. In their view, innovations are not things that are forced upon us from outside, but arise from our culture and subsequently change it [11].

This complexity is intensified even further for the national government's innovation policy because of the shifts in competencies and activities between different administrative levels. While the regional level is winning in significance and the international level, headed by the EU, is manifesting itself more strongly, it would still seem that the national level finds itself in an extremely difficult position. This makes the multilevel, multiplayer character of innovation processes even more intense [12].

This complex character of innovation confronts players involved in innovation processes with many questions and challenges. Questions and challenges that become even more complex because the context in which innovation processes take place is changing very rapidly. The next section deals with three major changes, as well as their consequences for research and management of innovation processes.

3. Sliding panels

3.1. Introduction

Innovation processes are complex societal phenomena that are strongly linked to the factors of time and context. This statement implies that small countries such as the Netherlands can also exert a significant influence on the way new knowledge and technology can contribute towards realising national objectives. In his revolutionary book 'The Competitive Advantages of Nations', Michael Porter [13] makes this quite clear in an excellent manner by showing how relatively small regions such as Emilia Romagna in Italy are able to lay claim to a prominent position in international competition by making well-considered use of their comparative advantages. However, this context has changed

considerably over the past few decades. Geert Mak even said it in his book '*Hoe God verdween uit Jorwerd*' (How God Disappeared from Jorwerd), in which he describes the development of an 'average' Dutch village over the last 50 years: ''more has changed in our villages over the past 50 years than over the entire period before that'' [14]. More specifically, over the past few decades, three developments have had a strong influence on the management of innovation processes and have confronted innovation studies with new questions.

3.2. Structural changes in our economic system

Important sectors of our economic system are currently going through a period of structural transition. This results in changes within one sector, shifts between sectors, mergers and the emergence of completely new sectors. Moreover, partly because of a growing intensity of knowledge, the boundaries between the agricultural, industrial and services sectors are becoming blurred. Agriculture gets more and more industrialised whereas the industrial and the services sector become more and more intertwined. In the Netherlands the traditionally knowledge-intensive agricultural sector is apparently going to rack and ruin because of the unmistakable successes of the past. The environmental problems caused by this success result in the indisputable obligation to bring about structural change. Changes that are not only better for the environment, but which also lead to an upgrading of this sector, changes that can be summarised as 'from mass production to specialisation'. That this process of—to use Schumpeter's words [15]—creative destruction is not a painless process has again been made quite clear by the recent swine fever, BSE, foot-and-mouth disease and manure crises.

The significance of the secondary sector, industry, is declining strongly, while at the same time the significance of the private services sector and—to a lesser extent—the noncommercial services sector, is increasing enormously. Science and technology-based innovations play a key role in this respect. In its Central Economic Plan, the Netherlands Central Planning Office points out that while the ICT sector makes up only 5% of the Dutch economy, it is still responsible for 25% of our economic growth [16]. The enormous changes and issues this trend can bring about can be illustrated by the emergence of what is referred to as the 'Cultural Industry'. In Jacques Delors' white paper 'Growth, Competitive Strength, Employment. Towards the 21st Century: Roads and Challenges' potentially important role of 'Cultural Industry' in our economic system was pointed out [7]. When accepting his professorship in 'Cultural Industry' at the Erasmus University, Rotterdam, Paul Rutten stressed this analysis in his 'The Future of the Imagination Machine. The Cultural Industry in the 21st Century'. He put forward an argument that projected a picture of an economic sector that grows at a very rapid pace and in which major and structural changes take place (mega-mergers, monopolies, internationalisation) [17]. In Delors' white paper, however, it was also pointed out that Europe will only be able to get hold of a small slice of this huge cake if it continues to retain the sharp division between the cultural and the economic domains. Film directors in Europe have usually spent their entire budget before they actually finish making their films. In America, Walt Disney spent half of the

Lion King budget on marketing. The consequence of this difference in 'orgware' are tremendous: for years now, the top 10 of box office movies in EU countries, including the 'traditional film-making nations' such as France and Italy, has been dominated by American films. And whatever applies in the movie world also threatens to become true for other products of the 'Cultural Industry'. It would seem that Rutten agrees with Delors: the main players in the 'Cultural Industry' are mainly on the other side of the Atlantic. The major conclusion is again: excellence in producing inventions and excellence in producing innovations are two rather different types of competencies.

More or less the same argument can be made for developments in the life sciences. In this area too, cultural, institutional, organisational and managerial competencies are important factors determining the societal return on investments made in the development of science and technology.

3.3. Questions and challenges

All of this has enormous consequences for the study and management of innovation processes.

(a) Innovation processes in the 'new agriculture' will differ from those that applied in the 'old agriculture'. While in the 'old' agricultural sector, dominated by mass production, the request for new knowledge and technologies had a rather homogeneous character, the diversification of products in the 'new' agricultural sector will lead to the agricultural knowledge infrastructure no longer having a more or less homogeneous group as a customer, and will need to start anticipating the wishes of customers with very different needs and wishes. This development will have an enormous impact on the content, organisation and institutionalisation of the agricultural knowledge infrastructure and more in particular on the interface between the users and the producers of knowledge.

(b) While industry and services are constantly becoming more interwoven, it must be noted that innovation processes in industry differ fundamentally from those in the services sector [18]. While our understanding of these new innovation processes is growing, it has not reached yet a level that allows a substantial contribution to be made towards the management of innovation processes [19,20]. Many questions have still to be solved. Apart from the question of what the major differences are between innovation in services and innovation in the industrial sector, the question which role knowledge-intensive (business) services can play in innovation processes in (all) other sectors, plays an ever more important part.

(c) A recent and rather heated discussion focuses on the existence or nonexistence of the 'New Economy'. The major issue at stake here: does ICT change the rules of the game, and if so, how? To say the least, it would seem that economists are still unable to make up their minds about this.

Sustainability is another major issue in today's economy. Major questions here: are economic performance and sustainability at right angles? And what could be the role of ICT,

life sciences, materials technology, not to mention nanotechnology, in the development of a more sustainable economic system? With regard to the last question, expectations are rather high, but very little empirical proof has been available until now to support these expectations. Insight into the relationship between innovation and sustainability is still in its infancy.

(d) The growing importance of innovation in services and the growing insight into innovation processes in general stimulate the need for indicators that not only measure the (hard) input variables like investments in R&D and the number of scientists, but also the far more intangible throughput and output variables. Although the Europeans Commission's 'Community Innovation Survey' is an important step forward, a lot of work—on the conceptual as well as on the operational level—still has to be done.

3.4. Broadening of decision-making processes and the network society

The broadening of decision-making for innovation processes in terms of players and aspects has become manifest over the past few decades, and it is expected that this trend will continue in a more intense form in the future [21]. An increasing number of players wish to become involved in the way innovation processes progress, and—partly because of this—this decision-making is starting to involve an increasing number of different aspects. This trend is typical of a much wider development, known in public administration circles as the emergence of 'meta-management'. Reliance on the old institutions continues to decrease. Not only are a constantly higher number of *Neue Kombinationen* formed, but the boundaries between the institutions and organisations are also becoming less significant. One important characteristic of this process is the transition from 'weakly-linked systems consisting of discrete components' to 'strongly-linked systems consisting of fuzzy components'.[1] The old top-down Taylorist model would seem to be on the wane. The management of societal change processes is taking place more and more in complex networks, in which it is impossible to pinpoint an absolutely dominant player, and in which success and failure are strongly associated with the ability of all parties concerned to form wise alliances and—partly thanks to this—to mobilise the creative potential of users. Hagedoorn [23] points to the growing number of strategic, technology-based alliances between firms. Numerous problems with dot com firms, failing automation projects, discussions on life sciences-related products (food, drugs) demonstrate the dependence of innovation processes on the acceptance by users and—perhaps even more importantly—on the ability to mobilise and use the creative potential of users to improve the innovation process. Other laws apply in this 'network society' or 'knowledge economy' than in the hierarchical variant. More and more often do we see the main goal being the optimisation of *chains* or *systems* of organisations, rather than a maximisation of the performance of components (e.g., companies).

In terms of performance, organisations, and thus companies too, are constantly made more dependent on the performance of other organisations (also their competitors) within the networks in which they are active. Encouraging effective alliances, bringing players with often

[1] In this connection, Gibbons [22] introduced the concept of the 'porous society'.

totally different interests into one and the same line, and acting as the intermediary are becoming increasingly more important tasks for administrators in both the public and the private domains.

Box 2
Changes in the 'strategy and management paradigm'

From 'weakly-linked systems with discrete components' to 'strongly-linked systems with fuzzy components'
The end of 'top-down' management, the growth of (horizontal) network management
The optimisation of chains and systems, instead of the components thereof
The growing importance of:
- management of the interface between organisations and the networks within which they operate
- the forming of strategic alliances
- the ability to mobilise the creative potential of players
- the flexibility of institutional systems
- institutional arrangements that facilitate horizontal policy

The aim towards sustainability reinforces the network characteristics
ICT as an amplifier and facilitator of the network characteristics

Without doubt, ICT is a significant—however by no means the only—factor in the transformation of this 'strategy and management paradigm' [24]. It is thanks to ICT that information is becoming more rapidly accessible to an ever-wider public. This leads to the breaking down of information monopolies, and the rapid and efficient exchange of information—a precondition for operating in networks—becoming possible. The call for a more sustainable society makes this network even stronger. Flexibility and the ability to eliminate (institutional) barriers and to stimulate initiatives that promote interaction between organisations and the networks within which they operate thus become crucial characteristics of the players involved in innovation processes, as Van der Steen [25] correctly suggests in her dissertation on the relationship between innovation systems and innovation processes.[2] This flexibility is sometimes difficult to detect in today's structures. One of the main reasons lies in the fact that subjects such as sustainability, the emergence of the Cultural Industry and the Information Society, in which innovation processes play a major role, are often to be found in the blurry area of responsibilities shared by different ministries. Seemingly, today's politics and the policy machinery are unable to muster up the flexibility needed to form—by way of *Neue Kombinationen*—institutional structures, and thus make it possible to pursue a horizontal and flexible policy. All of this is a huge problem for innovation management. After all, if—in addition to the lack of vision in terms of content—there are other obstacles that

[2] See also the OECD "Jobs Study" published in 1994, in which a heated argument is put forward for the flexibilisation of institutions, regulation and the effects of markets.

stand in the way of successful innovation processes, then they must be the barriers that have been put into place by virtue of institutional structures. The latter are reflections of the past, and while for innovations to be successful they must be linked to that past, they must invariably focus primarily on the future.

3.5. Questions and challenges

This broadening of decision-making on innovation must be subjected to further study in innovation studies. More particularly, the following themes should get more attention.

(a) Systems thinking gets a lot of attention in innovation studies nowadays. The actor network approach [26], innovation systems thinking [27–29], the clusters approach [30] and also recent developments in transition management [31,32] may illustrate this. Anyway, up to now innovation has very often been studied from the perspective of the individual firm. In the network society, however, innovating in chains, networks and systems becomes more and more important. This provides firms with many new questions at strategic, conceptual and operational levels. How to handle intellectual property rights, how to strike the balance between competition and cooperation, what are the implications for the 'corporate culture' of the far more porous character of the firm, are only a few of the many questions here.

(b) In this context also the role of (knowledge) intermediaries, for instance knowledge-intensive business services, in innovation processes is at stake. Is their influence growing, does their role change, what precisely is their contribution to innovation processes, do they play an important role as a link between innovation processes at firm level and the (innovation) systems in which these firms function?

(c) Users have an increasingly important role in innovation processes. Maybe this—together and linked with the genesis of the 'porous society'—is the major difference between innovations in this Kondratiev cycle when compared with the foregoing ones. This raises the question of how to organise the interface with users in such a way that innovation processes can benefit as much as possible from the creative potential of (potential) users. Consumers and, more generally, user–producer relations are being paid more and more attention in innovation studies [33–35] Constructive Technology Assessment [36,37] and interactive/participatory Technology Assessment [38] also put the interaction between users and producers at the forefront. Until now, however, these approaches have all too often played a marginal role.

(d) Broadening decision-making on innovation not only poses new questions for innovation researchers but also for policy makers. The genesis of the network society demands a new role for government and other players involved in innovation processes. The growing importance of users in innovation processes and the network character of innovation demand new concepts. As a result, the innovation policies of most OECD governments shifted over the last two decades from supply-oriented (production of knowledge), via diffusion-oriented, towards far more user/demand-oriented policies. Without any doubt, this trend will continue during the first decade of the 21st century and

will demand the development of concepts, methods, techniques and instruments that will enable players to fulfil their (partly) new roles.

3.6. Major changes in the knowledge infrastructure

The evolution of science and technology is constantly becoming a more costly affair. Each answer gives rise to new questions. The days when a secluded inventor working in the shed in his back garden was able to lay the basis for revolutionary change are far behind us. Although nations are very much aware of the significance of science and technology for their economic status, there are limits to the amount of money they are willing to spend on them. More than has ever been the case in the past, this leads to nations—and businesses too—having to choose which knowledge development they wish to invest in. In contrast to the past, these choices are no longer without commitment: choosing x implies that cuts will need to be made in y. In this respect, John Ziman speaks of ''science in a steady state'' [39]. Together with the increasing social and economic importance of knowledge, this development has led to organisations for applied research, and universities as well, being asked to account for themselves more specifically. Justification is often expected in terms of contributing towards solutions to societal problems. Whether this insistence on applicable knowledge is justifiable and wise is debatable. However, it is beyond doubt that the concept of pure basic science research, for which—as an American Nobel Prize winner once said—with the best will in the world there was absolutely no practical application that could be imagined [40], has been cast back to those university groups operating at the absolute forefront of science. Many other university researchers will see an increase in the number of requests to set out what they are able to do for the economy and the society of the future.

As a follow-up to the above, there is the demand for management of the knowledge infrastructure. The increasing trend for universities being expected to account for themselves is only one manifestation of an expansive phenomenon that is emerging in the international dimension: the blurring of the sharp division between the *production* and the *application* of knowledge. Scientists are gradually losing the exclusive right to be the producers of scientific and technological knowledge. The emergence of knowledge-intensive services (engineering firms, software houses, knowledge-intensive consultants) plays an important role in this respect. Recent research shows that these services play a crucial role in innovation processes, both in industry and in the service sector [18]. Gibbons et al., in their much-discussed book entitled 'The New Production of Knowledge', bring this trend under the heading of 'the social distribution of knowledge production'. They make it quite clear that there is talk of a revolutionary change in which culture, content and organisation of the knowledge infrastructure are a part. In their terminology: a transition from Mode 1 to Mode 2 science [41]. Table 1 sets out the main differences between Mode 1 and Mode 2.

This gives rise to a dilemma for universities and public research organisations [42]. Universities, because the demand for more specific orientation towards the problem in question calls for a multidisciplinary approach, while at the same time they are under a great deal of (scientific) pressure to score in the mono disciplines. Public research organisations, because on the one hand they are driven onto the market in order to demonstrate that they

Table 1

Mode 1 science	Mode 2 science
Academic context	Application-oriented
Disciplinary	Transdisciplinary
Homogeneous	Heterogeneous
Hierarchic and stable	Heterarchic and variable
Academic quality control	Quality measured on a wider set of criteria
Accountability to science	Accountability to society as well

produce 'practicable knowledge', and on the other hand because as soon as they do this with some success they are clipped around the ears and accused of 'unfair' competition. The observation made by Hendrik Snijders in his dissertation 'The One-Dimensional Science', that our researchers still prefer the (individual) *know* to the (communal) *can*, adds yet another complicating factor to this problem [43].

3.7. Questions and challenges

Innovation studies have to play an important role in making 'Mode 2 work' by developing insights that contribute towards a knowledge infrastructure that will maintain a healthy balance between creative science and problem orientation. Major questions and challenges in this context are:

(a) The 'Mode 1–Mode 2' debate attracted a lot of attention, but until now consequences in terms of missions, new institutional designs and relations have scarcely been drawn. So, for instance, the strategic position of the 'traditional' knowledge infrastructure vis-à-vis the knowledge intensive intermediaries[3] have hardly been paid any attention until now.
(b) 'Mode 2' raises many questions—which until now have hardly been addressed, let alone answered—with regard to the role of multi- and interdisciplinary research in highly monodisciplinary-oriented research systems, the measurement of quality control in situations where criteria other than the purely scientific matter, and the status of scientists in a society in which their exclusive right to the production of scientific knowledge is challenged.

4. Elements of a research agenda

4.1. Broadening of decision-making on innovation

The trends outlined in the foregoing all have contributed towards a broadening of decision-making on innovation. This confronts the players involved in innovation processes with new problems and challenges. This development poses new questions

[3] Den Hertog et al., label these organisations as the '2nd knowledge infrastructure', 1998.

for innovation studies that are still inadequately recognised and addressed. This relates in particular to the following challenges:

1. Innovation is becoming *more reflexive*. Insight into the nature of innovation processes is increasing, thanks to innovation studies and through learning by doing and learning by using among policy-makers, innovation managers in businesses and other parties concerned. This makes the considerable importance of the coevolution of innovation processes clear, and also the context within which these processes occur.
2. The emergence of *new kinds of innovation processes*. Whereas today's innovation studies focus mainly on agricultural, and chiefly industrial innovation processes, we see new kinds of innovation processes standing out because of the greater role played by tacit knowledge (innovation in services), other kinds of markets and the (far) greater importance of ethical aspects (biotechnology) or because of their network characteristics (ICT).
3. *Changes in the context* within which innovations occur. In a nutshell, it can be stated that (parts of) our society are developing from 'a system with weakly linked discrete components' to 'a system with strongly linked fuzzy components'. The context is also increasingly characterised by a multilevel structure. Internationalisation and region-alisation lead to the emergence of a very difficult position resulting in—particularly on the national level—roles, responsibilities and relationships that need redefining.

Innovation studies have been inadequate in incorporating the process of broadening decision-making on innovation as described above. Questions relating to this process should therefore have a prominent place on the agenda of innovation studies.

4.2. Three lines of study

In this section, an attempt will be made to identify elements of a research agenda for innovation studies that may be of use to players involved in innovation processes. Given this focus, apart from empirical research and theoretical reflection, improving insight into decision-making and the role of strategic intelligence are important lines of research. It is not the ambition to strive after completeness. The focus will be on the macro and meso levels and not on innovation processes at the level of individual firms and organisations. These having been said, three lines of research are formulated:

Empirical studies of innovation processes and innovation systems;
Critical reflection on innovation theories;
Analysis and support of decision-making processes.

4.2.1. Empirical studies of innovation processes and innovation systems

This relates to case studies of specific innovation trajectories, changes in the context within which innovation processes occur, and providing an insight into the dynamism of

innovation processes and innovation systems and how they interact. Given the trends described in the foregoing, case studies dealing with innovation processes in the area of the life sciences and in the services sector and research conducted at the sectoral level into the contribution made by ICT towards a more sustainable society are examples of specific trajectories. Historic and international comparative research into the development of innovation systems, as well as studies into the role of (knowledge intensive) intermediaries in the course of innovation processes, are examples of case studies at system level. Furthermore, studies that focus on changes in research systems in general and at sectoral level (agriculture, ICT, services sector) must also be mentioned here.

Together, these case studies could serve as the basis for the development of various types of indicators that can help to better understand and monitor the input, throughput and output of innovation processes and systems.

4.2.2. Critical reflection on innovation theories

As yet, the discipline of innovation studies is not a firmly integrated theoretical bastion. It can be typified as an evolving (inter)discipline that finds itself at the crossroads of sociological and historic scientific and technological research, economic innovation studies and policy studies. Within the broad cluster of approaches there are several theoretical schools that have made rapid progress over the past few decades and are becoming more and more interwoven. Today, there is a more or less robust body of knowledge concerning the nature of innovation processes and the organisational and societal embedment of innovations. It is because of this that we can justifiably speak of 'innovation studies'. Despite this growing core of shared insights, there is also a gap that can be distinguished between two major approaches in innovation studies. The first one is based on the analysis of innovation *processes* and attempts to understand better the dynamics of sociotechnological innovation processes. The second approach focuses on the analysis of innovation *systems* and is used to search for ways of deepening the level of understanding of the genesis of new organisations (institutions, structures, systems).

Within the school that uses processes as the point of departure for analysis, the *evolutionary* and *constructivist* approaches are the ones that are talked about the most. In these discussions the focus is on the players in the innovation process, and people let themselves be inspired by the thought that innovation processes are in many respects similar to the evolution processes we are acquainted with in biology [44–46]. The core of this approach is the actual conceptualisation of innovation as a process in which the generation of variations and making choices alternate. One major distinction from Darwin's theory of evolution is that the variations in biological evolution processes (mutations) are totally random, while the generator of the variations (potential innovations) can take into account the characteristics of the selection environment in innovation processes. In other words, the generation of variations is partly driven by the producers' expectations as to the most successful routes to take [47].

The second school can be characterised as a *systems approach*. The main idea behind this innovation systems approach is that the success of innovation processes is determined mainly by the degree to which the many organisations and players able to influence the

course of innovation processes coordinate their activities.[4] While the specific circumstances are analysed in less detail in this school, there are quite clear policy implications involved. This does not imply that in 'innovation systems literature' no attention is paid to processes, but the main emphasis is on structures. From this perspective it is the structure that determines the character of an innovation system and its behaviour, also in terms of transitions, path dependencies and inertia, over time.

While the two approaches are potentially complementary, they are not yet adequately interrelated. This inadequacy is significant in the light of the developments in the nature and the context of innovation processes as described above.

The two main approaches are clearly lacking in two specific aspects.

They are separate and offer no explanation for the coevolution of institutional structures and innovation (and learning) processes. This is a major deficiency for our understanding of the development of innovation systems or innovation networks, given that it is precisely in the interaction between processes and systems that the dynamism for the change in system structure and the substance of processes is localised [25].

As has already been said, this does not imply that innovation systems research does not pay attention to processes. A number of related approaches as actor network theory [48], transition management [31], constructive and participatory technology assessment [36,38] and cluster studies [49] focus on the development and transition of (innovation systems) as well as on the relation between innovation processes and the systems in which they develop. Until now, however, these approaches are often still young and/or not firmly integrated in the mainstream of innovation studies. Without any doubt, a lot can be gained by a further development and integration of these approaches.

Related to the foregoing, a central role is played in both approaches by discrete entities (businesses, government organisations, social groups). Developments are often described as a competition between mutually relatively independent organisations and/or technologies. The approach taken by Arthur [50] in his 'Competing Technologies' clearly illustrates this. Effectiveness in this interpretation stands for the optimisation of the performance of clearly distinguished organisations, and is often at the expense of other organisations within the same system. Theory offers no answers to the question of how effectiveness or performance should be understood in a network structure. Collaboration and competition within and among networks, as well as the question of what the consequences are for the strategies of organisations (To pull together or to remain a loner? To share knowledge or to shield it off?) and how they should be positioned in the networks in which they operate, are only dealt with indirectly.

Disciplines such as economics, public policy analysis and business administration are confronted with a lack of insight into the dynamics of innovation processes and systems

[4] In his contribution to the collection of texts by Barré et al., Freeman uses an analysis of the strength of the British during the first Industrial Revolution to give a meaningful example of the importance of these relationships. Freeman's proposition is that the success of the British in this period should not be attributed primarily to the strength of the system *components* (politics, economy, science and technology, culture) but rather to the cunning way in which these *subsystems were coordinated* [29].

and their mutual relationships. The exceptionally lengthy period of high economic growth in the last decade of the 20th century in the USA, without it—till very recently—being coupled to rising inflation and unemployment, gives rise to some economists assuming that structural changes in which knowledge plays an important role are under way in our economy. Not only as a production factor, but also as a product and a service. One notable feature of knowledge is that knowledge is easier to copy than tangible products. This undermines the meaning of the word 'scarcity'—which even today is the main variable in mainstream economics. The fact that the products of network technologies, such as faxes and PCs, become all the more in demand the greater their market penetration, brings up for discussion another basic rule of economics—that prices fall if supplies increase. Of note is that, within the community of established economists, these stories are generally dismissed as 'old ideas parading as new ones', or 'more of the same, no structural difference'. The discussion among economists on this subject is apparently—as we read every day in the newspapers—still in the early stages [1,51–54].

In turn, while scholars in the field of public administration and policy studies admit that there is a new 'strategy and management paradigm', they are still to a large extent searching in the dark for an answer to how this 'strategy and management paradigm' will be able to ensure that new technologies will not result in Orwell's '1984' becoming reality, but will contribute towards raising the democratic content of our society. The redefinition of the role and (re)organisation of the state forms a crucial theme in this debate [55–57].

And, finally, business administration experts and organisational sociologists discuss the question of how to interpret the far more open business strategies demanded by the network economy in their models [58,59].

Achieving substantial progress in terms of our understanding of innovation processes in relation to and in interaction with the systems within which they occur is inconceivable for all this theory development without a more far-reaching endogenisation of technological development within the theory.

To wind up, the foregoing is meant to be a plea for more focussing of theoretically oriented innovation studies on the interaction between systems and processes, the management of the interface between organisations and the systems within which they innovate, the changing character of research systems and their role in innovation processes, and the role played by the intermediaries in these innovation processes. Here, empirical analyses made in the first line of research are the main sources of inspiration. An attempt should me made, where possible, to contribute towards the endogenisation of innovation processes in the development of theories in other disciplines.

4.2.3. Analysis and support of decision-making processes

Taking the needs of the players involved as a starting point, insight alone is not enough. It is also important that we look at the consequences of this improved insight for the concepts, methods and techniques used by these players. This relates to aspects in terms of both *content* and *process* [60].

In terms of *content*, this relates to the nature of the strategic information required by the players involved in innovation processes to enable them to realise their goals. Insight into the potential of new technologies for the economy and society, the appreciation thereof by several different parties, the consequences that result from realising these potentials, and insight into the possibilities of exerting influence for those involved become more important. There is also the need for an understanding of the decision-making processes in innovation systems: who is involved, in what way, and from which angle? Research that looks at both aspects is relatively scarce and will need to be encouraged. In this respect, the lessons that have been learnt from the experience gained with technology foresight over the past more than 25 years improving our insight into the supply of new technology years can be used [61]. The same applies for the lessons learned from the development and use of technology assessment that help to clarify better the potential and impact of the conditions for innovations [21,37] and from evaluation studies of research programmes and innovation processes [62]. Also cluster studies that focus on the articulation of the demand for new technology are useful in this context [49]. Technology assessment and foresight in particular have undergone a radical evolution over the past few years. They have evolved from being predictive research into research that now takes the coevolution of innovation systems and innovation processes as the point of departure. They then provide information from this point of view that is able to help those involved to draw up scenarios for potential future developments. In this way, this kind of research helps players to anticipate—and thus give shape to—the course of innovation processes and the evolution of innovation systems.

In terms of *process*, this relates to the consequences of the emergence of the network society for the set of instruments used by policy makers and other parties involved in the innovation process in realising their goals. As was said earlier, the network society places high demands on the management of the interface between organisations and the networks within which they operate, the forming of strategic alliances, the ability to mobilise and use the creative potential of the players concerned, on the flexibility of institutions and systems, and on institutional arrangements that facilitate horizontal policy and collaboration. There is a great need for policy concepts and the associated instruments that promote flexibility and make a direct contribution towards the reinforcement of networks, and for the development of rules (and legislation) regarding competition and collaboration in networks, resulting in the public knowledge infrastructure becoming effectively integrated into innovation systems [63]. The concept of cluster policy that receives a lot of attention from policy makers is a good initial step in this direction, but many more steps will have to follow [30,64].

One important component of this set of instruments consists of instruments that help to eliminate many barriers between the players in innovation networks.[5] There have been many new developments underway in this field over the past few decades. Strategic workshops,

[5] In this context, Geurts speaks of gaps between [56]: administrators and citizens; experts and laymen; producers and the users of knowledge; different (scientific) disciplines; policy and science.

scenario workshops, electronic boardroom systems, and gaming and consensus development conferences are only a few of the many examples. In his dissertation, Mayer [57] gives a good overview of the opportunities these instruments offer, as well as of the associated problems. In his dissertation, yet to be published, Bongers gives a detailed study of the added value of electronic boardroom systems in innovation processes [65,66]. Both Mayer and Bongers reach the conclusion that while such instruments do offer potentially major opportunities, a deeper study into their functionality and the conditions for their use is called for.

5. Conclusion

An attempt has been made in this paper to analyse the questions and challenges that players involved in innovation processes and in their management have to face. The starting point for this analysis are the three trends introduced in the foregoing. The main characteristics of these trends are summarised in Box 3.

Box 3
Major trends

Structural changes in the economy:
- within sectors (agriculture)
- between sectors (from agriculture to industry to services)
- new sectors (cultural industry)

Thread: growing knowledge intensity
Changes in the 'strategy and management paradigm':
- the end of 'top down' steering
- the advent of the 'porous society'
- optimising systems instead of parts
- the growing importance of alliances, flexibility and mobilising the creativity of users

Changes in the knowledge infrastructure:
- from 'Mode 1' to 'Mode 2'
- the advent of second order knowledge infrastructure

Starting from these questions and challenges, and taking the state of the art and recent developments in innovation studies into account, research questions relevant for actors involved and innovation researchers were formulated. From this list of questions (summarised in Box 4), it becomes clear that a major conclusion of this paper is that the shifts in the context of innovation processes, more particularly the emergence of the 'porous society', will lead to a radical transformation of innovation systems in which

(knowledge intensive) intermediaries and the quality of the interface between users and producers play an increasingly important role.

Box 4
Elements of a research agenda

Empirical research into innovation processes and systems:
- improving insight into the nature of innovation in services
- improving insight into the nature of innovation in the life sciences
- research into the relationship between ICT and sustainability at sectoral level
- development of (intangible) throughput and output indicators of innovation processes

Reflection on innovation theories:
- understanding the dynamics of innovation in chains and clusters better
- improving insight into the role of (knowledge intensive) intermediaries in innovation processes
- improving insight into the interaction between innovation processes and systems contributing towards the endogenisation of innovation in other disciplines
- improving insight into the transition of innovation systems

Analysis and support of decision-making processes:
- improving insight into the potential, assessment and implementation of new technologies (technology assessment, foresight, evaluation, cluster studies)
- developing methods and techniques to support players in innovation processes and networks (scenarios, group support systems, gaming)

As has already been said, we did not strive for completeness. The agenda should be considered as an attempt to link user needs better to innovation studies. Innovation is the work of man, but making science and technology work is by no means easy. By working on this agenda, innovation researchers can help policy makers, managers and other actors involved improve their performance in trying to make science and technology work in such a way that it will serve their and society's goals better. This 'user orientation' is, together with the ambition of improving insight into innovation processes, at the heart of this young and multidisciplinary field of research. In this way, innovation studies are not only part of 'Mode 2', but at the same time can contribute a great deal to a smooth transition from 'Mode 1' to 'Mode 2'.

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