
Designing a model for innovation indicators from a systems perspective

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Abstract: We report on an empirically derived model for innovation indicators that enables a better measure and promotion of innovation. The model has been derived through an internet-based Delphi assessment, involving up to 32 experts. The first two Delphi rounds (April 2004–March 2005) were held through the internet and the third round (May 2005) was organised as a workshop in a face-to-face meeting. As a result of the Delphi assessment, we could derive a model of the innovation system with very high consensus among the experts. This model will make it possible in a next step to define innovation indicators that will enable policymakers to analyse the innovation system and monitor its evolution. A comparison with the European Innovation Scoreboard indicators shows that more indicators than used nowadays will have to be defined to make the model operational.

Keywords: innovation management; technology transfer; Delphi assessment; Science and Technology (S&T); Research and Development (R&D); systems perspective.

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1 Introduction

All economies are concerned with technological innovation and technology transfer issues. Despite these common concerns, there is little agreement about how innovation should be defined, and even less understanding of how innovation should be measured or quantified.

Literally taken, innovation means ‘novel’ or ‘renewal’, which can be derived from the Latin terms *novus* for new and *innovatio* for something newly created. From a more practical perspective, innovation refers to the economic realisation of new ideas or knowledge in terms of products, processes, services, or even concepts and structures. A most comprehensive definition of innovation is provided by the Oslo Manual (OECD/EUROSTAT, 2002), which was first issued in 1992. The third edition issued in 2005 expands the original framework to incorporate practical experience and advanced understanding of the innovation process. Most recent advances on the manual refer to the consideration of organisational and marketing innovations. Innovation is now defined as “...the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organization or external relations” (OECD/EUROSTAT, 2002, p.31).

Furthermore, a distinction can be made between innovation as a result of an invention and innovation as a result of research. While innovation resulting from invention generally occurs uncontrolled and often spontaneously, innovation resulting from research is coupled with large investments in education and research. In the work reported on in this paper, we solely refer to innovation resulting from research. The reason for this is that politicians and managers must decide how much input should be made for a quite uncertain output.

Traditionally, innovation is simplified as an input-output model, with some consideration for certain processes in-between. To stimulate these processes, funds are allocated by governments or enterprises, with the hope of attaining technological, and eventually economic, progress. The management of innovation relied in the 1960s on a technology-push concept. This concept was then replaced in the 1970s by the market-pull concept. The following decade was characterised by the chain-link concept, where research, market and clients were seen as an interconnected system. The last decade encountered the concept of the systems approach, in terms of a system of innovation in which firms are linked with research centres, government agencies, consultants and the consumers. More recently, the concept of social networks emerged, which is a combination of older approaches and the possibilities that information and communications technologies offer nowadays as part of the often referred to knowledge society (EU-DGE, 2004).

A major source of discussion refers to who should make the input. Clearly, governments make inputs to make society benefit from them, while enterprises make inputs to advance their own business. Because society and enterprises are strongly related, the inputs affect overlapping interests. Based on the principle ‘Who pays decides’, private industry is not in favour of government intervention when it comes to innovation.

An even more controversial issue is the measurement of the output. While the number of patents or publications is an easily quantifiable metric, its meaning in terms of Return on Investment (ROI) is questionable. Government agencies prefer as output

measures some societal impacts, while enterprises regard the impact on the market as the crucial output measure. Again, market impact and societal impact are not fully disconnected concepts.

The European Innovation Scoreboard (EIS) is the main statistical tool of the European Trend Chart on Innovation (Cordis, 2006). EIS was developed by the European Community and it gets updated annually. It comprises five sets of categories referring to:

- 1 innovation drivers
- 2 knowledge creation
- 3 innovation and entrepreneurship
- 4 applications
- 5 intellectual property.

The primary purpose of EIS is to measure the relative strengths and weaknesses of innovation performances of EU member states. Each member state is contrasted to the average of the EU member states, for each indicator. Moreover, a limited number of indicators can be used to contrast the performances of the EU with those of the USA and Japan. EIS is one component of a much broader benchmarking exercise of the Directorate General Enterprise covering European enterprise policy and competitiveness as a whole.

Acknowledging the complexity of modelling and measuring innovation – and as a consequence of optimising decisions involving the promotion of innovation – the Organization for Economic Cooperation and Development issued in January 2004 a set of key challenges and opportunities regarding science and innovation policymaking (OECD, 2004). Among these are:

- 1 an increasing pressure of science systems to respond better to a more diverse set of stakeholders
- 2 the need to adapt to changes in the process of knowledge creation and transfer
- 3 the need for a shift from island-based research to networked systems of innovation production and demand
- 4 the need for reforms in public governance of research
- 5 the need for more targeted output from public research
- 6 the call for multi-disciplinary research with international cooperation and more mobility of researchers
- 7 the call for more efficiency in research organisations (including research-industry relations)
- 8 the need for countries to install an efficient and flexible science-innovation interface and to conduct comprehensive reforms that strengthen industry-science links
- 9 the need for changes in governance and funding structures to make public research organisations more focused on economic and societal needs.

The World Bank has also identified a set of key concerns regarding technological innovation (World Bank, 2004):

- 1 Development increasingly depends on a country's ability to understand, interpret, select, adapt, use, transmit, diffuse, produce, and commercialise scientific and technological knowledge in ways appropriate to its culture, aspirations and level of development.
- 2 S&T has always been important for development, but the unprecedented pace of advancement of scientific knowledge is rapidly creating new opportunities for, and threats to, development.
- 3 The World Bank could have a greater impact if it paid increased attention to S&T in education, health, rural development, private sector development and the environment.
- 4 The World Bank's strategy emphasises four S&T policy areas: education and human resources development, the private sector, the public sector and information communications technologies.

The increasing awareness of not only measuring innovation processes but also steering them in a desired direction is a call that is common to all decision-makers. A conceptual model that was developed to respond to this call for the system of Information and Communications Technology (ICT) has been proposed by Beroggi *et al.* (2005). The model focuses on the policymakers. The decisions of the policymakers affect the development of new ICT and the potential benefit that ICT can offer. ICT and the potential benefit, together with the willingness of people to use ICT, affect the resulting use of ICT. The consequences of using ICT can be seen as a feedback to the policymakers regarding their policy decisions.

The purpose of the research presented in this paper was to develop such a dynamic feedback model for the innovation system, similar to the one that was developed for the ICT system. Prior to doing that, we wanted to understand what the different facets of the innovation system were. For this purpose, we used the challenges and concerns from OECD and the World Bank, as listed above, to derive a set of three hypotheses about the innovation system and the definition of indicators for that system:

H1 There is not a common understanding about the definition of innovation indicators.

H2 There is not a common view on the goals of innovation indicators.

H3 There is, however, a common view on how to define a model for innovation indicators using a systems perspective.

We decided to test these hypotheses with a Delphi assessment that took place between April 2004 and May 2005 and that involved experts in the field of innovation promotion and management. In the next section, we describe the methodology used to test these hypotheses. Subsequently, we discuss the results in Section 3. As a result of assessing the hypotheses, we derive a model of the innovation system in Section 4. Finally, we discuss the application of the proposed model in Section 5.

2 Research method

To test the three hypotheses, the concept of the Delphi assessment was applied (Adler and Ziglio, 1996). A Delphi assessment consists of multiple, sequential rounds of posing statements to experts about a certain topic for their anonymous assessment. Each round provides feedback, which is processed to identify consensus or dissent among the experts. The statements can be modified after each round, in order to promote consensus.

The Delphi assessment thus provides much more meaningful results than a simple questionnaire or a focus group meeting. The major problem of the Delphi assessment, however, is the high number of dropouts that usually occurs in each round.

In order to keep the number of dropouts low, a carefully selected set of experts from industry, academia and public agencies has been chosen. In total, 46 experts were initially invited to participate in the internet-based Delphi assessment. The experts were selected from various leading institutions in Switzerland and abroad, including the Federal Office of Education and Research, Federal Office of Economics, Department of Education and Technology, Federal Statistical Office, Center for Science and Technology Studies, European Committee, Eurostat, Avenir Suisse, *economiesuisse*, OSEC Business Network, Steinbeis Foundation, different national and international universities, as well as various regional innovation transfer centres.

A total of 32 statements, grouped into four sets, were posed to the experts to assess the three hypotheses. The first two sets were defined to test Hypothesis 1, the third set to test Hypothesis 2, and the fourth set to test Hypothesis 3.

- 1 Two statements regarding the definition of S&T and R&D (to test Hypothesis 1; there is not a common understanding about the definition of innovation indicators):
 - a The result (*i.e.*, the output) of an innovation effort can be: (a) a new technology (*e.g.*, the telephone), (b) new knowledge (*e.g.*, the deciphering of the genetic code) or (c) a new process (*e.g.*, e-banking).
 - b Science and Technology (S&T) is primarily defined as the innovation, which results from basic research, while Research and Development (R&D) is primarily defined as the innovation, which results from applied research.
- 2 Ten statements regarding the common understanding of what innovation means (to test Hypothesis 1; *i.e.*, there is not a common understanding about the definition of innovation indicators). These ten statements were chosen from the literature to see how the experts judge well-documented findings:
 - a Patents capture only about 10%–15% of the total R&D value, which makes the number of patents an inadequate indicator to measure innovation (Griliches, 1992).
 - b Instead of using patents and publications as indicators, the number of references (citations) is a more reliable metric for the innovation potential (Griliches, 1992).
 - c What scientists see as good research does not have to be good innovation, which is also referred to as the productivity paradox (Geisler, 2000).
 - d Researchers and research centres are under increasing pressure to respond better to a more diverse set of stakeholders (OECD, 2004).

- e Research and Development needs to shift from island-based research to networked systems of innovation production and demand (OECD, 2004).
 - f The most important factors affecting innovation success are management decisions; especially managers with a large network can influence innovation projects significantly (Cooper and Kleinschmidt, 1995).
 - g One of the major challenges regarding the development of a measurement system to assess innovation is to match the set of technology indicators, reflecting the technological progress, to the set of social indicators, reflecting the societal and economic benefits (Geissler, 2000).
 - h Scientists value material incentives (*e.g.*, salaries, bonuses) higher than intangible values, such as staff development, flexibility, or social status (Staudt *et al.*, 1991).
 - i The potential benefit of innovation depends on how a country is prepared for that particular innovation (World Bank, 2004).
 - j Government promotion of innovation is not sufficient to stimulate knowledge-transfer between research and industry; more entrepreneurial thinking is imminent (Conceição and Heitor, 2004).
- 3 Ten statements regarding the goals of the innovation indicators (to test Hypothesis 2; *i.e.*, there is not a common view on the goals of innovation indicators). The goals of the innovation indicators refer to the:
- a identification of strength and weakness of the innovation system
 - b control of the innovation system
 - c national comparison of innovation performance
 - d international comparison of innovation performance
 - e monitoring of the dynamics in the innovation system
 - f measurement and monitoring of the transfer of innovation
 - g promotion of collaboration between Public Research Organizations (PRO) and industry
 - h harmonisation of university teaching and industrial needs
 - i optimisation of policy investments
 - j optimisation of policy efforts.
- 4 Ten statements regarding the definition of a model for innovation indicators using a systems perspective (to test Hypothesis 3; *i.e.*, there is a common view on how to define a model for innovation indicators using a systems perspective):
- a A modelling approach is required to capture the whole innovation system.
 - b Return on Investment (ROI) indicators are needed to measure the benefits of innovation.

- c Transfer centres are important to disseminate and to promote innovation.
- d Technology transfer as well as knowledge transfer must be considered in the model.
- e A network of innovation transfer must be modelled instead of simple processes of innovation management.
- f Indicators for innovation must be grouped into those referring to the idea of innovation, the process of innovation and the result or impact of the innovation.
- g The universities of applied sciences play more and more a crucial role for innovation creation and innovation dissemination.
- h The involvement of industry in university education must be considered in the model; *e.g.*, the creation of corporate universities.
- i Double appointments of people in academia and industry play a crucial role in the innovation model.
- j Part-time education is important in the innovation model as an interaction between academia and industry.

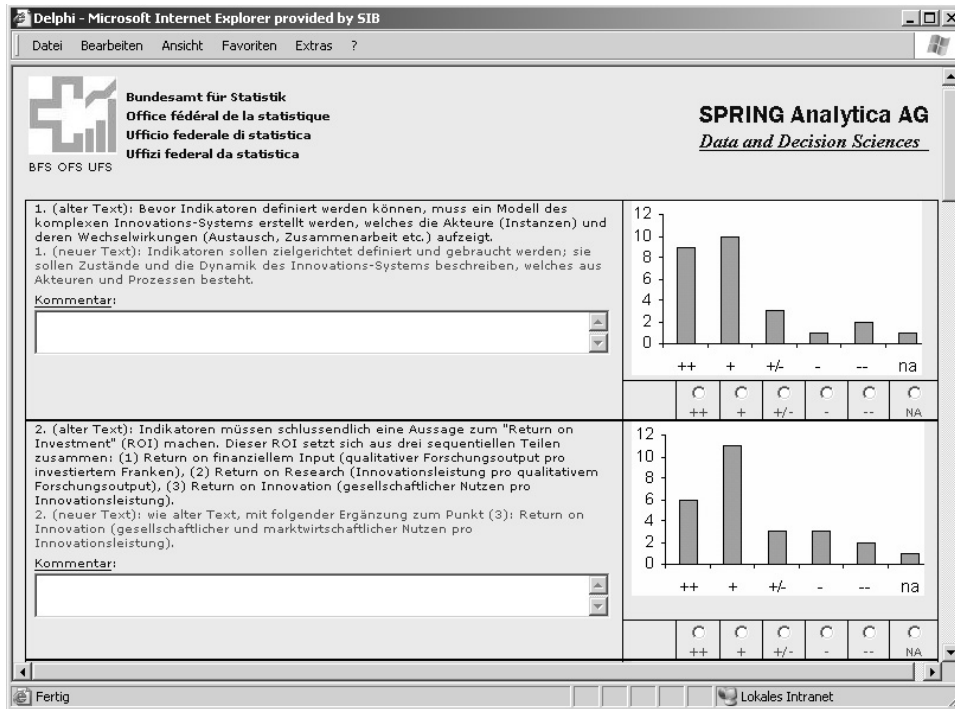
These four sets of a total of 32 statements were placed on an internet website for the experts to express their opinion on in the first and the second Delphi round. The first Delphi round lasted from April to December 2004, the second Delphi round from January to March 2005, and the third round, the onsite workshop, took place in May 2005.

Figure 1 shows a screen view that was used for the second Delphi round on the internet. The distributions of the answers from the first round were portrayed in the second round as frequency diagrams on the right-hand side of the screen, next to each statement. Moreover, minor changes to the original text of round 1 were made, with the objective of increasing consensus in the second Delphi round. The results of the first round are discussed in Section 3.1 and those of the second round in Section 3.2. The results of the third round, which was held as a workshop, are discussed in Section 3.3.

Of the 46 invited experts, 26 participated anonymously in the first Delphi round. This corresponds to a response rate of 43%. Because the names of the experts who participated in the first round were not known, all 46 experts had to be invited to participate in the second Delphi round. In the second round, which also took place on the internet, a total of 20 experts participated. However, of these 20 experts, only 14 had also participated in the first round. The other six experts were among the 46 invited experts who did not participate in the first round, but who decided to participate in the second round. These numbers correspond to a total dropout rate in the second round of 23%; however, the active dropout rate; *i.e.*, considering only the experts who participated in both rounds, is 46%.

The purpose of a Delphi assessment is to improve an existing, or to confirm a non-existing, consensus among the experts. A consensus measure was introduced, as the percentage of experts who agree with a statement, compared to those who disagree.

Figure 1 Screen view of the second Delphi round on the internet with the distribution of the assessments of the first round

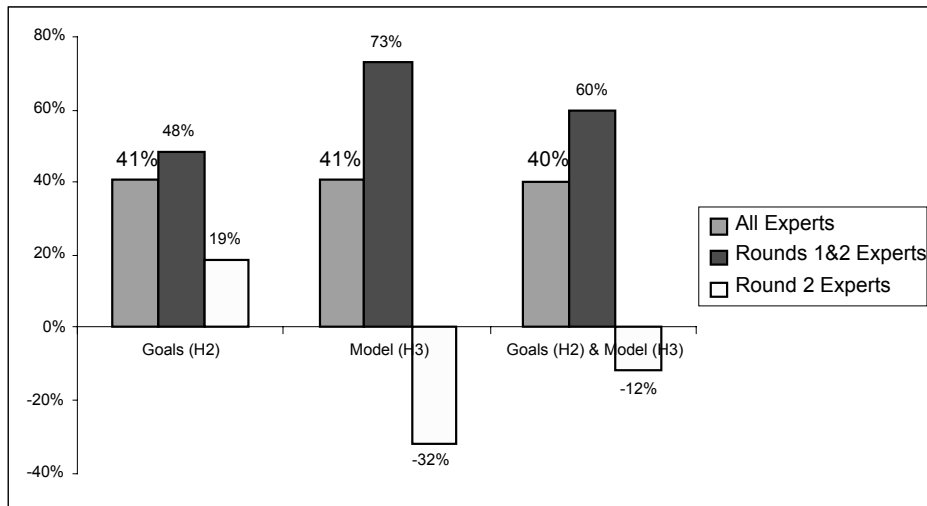


The first two sets of statements, which referred to Hypothesis 1, *i.e.*, the common understanding among the experts about the definition of innovation indicators, were just used to identify experts who seem to be too controversial to be considered for a consensus process. For that reason, we were not aiming at a consensus for Hypothesis 1, but at identifying possible outliers, which would jeopardise the consensus process.

The consensus measure was therefore computed only to test Hypotheses 2, *i.e.*, for the third set of statements, those referring to the goals of innovation indicators, and Hypothesis 3, *i.e.*, the fourth set of statements, those referring to the definition of a model for innovation indicators using a systems perspective. For these two hypotheses, we hoped to find a consensus in the group. Figure 2 shows the changes in consensus between the first and the second Delphi round, for Hypotheses 2 and 3.

Figure 2 shows that the highest consensus improvement between the first and the second round occurred for experts who participated in both rounds. The consensus of those who participated only in the second round, compared to the consensus of the first round, was even negative, which implies an increase of dissent. This result is not too surprising since the Delphi method is tailored to a group of experts seeking consensus, and for that the experts should participate in both rounds. Since we did not want to exclude experts in the second round based on the fact that they did not participate in the first round, we can conclude from Figure 1 that we had to accept a less strong consensus, than what we could have hoped for, if we had only accepted experts in the second round who also did participate in the first round.

Figure 2 Changes in consensus between first and second Delphi round. ‘All experts’ refers to those experts who have participated in both rounds as well as those who participated just in one of the two rounds; ‘Rounds R1&2 Experts’ refers to those experts who participated in both the first and the second round; and ‘Round 2 Experts’ refers to those experts who participated in the second round but not in the first round.



The three columns on the left in Figure 2 refer to the consensus improvement for Hypothesis 2, *i.e.*, the ten statements referring to the goals of innovation indicators. All the 26 participants in the second round had a consensus improvement of 41% over the results obtained in the first round. However, those who participated also in the first round had a consensus improvement of 48%, while those who only participated in the second round had a consensus improvement of only 19%.

The three columns in the middle of Figure 2 refer to the consensus improvement for Hypothesis 3, *i.e.*, the ten statements referring to the definition of a model for innovation indicators using a systems perspective. It is striking that there is a strong discrepancy between the experts who participated in both rounds and those who only participated in the second round. While the experts who participated both rounds had a consensus improvement of 73%, those who participated only in the second round had a consensus deterioration of 32%.

Finally, the three columns to the right show the aggregated consensus improvement for Hypotheses 2 and 3, *i.e.*, the goals of innovation indicators and the definition of a model for innovation indicators using a systems perspective. The same tendency can be asserted, namely, that the consensus of the experts who participated only in the second round deteriorated (-12%) compared to the experts who participated in both rounds (+60%).

The third Delphi round took place as an onsite workshop, to which all 46 initially contacted experts were invited to participate. The workshop was attended by 20 experts. Because of the anonymous character of the Delphi assessment, it was not known which of those 20 experts had participated in which of the first two rounds.

3 Results from the Delphi assessment

3.1 Results from internet Delphi Round 1: Hypothesis 1

The purpose of Hypothesis 1 was to identify potential outliers among the experts, which could jeopardise the consensus process. Since the first two sets of statements referred to Hypothesis 1, these two sets were not considered any further in the subsequent two Delphi rounds.

The findings regarding Hypothesis 1 are summarised below. These findings were derived from the votes that the experts expressed for the statements and also from comments they made. All percentage values in parentheses (%) refer to the percentage of experts who agreed on the corresponding statements.

- 1 Definition of innovation – two approaches prevail for the definition of innovation. The first is the economic approach, where the R&D process is emphasised up to the introduction to the market. The promotion of innovation is seen, among other things, in the promotion of the R&D process; societal (*i.e.*, subjective) utility indicators are deemed to be important. The second approach is the free market approach, where not the process, but rather the success in the market is crucial. Innovation consists of incremental changes of existing products and processes or happens also purely coincidentally. The promotion of innovation is seen among other things in the improvement of the free market conditions; objective market indicators are deemed to be important. These assessments confirm our first hypothesis, namely that there is not a common understanding about the definition of innovation indicators.
- 2 Research and innovation – a direct link between research and innovation has not been recognised (85%). The (public) research is under increased commercial pressure (90%). An efficiency increase in the sense of a cross-linkage or a reduction of publicly funded research is endorsed by a majority (75%). Official promotion is seen as being of limited efficiency; business thinking in research is considered to be appropriate (100%). The promotion of cooperation between public R&D places and industry (50%), as well as the harmonisation between university teaching and practice, are not endorsed (32%). Very well supported is the mobility (79%) and the associated knowledge transfer between universities and industry (81%). The majority of experts, however, endorse the optimisation of the public hand involvement (60%) and the optimisation between the public hand and the economy (75%).
- 3 Classical indicators – the appropriateness of classical indicators is assessed contradictorily. For example, patents are seen as having a limited meaning as a measure of innovation (72%); moreover, the contradictory perception of the meaning of this indicator became obvious. While one expert commented that “A patent shows at least that a concrete market value exists”, another experts stated that “A patent application does not have to mean that the innovation is useful in a marketing sense”. Publications are not at all seen as a more meaningful measure of innovation than patents (44%).
- 4 Goals of indicators – strong agreement among the experts exists regarding the goals of innovation indicators (>80%): monitoring and comparison of regional and temporal changes. As an inappropriate purpose of innovation indicators is considered the monitoring and control (promotion and change of direction) of the innovation

system (50%). For the definition of the indicators a model must be defined, which reflects the relationships between the actors of the innovation system (84%), which are research centres, industry, education instances, tertiary sector (and civil companies) (94%). It is desirable to capture the ROI of innovation (74%). Indicators should be defined for different phases of innovation, including the innovation itself, as well as the development and the commercialisation phases (73%).

- 5 Innovation-transfer – the role of the innovation transfer organisations was partly not known, and their value was assessed contradictorily (53%). Considering the statements made with respect to research and innovation, it is surprising that not only the transfer of technology is considered important, but also the transfer of knowledge (89%).

From these findings reported above we could confirm Hypothesis 1; *i.e.*, that there is not a common understanding about the definition of innovation indicators. However, there was sufficient initial consensus among all the experts to continue with the Delphi assessment in the second round. Moreover, there were no experts who ought to be considered outliers, jeopardising the consensus process. As a result of the first round, we could invite all experts to participate in the second Delphi round.

3.2 *Results from internet Delphi Round 2: Hypothesis 2*

The consensus improvement for the ten statements that referred to the goals of innovation indicators (third set of ten statements described in Section 2) are shown in Figure 3. Most remarkable is the low consensus in the first round for ‘Promote collaboration between Public Research Organization (PRO) and industry’, and the strong consensus improvement in the second round. On the other hand, the low consensus for ‘Harmonise university teaching and industry requirements’ could not be improved significantly in the second round. This is quite remarkable since universities of applied sciences have been established for the major purpose of acting as relays between academia and industry.

Also remarkable is the low consensus for defining innovation indicators to control the innovation process. Controlling the innovation process refers to optimising decision-making about innovation, and especially about research and development. On the other hand, the optimisation of policy investments encountered initially little support, while the consensus improved to over 80% in the second round. More support was expressed for the optimisation of efforts between policymakers and industry.

We conclude from these experts’ assessments regarding the ten statements referring to the goals of the innovation indicators after the second Delphi round, that optimal decision-making has not yet been identified as a key issue for optimising the innovation process. Thus, the findings support our second hypothesis, namely, that there is not a common view on the purpose and objective of innovation indicators.

The results of the consensus improvement for the ten statements referring to the modelling approach (Hypothesis 3) after two Delphi rounds are shown in Figure 4. Remarkable is the fact that the consensus for the importance of technology transfer centres is low. In the second round, however, the consensus improved to 100%.

Figure 3 Consensus improvement (%) in the second Delphi round for ten statements referring to the goals of innovation indicators (Hypothesis 2)

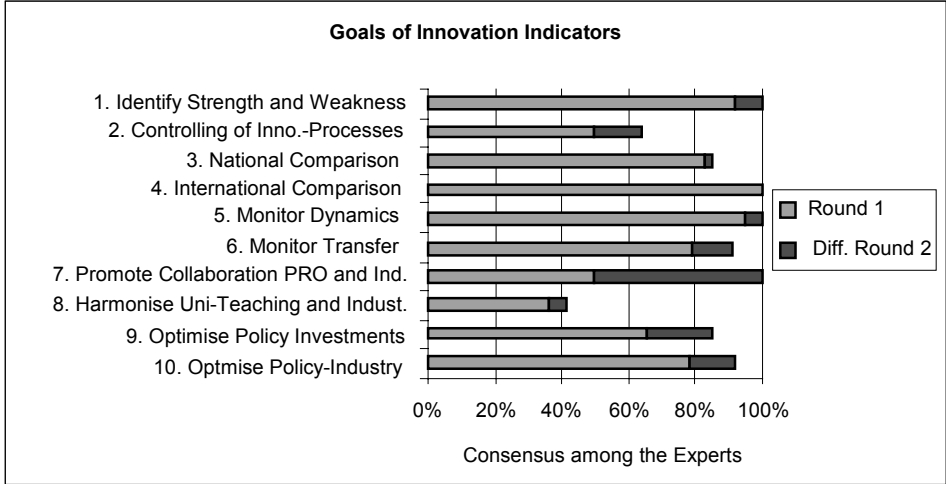
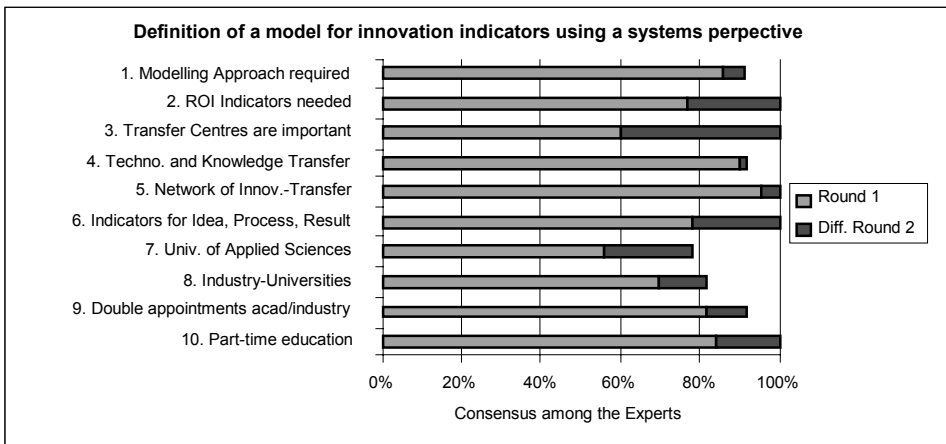


Figure 4 Consensus improvement (%) in the second Delphi round for ten statements referring to the definition of a model for innovation indicators using a systems perspective (Hypothesis 3)



Although there was a quite strong consensus regarding the ten statements referring to the definition of a model (Hypothesis 3), the third Delphi round should even strengthen this consensus among the experts. This third Delphi round was organised as an onsite workshop where the experts could discuss in a face-to-face setting the relevant issues and arrive at a stronger consensus.

3.3 Results from the workshop in the third Delphi round: Hypothesis 3

The aim of the onsite workshop was to address in more depth the ten statements that referred to developing the model for innovation indicators from a systems perspective (Hypothesis 3). As a result of the workshop, the consensus for all those ten statements reached after two Delphi rounds could be augmented in the workshop to 100%.

The fourth set of ten statements defined in Section 2 referred to Hypothesis 3 (Figure 4). The detailed definition of those ten statements and the conclusions that were reached are discussed subsequently. The percentage numbers in parentheses (%) next to each statement refer to the consensus after two Delphi rounds; *i.e.*, prior to the onsite workshop.

Statement 1 (100%) “Indicators should be defined and used goal-oriented; they should describe states and dynamics of the innovation system, which consists of actors and processes.”

The necessity for a comprehensive modelling approach was unanimously acknowledged. The outdated approach based on counting patents and publications should be replaced with a modelling approach. Thereby, the ERIC principle, which sees innovation as consisting of four elements: E: Education, R: Research, I: Innovation, C: Commercialisation, should be considered.

Statement 2 (92%) “Indicators must eventually refer to the Return on Investment (ROI), which is made up of four parts: (1) return on financial input (qualitative research output per invested monetary value), (2) return on research (innovation effort per qualitative research output), (3) return on innovation (societal and economic utility per innovation effort).”

It became clear that innovation must have an added value. For policy investment decisions, the added value refers to societal benefits, while for business decisions, the added value refers to economic benefits. At the policy level, it was suggested that Switzerland should focus on selected industries, where a special international competitive advantage can be generated.

Statement 3 (82%) “The transfer of innovation (from research to industry and from industry to the market) is an important aspect.”

Innovation transfer is the central element of innovation management. The European Commission has established in 1995 the IRC network, which consists of 72 Innovation Relay Centers (IRCs).¹ These centres were established to promote innovation transfer throughout Europe. The IRC network has become especially crucial for the transnational technology transfer.

Statement 4 (78%) “With respect to measuring innovation transfer, one has to consider not only the transfer of new products (technology transfer) but also the knowledge transfer, such as the mobility of scientists and specialists, the exchange of ideas and research results, etc.”

Very strong emphasis was placed on the exchange of knowledge in terms of a knowledge society. Switzerland as a knowledge society for research and education should play a crucial role. Especially for the Bologna reform in the tertiary education system in Europe, attention must be paid to knowledge transfer in terms of applicable skills. As an example, educational programmes in data and knowledge analysis and processes should focus on applications, such as database marketing and knowledge management.

Statement 5 (100%) “Innovation transfer takes place within and across the following institutional organisations (national and international): (1) research centres (private/public), (2) industry (SMEs and enterprises with own R&D), (3) educational institutions (universities of applied sciences and of basic research), (4) tertiary sector/service providers and (5) other groups, such as society (e.g., consumers) and other actors.”

This relatively transparent network approach of a model to measure and promote innovation was even extended to a model of an ecosystem. This means that innovation should only be measured at the neuralgic points of the system instead of focusing on all the details at the micro level.

Statement 6 (100%) “For each of the three phases of innovation: (1) innovation intention (a priori evaluation), (2) innovation development (monitoring evaluation) and (3) innovation implementation (a posteriori evaluation) indicators should be defined. By doing so, care must be taken for the blurry boundaries between these three phases.”

This statement was integrated into the ERIC model by associating the innovation intention to research (R), the development to the innovation process (I) and the implementation to the commercialisation (C). The fourth element of the ERIC model, education, is a generic concept that refers to all the other three elements.

Statement 7 (92%) “In contrast to the traditional role of universities, the universities of applied sciences should take on a complementary role in innovation transfer.”

As a decisive element for innovation transfer, the experts identified a clear allocation of competences to the rapidly changing tertiary educational landscape. The experts further argued that three classes of institutions for higher education will eventually emerge:

- 1 universities of liberal arts, focusing on societal and cultural disciplines
- 2 universities of sciences, focusing on all sciences
- 3 universities of applied disciplines, focusing on transfer disciplines, such as management, engineering, law and healthcare.

Statement 8 (100%) “A strong and more direct engagement of enterprises in the innovation transfer process plays a crucial role; e.g., through the establishment of corporate universities.”

A classical example for this development in Switzerland is the 2004 newly founded Credit Suisse Business School. The school also calls itself a corporate university. Recently, a Bachelor's programme in Banking and Finance was the first programme to be accredited by the Swiss Government, which was developed by a corporation and tailored to its own employees.

In the same direction points the first accreditation by the Swiss Government of a private school as a university of applied sciences. Up to now, all universities of applied sciences had been state schools.

Statement 9 (100%) "In addition to the mobility of the experts, the structural flexibility plays a crucial role (e.g., flexible work conditions for scientists, which allow them to work partly in industry)."

A central aspect for an effective innovation exchange is the mobility among research, education and industry. This refers to more than just the planning and the execution of joint programmes and well known synergy effects. Of vital importance will be a structural change that allows experts to advance their careers by moving forth and back between academia and industry.

Statement 10 (91%) "In addition to the serial knowledge transfer (e.g., education, followed by work in industry) special attention must be given to the parallel knowledge transfer (e.g., part-time educational programmes, continuous education)."

The newly introduced Bologna reform for tertiary education classifies courses according to four competences: method, subject, social and transfer competences. The latter competence could be realised in the form of projects. More realistic, however, is a wider implementation of part-time educational programmes, which allows students to pursue their careers while being enrolled in an academic degree programme. This would contribute significantly to a continuous exchange of knowledge between academia and industry.

This third Delphi round, organised as a face-to-face consensus workshop, clearly confirmed Hypothesis 3, namely, that there is a common view on how to go about to define innovation indicators using a systems approach. In the subsequent section, we will derive a model from a systems perspective based on the consensus process of the three Delphi rounds.

4 A model of the innovation system

In the discussion of the ten statements during the third Delphi round, which took place in the form of a workshop, it became clear that the consensus among the experts could be strengthened even more. Based on this consensus, a model of the innovation system could be derived.

The model distinguishes three levels (see Figure 5):

- 1 The policy and management decision-makers allocate financial resources and define the regulatory constraints to promote innovation. In analogy to a control system, their decisions are based on the benefit which results from previous decisions and their consequences. The benefit from the viewpoint of the user of the innovation is made up of the turnover and the newly created jobs. The benefit from the viewpoint of the developer of the innovation is made up of the profit, which can be generated with the innovation. The decision-makers influence the innovation transfer by improving the policy and management constraints for the ones creating the innovation (*i.e.*, those making the innovation offer), as well as the constraints for those taking over the innovation (*i.e.*, the ones requiring innovation). Moreover, policymakers and management influence education and research in S&T and management.
- 2 The transfer level is where the innovation transfer between innovation providers and innovation seekers takes place. For example, a research lab develops new technologies and a manufacturing firm seeks exactly this technology to develop new products. Innovation transfer can be purposively promoted, for example through IRCs. These IRCs could be private or public organisations, transfer centres at universities and at technology parks, or also consulting companies.
- 3 The S&T level comprises, on the one hand, the development of new technologies and processes and, on the other hand, the management of these new technologies and processes, *i.e.*, the commercialisation of innovation. Only a strong synergy between technological development and management of commercialisation can result in a successful innovation transfer. The know-how about the subject, both about the technology as well as about the management, must flow into the process of innovation and into the process of commercialisation.

The links shown in Figure 5 in the bottom-right area referring to management and commercialisation correspond to the model for promoting innovation management, which was proposed by the European Commission (EU-DGE, 2004). The same links also hold for the S&T area, shown in Figure 5 on the bottom-left area.

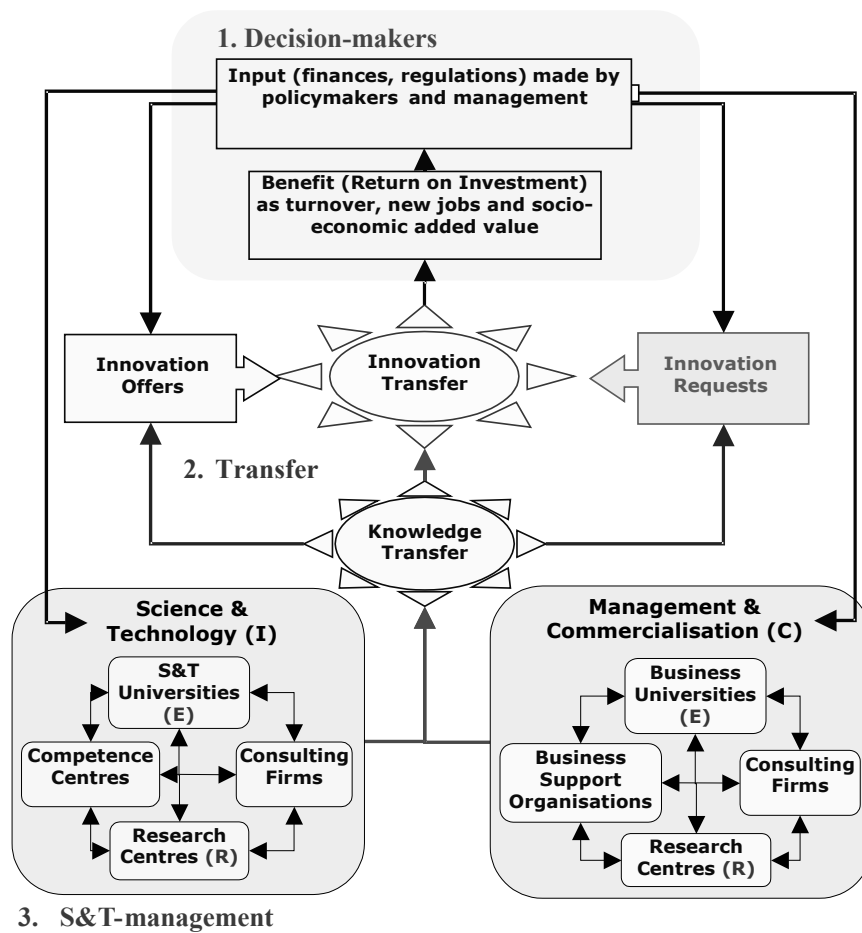
For S&T, the analogous reciprocal effect as stated for M&C, between education (university) and research, takes place, which is supported by specialised technical and consulting firms. A new positioning of the universities, in accordance with Statement 7, is thereby indispensable.

As next step, the experts recommended to apply this model to a selected technological area. Conceivable areas are bio-technology or nanotechnology, but socio-scientific areas, like the educations or health services, are also to be considered.

For the different elements of the model shown in Figure 5, quantifiable innovation indicators must be defined with which the performance of the innovation system on different levels can be assessed. The levels refer to regional, industry-specific and market-relevant aspects. On the transfer level (Figure 5) primarily three aspects are to be measured:

- 1 the supply of innovation offers by research centres and the innovation requests by industry
- 2 the matching of innovation suppliers and innovation searchers
- 3 the successful transfer of innovation between innovation suppliers and innovation searchers.

Figure 5 Model of the innovation system with the elements of the ERIC model (E: Education, R: Research, I: Innovation, C: Commercialisation). S&T refers to the different disciplines, such as engineering, social sciences, pedagogy, medicine, *etc.*



These three groups of indicators lead finally to the benefit of the innovation, both for the supplier, as well as for those searching for innovative solutions. The resulting benefit of this innovation transfer provides then the basis for the decision-makers to optimise their allocation of resources. This closed loop between policymaking, innovation transfer, benefits of innovation, back to policymaking, makes the model dynamic in nature.

With the gathered data, the statistical grounds for policy decision-making can be generated. While different indicators are already available, it will be necessary to define new indicators, in order to be able to comprehend the whole innovation system at all levels. This comprehension will eventually provide the basis for more informed policy and managerial decision-making and system optimisation.

5 Application of the model

The application of the proposed dynamic model for innovation management should be accomplished in a three-step approach:

- 1 selection of the innovation system
- 2 identification of existing indicators that can be used
- 3 definition of additional indicators to complete the model
- 4 quantification of all indicators
- 5 data analysis and decision-making.

To indicate the application of this five-step approach, we will briefly compare the development of the model to the development of the European Innovation Scoreboard (EIS) indicators. In order to derive the EIS indicators, a conceptual framework was defined (Sajeva *et al.*, 2005). This conceptual framework sees innovation as the process that leads to the adoption and diffusion of new technologies, which in turn will create new processes, products and services (Sajeva *et al.*, 2005).

In contrast to our proposed model, the EIS conceptual framework distinguishes only two main groups of indicators, those referring to the innovation input and those referring to the innovation output. Table 1 shows the 26 indicators of EIS 2005.

Another relevant difference between our proposed model and the methodology used to derive the EIS indicators is the aim of the EIS to aggregate all indicators into one single index, the Summary Innovation Index (SII). The SII is computed by first normalising the measures for all 26 indicators between 0 and 1. Then, the normalised values are aggregated as the non-weighted average over all 26 indicators.

Clearly, the EIS is meant to be used to compare nations' performances. For that purpose, the reduction of a 26-dimensional measure to one single value makes sense. For the purpose of our model, however, where the innovation measures must provide the basis for dynamic decision-making, too much information would get lost with such a dimension reduction.

The integration of as many of these 26 EIS indicators as possible into our proposed model must be done by considering the system for which innovation is to be measured. The application of EIS 2004 to a region, *i.e.*, the definition of a Regional Innovation Scoreboard (RIS), has been proposed for the Federal Lands of Baden-Württemberg, Bavaria, and North Rhine-Westphalia (Iking and Langhoff, 2004). Of the 28 EIS 2004 indicators only 11 could be used for RIS, while three new indicators have been added, which were not included in EIS 2004.

Table 1 EIS 2005

INPUT – innovation drivers

- New S&E graduates per 1000 population aged 20–29
- Population with tertiary education per 100 population aged 25–64
- Broadband penetration rate (number of broadband lines per 100 population)
- Participation in life-long learning per 100 population aged 25–64
- Youth education attainment level (% of population aged 20–24 having completed at least upper secondary education)

INPUT – knowledge creation

- Public R&D expenditures (% of GDP)
- Business R&D expenditures (% of GDP)
- Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures)
- Share of enterprises receiving public funding for innovation
- Share of university R&D expenditures financed by business sector

INPUT – innovation and entrepreneurship

- SMEs innovating in-house (% of SMEs)
- Innovative SMEs cooperating with others (% of SMEs)
- Innovation expenditures (% of turnover)
- Early-stage venture capital (% of GDP)
- ICT expenditures (% of GDP)
- SMEs using non-technological change (% of SMEs)

OUTPUT – application

- Employment in high-tech services (% of total workforce)
- Exports of high technology products as a share of total exports
- Sales of new-to-market products (% of turnover)
- Sales of new-to-firm not new-to-market products (% of turnover)
- Employment in medium-high and high-tech manufacturing (% of total workforce)

OUTPUT – intellectual property

- New EPO patents per million population
- New USPTO patents per million population
- New Triad patents per million population
- New community trademarks per million population
- New community industrial designs per million population

With respect to our proposed model, the EIS indicators referring to the innovation drivers would have to be separated into the two educational groups – engineering and management. The indicators referring to knowledge creation are all useful for our model. The indicators referring to innovation and entrepreneurship are well suited for our model,

but should be complemented by indicators referring explicitly to the transfer of innovation. These refer to the organisations that promote innovation by matching innovation requests with innovation offers. Possible indicators would be the effort to publish innovation offers and requests, the number of negotiations initiated between those offering innovation and those searching for innovative solutions, and the number of successful innovation transfers between the two parties.

The EIS indicators referring to application are directly usable in our model, although they might require some sector-specific specifications. The indicators referring to intellectual property, however, are of little use for our model, since the usefulness of patents was assessed to be highly questionable as an innovation indicator from a systems perspective.

6 Conclusions

We have presented the results of a three-stage internet-based Delphi assessment about a novel systems perspective to define a model for innovation indicators. The results after two Delphi iterations showed that although there is neither a joint understanding of innovation, nor a joint view on the goals of innovation indicators, there is, however, high consensus about the need to use advanced modelling techniques. The derived innovation model, as a result of the third Delphi round, focuses on the decision-makers, who need to understand the dynamic network structure of innovation creation, diffusion and adoption.

Clearly, one can question what the difference is between the well-known innovation indicators, such as the ones proposed in the European Innovation Scoreboard, and the indicators that will result from the model proposed in this paper. The answer to this question is threefold.

First, the indicators derived from this approach are based on a model that puts the decision-makers at the centre of the system, while the EIS indicators aim primarily at country comparisons. This assures that the indicators are derived to support the decision-making process, rather than to solely perform comparative assessments at a national level.

Second, the model proposed in this paper is dynamic in nature, which takes into account that the goals of the decision-makers can change in time, while the EIS indicators are more static in nature.

Most important, however, is the third aspect. The indicators must provide an overall assessment of the innovation system as a whole. This means that the multi-dimensional indicators must be aggregated to an overall multi-dimensional assessment, from which policies can be derived, taking into account limited financial resources and prevailing legal constraints.

This means that the proposed model allows an assessment of the state of the system, taking into account its dynamics as well as its multi-dimensionality. Instead of comparing two systems, indicator-by-indicator, the two systems can be compared overall in terms of their performance.

As a result, recommendations to the decision-makers would not be made in terms of how well the system performs overall, but as to how the performance of one indicator affects the performance of the other indicators. Such an interconnected approach to statistical data analysis provides the means for policy and management decision-makers to control the performance of an innovation system.

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Note

- 1 <http://irc.cordis.lu>