Project Number:	7PM- 266588
Project Title:	SISOB (An Observatorium for Science in Society based in Social Models)
Deliverable Type:	Report
Deliverable Number:	2.2
WP:	2
Version:	6
Date:	July 3, 2011
Title of Deliverable:	**Requirements document and Specification of conceptual model**
Editor:	Richard Walker
Authors:	Richard Walker (FrontiersIn), Judith Alexander (FrontiersIn), Beatriz Barros (UMA), Melissa Cochrane (FrontiersIn), Eduardo Guzman (UMA), Aldo Geuna (FR), Ulrich Hoppe (UDE), Raimondo Iemma (FR), Soos Sandor (MTA KSZI), Sam Zeini (UDE), Cornelia Lawson (FR), Tilman Göhnert UDE)
Dissemination level:	PU
Keywords:	Impact, outcomes, social impact of science, indicators, proximal, distal, actors, relationships, networks, network analysis, institutions
Abstract:	This report describes a Conceptual Model designed to provide a unifying framework for the studies and tools planned for later phases of the SISOB project. The model defines a shared vocabulary for use within the project, and makes explicit the central assumptions underlying the work of the project. After a summary review of the relevant literature and of basic assumptions, the report outlines the main entities and relationships in the model and provides a preliminary picture of the way the model will be operationalized in the planned case studies.

Capacities. Science in Society.

Collaborative Project
SISOB (An Observatorium for Science in Society based in Social Models)

Grant Agreement No: 266588
Project Runtime: 01/2011 – 12/2013

Version history

Version	Date	Description
Version 1	10/6/2011	Produced by RW after Budapest meeting
Version 2	21/6/2011	Incorporates feedback from partners
Version 3	26/6/2011	Incorporates initial versions of case studies
Version 4	29/6/2011	Incorporates revised versions of case studies
Version 5	02/7/2011	Incorporates complete peer review study
Version 6	03/7/2011	Incorporates revised version of knowledge sharing study

Executive Summary

The goal of the SISOB project is to provide policy makers and their advisors with new tools to help them in *ex ante* and *ex post* analyses of science policy decisions. The majority of studies to date have focused on the impact on the networks of academic, scientific and industrial actors that *produce* scientific knowledge and artifacts (*science production systems*). SISOB will extend these analyses to the broader *science-society system,* which not only influences its decisions and consumes its products, but provides the socio-political context in which the *science production system* operates-

This report presents a “conceptual model” of the social impact of science, designed on the one hand to define a shared vocabulary for use within the project, on the other to make explicit the central assumptions that underlie our work. These may be briefly summarized as follows.

1. Scientific practices are embedded in a social and economic context that exerts a deep influence over the scientific endeavor and plays a key role in determining the way scientific knowledge is ultimately used.
2. The embedding of science in society depends on multiple, overlapping relationships and flows of information among a multitude of actors. These relationships can be usefully analyzed and visualized using the tools of Network Analysis.
3. The way in which scientific knowledge and artifacts are produced and used varies significantly between disciplines.
4. The mechanisms determining the impact of scientific knowledge and artifacts are non-linear and involve not only the *quality and characteristics* of the knowledge and the artifacts themselves, but the *context* in which they are received and used.
5. The outcomes of decisions by science policy-makers can be usefully divided into *proximal outcomes*, with a direct, causal link to a particular policy decision and *distal outcomes*, that depend to a large extent on future developments. In principle, *proximal outcomes* can and *distal outcomes* cannot be predicted.
6. Some scientific communities are far more productive and make a far greater contribution to society, than others.
7. Scientific discoveries and inventions affect many different aspects of society. Different decision-makers will make different evaluations of the same outcomes. It is thus methodologically impossible to summarize the impact of scientific knowledge and inventions in any single indicator.

The social impact of science depends on a broad range of factors, some linked to the way scientific knowledge is *produced*, some to the way it is *distributed* to actors outside the knowledge production system, and some to the way it is *received, applied*, *exploited and consume*d. All involve social relationships and flows of information among actors (individuals, groups, institutions) working in different contexts and settings. These interactions and the context in which they take place constitute a

complex social system whose dynamics unfold on a global scale over long periods of time.

The SISOB conceptual model describes these interactions in terms of entities (human and institutional actors, artifacts, context factors, knowledge, systems and actors) and relationships among these entities. We provide a detailed account of the model and go on to show how it can be operationalized in the three case studies (mobility, knowledge sharing and peer review).

In all these studies, the human actors are researchers who externalize their knowledge in artifacts (papers, patents, prototypes etc.) and who belong to institutions (also considered as actors). The mobility study investigates how researcher mobility (between institutions, between academia and industry, between lower and higher prestige jobs) affects researchers' personal productivity, and ultimately the productivity of the institutions to which they belong. The knowledge sharing study examines flows of information among researchers and their institutions, as indicated by the content of the artifacts they produce. Finally, the peer review study focuses on the way co-authorship networks, citation networks and author-reviewer networks (the networks linking researchers who have reviewed each others' papers influence the functioning of the peer review system, and thus the productivity and reputation of researchers and their institutions.

Table of contents

1 Objectives and structure of this document

The goal of the SISOB project is to provide policy makers and their advisors with new tools to help them *ex ante* and *ex post* analyses of science policy decisions. The majority of studies to date have focused on the impact on the networks of academic, scientific and industrial actors that *produce* scientific knowledge and artifacts (the *science production system*). SISOB will extend these analyses to the broader *science-society system,* which not only influences its decisions and consumes its products but which provides the context in which it operates.

Given these goals, we will conventionally define the *social impact of science* to encompass any impact that extends beyond the *science production system.* Our analysis will thus include factors that are not traditionally included in traditional *Social Impact Assessment* (for an overview of common practices in this area see [1]). In particular, SISOB includes in the scope of its analysis the economic and, potentially, the environmental impact of science policy decisions.

In this report, we present a "conceptual model" of the social impact of science, as defined above. The model is designed to provide a unifying framework for the studies and tools planned for later phases of the SISOB project. It therefore has two main goals: on the one hand to define a shared vocabulary for use within the project, on the other to make explicit the central assumptions that underlie our work.

This remainder of this document will be structured as follows. Chapter 2 briefly reviews existing research on the social impact of science and related work, in particular methods for "Social Impact Assessment", outside the domain of science policy studies. Chapter 3 introduces the Conceptual Model, its relationship to the overall goals of the SISOB project, and its underlying assumptions. Chapter 4 presents the model itself. Chapters 5-7 present operationalized versions of the model for the SISOB's three cases studies, dedicated respectively to mobility, knowledge sharing, and peer review.

2 The social impact of science: current research

2.1 Overview

In many areas of policy-making, the need for ex ante and ex post Social Impact Assessment (SIA) is widely accepted. Agricultural regulators, for example, realize that their policies may have far reaching effects on rural communities and need to be assessed before implementation [2]; philanthropic organizations are slowly developing methods to measure the social impact of their projects and investments [3].

Modern authors see Social Impact Assessment as an intrinsically political process in which the framing of the questions that need to be answered is part of the process and many practitioners believe that it cannot be effective without direct involvement of the actors and communities concerned [4]. Other commentators have pointed to methodological difficulties. For instance, many "desktop" studies focus on impacts that are easily quantifiable rather that those that are actually important to the communities involved [1]; standard techniques for identifying causal relationships between micro-scale effects (on individuals and families) and macro-scale effects (on whole communities) are fraught with difficulties [2]. Nonetheless it is hard to contest that evidence-based decision-making is preferable to decision-making that ignores the evidence and it is not necessary to abandon the idea of causality. As Luhmann has puts it, "We can accept causality as a schema for describing the world without agreeing to the specific attribution of causality by a certain observer in a certain situation (...) the primary function of causal constructions is to draw attention to and to conserve differences" (translation by U.H. from [5]).

In science policy making, evidence-based policy making would require that decisions should be informed by evidence of their potential impact. It is significant, therefore, that the literature on the impact of science policy decisions is relatively poor, with the majority of studies focusing on the impact on the "science-production system" and the economy while relatively few have examined their broader social and cultural impact.

2.2 Impact of "science policy" decisions on the "science production system"

The main "target" for science policy decisions is the "science production system". It is natural therefore that many studies have focused on the impact of policy on scientific productivity, employment, etc.

An example of this approach is the comprehensive assessment of trends in scientific research in Spain by Jiminez-Contreras et al [6]. The analysis, which is very thorough, shows how government policies have led to radical change in patterns of publication by Spanish researchers and a major opening to the international scientific community. The authors have been unable to find comparable analyses of policy outcomes for other countries. However many countries regularly assess the productivity of their universities and research institutions, thereby implicitly evaluating the effectiveness of past policy. In the United Kingdom, for example, the government conducts regular "Research Assessment Exercises" that compare the productivity and quality of research at different universities and research groups. The most recent report confirms the high productivity of the British "science production system" [7].

2.3 The economic impact of science policy decisions

2.3.1 Macro-economic impact

Many studies have investigated the macro-economic impact of investment in research and development. The majority have focused on the impact on economic growth and productivity using econometric methods originally proposed by Solow [8]. The general conclusion is that investment in research has a strongly positive impact with significant local spill-overs (for a concise review of the large literature see [9]). These effects are mediated by increases in the stock of useful knowledge, training of skilled graduates, the creation of new scientific instrumentation and methodologies, the creation of networks and increases in social interaction, improved capacity for scientific and technological problem-solving, and the creation of new firms [10].

The literature includes many country studies showing how these effects have worked out in specific settings. Perhaps the most useful are the reviews of country innovation policy, regularly published by the OECD (see [11] for an index of available studies). Other studies have looked at the economic impact of particular classes of research investment, in particular in healthcare [12] and in agriculture [13-15]. We observe that these studies are limited to areas of applied research with well-defined "products" (new treatments, new kinds of seed, new pesticides etc.)

2.4 Non-economic impact of scientific policy

It is intuitively obvious that science and science-policy decisions do not just influence productivity, growth, employment etc. but society as whole (e.g. beliefs and practices, health, quality of the environment, quality of life, quality of work, subjective expectations related to these parameters). A review by Godin and Dorin proposes a taxonomy of this kind of non-economic impact [9] (see Figure 1) and studies of research of healthcare and agricultural research frequently examine these issues (see for example [12, 14, 15]). In general, however, the volume of studies on these issues is much lower than that of studies studying scientific productivity or economic impact.

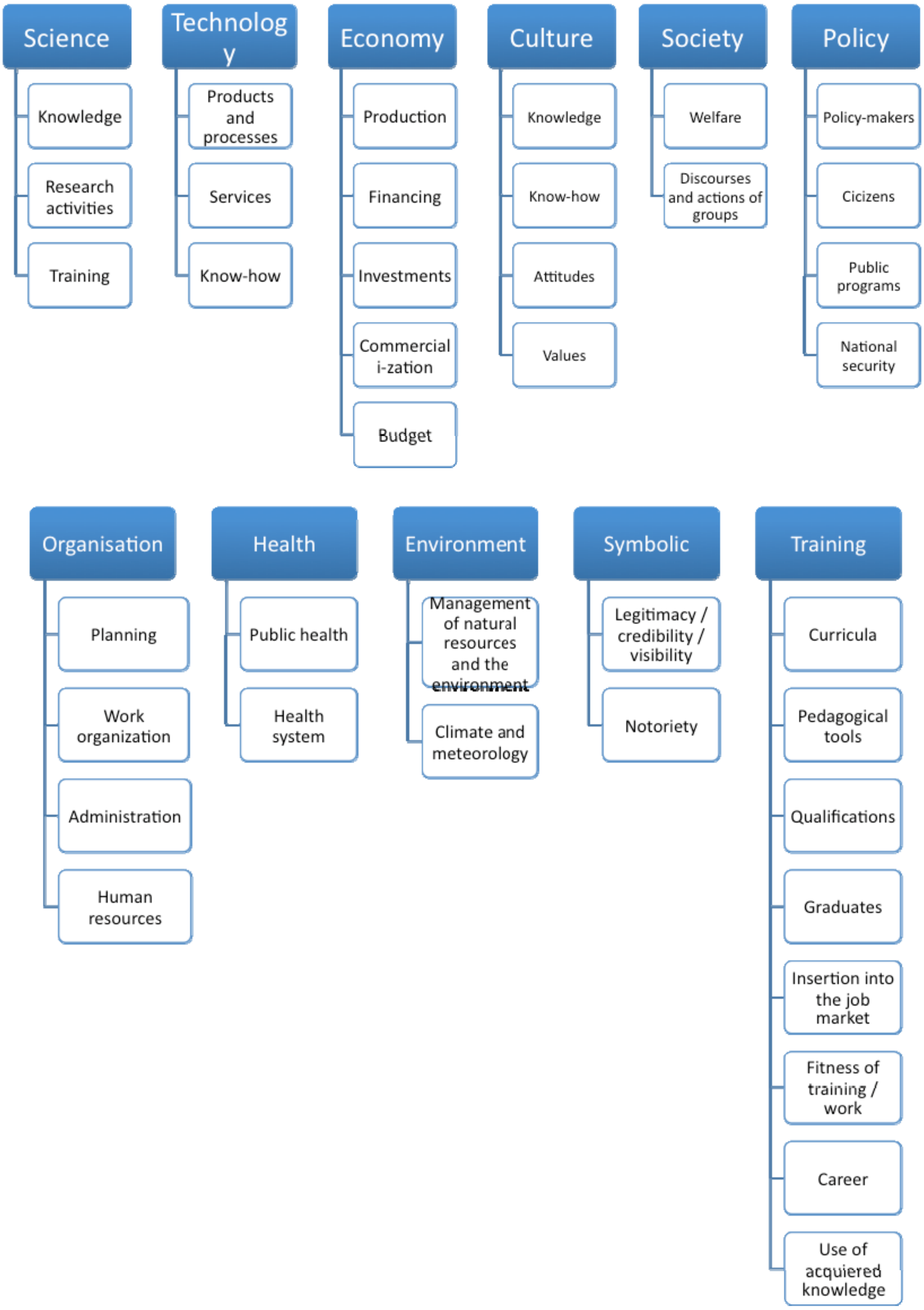

FIGURE 1: TAXONOMY OF NON-ECONOMIC IMPACTS OF SCIENCE (REDRAWN FROM GODIN AND DORE [9])

3 The SISOB Conceptual Model –Premises and Methodology

3.1 SISOB and the SISOB Conceptual Model

The goal of SISOB is to provide analytical instruments that ultimately feed into practical support tools for decision-makers and their advisors. In terms of the Conceptual Model described later in this deliverable, we define a *decision-maker* as an individual whose decisions influence and shape the production of scientific knowledge and the impact of science on society. Examples include lab heads, university presidents, editors of journals, reviewers, government and funding agency officials and many others.

Decision-makers rationalize and justify their decisions in terms of societal goods: growth and employment, public health, the environment, inclusiveness, security, military strength and so on. The brief literature review in the previous chapter shows that some of these goods have been studied in far greater depth than others. SISOB will focus, therefore, on those dimensions of impact that have been least studied so far – namely the social outcomes of scientific policy decisions. Inevitably the tools the project creates will incorporate assumptions about the way decision-makers affect science and the way science impacts society. The next paragraph will attempt to make these assumptions explicit.

3.2 Assumptions

3.2.1 Social embedding of science

Practitioners of the hard sciences and social scientists often have very different views of the "scientific production process" and the way this process impacts society. Physicists and biologists tend to think in terms of a linear process in which scientists *produce* knowledge and technologists and society *consume* the end products. Social scientists, by contrast, see scientific practices as embedded in a broader social and economic context that exerts a deep influence over the scientific endeavor and which plays a key role in determining the way scientific knowledge is ultimately used. In extreme cases, this view can lead to a relativist epistemology that questions the objectivity of scientific knowledge and the very concept of scientific progress. However, it is perfectly possible to reject these views and still accept that the relationship between science and society is bidirectional and that social context and culture play a vital role in determining policy decisions and their impact. This is the first basic assumption underlying the SISOB conceptual model.

3.2.2 Actors, relations among actors and information flows

The embedding of science in society depends on multiple, overlapping relationships and flows of information among a multitude of actors: junior and senior scientists, policy-makers, industrial managers, journal editors, reviewers etc. The second key assumption of SISOB is that these relationships can be usefully analyzed and visualized using the tools of Network Analysis.

3.2.3 Disciplinary differences

The way in which scientific knowledge and artifacts are produced and used *varies significantly between disciplines*. In the social sciences, for instance, the main outputs from research are scientific papers; in engineering disciplines and medicine, on the other hand, papers are merely reports of the main outputs, which may, for example be prototypes, drugs, production methods or treatment protocols. In each discipline, there are specific mechanisms translating research outcomes into social impact

3.2.4 The non-linear nature of social impact

The mechanisms determining the impact of scientific knowledge and artifacts are non-linear and involve not only the *quality and characteristics* of the knowledge and the artifacts themselves but the *context* in which they are received and used (e.g. market needs and opportunities, social attitudes and beliefs, opportunities created by other scientific and technical developments, competing products etc.)

3.2.5 Proximal and distal impact

The outcomes of decisions by science policy-makers can be divided into proximal and distal outcomes.

Proximal outcomes are short to medium term outcomes with a direct, causal link to a particular policy decision and that depend only to a limited extent on unpredictable future developments (e.g. developments in scientific knowledge, economic and social developments). Examples include the creation of jobs as a direct result of investment, health benefits deriving from the development of a new vaccine, royalties from the patent for the vaccine. Lead times for proximal outcomes are usually short (usually less than 10 years). At least in principle, they can be predicted with a measurable level of confidence.

Distal outcomes are long-term outcomes that depend to a large extent on unpredictable future developments (e.g. in scientific knowledge and technology, in societal needs). Many such outcomes are the result of combinations of different artifacts. For example the modern computer is a distal outcome of developments in abstract mathematics (Boolean algebra, theory of computation), electronics (the thermionic valve, the transistor), optics (optical lithography) and many other disciplines, and was strong influenced by social and economic context (new military needs during World War II, new corporate needs in the 1950s and 1960s, the emergence of a consumer electronics market in the 1980s and 1990s). Examples of distal outcomes include the creation of new industries, major improvements in public health and the development of new patterns of consumption. The lead time for distal results is typically many decades. Given the role of context and of unpredictable scientific and technological developments distal results are in principle *unpredictable.*

3.2.6 Some scientific communities have a greater social impact than others

Historically, some scientific communities have been far more productive and have made a far greater contribution to society, than others. SISOB is based on the assumption that part of these differences can be explained by differences in the pattern of relationships and the flow of information between actors inside and outside the scientific community.

3.2.7 No single way of evaluating social outcomes

Scientific discoveries and inventions affect many different aspects of society, from levels and distribution of income to patterns of employment, from health to the environment, from security and military power to inclusiveness and social equality. Different decision-makers will make very different evaluations of the same outcomes. The SISOB model thus assumes that it is methodologically impossible to summarize the impact of scientific knowledge and inventions in any single indicator. Rather SISOB will attempt to provide a multi-dimensional picture of outcomes, allowing decision makers to evaluate them in the ways that best fit their needs and priorities.

3.3 The Conceptual Model and SISOB tools

One of the main goals of the SISOB conceptual model is to inform the design of SISOB tools. The project will create two sets of tools, the first oriented towards decision and policy-makers, the second for specialist scientometrists, or, more generally, for researchers interested in the structure and dynamics of the science production system. The characteristics of these tools will be strongly influenced by the considerations outlined in the previous section.

- The tools will allow users to characterize and visualize relationships and flows of information within a given scientific community (a lab, a university, a region, a country, a project, a discipline), between individual researchers within this community, and between the community and specific external actors (e.g. decision-makers, opinion-makers, investors etc.) in the rest of society.
- They will allow users to analyze bibliometric, social and economic indicators relevant for the assessment of the proximal impact of a given decision and to compare relationships and flows of information between different communities (e.g. different labs, universities, disciplines etc.).
- They will make it possible to analyze *changes* in these relationships and flows.
- They will provide users with a multidimensional picture of the working of specific scientific communities, embedded in society. The goal is not to *evaluate* different outcomes, but to provide decision- and policy- makers with information that can help them to make their own evaluations.

The conceptual model is guided by these requirements.

3.4 Methodology

The model has been developed in three stages:

1. **Definition of vocabulary:** definition of the entities in the model and the relationships between these entities
2. **Abstract modeling:** modeling of the main assumptions underlying the design of the tools and the case studies
3. **Operationalization of the model:** operationalization of the model for the three case studies.

4 The Conceptual Model

4.1 Overview

The social impact of science depends on a broad range of factors, some linked to the way scientific knowledge is *produced*, some to the way it is *distributed* to actors outside the science production system, and some to the way it is *received, applied*, *exploited and consume*d. All involve social relationships and flows of information among actors (individuals, institutions) working in different contexts and settings. These interactions and the context in which they take place constitute a complex social system whose dynamics unfold on a global scale over long periods of time. The SISOB conceptual model describes these interactions in terms of entities and relationships (see Figure 2) Reader should treat the entities defined at the bottom level of the hierarchy as examples only. While we have attempted to identify the main classes of actor, artifact, outcome etc. needed for our studies we make no claim to have produced an exhaustive list.

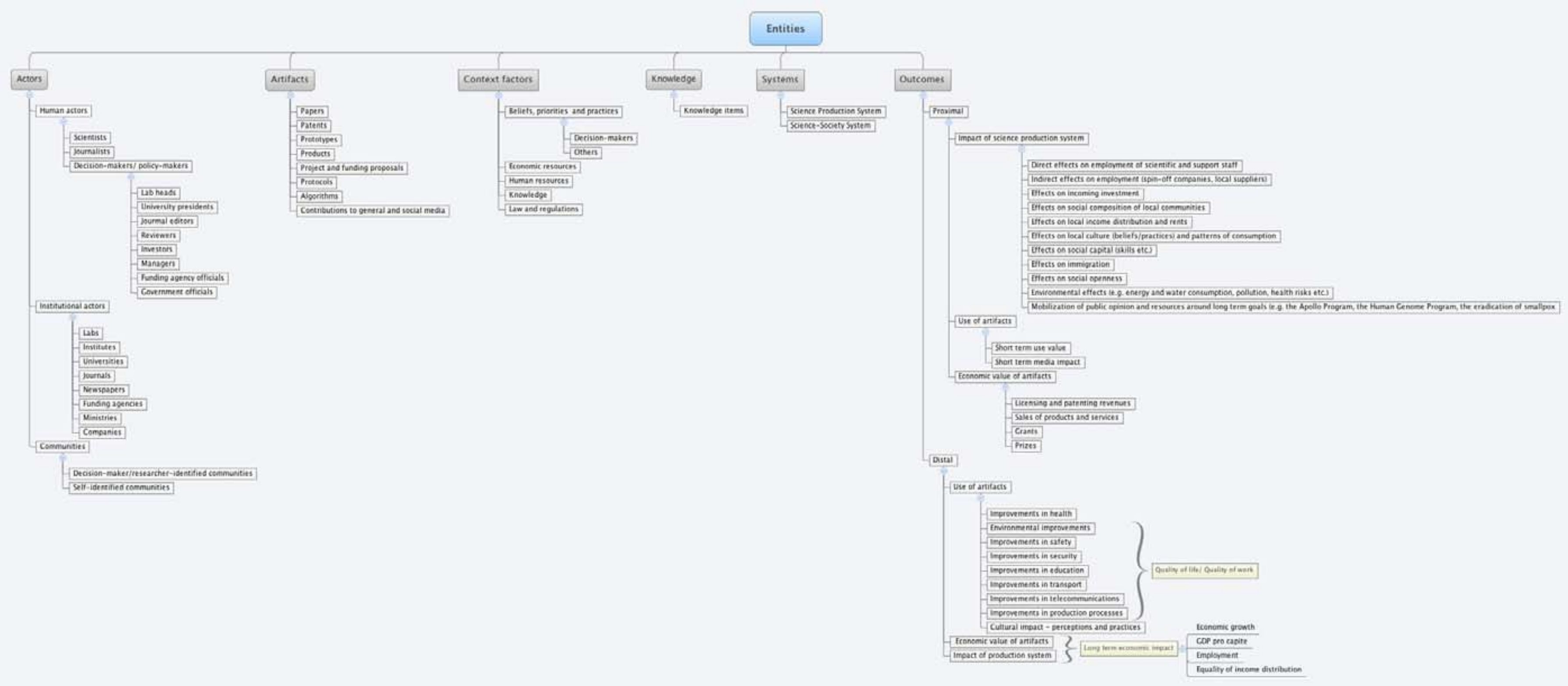

FIGURE 2: ENTITIES IN THE SISOB CONCEPTUAL MODEL

4.2 Entities

4.2.1 Actor

4.2.1.1 Definition

Actors are agents whose actions affect the production, distribution or use of scientific discoveries and inventions. They may be either individuals or institutions.

4.2.1.2 Examples

Typical human actors include scientists, heads of laboratory, university presidents, editors of journals, reviewers, journalists, investors, managers, funding agency officials, government officials and politicians. These actors play a critical role in mediating the flow of knowledge and artifacts within and between institutions and communities

Typical institutional actors include laboratories, institutes, universities, conferences, associations, journals, newspapers, funding agencies, and ministries.

4.2.1.3 Note

The same actor may occupy several different *roles*. For example, a single scientist may be a *producer* of papers and tools, *a distributor* of information to other scientists and the press and a *user* of papers and tools produced by other scientists.

4.2.2 Decision-maker/policy-makers

4.2.2.1 Definition

Decision-makers and policy-makers are a special class of actor whose decisions affect the structure and/or the functioning of a *system* (see below). This effect may be direct, as when a hiring or investment decision directly affects the working of a system, or *indirect*, as when a policy decision changes the *context* in which a system operates.

4.2.2.2 Examples

Examples of decision/policy-makers include lab heads, university presidents, journal editors, reviewers, investors, managers, funding agency officials and government officials

4.2.3 Community

A community is a set of actors that share one or more attribute. Communities may be researcher/decision-maker identified (e.g. the set of all actors affected by a given policy decision) or self-identified (e.g. a set of actors that sees itself as sharing a set of common interests. In many cases a community may be structured around an institution (e.g. a conference, a journal, university).

4.2.3.1 Examples

Examples of *researcher-identified communities* include the set of all actors affected by a policy decision on animal research, or investment, or researcher salaries.

Examples of *self-identified communities* include all scientists working a certain lab, or a certain university, a certain country, or a certain community.

4.2.4 Knowledge item

4.2.4.1 Definition

A knowledge item is a piece of intangible information created by an actor that can be passed on to or used by another actor and externalized in an artifact.

4.2.4.2 Examples

Knowledge of specific experimental, production or medical techniques

4.2.5 Artifact

4.2.5.1 Definition

Artifacts are human-created, tangible objects that externalize knowledge generated by scientists.

4.2.5.2 Examples

"Traditional" scientific artifacts include scientific papers, patents, prototypes, project and funding proposals, industrial products, production methods, algorithms, treatment protocols and so on. In recent times, however, non-traditional artifacts such as articles in the general media, contributions to social media and web sites are beginning to play an important role not only in policy debates (e.g. for instance the debates on climate change and on nuclear energy) but even in "hard science" (e.g. in publicizing Grigori Perelmann's recent proof of the Poincaré conjecture [16]). The SISOB conceptual model defines the concept of "Artifact" to include these novel externalizations of scientific knowledge. It also recognizes that different disciplines typically produce different kinds of artifacts each with their own characteristic modes of production and consumption.

4.2.6 Context factor

4.2.6.1 Definition

A context factor is a political, legal, cultural, economic or other factor that affects the structure and/or performance of a system (see below).

4.2.6.2 Examples

Examples of context factors include:

- Priorities, knowledge, practices and beliefs of decision and policy-makers
- Priorities, knowledge, practices and beliefs of other actors
- Economic and cultural incentives and disincentives
- Availability and distribution of economic resources
- Availability and distribution of human resources
- Availability and distribution of knowledge
- Law and regulations

4.2.7 System

4.2.7.1 Definition

A system is an object of study (e.g. by scholars, by decision makers) consisting of a set of actors involved in the production and/or distribution and/or use and exploitation of artifacts. Actors in a system are implicated in multiple, potentially overlapping networks. The performance of a system is characterized by a set of *performance indicators.*

4.2.7.2 Examples

Examples of a system are the set of scientists working for a given institution, the set of scientists working in a country, the set of labs and companies working in a given region of a country

4.2.8 Science production system

4.2.8.1 Definition

A science production system is a system, consisting of a set of actors involved in the production of artifacts. Actors in a *Science Production System* are likely to be implicated in multiple, potentially overlapping networks. A science production system is characterized by a *set of scientific performance indicators*

4.2.8.2 Examples

Examples of a science production system include the set of scientists working in a specific lab, a specific region, a specific funding program, a specific region or a specific country

4.2.9 Science-society system

4.2.9.1 Definition

A science-society system is a system consisting of a set of actors centered on a science production system but also including external actors (people, institutions) involved in the distribution, and consumption of artifacts. A science-society system can be partially characterized by a set of *social and economic performance indicators.*

4.2.9.2 Examples

Examples of science-society systems include sets of scientific and non-scientific actors producing and using knowledge and artifacts in the same region or the same country.

4.2.10 Outcomes

4.2.10.1 Definition

An outcome is the result of a given policy decision on a system, as measured by a *performance indicator*[1]*.* A social outcome is an impact on a science-society system.

Outcomes may be either proximal or distal (see section 3.2.5) and can be classified according to whether they are determined by:

- Science production system
- The use of artifacts
- The economic value of artifacts

4.2.10.2 Examples

Examples of the impact of the *science production system* include direct effects on the employment of scientific and support staff, indirect effects on employment (spinoff companies, local suppliers), effects on incoming investment, effects on the social composition of local communities, impacts on local income distribution and rents, effects on local culture (beliefs and practices) and patterns of consumption, effects on social capital (skills etc.), effects on immigration and emigration, effects on social openness, environmental effects, and the mobilization of public opinion and resources around long-term goals (e.g. the Apollo project, the Human Genome Project, the eradication of smallpox). The majority of these effects are proximal and in principle predictable.

The reader will observe that many of these effects appear a second time as "context factors". This implies the existence of complex networks of effects in which policy-decisions affect context, which in turn influences the long-term effects of the decision. The existence of such networks is one of the factors that determine the non-linear nature of scientific impact.

Examples of impacts deriving from the *use of artifacts* include improvements in public health, environmental improvements, improvements in safety, security, education, transport, telecommunications and production processes. Many of these impacts can be summed up under the headings "improvements in quality of life" and

[1]Performance indicators will be discussed in more detail in D4.2.

"improvements in quality of work". With some notable exceptions, the majority of these outcomes are distal and difficult to predict.

Proximal impacts deriving from the *economic value of artifacts* include licensing and patenting revenues, sales of products and services grants and services. Distal impacts include long term effects on economic growth, GDP pro capite, employment and income distribution and are, again, difficult to predict.

4.3 Relationships

Entities in the model are linked by *relationships.* At its current stage of development the model includes the relationships listed below. Others may be introduced by the Case Studies.

4.3.1 BELONGS TO

4.3.1.1 Example

anActor BELONGS TO anInstitution

anActor BELONGS TO aCommunity

4.3.2 PRODUCES

4.3.2.1 Examples

anActor PRODUCES anArtifact

anActor PRODUCES aKnowledgeItem

4.3.3 DISTRIBUTES/PASSES ON

4.3.3.1 Examples

anActor DISTRIBUTES anArtifact TO anotherActor

anActor DISTRIBUTES knowledge TO anotherActor

4.3.4 USES/EXPLOITS

4.3.4.1 Examples

anActor USES aKnowledgeItem

anActor USES anArtifact

4.3.5 INCORPORATES

4.3.5.1 Examples

anArtifact INCORPORATES knowledge

an Artifact INCOROPORATES anotherArtifact

4.3.6 AFFECTS

4.3.6.1 Example

aContextFactor AFFECTS aSystem

aDecisionMaker AFFECTS aSystem

4.4 Networks

A network consists of a set of unipartite or bipartite relationships among entities (normally actors and/or artifacts and/or knowledge). Typical examples include co-authoring networks (the network of showing the relationships among authors who have coauthored a paper), institutional networks (the network of scientists who belong to the same institution, or who have once belonged to the same institution), knowledge sharing networks (networks representing flows of information between actors). In a typical system, actors participate in multiple networks.

Networks can be characterized in terms of Network Indicators. Candidate indicators will be discussed in forthcoming deliverable D4.1, due for release simultaneously with this report.

4.5 Representing the model

The vocabulary above makes it possible to model the two way interactions between scientists engaged in the production of knowledge and artifacts, other actors in science-society systems and the general context in which these actors act and take decisions. Figure 2 provides a schematic visual representation of these interactions.

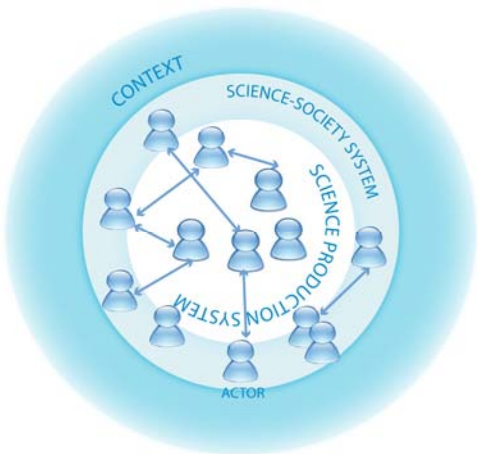

FIGURE 3: VISUAL REPRESENTATION OF THE MAIN ENTITIES IN THE MODEL

The main features of the model can be summarized as follows:

- The central entities in the model are *science-society systems* in which scientists and scientific institutions interact with other actors (decision-makers etc.) to produce, distribute and use *knowledge* and *artifacts*. It is important to realize that the boundaries of these systems are defined by the needs of particular studies and decision-makers. Different decision-makers with different roles and priorities will choose different boundaries.
- Within these systems, the set of human and institutional actors involved in the production of science can be treated as a *science production system.* As in the case of science-society systems, the boundaries of science production systems are somewhat arbitrary. The same actor may well participate in many different systems.
- The performance of science-society and science production systems depends significantly on *relationships* and *information flows* between *actors* within the system and belonging to different systems. Policy actions may influence and modify these relationships.
- The performance of these systems depends on a broad range of social, cultural, economic and legal factors. These constitute the *context* in which the system operates.
- This abstract model offers no explicit representation of the complex causal mechanisms linking the characteristics of science-society systems, the context in which they operate and performance. It nonetheless makes it possible to study significant correlations

4.6 The Case Studies – Operationalizing the Model

The three case studies in the SISOB project make no attempt to represent the complete set of entities and relationships and flows in science-society systems. Rather, each study casts light on a particular set of entities and relationships and a particular set of hypotheses concerning the effects of these entities and relationships on system performance. In other words each case study will be based an *instance* of the abstract conceptual model. Creating such an instance involves the specification of

- The main hypotheses for the study
- Relevant systems, actors, artifacts and knowledge
- Relevant attributes for these entities
- Ways of measuring these attributes (metrics, tolls)
- Relevant relationships among these entities
- The networks formed by these relationships
- Context factors affecting the structure and functioning of these networks.

In the following three chapters, we will present tentative models for each study. Subsequent deliverables will revise, refine, and enhance the initial models.

5 Operationalizing the model – Researcher Mobility

5.1 Background

As discussed in 2.3.1 econometric studies have conclusively demonstrated the importance of "science production systems" for economic growth and competitive advantage. As a result, policy makers across the world are looking for strategies to encourage the productivity of these systems. One frequently proposed strategy is the creation of research networks. It is widely believed that mobility of scientific personnel can make a major contribution to this process. Mobility of academics has thus become a major goal of EU policy for the European Research Area [17, 18].

5.2 Goals and hypotheses of the case study

It is commonly assumed that mobility of scientists facilitates knowledge and technology transfer, creation of networks and productivity. However, the nature of these relationships has yet to be fully explored and the concept of "mobility" needs to be better specified.

The Mobility case study will consider inter-institutional "real" labor mobility (as suggested in [19]). In other words, the study will be restricted to changes in job involving a move from one institution to another, and exclude moves within the same institution and early career mobility (e.g., postdoctoral research stays). More specifically, the study will take account of four classes of mobility:

- *Geographical Mobility*: intra- and inter-regional mobility within the same academic market
- *Sector Mobility*: transitions from academia to industry or vice versa (inter-sector mobility)
- *Functional Mobility:* transitions to a different function (inter- functional mobility)
- *Career Mobility*: transitions to a higher/lower position or to a more/less prestigious university (up- and downwards mobility).

To add additional perspective, the case study will also cover a less traditional form of mobility, that we have termed "Virtual Mobility" (cases when a researcher has concurrent multiple affiliations giving access to different resources and networks).

The study will begin by measuring the differential impact of these four dimensions of mobility on the productivity, career trajectory and networks of individual researchers. However, mobility not only affects individual academics, but shapes (academic) society as a whole. We will therefore use data on individual mobility to identify and describe migration patterns across universities, regions and sectors. Our underlying hypothesis is that mobile researchers are carriers of tacit knowledge, encourage novel recombinations of locally generated knowledge and contribute new knowledge to the receiving institution or region. We further hypothesize that geographical mobility can play a vital role in network building and promote awareness of different academic markets. If this is true, regions or universities in which a high proportion of mobile researchers from other regions and universities will be scientifically more productive than regions or universities with a lower proportion. We suggest that geographical mobility helps to create knowledge flows between academia and industry, benefitting the innovation process as a whole. Finally, we hypothesize that these relationships are bidirectional: mobility contributes to the production of knowledge and career development, therefore contributing to the overall productivity of the science production system; high productivity, in turn, facilitates knowledge transfer and dissemination, potentially contributing to mobility.

Against this background, the specific goals of the case study are to:

- Assess the impact of mobility on researcher performance
- Evaluate the relationship between productivity and different kinds of mobility (see above) and related causal mechanisms
- Identify and describe migration patterns between universities, regions and sectors
- Assess the impact of mobility on receiving and sending institutions and regions

5.3 The model – an overview

The effects of mobility on the productivity of individual researchers will be assessed using five simple models, based on panel data approaches:

- Researcher productivity as a simple function of job mobility within one year of the researcher's PhD
- Researcher productivity as a simple function of job mobility since the year of his/her first appointment
- Researcher's productivity as a simple function of different kinds of job mobility
- Pre- and post-mobility productivity (considering mobility in a given time window)
- The relationship between mobility and productivity in a window of time around the date when the researcher moved (the time window will be defined by the number of years spent in the pre-mobility job)

Additional models will represent the effect of mobility on the development of regions and institutions, again using a panel data approach. The models will represent:

- Changes in the scientific impact of a region/institution as a simple function of the proportion of researchers from other regions/institutions in the total number of researchers
- Changes in the scientific impact of a region/institution as a simple function of the proportion of researchers from other regions/institutions disaggregated by type of mobility

Figure 4 summarizes these relationships and hypotheses.

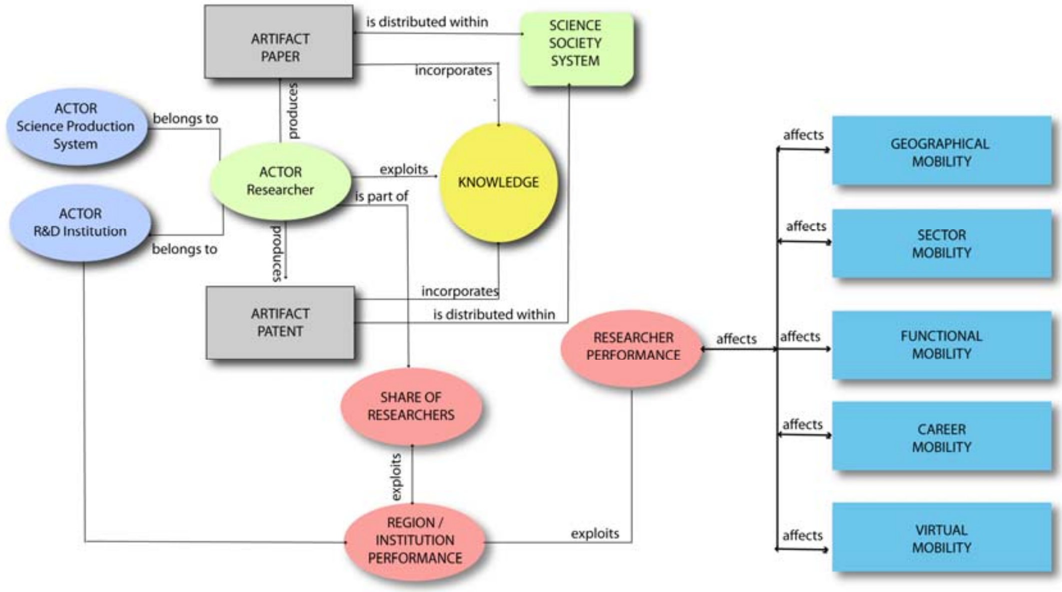

FIGURE 4: ENTITIES AND RELATIONSHIPS IN THE MOBILITY CASE STUDY

5.4 Model entities

5.4.1 Researcher (actor)

5.4.1.1 Definition

A person holding a research position within an academic institution and performing research activities in a particular scientific domain.

5.4.1.2 Examples

Assistant Professor, Associate Professor, Full Professor

5.4.1.3 Attributes[2]

- Year of birth
- Gender
- Grade or Academic Rank
- Current position
- Previous position(s) held
- Current affiliation
- Previous affiliation(s)
- Class of institution (university ranking, department wealth or prestige)
- Research field

[2] Mobility is identified and measured by analysing this data across time and space.

5.4.1.4 Measurements of attributes

- Data in CVs
- Other sources (e.g. web pages, university publications)

5.4.2 University (actor)

5.4.2.1 Definition

An academic institution that employs researchers.

5.4.2.2 Examples

Università di Torino

5.4.2.3 Attributes[3]

Size (Number of students, number of staff)

Class of institution (university ranking or prestige)

Wealth (Block Funding)

5.4.2.4 Measurements of attributes

University web pages, university publications

Academic literature repositories (e.g. Web of Science, Scopus)

5.4.3 Paper / article (artifact)

5.4.3.1 Definition

Academic work, usually published in an academic journal or in conference proceedings, and which present original research results and/or reviews existing results.

5.4.3.2 Examples

- Academic paper

5.4.3.3 Attributes

- Author(s) name
- Author(s) affiliation
- Year of publication
- Publication context (e.g. name of the Journal)
- Scientific field
- Keywords

[3] Mobility is identified and measured by analysing this data across time and space.

- Number of citations

5.4.3.4 Measurements of attributes

- Academic literature repositories (e.g. Web of Science, Scopus)

5.4.4 Patent (artifact)

5.4.4.1 Definition

Set of (exclusive) rights granted by a national or supranational authority to an inventor or their assignee for a limited period of time in exchange for a public disclosure of an invention, usually result of scientific research.

5.4.4.2 Examples

Patent

5.4.4.3 Attributes

- Inventor(s) name
- Inventor(s) affiliation
- Assignee(s) name
- Assignee (s) affiliation
- IPC-code
- Priority year

5.4.4.4 Measurements of attributes

Patent repositories (e.g. EPO, DWPI)

5.4.5 Researcher output (performance indicator)

5.4.5.1 Definition

Volume and quality of artifacts produced within a given time window

5.4.5.2 Examples

Number of Publications/year

5.4.5.3 Attributes

- Number of publications in a given time window
- Number of citations per paper in a given time window
- Number of patents in a given time window
- Number of citations per patent in a given time window
- Grants amount awarded in a given time window

5.4.6 Researcher productivity (performance indicator)

5.4.6.1 Definition

The ratio of output (publications) to input (time/grant)

5.4.6.2 Examples

5.4.6.3 Attributes

- The ratio of individual productivity to average productivity in the discipline (relative productivity)
- The ratio of the number of co-authors from the same university to the number of co-authors (Inbreeding)

5.4.7 Researcher knowledge sharing (social capital indicator)

5.4.7.1 Definition

An individual scientist's relatedness to other scientists through co-location / co-publication / co-patenting etc.

5.4.7.2 Examples

Co-publication links

5.4.7.3 Attributes

Number of publications/patents with researchers from current/previous institutions

Citations by authors belonging to current/previous institutions

5.4.8 Impact of Region/Institution (performance indicator)

5.4.8.1 Definition

Impact of artifacts within the region/institution in a given time window

5.4.8.2 Examples

- Number of citations by authors belonging to other regions/institutions

5.4.8.3 Attributes

- Number of citations by authors from a given region/institution, in a given time window
- Value of grants received in a given time window

5.5 Model relationships

The model highlights a set of relationships between entities, among which the ones hereafter reported:

A researcher BELONGS TO a Science Production System

A researcher BELONGS TO an institution

A researcher PRODUCES a paper

A researcher PRODUCES an invention (patent)

A researcher DISTRIBUTES a paper within a Science-Society System

A researcher DISTRIBUTES an invention (patent) within a Science-Society System

A paper INCORPORATES knowledge

A patent INCORPORATES knowledge

A researcher EXPLOITS knowledge INCORPORATED in a paper

A researcher EXPLOITS knowledge INCORPORATED in a patent

Geographical mobility AFFECTS the performance of a researcher

Sector mobility AFFECTS the performance of a researcher

Functional mobility AFFECTS the performance of a researcher

Career mobility AFFECTS the performance of a researcher

Virtual mobility AFFECTS the performance of a researcher

The performance of a researcher AFFECTS Geographical mobility

The performance of a researcher AFFECTS Sector mobility

The performance of a researcher AFFECTS Functional mobility

The performance of a researcher AFFECTS Career mobility

The performance of a researcher AFFECTS Virtual mobility

The performance of a researcher AFFECTS the performance of a region/institution

The share of mobile researchers in a region/institution AFFECTS the performance of a region/institution

The performance of a region/institution AFFECTS the share of mobile researchers

5.6 Model networks

The relationships above define a number of networks including the following:

- Collaboration networks: networks of researchers who jointly carry out research and jointly produce artifacts.
- Institutional networks: networks of researchers belonging to the same institution in a given timespan.
- Thematic networks: networks of researchers working on the same research topic in a given timespan.

6 Operationalizing the model – Knowledge Sharing

6.1 Background

The goal of this case study is to study flows of knowledge between actors in science production and science society systems, with a special emphasis on their social dimensions and impact. In this process, it is important to highlight a fundamental difference between knowledge sharing and sharing of tangible goods: actors who share their knowledge incur no direct costs (although there may be some indirect or transactional costs).

Recent research on knowledge creation and sharing has introduced a number of novel concepts, in particular the concept of "Mode 2 science" [20]. In this view, knowledge production is a transdisciplinary enterprise involving heterogeneous groups of actors. This means that, to understand the production of knowledge, we need to take into account the context in which it is produced and in particular the "knowledge market" to which it is delivered. It follows that analysis should not be restricted to "knowledge producers" but should also take account of other stakeholders such as regional policy makers and knowledge consumers (e.g. industry). Analysis of context factors can help to relevant identify networks and value chains.

By looking at how knowledge is externalized and spread within the scientific community, and how it is transferred to other areas of the society, we can identify specific patterns in the knowledge generation process. This leads to the idea of artifacts (or sets of inter-connected artifacts) as "boundary objects" [21] embedded within scientific communities. Such boundary objects are abstract or concrete objects that are vague enough to allow collaborating actors from different social worlds to interpret them from their own perspectives but robust enough to keep their own identity and momentum despite these differences in interpretation. When scientists from one social world or culture work with policy makers from another, artifacts can be seen as the "glue" between them. For instance, a policy maker does not understand know how a prototype works to make a decision, e.g. to found a new research center. Mapped onto time-based dynamic network models, flows of artifacts can serve as a simple but robust indicator of knowledge sharing. This is what Knorr Cetina has called "sociality with objects" [22].

Given this concept of knowledge sharing, the SISOB Conceptual Model needs to be open enough to cope with heterogeneous and transdisciplinary interactions involving actors from inside and outside the science production system. The transdisciplinary character of Mode-2 science with its strong focus on the application of scientific knowledge and products suggests the need to complement macro-level economic indicators with indicators at a relational or network level. Studies of relevant networks may make it possible to identify "scaling" mechanisms linking micro-level phenomena (e.g. the effect of a successful product on an individual firm) to macro-level phenomena (e.g. the effects on a network of such firms) [2].

The main goal of the case study is to measure and describe how knowledge is generated and spreads within and between scientific communities. From a pragmatic point of view we will track flows of relevant *artifacts* (externalizations of knowledge) between individuals and between institutions. This work will complement the study of human mobility in WP6.

In line with the definition of *artifact* in the conceptual model, we will not restrict our study to scientific papers but will also consider prototypes, software, articles in the general media and contributions to social media. Different classes of artifact use different "transport mechanisms" of which scientific publication is only one. Other typical examples include individuals taking prototypes and software with them when they move between universities or from universities to industry, the release of software to open sources repositories, and the sharing of key findings through the general or social media.

Knowledge about artifacts and their contextual interpretation is a kind of meta-knowledge that may be incorporated into other "descriptive" artifacts. The interpretation of content and quality will typically differ between contexts and different actors. For example, a student annotating a paper may simply note that it is important for an exam; a senior researcher is more likely to add detailed critical comments [23]. Thus, in general, meta-knowledge determines contextual factors and perspectives (incl. disciplinary and role-dependent perspectives) for the interpretation of artifacts. The Knowledge Sharing case study will extend the concept in two directions. First we will consider meta-knowledge referring not just to a single artifact but also to sets of interrelated artifacts. Second we will look at the specific kinds of meta-knowledge that are relevant in different disciplines as well as other professional domains, e.g. funding agencies or policy makers.

6.2 Goals and hypotheses of the case study

The domains to be studied in the case study are not yet fully defined. They will probably include nanotechnology and specific subdomains of the life sciences and/or communities engaged in the production of "open source software". Within the domains finally chosen, the study will attempt to identify patterns and indicators describing the flow of knowledge (and artifacts) within communities of researchers, entrepreneurs, policy makers, investors and citizens with an interest in science. Given that the domains are prototypical examples of Mode-2 science, we hope that the methods we develop in our study will also be applicable to other domains.

Our initial hypotheses and research goals can be summarized as follows.

- By exploiting semantic relationships between knowledge objects, we can identify links between researchers, indicating "congruence of interests" between actors and opportunities for sharing knowledge. We expect that these links have a positive influence on performance [24].

- Nano-science is less standardized and more diverse than other domains of science, and uses knowledge from a broader range of disciplines [25]. We thus expect that that knowledge brokers [26] will play a more important role in nano-science than in other disciplines we study.
- Block modeling will allow us to observe heterogeneous actors in a typical mode-2 setting within a core-periphery structure. We thus expect that peripheral actors such as funding agencies and research consultants play an important role in knowledge sharing and mediation. Once such mediators (or brokers) have been identified, it may be possible to identify and analyze other mediating objects and to observe how these structures change over time.
- Different publication cultures in different research disciplines will have different publication cultures show be reflected in different network patterns (e.g. looking in co-authoring networks).

6.3 The model – an overview

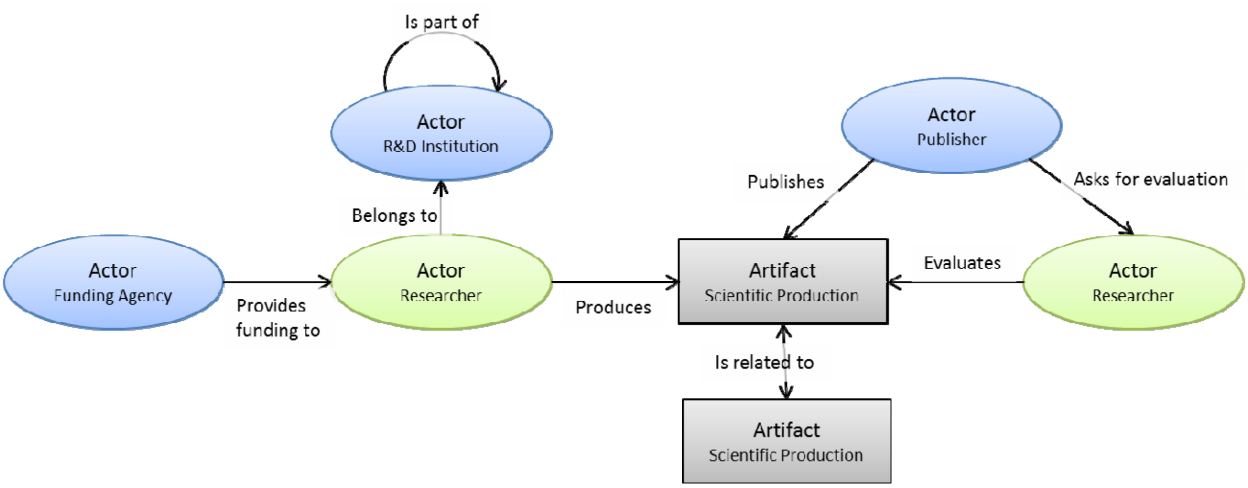

FIGURE 5. SCHEMATIC OVERVIEW.

Figure 5 provides an overview of the entities and relations of interest for our case study. In these networks, the nodes are actors. The human actors are individual researchers. The institutional actors are R&D institutions, funding agencies and publishers. The artifacts consist of scientific publications, patents, prototypes and other products as defined in the Conceptual Model. The study will focus on relationships between researchers, between researchers and institutional actors, between researchers and artifacts and between artifacts.

Figure 6 provides a more concrete illustration of these networks. In the figure, the artifacts are a prototype demonstrated at a conference and a paper describing the prototype, published in the conference proceedings.

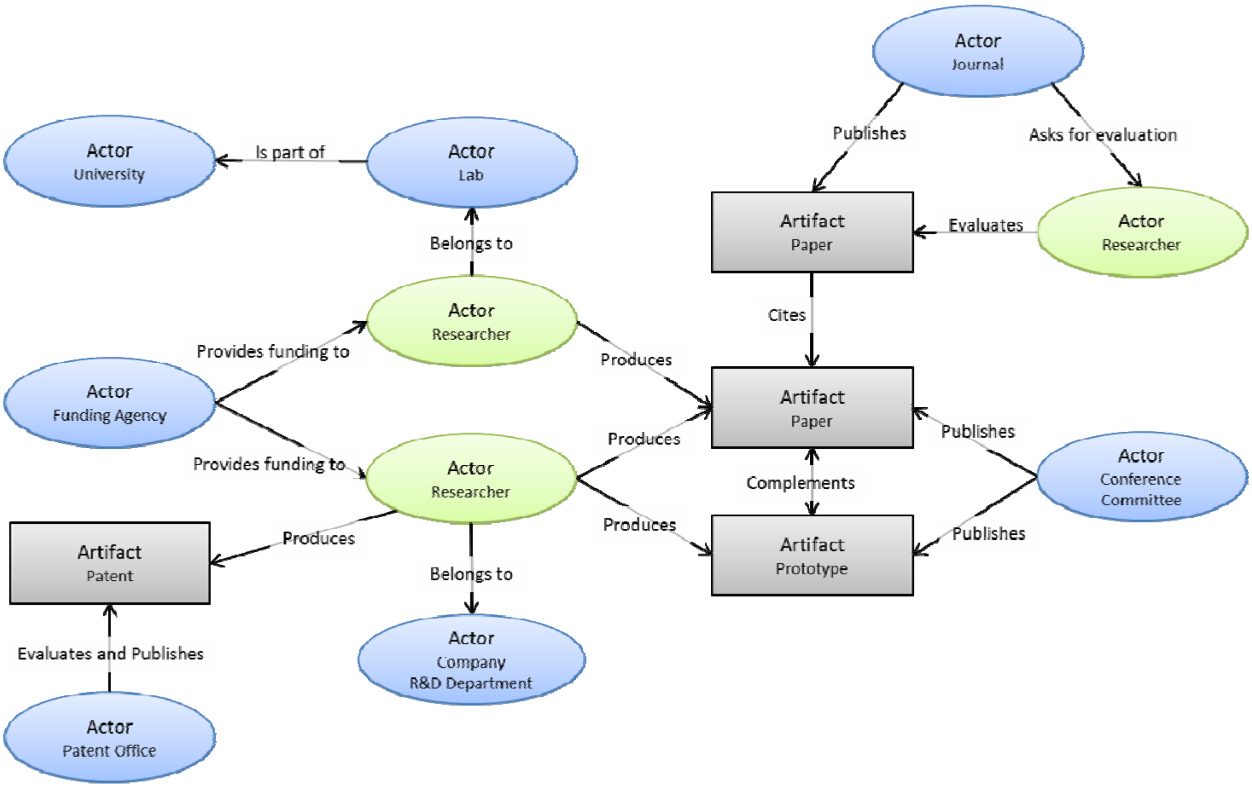

FIGURE 6. ILLUSTRATION OF THE MODEL.

As knowledge sharing is a process with a temporal dimension most of the entity attributes and even some of the relations have a temporal component. Examples are the positions as researcher attribute or the “belongs to” relation. The “positions” attribute does describe the current position as well as the positions held so far. The “belongs to” relation may be marked with temporal information showing when a researcher was working for a specific R&D institute.

6.4 Model entities

Researcher (actors)

Definition

Researchers are persons who do research. In this case study, the same researcher may have several roles (e.g. author or reviewer) depending on the context of observation.

Attributes

- Positions
- Academic grades
- Publications
- Affiliations

R&D Institution (actors)

Definition

R&D institutions are institutions that employ researchers. They may be ordered hierarchically, e.g., a lab belongs to a university.

Examples

- University
- Lab
- Institute
- Company

Publisher (actors)

Definition

Publishers are institutional actors who manage the publication of artifacts.

Examples

- Journal
- Conference
- Patent office

Funding agency (actors)

Definition

Funding agencies are institutional actors that support financial support to researchers.

Overall network measures (performance indicator)

Definition

Overall network measures are measurements that describe a whole network. The case study will use these measures to describe and compare different networks.

Examples

- Number of nodes and connections
- Density of the networks

Network measures for connected components (performance indicator)

Definition

Network measures for connected components are measures that describe the connected components of a network. The study will use network measures to describe and compare components of networks. The use of these measures makes it possible to compare components within and between networks.

Examples

- Diameter
- Average path length

Centrality measures (performance indicator)

Definition

Centrality measures describe single nodes of a network and can be used to compare nodes within and between networks.

Examples

- Degree centrality
- Closeness centrality
- Betweenness centrality

6.5 Model relationships

Researchers BELONG TO institutions

Researchers PRODUCE scientific productions

Researchers EVALUATE scientific productions

Publishers PUBLISH scientific productions

Publishers ASK FOR EVALUATION researchers

Scientific productions ARE RELATED TOother scientific productions

(special cases: x CITES y, x COMPLEMENTS/ILLUSTRATES y)

Institutions are PART OF institutions

6.6 Model networks

The relationships above define a number of networks including the following

- Researcher networks, based on
    - Co-authoring: networks of researchers who have created scientific productions together
    - Citation: directed networks of researches in which two researchers are connected if one has cited works of the other
    - Co-citation: networks of researchers who have cited the same work
    - Institution membership: networks of researchers who have worked for the same institution at the same time

- Publisher networks, based on common authors: networks of institutional publishers who have published work by the same researchers
- Institution networks, based on co-production: networks of institutions which have members who have created scientific productions together
- Funding agency networks, based on co-funding: networks of funding agencies who have funded the same researchers
- Mobility networks, based on researcher mobility: networks of institutions who have received researchers from other institutions

The study will examine how these networks develop over time as researchers move between institutions and take their knowledge with them. We will also examine the possibility of using ontologies to represent domain specific knowledge. By using ontologies it may be possible to identify relationships between artifacts based on relationships between the concepts incorporated in the artifacts.

7 Operationalizing the model – Peer review

7.1 Background

Modern academics dedicate a large part of their time to writing scientific papers and funding proposals. In both cases, success depends on peer review, contributing in this way to the productivity and reputations of researchers and their institutions.

The studies reviewed in D2.1 suggest that implicit and explicit social relationships play an important role in the peer review system. According to these studies, reviewers tend to prefer papers coming from their own institutions or from institutions of similar prestige [27], those written by authors of their own nationality [28] and gender [29, 30], and those coming from authors who share their own approaches and prejudices [31, 32].

These findings are often interpreted in terms of "old boy networks" and various forms of "cronyism". Wade, for instance, cites a widely held opinion that "The peer review system consists of a group of committees whose members hand out grants to each other and to their friends" [33]. However this is not the only possible explanation. When a reviewer gives a favorable review of a paper from an author belonging to a given network, it could be because she is biased, but it could be because authors belonging to the network write better papers — perhaps because the network facilitates the emergence of shared standards of quality.

7.2 Goals and hypotheses of the case study

Regardless of causal interpretations, the probability that a paper or funding proposal will pass review probably depends, at least in part, on similarity and social relationships between reviewers and authors. If this is so, these relationships, and the networks they form, could play a significant role in determining, not only the careers of individual authors, but the overall success of institutional actors (departments, universities etc.). The goal of our study is to investigate this hypothesis. We will use two main data sets:

- Data on authors, reviewers, and review results for 3,074 papers, in a broad range of life science disciplines, submitted for publication in journals managed by the Frontiers In Publishing House
- Data on authors, reviewers, and review results for approximately 600 papers on Artificial Intelligence, submitted to UMAP2011, a large annual conference on user modeling

Data from these sources will be augmented with data collected from standard sources of bibliometric indicators and university rankings and by web crawling.

The study will begin by attempting to replicate the following results from previous work:

- Papers with a female lead author receive a higher score from female reviewers
- Papers with a female lead author receive a lower score from male reviewers than papers with a male lead author
- Papers with an author from an institution in a given geographical area receive a higher score from reviewers from the same area
- Papers with a lead author from a top ranking institution receive a higher score than papers whose lead author comes from a lower-ranking institution
- Papers with a highly cited lead author receive a higher score than papers with less cited lead authors.
- The correlation between citations and reviewer scores is very low

The study will then go on to examine the possible influence of social networks over the peer review process. We will focus on three classes of network:

- Author-Reviewer networks (networks created using the relationship <researcher> HAS REVIEWED PAPER by <researcher>)
- Co-authoring networks (networks created using the relationship <researcher> HAS CO-AUTHORED A PAPER with <researcher>)
- Citation networks (networks created using the relationship <researcher> HAS CITED PAPER by <researcher>)

The study will explore the characteristics of these networks and the relationship between them. It will go on to test the following hypotheses:

- The mean score reviewers gives to papers by a given author is inversely related to the reviewer's distance from the lead author in author-reviewer networks
- The mean score reviewers gives to papers by a given author is directly related to the lead author's position (centrality) in these networks
- These effects are additional to the effects of co-authoring and citation networks

The final stage of the study will tentatively explore how the micro-level effects of author-reviewer networks (effects on the productivity of individual authors) translate into effects on the macro-level (effects on the productivity of departments and universities). To this end we will construct three classes of "institutional network":

- Institutional author-review networks (networks based on the relationship: <researcher from institution x> HAS REVIEWED PAPER by <researcher from institution y>
- Institutional co-authoring networks (networks based on the relationship: <researcher from institution x> HAS CO-AUTHORED PAPER with <researcher from institution y>
- Institutional co-citation networks (networks based on the relationship: <researcher from institution x> HAS CITED PAPER by <researcher from institution y>

On this basis the study will examine the following macro-level hypotheses.

- The mean score reviewers from a given institution give to papers by authors from a given institution is inversely related to the distance between the their respective institutions in the institutional author-reviewer network.
- The mean score is directly related to the centrality of the lead author's institution in the institutional author-reviewer network
- These effects are additional to the effects of institutional co-authoring and citation networks
- These effects are stronger than the effects obtained by summing individual effects.

7.3 The model – an overview

In the model, the main entities are *researchers* (the actors for this study) and *papers* (the artifacts). Researchers and actors are connected by three primary relationships: researchers can *author* papers, they can *review* them and they can *cite* them. These primary relationships create secondary relationships among researchers: a researcher can be related to another researcher by the fact she has coauthored a paper with her, or by the fact she has reviewed or cited one of her papers. Figure 7 provides a schematic representation of these relationships.

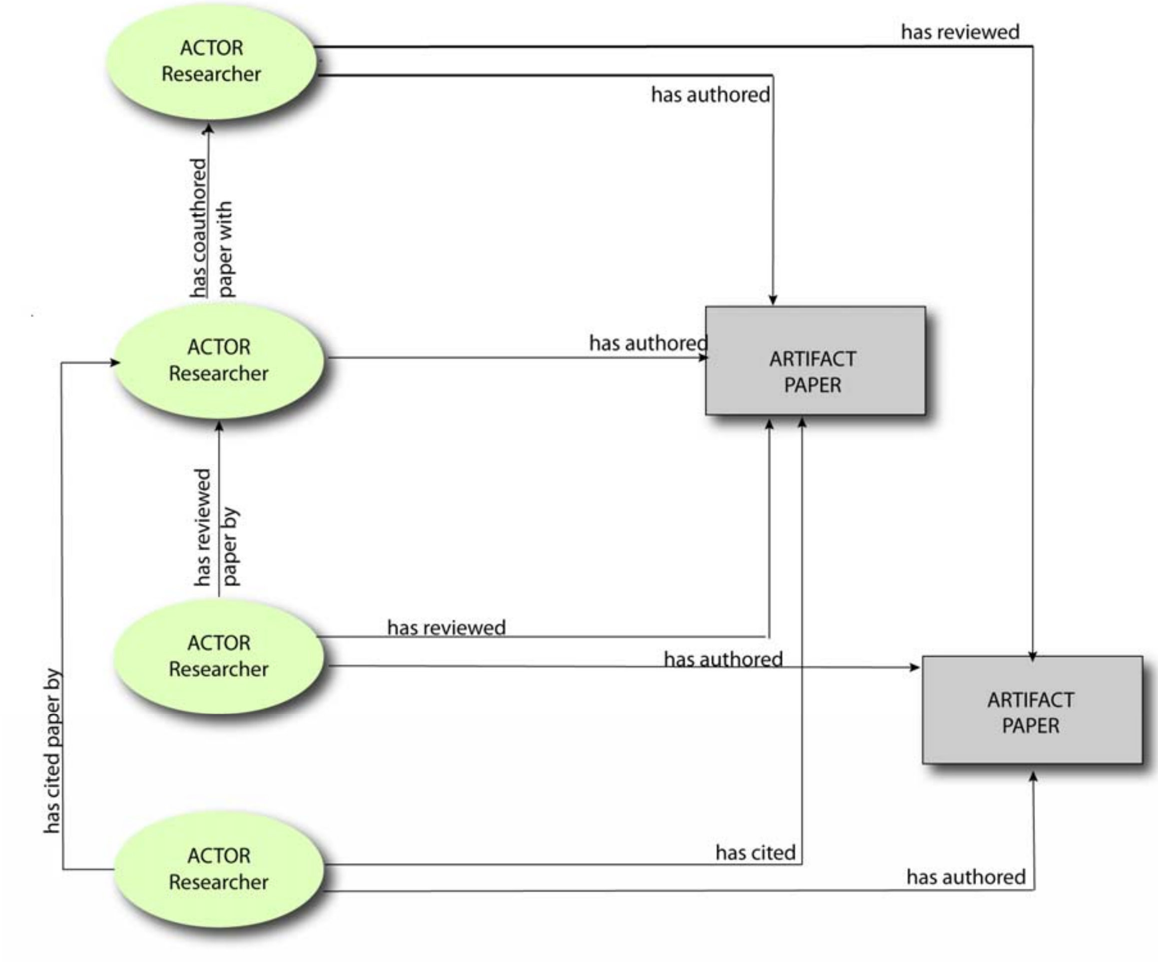

FIGURE 7: ENTITIES AND RELATIONSHIPS IN THE PEER REVIEW STUDY

The relationships just described form networks of researchers (co-authoring networks, citation networks, author-reviewer networks). Indirectly these networks give rise to network among the institutions to which the researchers belong. The central hypothesis of the peer review study is that these networks and the position of authors and institutions within the network influence review results and thus, indirectly, overall institutional performance (the performance of a science production system. Figure 8 provides a stylized representation of this hypothesis. In this diagram, the nodes in the network are researchers, and the edges represent a relationship between two researchers in a co-authoring, citation or author-reviewer network. Readers should note that the model makes no assumptions about mechanisms of causality. While network-related effects on review results may reflect "cronyism", they may also be the result objective differences in the quality of work of authors in different positions in the network.

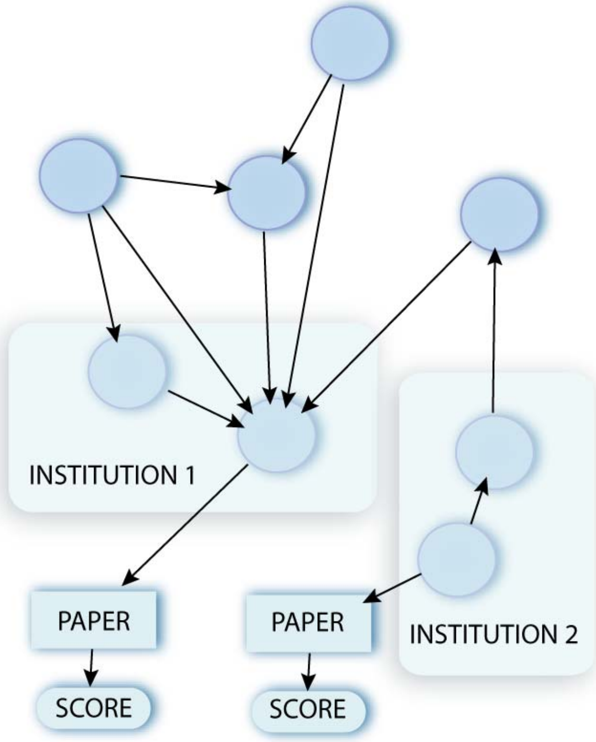

FIGURE 8: STYLIZED AUTHOR-REVIEW/ CO-AUTHORING AND CITATION NETWORKS AND HYPOTHETICAL RELATIONSHIP OF NETWORK POSITION TO REVIEW SCORES

7.4 Model entities

7.4.1 Researchers (actors)

7.4.1.1 Definition

A researcher is any person engaged in the production of scientific research. Researchers may be both authors of papers and reviewers of papers.

7.4.1.2 Attributes

- Gender
- Institution
- Class of institution (university rankings)
- Productivity
- Reputation

7.4.1.3 Measurements of attributes

- Total number of publications
- Citations
- H-index
- Other bibliographic indicators

7.4.1.4 Measurement tools

- ISI – Web of Science
- Google Scholar

7.4.2 Institutions (actors)

7.4.2.1 Definition

An institution is a university, a university department or a laboratory engaged in the production of scientific research

7.4.2.2 Attributes

- Country
- Reputation
- Productivity

7.4.2.3 Measurements of attributes

- Ranking
- Total publications in discipline
- Total citations in discipline

7.4.2.4 Measurement tools

- SISOB tools

7.4.3 Papers (artifacts)

7.4.3.1 Definition

A paper is a peer-reviewed article submitted for publication/published in a journal or a conference

7.4.3.2 Attributes

- Title
- Date of submission
- Date of review
- Date of publication
- Score on review
- Citations
- Reviews by readers (Frontiers only)

7.4.3.3 Measurement tools

SISOB tools

7.5 Model relationships

aResearcher BELONGS TO anInstitution

aResearcher HAS AUTHORED aPaper

aResearcher HAS COAUTHORED with aResearcher

aResearcher HAS REVIEWED PAPER BY aResearcher

aResearcher HAS CITED PAPER BY aResearcher

7.6 Networks

The relationships above define the following networks:

- Author-Reviewer networks (networks created using the relationship <researcher> HAS REVIEWED paper by <researcher>)
- Co-authoring networks (networks created using the relationship <researcher> HAS CO-AUTHORED a paper with <researcher>)
- Citation networks (networks created using the relationship <researcher> HAS CITED a paper by <researcher>)
- Institutional author-review networks (networks based on the relationship: <researcher from institution x> HAS REVIEWED paper by <researcher from institution y>
- Institutional co-authoring networks (networks based on the relationship: <researcher from institution x> HAS CO-AUTHORED a paper by <researcher from institution y>
- Institutional co-citation networks (networks based on the relationship: <researcher from institution x> HAS CITED a paper by <researcher from institution y>

REFERENCES

1. Fenton, M., *Guidebook on Social Impact Assessment*, 2005, NSW Department of Planning: Sidney, Australia.
2. Schirmer, J., *Scaling up: Assessing social impacts at the macro-scale.* Environmental Impact Assessment Review, 2011. **31**(3): p. 382-391.
3. Rockefeller Foundation and Goldman Sachs Foundation. *Social Impact Assessment - A discussion among grantmakers*. 2003 [cited 2011 June 29]; Available from: http://www.riseproject.org/Social%20Impact%20Assessment.pdf.
4. Rickson, R.E., J.S. Western, and R.J. Burdge, *Social impact assessment: Knowledge and development.* Environmental Impact Assessment Review. **10**(1-2): p. 1-10.
5. Luhmann, N., *Kausalität im Süden.* Soziale Systeme - Zeitschrift für soziologische Theorie, 1995. **1**(1): p. 7-28.
6. Jimènez-Contreras, E., et al., *The evolution of research activity in Spain: The impact of the National Commission for the Evaluation of Research Activity (CNEAI).* Research Policy, 2003. **32**(1): p. 123-142.
7. Zinovyeva, N., *Academic Inbreeding in Spain: Evidence from a Randomized Natural Experiment.* Mimeo, 2011.
8. Solow, R.M., *Technical Change and the Aggregate Production Function.* The Review of Economics and Statistics, 1957. **39**(3): p. 312-320.
9. Godin, B. and C. Dorin, *Measuring the impacts of science beyond the economic dimension*, in *CSIIC Working Paper*2004.
10. Salter, A.J. and B.R. Martin, *The economic benefits of publicly funded basic research: a critical review.* Research Policy, 2001. **30**(3): p. 509-532.
11. OECD. *OECD reviews of innovation policy*. 2011 [cited 2011 June 26]; Available from: http://www.oecd.org/document/62/0,3746,en_2649_34273_38848318_1_1_1_1,00.html.
12. Buxton, M., S. Hanney, and T. Jones, *Estimating the economic value to societies of the impact of health research: a critical review.* Bulletin of the World Health Organization, 2004. **82**(10): p. 733.
13. Doyle, C.J. and M.S. Ridout, *The impact of scientific research on UK agricultural productivity.* Research Policy, 1985. **14**(2): p. 109-116.
14. Alwang, J. and P.B. Siegel, *Measuring the impacts of agricultural research on poverty reduction.* Agricultural Economics, 2003. **29**(1): p. 1-14.
15. Alene, A.D., et al., *Targeting agricultural research based on potential impacts on poverty reduction: Strategic program priorities by agro-ecological zone in Nigeria.* Food Policy, 2007. **32**(3): p. 394-412.
16. Harding, L. *Grigory Perelman, the maths genius who said no to $1m*. 2010 [cited 2011 June 29]; Available from: http://www.guardian.co.uk/world/2010/mar/23/grigory-perelman-rejects-1m-dollars.

17. European Commission, *High-level Expert Group on Improving Mobility of Researchers*2001, Final report: Brussels.
18. The European Commission, *Europe 2020. A strategy for smart, sustainable and inclusive growth*, 2010: Bruxelles.
19. Crespi, G., A. Geuna, and L. Nesta, *The mobility of university inventors in Europe.* The Journal of Technology Transfer, 2007. **32**(3): p. 195-215.
20. Gibbons, M., et al., *The new production of knowledge: the dynamics of science and research in contemporary societies*1994, London: Sage.
21. Star, S.L. and J.R. Griesemer, *Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39.* Social Studies of Science, 1989. **19**(3): p. 387-420.
22. Knorr Cetina, K., *Sociality with objects: social relations in postsocial knowledge societies. .* Theory, culture & society, 1997. **14**(4): p. 1-30.
23. Evans, J.A. and J.G. Foster, *Metaknowledge.* Science, 2011. **331**(6018): p. 721-725.
24. Mika, P., T. Elfring, and P. Groenewegen, *Application of semantic technology for social network analysis in the sciences.* Scientometrics, 2006. **68**(1): p. 3-27.
25. Jansen, D., R. von Görtz, and R. Heidler, *Knowledge production and the structure of collaboration networks in two scientific fields.* Scientometrics, 2010. **83**(1): p. 219-241.
26. Burt, R.S., *Structural Holes and Good Ideas.* The American Journal of Sociology, 2004. **110**(2): p. 349-399.
27. Peters, D.P. and S.J. Ceci, *Peer-review practices of psychology journals: The fate of published articles, submitted again.* The Behavioral and brain Sciences, 1982. **5**: p. 187-195.
28. Link, A.M., *US and Non-US Submissions.* JAMA: The Journal of the American Medical Association, 1998. **280**(3): p. 246-247.
29. Wenneras, C. and A. Wold, *Nepotism and Sexism in Peer-Review.* Nature, 1997. **CCCLXXXVII**: p. 341-343.
30. Sandström, U. and M. Hällsten, *Persistent nepotism in peer-review.* Scientometrics, 2008. **74**(2): p. 175-189.
31. Travis, G.D.L. and H.M. Collins, *New Light on Old Boys: Cognitive and Institutional Particularism in the Peer Review System.* Science, Technology, & Human Values, 1991. **16**(3): p. 322-341.
32. Mahoney, M.J., *Publication prejudices: An experimental study of confirmatory bias in the peer review system.* Cognitive Therapy and Research, 1977. **1**(2): p. 161-175.
33. Wade, N., *Peer review systems: How to hand our money fairly.* Science, 1973. **179**: p. 158-61.