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Kasia Zalewska-Kurek

Strategies in the production and dissemination of knowledge

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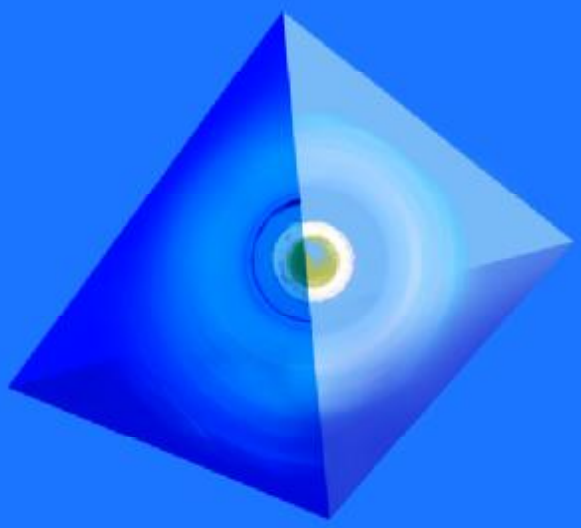

STRATEGIES IN THE PRODUCTION AND DISSEMINATION OF KNOWLEDGE

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DISSERTATION

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To Dawid

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Introduction

1. The main research question

Nothing in science is neither produced in isolation nor comes totally unnoticeable for other researchers. Although this is not always acknowledged, even discoveries made by isolated researchers finally reach the scientific community and sometimes even the outside world. Despite of such ivory tower researchers, in general not many discoveries would be made without sharing resources, i.e. exchanging ideas, knowledge, facilities, etc. For example the overall majority of experiments in high-energy physics would not be possible without a large research enterprise such as CERN where many researchers and unique scientific instrumentation are gathered. There are many more examples of collaborative science next to physics such as in astronomy (Hubble telescope), biology (genome project), etc. Collaboration is also of relevance in more moderate research enterprises.

It is of interest to national governments, international governing bodies, and policy makers as well as to research groups or research institutes to increase the production of discoveries and breakthroughs thereby adding to the development of scientific knowledge in general and bringing competitive advantage in particular. We observe this for instance at the international level with the European Union desiring researchers to produce more and better knowledge to gain competitive advantage over the USA, China or Japan. The question that both policy makers and researchers are struggling with is how to manage the research process in such a way that researchers will indeed increase the production of scientific knowledge. One way adopted by both policy makers and researchers is facilitating collaboration between researchers (e.g. Lee & Bozeman, 2005). It is well documented that collaboration between researchers increases productivity of researchers (Lotka, 1926; Hagstrom, 1965; Price & Beaver, 1966; Zuckerman, 1967; Pao, 1982; Pravdic & Oluic-Vulovic, 1986; Birnholtz, 2005; Lee & Bozeman, 2005; Louis et al, 2007).

From the literature (e.g. Lee & Bozeman, 2005; Hessel & Lente, 2008) we recognise a need for a study of the mechanisms governing the research process and leading to the production of knowledge. To this end, we study collaboration and the resulting sharing of resources in the research process. We focus on the interaction between researchers in the research process as well as on the interaction between science and society at large with the goal to produce scientific knowledge. Any knowledge intensive society is in need of scientific achievements and demands scientific knowledge to be useful and applicable e.g. into technology. Nowadays, the society seeks for new discoveries and commits itself to the development of science. This commitment is expressed in the participation of the society in granting scientific research.

The society and the researcher can be seen as two actors and, as in any interaction between two or more actors, there are specific conditions governing this interaction and mutual participation, for instance by specifying requirements on research goals to

be attained. At the same time, researchers have the need to acquire financial support from the societal environment as the costs of doing research have rapidly increased resulting in a higher demand for research funding (Ziman, 1994; Gibbons et al, 1994). Science as a growing industry has been seen to twig into more and more disciplines each involving more financial support in its own (Ziman, 1994). The interest of the societal environment in scientific research and the need for new funding sources by researchers continue and will continue to trigger closer strategic relationships between researchers and their societal environment.

This strategic relationship with its aim to produce scientific knowledge is the main focus of this dissertation. We deal with the organisation and management of the research process. From an analysis of the situation outlined above the main research question addresses '*What conditions regarding research and the organisation of research do serve the researcher in the production of knowledge?*' This more general question is being answered in this thesis whereby each chapter discusses a set of specific sub-questions, such as:

- what are the main elements of the strategic relationship between the researcher and his environment?
- what are valid and reliable observables for the positioning model?
- what is the organisation of the production of knowledge?
- does strategic positioning affect the production of scientific knowledge?
- what are the elements required for developing business models in science supporting the production of knowledge?'

2. The model of strategic positioning

The strategic relationship established between the researcher and his environment, like any other relationship, is seen as a (temporary) strategic alliance, joint venture, merger or possibly even an acquisition between business partners. Such an alliance can be established between two organisations, i.e. the researcher or research institute and the environment. The environment of the researcher that we have in mind is the abovementioned societal environment and its representatives such as government, funding agencies, industry, etc., and also other researchers, research groups or research institutes bound in joint research projects or programmes. To analyse the relationship between the researcher and his environment we develop a model analysing the strategic positioning of the researcher in this environment. This model analyses sharing of heterogeneously distributed resources (strategic interdependence) between researcher and environment, and governing of research (organisational autonomy) (Haspeslagh, Jemison, 1991). Attaining set strategic goals may require different necessities for sharing resources and for governance. The model is further discussed in detail in chapters 1 and 2. The overriding result of the model is that it leads to a continuum of modes in which we can distinguish four characteristic or typical modes of strategic positioning: the well-known mode1, also known in the literature as the ivory

tower, and mode2, also known as strategic research (both introduced by Gibbons et al., 1994), and the newly introduced mode0 and mode3. The latter we called the research entrepreneur. Each mode is a specific combination of a low or high necessity for strategic interdependence or organisational autonomy. In mode1 researchers are producing knowledge without the intervention of the societal environment. In the positioning model it represents the combination of low necessity for interdependence and high necessity for autonomy. The researcher is highly autonomous and not connected to the societal environment. The mode1 researcher directs his own research and makes independent decisions on what to produce. The mode2 researcher is directed by his environment as he has a high necessity for interdependence combined with a low necessity for autonomy. The researcher matches his research goals to existing research programmes based on the demand of the societal environment. The mode2 researcher listens to the environment and fulfils the demanded societal needs. These two modes are known and often used in the literature (e.g. Harvey et al., 2002; Fujigaki & Leydesdorff, 2000; Kelemen & Bansal, 2002; Swan et al., 2007; Estabrooks et al., 2008). The strategic positioning model adds to the description of these modes by making the modes observable as distinct from each other and can then be applied in empirical research. Next to these modes, the model predicts two modes resulting from two different, yet unexplored combinations of the two dimensions of strategic interdependence and organisational autonomy. These modes we call mode0 and mode3. Mode0 is a combination of low necessity for both interdependence and autonomy. In mode0 it is not necessary for the researcher to establish a strategic relationship with the societal environment to attain his goals. Not is it necessary to be highly autonomous. This mode resembles a sort of holding construction between two or more organisations, as we also know in industry. The fourth mode of strategic positioning, mode3 or the research entrepreneur, is newly introduced in this dissertation. The research entrepreneur is shown to be the most autonomous and at the same time most interdependent researcher in all of the modes of strategic positioning. This means that he sets research goals and directs research being at the same time intertwined with his environment.

This model and the empirical studies add to the discussion on the relationship between science and society aimed at the production of scientific knowledge (in e.g. Gibbons et al, 1994; Leydesdorff & Etzkowitz, 1998; Special Issue of British Management Journal, 2001; the Academy of Management Journal, 2001; Special Issue of Research Policy, 2006; Organisation Studies workshop: The Generation and Use of Academic Knowledge about Organisations, 2007). In this discussion Gibbons raised in 1999 the need for a new social contract between research and society that would result in mutual interactions and in a 'socially robust' scientific knowledge production (Gibbons, 1999). The research entrepreneur is proposed as an answer to this need: the research entrepreneur interacts with the societal environment in such a way that "he speaks to the environment and the environment speaks back to him". The research

entrepreneur "speaks to the environment" by developing, like a business entrepreneur, appropriate strategies to create demand for his scientific products, in this way influencing his societal environment. In this context, he influences strategies and policies developed by his environment. The environment "speaks back to him" by developing appropriate strategies reflecting its interests and accounting for the strategies developed by the researcher, resulting in possible and new research policies.

This model can be applied in developing strategies and policies for research as such and in its interaction with society. This is possible because in the positioning model the inside-out view next to the classical outside-in view is also taken into account. This combined view allows an analysis of the researcher and his goals in his environment. Discussions on the relevance of this model in practice are presented in chapters 2 and 3.

3. Business models

The discussion in this dissertation expands then into a discussion on business models for science. This discussion is a follow up on the discussion on scientific information and its role in the research process and the consequences for the publishing system (Roosendaal & Geurts, 1997; Roosendaal 2004; Roosendaal et al, 2004). In fact, the last chapter is based on an article that was published first, before the opening article. It was when analysing business models, that we realised that business models in science cannot be developed without knowing the mechanisms ruling the production of knowledge. As we argue in chapter 4, business models do not only consist of the cost and profit structure but also of the value proposition, strategic positioning, value chain, market segment, and competitive strategy. Only a thorough knowledge of all these elements allows developing appropriate business models including cost and profit structures.

The discussions on scientific information and business models for scientific information are in essence about serving the researcher in the research process. Scientific information should serve the researcher in research and at the same time it should give a distinct competitive advantage over other researchers. The research environment is rather competitive where the degree of this competitiveness depends on the scientific domain (Merton, 1957; Gaston, 1971, 1973; Hagstrom, 1965, 1974). Scientific information is crucial for researchers competing for recognition among their peers and/or for financial resources in the societal environment. The premise in this thesis is that scientific information is prerequisite to the production of knowledge and it is for this reason that it should be shared. This sharing leads us then to a suite of business models for scientific publishing. Following the above arguments, we then can recognise two main parameters that any publishing business model should comply with: availability and selection. We argue in chapter 4 that these two parameters are of direct importance for the production of knowledge.

Based on these arguments we present an approach to business models in science starting from the perspective of creating value in scientific publishing. In fact, this

approach can be applied for any value proposition in the research environment by specifying the parameters for this specific value proposition. These business models have possible applications for research groups, institutes or universities striving to improve their performance in teaching or in research.

4. Parsons

The premise in this dissertation is that the research environment is strongly connected with the societal environment as the researcher is an actor within this society. As such he is not only a part of the science system but he is also related to the societal environment. This means that he produces knowledge that can be utilised by other actors in the societal environment. In this respect, the researcher is a social actor as a representative of the environment and at the same time interacting with this environment. Such an interaction results in a strategic relationship that the researcher establishes with the societal environment. On the basis of this premise we study how the researcher functions as a social actor in his environment. To analyse this we lean on some of the ideas of Talcott Parsons[1] regarding the social system (applications can be found in chapter 2 & 3). One of the main ideas that we lean on is the idea of a social system consisting "in a plurality of individual actors interacting with each other in a situation which has at least a physical or environmental aspect, actors who are motivated in terms of a tendency to the 'optimisation of gratification' and whose relation to their situations, including each other, is defined and mediated in terms of a system of culturally structured and shared symbols" (Parsons, 1951 p.5). Furthermore, "a social system is a mode of organisation of action of elements relative to the persistence or ordered processes of change of the interactive patterns of a plurality of individual actors" (Parsons, 1951, p.24).

Actions within each social system can be comprehensively defined in terms of four functions. These functions are: 'goal attainment' ("providing for the effective expenditure of resources for use in the pursuit of particular goals" (Mayhew, 1982, p.23)), 'adaptation' ("or securing generalised resources for use in achieving the varied output goals of the system" (ibid. p.23)), 'latency' ("or maintaining the stability of the overall structural reference points and boundaries that define the system" (ibid. p.23)), and 'integration'("or providing for the coordination of the diverse elements and units within the system" (ibid. p.23; Parsons, 1951). The idea of these four functions is that a (social) system is constituted by actions leading to set goals and that these set goals are reached only when fulfilling the adaptation, latency and integration functions.

1 As we make use of a few ideas only, we do not mean to discuss all of the ideas of Parsons and his theory neither critiques of these (e.g. Merton, 1968; Tausky, 1965). A detailed analysis of critiques can be found in Kraaijenbrink (2006).

The four functions scheme can be formalised as: G = G (A + L + I).

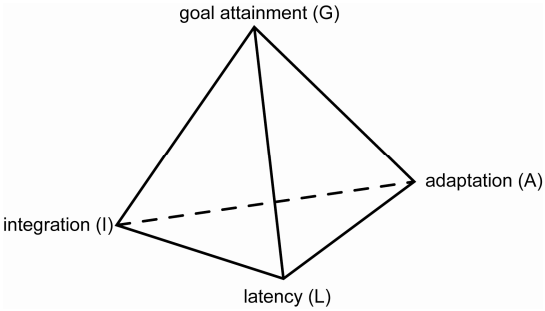

Figure 1. Representation of the four functions and possible relations between the functions.

Each function can be fulfilled on whatever level of aggregation of analysis, and each time the same formal distinctions will be made, like with Chinese boxes or Russian puppets. We take the functions for granted and then taking into account the properties of them we define boundary conditions for each appropriate level. We analyse the environment of the researcher respectively the scientific research institute by specifying its functions and setting the boundary conditions appropriate for each level of analysis. This approach is used because of its ability to describe and explain the complexity of actions undertaken by researchers in their scientific habitus.

The familiar model of the four functions introduced by Parsons is traditionally projected in two-dimensional space and ipso facto fixes the relations between the functions. Using three-dimensional space represented by a tetrahedron instead lifts the requirement to prescribe a priori interactions or relations between the functions or even the hierarchy of the functions (see figure 1).

Our interest focuses on the way science is organised as part of the societal environment, and on the researcher as a gatherer and producer of knowledge, not per se as a thinker or experimenter. In this respect a researcher or a scientific research institute is a social actor. Parsons (1968) (but earlier also Kant) states that an actor basically can react positively or negatively to another actor, and that he can focus on the situation of the other actor (independent of the intentions of the other actor) or focus on the intention of the other actor (not taking into account the situation of the other). In combining these two dimensions four behavioural types emerge. An actor may firstly induce the other (positive sanction with a focus on the situation of the other). Secondly, he may react with a positive sanction in reacting to the intention of the other and herewith persuading the other. Thirdly, he may react negatively on the other actor's situation. And lastly, he may impose or threat with negative sanctions on the intention of the other and herewith activate the other actor's commitment. Thus actors may induce, deter, persuade, or activate the other actor (more discussion in chapters 1 and 2).

A second observation of Parsons is that in fact society and therefore also the researcher in its social environment constitutes a system in which various actors are specialised in certain actions. A system of actions should have a goal (goal attainment), produce something (adaptation), be more or less stable (latency), and should be integrated as a system (integration). An attractive characteristic of the Parsonsian approach is that the earlier mentioned basic action types at the system level appear as 'function' specific or dominant action types. These action types are then more or less institutionalised. The goal setting in a system is dominated by deterrence which is driven by effectiveness, expressed in authority (political capital) and transferred or exchanged by exertion of power. The production or adaptation is based on inducement which is driven by utility, measured in economic capital and generally transferred by money. The stability of the system (latency or pattern maintenance) is dominated by activating the other actor (driven by integrity), is expressed in knowledge (capital) and transferred by commitment or engagement. The cohesion or integrative specialisation is dominated by persuasion of each other leaning on solidarity, expressed in prestige and exchanged by the exertion of influence. Exchanges between actors on whatever level of aggregation are supposed to be always in a (dynamic) equilibrium.

5. Social systems of action defined in this research

The research presented in this dissertation is structured into a number of levels of aggregation of which some are analysed and tested in an empirical study. At each level we define the system that will serve answering the research questions. As each function can be defined again by four functions at each different level, the number of possible systems is substantial. We limit the number of systems to the most relevant for the purpose of this research. Given the characteristics of each function the four functions are specified for each subsystem separately and dependently on the specific characteristics of a system. The most aggregated level here is the system of strategic positioning. The researcher and his environment establish a relationship with each other as social actors, and both strive to produce scientific knowledge (goal attainment function). The means used for producing knowledge in research are strategic resources, such as e.g. knowledge, skills, time, research facilities and funds, shared between these two actors (adaptation function). Both actors, each to a certain extent, govern the system by making decisions regarding research goals and directions. These decisions are founded on their experience, norms and values (latency function). Collaboration between the actors understood as managing the relationship serves the integration of each action and so adding to the production of knowledge (integration function).

From the strategic positioning system we transit to another level via the production of knowledge function. We focus on scientific information and its role in the research process (this discussion on the role of scientific information can be found in chapters 4 and 5). Therefore, we define four functions for the process of making research results public as scientific information and for the acquisition of scientific information.

Researchers when making research results public have the goal to claim intellectual property for their scientific discoveries (goal attainment function). They claim intellectual property by means of a scientific publication (adaptation function). When making results public researchers acknowledge the work of others as they scrutinise the existing knowledge and scientific information in their research (latency function). Scientific publications are therefore subject to the established peer review process. Following Gross (1990), the peer review process can be seen as a negotiation process between the authors and the scientific community. The level of this negotiation then depends on the level of claims made in the article, and this level of claims determines how strict the review process will be: "The higher the level, the higher the article's status; the higher the status, the more difficult the negotiations" (Gross, 1990). As we argue in chapter 4, peer review serves the recognition of the researcher by 'branding' his contribution to the development of his scientific domain. In the peer-review process the quality of claims is being controlled (integration function).

When producing knowledge, researchers acquire scientific information for scrutinising in research. According to Rooy (1995), there are three main information needs of scientists: awareness of knowledge, awareness of new research outcomes and specific information. These information needs triggered the distinction between two types of acquisition: collecting and selecting. Both types of activities are seen as systems of actions and four functions are specified for each system.

Collecting is the daily, routinely acquisition undertaken in order to keep abreast with new developments in a scientific domain (goal attainment). This means gathering scientific information new to the domain. To be up-to-date they browse or scan various information sources such as e.g. scientific journals, databases or the Internet (adaptation). Researchers develop their own ways to assess what information is relevant for them and what can be collected (latency). Collecting is making an overview of a scientific domain in which the researcher operates and having scientific standards relevant to the researcher (integration).

Similar arguments apply for selecting, the difference being that the goal is to solve a specific information problem (goal attainment). Each time researchers acquire scientific information, they make use of information sources (adaptation). These sources used by researchers in selecting may be different than used for collecting. They usually acquire information from their scientific domains defined by the journals they read and the conferences they attend (integration).

These descriptions of the social systems and functions described above and the way we analyse them are rather general. The operationalisation of the four functions for the strategic positioning, making research results public, and acquisition of scientific information is presented in chapters 2 and 3 respectively. As we will see in these chapters, the four functions of Parsons were proven to be instrumental in developing the presented and tested model of strategic positioning.

6. Research implications

Empirical testing of the positioning model proves that this model is feasible and can be successfully applied in studying the performance of the researcher in the environment. A potential application includes further developing the model and testing the relevance of the concepts of strategic interdependence and organisational autonomy in other research activities than dealt with in this thesis. Such an application can be expanded to e.g. studying the performance of researchers in teaching as well the valorisation of scientific knowledge. For these other applications, the model would need to be redefined in terms of the appropriate system and by specifying the four functions as they depend on the research goal at hand.

An important and more practical application of the model of strategic positioning is in research management and organisation. The model can serve as a tool for developing strategies for researchers, research groups or research institutes. It can also serve policy makers in developing research policies as the model offers an understanding and awareness of the researcher's choices, intentions and situation, it allows policy makers to analyse strategies of universities and research institutes. This may improve the development of appropriate research policies and decisions about the allocation of resources.

The developed concept of business models can be applied in a broader sense in the management of research in enhancing the performance and sustainability of organisations such as research groups or research institutes or universities.

Structure of the dissertation

This dissertation is a collection of articles of which two have been published, one is under review, and two will be submitted for publication.

The dissertation consists of two parts. The first part focuses on the concept of strategic positioning of the researcher in his environment. The second part takes the developed model of strategic positioning to discuss further applications, such as issues of research management and in particular business models in research and in scientific information.

The first part consists of three chapters. Chapter 1 opens the discussion on the strategic positioning and discusses two sub-questions: '*What are the main elements of the strategic relationship between the researcher and his environment?*' and *'What are valid and reliable observables for the positioning model?'* In this chapter we introduce the positioning model and report on the first results of an empirical study on contractual obligations of the MESA+ Institute for Nanotechnology with its societal environment. The feasibility of the model in creating observables for the different modes of strategic positioning of the researcher, in this case MESA+, is confirmed. This paper is published in *Science & Public Policy*.

Chapter 2 focuses on a discussion of the impact of the strategic positioning of the researcher on the production of knowledge. More specifically, it discusses the differences between the various modes of positioning in the production of knowledge resulting from the strategic positioning model. These differences in modes are measured in terms of the energy or the effort the researcher spends in doing research as well as in managing this research including the acquisition of resources. In this study the energy is measured to assess what it costs the researcher to produce knowledge in different research settings, i.e. in dealing with different restrictions on research. In this chapter we also expand on answering the question '*what are valid and reliable observables for the positioning model?*' This paper is submitted for publication.

Chapter 3 deals with the question *'does strategic positioning affect the production of knowledge?"* It reports the results of testing the positioning model in the research environment. The model was tested in an empirical study comprising of a number of researchers from the MESA+ and IGS institutes, both at the University of Twente. The model predicts values for the production of knowledge. This paper will be submitted for publication.

The second part consists of two chapters. This part discusses business models for scientific publishing focusing on how these business models are related to the research process. It shows possible applications of the positioning model in the research environment by answering the question '*What are the elements required for developing business models in science supporting the production of knowledge?'* The paper of chapter 4 will be submitted for publication. The paper of chapter 5 is published in 2006 in *Information Services & Use*.

Part I.

Chapter 1: The research entrepreneur. Strategic positioning of the researcher in his societal environment*

Kasia Kurek, Peter A.T.M. Geurts & Hans E. Roosendaal

At present, two modes of the strategic relationship of the researcher with his environment are known. These are the 'ivory tower' and 'strategic research', known also as mode1 and mode2. In this paper, we develop an analytical model that not only predicts these two well-known modes but also leads to a new, third mode - the research entrepreneur.

The research entrepreneur is directing his environment by creating demand for his scientific products instead of supplying on the demand of his environment.

The first results of a few cases from an empirical study conducted at the MESA+ Institute for Nanotechnology confirm the feasibility of the model in creating observables for the different modes of strategic positioning of the researcher, in this case MESA+.

* published in *Science & Public Policy,* 34(7), 2007. DOI: 10.3152/030234207X244810

1. Introduction

The scientific research agenda is largely determined by the relationship between research and the society at large. This relationship is presently in flux, moving towards intertwinement of research and society. Researchers and practitioners involved in this discussion elaborate on the future role of university and society in the production of knowledge. This subject was addressed in a number of papers (Keleman & Bansal, 2002) and journal issues such as e.g. in a Special Issue of British Management Journal (Hodgkinson, 2001), the Academy of Management Journal (2001) and in a Special Issue of Research Policy (Leydesdorff, Meyer, 2006). In 1999, Gibbons explicitly raised the need for a new social contract between research and society that would result in mutual interactions and in a 'socially robust' scientific knowledge production (Gibbons, 1999). To the best of our knowledge no adequate solution has been given up till now. The delivered solutions (e.g. Leydesdorff, Etzkowitz, 1998; Novotny et al., 2003; Swan et al., 2007) are primarily based on descriptions of the observed relationships between research and society. This, however, doesn't lead to the study of the mechanisms of such relationships and are therefore as a consequence not informative about the goals and choices of the researchers and their institutes behind such relationships. To arrive at a more systematic and comprehensive, i.e. more analytical approach to this relationship, we develop a model explaining this relationship and the strategies behind it, starting from the researcher instead of its societal environment.

This relationship between society and researcher should reward both parties. For the society the relationship is rewarding if the research product being the result of the relationship will be serving society; for the researcher if this will serve him to attain his goals. The decision to enter the relationship with society, more specific the societal environment is a choice of the researcher. At present, two modes of such a relationship of the researcher and his environment are known. These are the 'ivory tower' and 'strategic research', known also as mode1 and mode2 (Gibbons et al., 1994). In this paper[1], we develop an analytical model that not only predicts these two well-known modes but also leads to a new mode, mode3 - the research entrepreneur. The research entrepreneur, compared to the researcher in mode2, is more leveraging in the relationship with the societal environment. The research entrepreneur is directing his environment by creating demand for his scientific products instead of supplying on the demand of his environment.

Generally, like in the above mentioned studies of the relation between research and society, the choices of researchers and their institutes are studied as reactions to changes of policies and developments in the environment such as social and technological change and change in the policy of the government. In studying the setting

[1] An earlier version of this paper was presented at the 40th Anniversary SPRU conference in September 2006 (http://www.sussex.ac.uk/Units/spru/events/ocs/index.php)

of goals and the choices related to these we start from the researcher in his environment and his long term priorities. This is an inside-out perspective allowing us to study and understand the strategies of these researchers. This model thus enables us to analyse strategies being developed by the researcher, at different levels of aggregation as an individual researcher, a research group, or a research institute. The starting point for developing such strategies is always the researcher influencing and being influenced by his environment. This environment defined as the world outside the researcher at a given level of aggregation is thus a dynamic environment and can include another researcher, government as well as industry. Both the researcher and his environment can develop strategies, e.g. to improve each strategic or competitive position. This view is fundamentally different from the view of the societal environment influencing the researcher, i.e. only the outside-in view, generally taken in the policy studies concerned.

The main goal of the researcher is to contribute by scientific research to scientific knowledge. To attain this goal the researcher seeks partners to share heterogeneously distributed strategic resources, such as research facilities, knowledge, funds, etc. Next to sharing resources, the researcher has to make the strategic choice (see also: Knorr-Cetina, 1981:33-48, Laudel, 2006) to what extent he is willing to accept the other partner to participate in governing research. Strategic choices are an integral part of the strategy leading to the strategic position of the researcher given his specific goals. These choices are strategic in the sense that making them structures the researcher's further behaviour because every such a choice limits the next choice he makes, e.g. setting research goals affects further choices regarding the acquisition of resources offered by the societal environment. Goals of the researcher are strategic in the similar sense as they structure the researcher's behaviour and his choices. If not explicitly mentioned, choices as well as goals, resources and relationships are considered as strategic in this paper. The strategy that the researcher develops, and therefore the strategic positioning, is not always conscious and explicit. Especially, individual researchers with their primary focus on conducting research often do not reflect consciously on strategic character of their choices. Nonetheless, the researcher has a goal, with long term consequence, to attain, such as a career in industry, tenure or growth of the research enterprise, even if not explicit.

In any relationship the issue of trust is a relevant issue (Hummels, Roosendaal, 2001). This paper deals specifically with strategic positioning of the researcher in the societal environment. This model of strategic positioning considers trust, as trust is not a specific object of study, as a ceteris paribus condition.

The strategic positioning of an individual actor as well as of a more complex organisation within their broader environment is subject of strategic management studies. These studies analyse long-term goals of organisations and the way these goals are attained in positioning. In this paper we make use of the models providing such

analyses in order to develop an analytical model of the strategic positioning of the researcher within his environment.

2. Strategic position of the researcher

The strategic position that the researcher establishes to attain his goals, is expressed in the negotiated and agreed relationship between the researcher and his environment. This being the case, this relationship, like any other relationship, is seen as a (temporary) strategic alliance, joint venture, merger or an acquisition between business partners. Such an alliance can be established between the researcher and his societal environment, even with another researcher or research group bound in a joint research project or programmes. An example of a relationship between two individual researchers is the relationship between a PhD student and his supervisor sharing heterogeneous resources like knowledge, skills, facilities and research funds. To describe this relationship we can then apply the established strategic management model for such a strategic relationship (Haspeslagh, Jemison, 1991). This model assumes that collaboration will be maintained if and only if this collaboration results in creating added value for both partners as compared to the situation in which such collaboration does not exist. This model contains two general dimensions to characterise the relationship: the organisational autonomy and the strategic interdependence of each of the partners in the relationship. This model can be applied to any relationship, i.e. irrespective of the nature of this relationship, between two or more partners because there is always an exchange of resources and partners always have some degree of organisational autonomy that can be measured in a relationship at hand.

Strategic interdependence is defined as the deliberate sharing of heterogeneously distributed resources, assets and capabilities between the partners in order to achieve a joint goal. Strategic interdependence is thus a necessary but not sufficient condition for an effective collaboration, meaning that close collaboration goes hand in hand with a position of high strategic interdependence, and vice versa.

Organisational autonomy of the researcher is defined as self-governing in deciding about the directions of research in a competitive environment, including setting goals, in which scientific knowledge is being created and scientific information is being used. A high position in organisational autonomy allows actors to make autonomous strategic decisions regarding setting goals and establishing how to attain these goals. A position of high strategic interdependence does not necessarily exclude a position of high organisational autonomy of the researcher. A strategic position is defined then as a combination of positions in organisational autonomy and strategic interdependence.

In this research, the assumption is made that in any relationship the partners strive in principle to maximise each own organisational autonomy and to minimise each own strategic interdependence. However, in a relationship partners may give up organisational autonomy and accept strategic interdependence, both to an acceptable

degree. This depends on the attractiveness of the goal, a long term goal dictating what kind of collaboration is acceptable, e.g. career, the growth, of the group or institute, etc. If this goal is very attractive partners may compromise their mid-term goals. The feasibility of achieving a goal determines such an acceptable position in either organisational autonomy or strategic interdependence. This means that the positions in organisational autonomy and strategic interdependence can be different for each different collaboration, i.e. having a different goal between the same partners will then result in a different mode of a position.

A model of possible modes of strategic positioning based on these two dimensions: organisational autonomy and strategic interdependence is shown in figure 1.

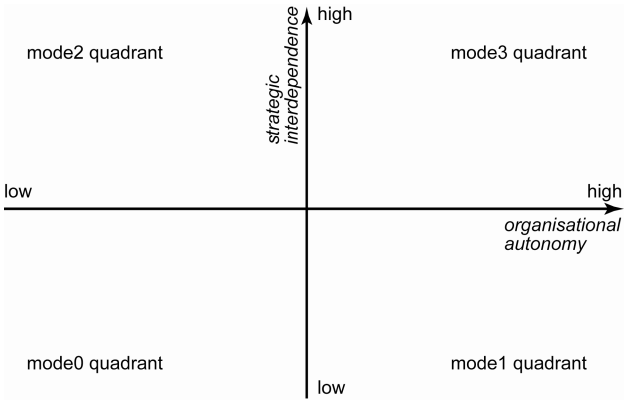

Figure 1. Types of modes of strategic positioning.

This model provides a typology of modes of positioning. In reality these modes are not discrete but continuous. The four distinct modes contain a variety of different positions along the axes. The first type is characterised by both a position of low organisational autonomy and low strategic interdependence. In the mode0 situation (see figure 1) there is no strategic relationship between the researcher and the societal environment. An example of such a mode is a researcher in the Middle Ages associated with and paid by a sovereign. This mode is rather irrelevant for this discussion.

A second type is a position of high organisational autonomy and low strategic interdependence. In mode1 (see figure 1), the researcher sets research directions driven by scientific curiosity. There is a position of low relationship between the researcher and his societal environment. Therefore, the researcher does not need to take into account societal needs and demands when setting these research goals. Results of research are not necessarily meant to be of societal relevance. Therefore, the researcher communicates and collaborates with his research environment and not with the societal environment. In this case, the researcher is not connected to the societal environment and therefore does not influence this environment. This type of

researchers' positioning is well-known as 'ivory tower' or 'free research' (Gibbons et al., 1994).

The third type is a position of low organisational autonomy and high strategic interdependence. In this mode2 (see figure 1), the societal environment directs the researcher. It influences research directions taken by the researcher and ipso facto influences the scientific products the researcher delivers. This means that the researcher matches his own research problems to existing research programmes based on the demand of the societal environment. According to Novotny et al. (2003) the researcher is "context-sensitive". Examples of this mode are consultancy and research outsourced by a financial partner if this partner demands particular studies to be carried out and the researcher complies. In this case, the researcher does not influence his societal environment in creating demand for his scientific products but supplies in reaction to the demand by the societal environment. The researcher listens to his environment and fulfils societal needs. By the societal need we mean a need which is explicitly expressed by the partner of the researcher, as a representative of the societal environment, in the relationship. The properties of this mode show that this mode is comparable with Gibbons' mode2 or strategic research as broadly described by him, his co-authors, and Ziman (Gibbons et al, 1994, Ziman, 1994).

Given the fact that the model adequately predicts these two well-known relationships of ivory tower researcher and the mode2 researcher means that the model is consistent. Given this consistency, the model postulates a fourth possibility, which has to be observed empirically. Failure to observe this mode means that as a characteristic of a deductive model the model has to be revised. This fourth possibility is characterised by a position of high organisational autonomy and high strategic interdependence. We call this mode mode3: the research entrepreneur. This represents a new type of positioning of the researcher and his research with respect to the societal environment.

The mode3 position of high organisational autonomy and of high strategic interdependence means that the researcher shares resources with his environment like the mode2 researcher. But contrary to the mode2 researcher, the research entrepreneur has the opportunity to autonomously determine directions of research. He retains his own responsibilities for directing a project. The research entrepreneur is an answer to the need for a social contract rewarding all the parties, as proposed by Gibbons (1999): the research entrepreneur interacts with the societal environment in such a way that "he speaks to the environment and the environment speaks back to him". The research entrepreneur "speaks to the environment" by developing, like a business entrepreneur, appropriate strategies to create demand for his scientific products, in this way influencing his societal environment. In this context, he influences strategies and policies developed by his environment. The environment "speaks back to him" by developing appropriate strategies reflecting its interests and accounting for the strategies developed by the researcher, resulting in possible research policies. The two

parties, the researcher and the societal environment are keen on establishing this relationship; the researcher because his research will be funded and his research interests will be realised, the societal environment because scientific results will be applicable and appropriate policies can be set. Being a part of the societal environment (we will elaborate on that in the next paragraph) the research entrepreneur can recognise and define a societal need for improving and further developing new or existing products, and deliver such a product.

The research entrepreneur is, instead of just oriented towards society, fully intertwined with this societal environment and strategically interdependent of this environment. At the same time, as stated above, the research entrepreneur is highly autonomous. This position of high autonomy is expressed in decisions regarding research goals to achieve, potential collaborators, or potential users of research results. The research entrepreneur acting within his societal environment and having a clear strategic position towards this environment increases his ability to influence this environment.

Summarising, the model proposes a continuum of modes of strategic positioning elucidated along four ideal types. Given the fact that there is a continuum we argue that one and the same actor can display a combination of different positions in different relationships compatible with his goals. The model of strategic positioning allows an inside-out approach in developing strategies next to an outside-in approach in developing strategies and setting policies. Only the presented model of strategic positioning combines these two approaches and can therefore predict the new mode3, next the well known mode1 and mode2.

The model can be easily applied to analyse relationships between the researcher and the company in which he is appointed. The company is seen as the societal environment in which the researcher positions himself. Take Google as an example. Google allows its researchers to spend 20% of their work time on projects of their interest, projects that are not necessarily in their job descriptions (source: Google Jobs). The researchers set their research goals autonomously at the same time being employees of the company. Very often these projects become Google commercial products after all. This is a positioning close to the mode3 positioning. The researcher working in industry can, like the researcher working in academia, position himself in different modes; have different degrees of organisational autonomy in different projects. This can be a positioning like the mode2 researcher (in Development) or the mode3 researcher (as in the example of Google).

Given the definition of the researcher and his societal environment this model is applicable to all situations in which the researcher is involved.

3. The distinction between research entrepreneur and academic entrepreneurship

The concept of the research entrepreneur is distinctly different from the concept of academic entrepreneurship described in depth in the literature (e.g. Louis 1989; Balazs,

1996; Leydesdorff, Etzkowitz, 1998). The difference between these two concepts originates from the methodological approach. Given his goals, the research entrepreneur is predicted from an analytical model (being by definition a deductive model), as are the other modes. This model does not only describe the relationship between the research and its societal environment but analyses the parameters of such a relationship and results in observables of different modes. The concept of academic entrepreneurship is a product of a purely descriptive (i.e. inductive) model.

The concept of academic entrepreneurship is elaborated in the triple helix model (e.g. 1998) by Leydesdorff and Etzkowitz in terms of relations between entrepreneurial university, industry, and government, and their dynamics. The entrepreneurial university is then described as "independent of state" but "interacting with other spheres" (Etzkowitz, 2003b), following directions when making connections with business for research contracts and transferring knowledge to society, and creating innovations (e.g. 2003a, b). Etzkowitz's description of the entrepreneurial university is based on a typology using the following dimensions: independence of state and the interaction with other spheres. However, independence of state is a specific aspect of organisational autonomy because it implies the relationship with the government only, leaving out other partners such as research institutes, etc. whereas the dimension of organisational autonomy does not exclude any partner. The interaction with other spheres is a specific aspect of strategic interdependence as it does not address a joint effort in doing research by sharing heterogeneous resources. These dimensions of the entrepreneurial university are also aspects of the general dimensions because this model concerns only one level of aggregation: the university level. The model of strategic positioning introduced in this paper analyses the researcher at different levels of aggregation. In this respect the dimensions of independence of state and the interaction with other spheres are a subset of the general dimensions we use as the general dimensions are translated to the university level. Moreover, Etzkowitz defines as the most important characteristic of academic entrepreneurship "that the problem definition comes from outside sources as well as from within the university and scientific disciplines" (2003b). As argued in this paper the problem definition is important but only one aspect of the positioning that indicates the position in autonomy of the researcher.

As the dimensions of Etzkowitz are specific aspects of organisational autonomy and strategic interdependence, our model of strategic positioning is able to predict not only mode1, mode2 and mode3 but also the entrepreneurial university as described by Etzkowitz. The entrepreneurial university has then a different position than mode3 in the continuum of modes of strategic positioning. In the entrepreneurial university the researcher interacts with his environment but the model does not address the sharing of heterogeneously distributed resources. The position of organisational autonomy is not that high as for the research entrepreneur. This being the case, the Triple Helix

researcher will be positioned in the mode3 quadrant, but closer to the mode2 quadrant (see figure 2) than the research entrepreneur.

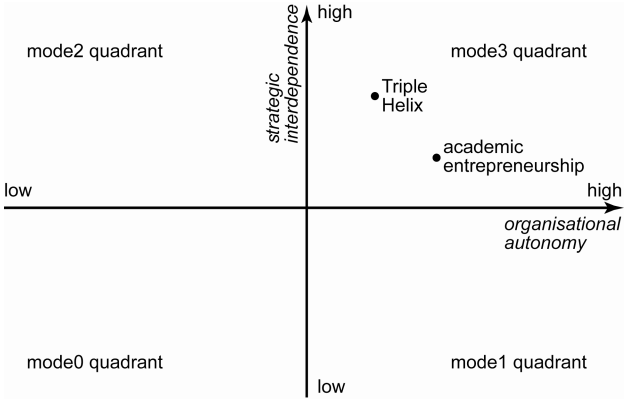

Figure 2. The position of Triple Helix and of academic entrepreneurship on the continuum of strategic positioning.

In the literature also other concepts of academic entrepreneurship are discussed. Academic entrepreneurship is characterised as obtaining research funds from companies willing to buy research results, generate supplemental income, and create commercial value that results in patents and start-ups (e.g. Louis et al., 1989), or as commercialisation of the intellectual resources of the researcher (e.g. Oliver, 2004), or as "the attempt to increase individual or institutional profit, influence, or prestige through the development and marketing of research ideas of research-based products" (Louis et al., 1989).The research entrepreneur as a mode of strategic positioning is the result of the positioning leading to the attainment of the goals of the researcher. As strategic positioning includes making choices, the research entrepreneur mode is a choice of the researcher. The research entrepreneur refers to an entrepreneur in research – the researcher strategically managing the research enterprise[2]. The concept academic entrepreneurship does not include these aspects. This concept can be, however, explained by the model of strategic positioning. The academic entrepreneurship will be positioned in the mode3 quadrant (see figure 2) as it has, as defined before, a position of high strategic interdependence and of rather high organisational autonomy, but not as high as the research entrepreneur.

Furthermore, the notion of mode3 we present differs from the mode3 presented by Huff (2000) and Huff & Huff (2001) in the sense that these authors describe their mode3 in terms of final scientific products rather than explain what determines the

[2] The research enterprise is defined as an individual researcher or a group of researchers performing activities contributing to scientific research which adds to the production of knowledge.

creation of such products. In the mode3 proposed by Huff the behaviour of the researcher is characterised by the modes of knowledge production (according to Gibbons, 1994, Huff 2000). The approach of Hodgkinson et al. (2001) proposing a typology to study the researcher's behaviour using the dimensions: 'theoretical and methodological rigour' and 'practical relevance' or the approach of Stokes (1997) with the dimensions of 'fundamental understanding' and 'consideration for use' is different. The dimensions used by Hodgkinson and Stokes are specifications of the general dimensions of organisational autonomy and strategic interdependence used in this paper because Hodgkinson and Stokes limit their discussions to the research environment, i.e. to research and results of this research only, without considering restrictions on this research imposed by its societal environment. Furthermore, as these approaches are based on limited aspects of the dimensions of strategic positioning they result in different modes characterising different types of research rather than modes of strategic positioning. The degrees of 'theoretical and methodological rigour' or 'fundamental understanding' are aspects of organisational autonomy. This is because it is the choice of the researcher what methodology or theory to use as well as whether he is willing to give up his autonomy and let his societal environment direct theoretical and methodological rigour in a joint research project. Organisational autonomy includes theoretical and methodological choices but those are not the only ones to be made in a collaboration. 'Practical relevance' and 'consideration for use' are both aspects of strategic interdependence because it's again the choice of the researcher to share his scientific product with his societal environment and to commercialise it.

4. Analysis of the strategic positioning of the researcher

Organisational autonomy and strategic interdependence measure the positioning of a single actor but can only be observed in the relationship with the other partner. Therefore, to identify the positioning of the researcher we will analyse his relationship with his societal environment. Following Gibbons, any social relationship, especially the relationship between the researcher and his environment, is "an agreement built on trust which sets out the expectations of the one held by the other, and which – in principle – includes appropriate sanctions if these expectations are not met" (1999). This goes back to Talcott Parsons (1963).

To analyse this relationship we lean explicitly on the generalised media of interchange that were systematically explored for the first time by Parsons (Parsons, 1963) and later by Habermas (adding law as an additional medium; 1987) and Luhmann (adding truth and love; 1995). The main idea is that social actors having a goal to attain interact in a structured way. Goals drive actors to make choices and then perform subsequent actions. These choices and actions are organised in a social system. Knowledge about the organisation of actions allows us to predict actors' behaviour in any other situation. This can be used in developing an analytical and at a further stage a predictive model. The use of these ideas implies that we consider science and also society at large as social systems in which researchers act as social actors.

The researcher making choices is being influenced by other actors: his research environment and his societal environment. By analysing the relationship between the researcher and his environment we can actually measure how the choices of the researcher are influenced by his environment.

The researcher starts establishing a relationship with a goal in mind that he strives to achieve. This goal is expressed in his intentions and situation. The researcher confronts then his intentions and situation with intentions and situation of his environment. The intentions, but not the goal, are negotiable. The negotiation process ends with an agreement that is an expression of intentions and situations of the partners including incentives as positive sanctions and negative sanctions. These sanctions could be used in case the partners deviate from situations and intentions they agreed upon. The agreement is then the enactment of the negotiation. The choices the partners make afterwards are executed in terms of positive or negative sanctions included in such an agreement. The choices of the researcher result in his position in organisational autonomy and in strategic interdependence in a relationship he accepts in this specific relationship. We can then observe positions in organisational autonomy and strategic interdependence in potential sanctions on which the partners agreed. An analysis of contracts between research and environment will result in a partial reconstruction of this negotiation process.

The negotiation on the research direction is usually a direct act between the researcher and his societal environment. Even if research contracts are entered at the institute level it is the researcher who makes the choices. Various institutions such as technology transfer offices and lawyers function as support of the researcher but are not directly involved in the negotiation deciding on the research directions.

In a social relationship, actors affect each other's intentions and situations by using positive or negative sanctions. The actor then controls and changes the situation another actor is placed in, independently of another actor's intentions, or the actor affects another actor's intentions, independently on changes in his situation (Parsons, 1963; Geurts, 1992). This makes another actor a dependent one. In practise, both partners affect both the intention and the situation of each other in a relationship by using the same sanction. In the analysis of a relationship between the researcher and his environment positive sanction refers to the reward that a dependent partner of a relationship can gain, e.g. the value created in research benefiting for both partners. A negative sanction refers to conditions of a contract which must be met by the dependent actor. If the dependent actor behaves against the contract, the contract and the relationship are broken.

Intentions of the researcher refer to scientific aspects of the research enterprise including directions of research and management of research, the acquisition of scientific information, exchange of scientific information between the partners, and the dissemination of scientific information to the societal environment. Intentions of the societal environment refer to research results this environment is able and willing to

apply. The situation of the actor (the researcher or his societal environment) refers to organisational aspects of the research enterprise.

A relationship between the researcher and his environment is then analysed in terms of four types of behaviour as proposed by Parsons (1963). These types of behaviour are used by the partners to get the other to comply with their demands.

Table 1. Types of actor's behaviour towards another actor and currencies of exchange (in brackets) (Parsons, 1963, p.44).

	intention	**situation**
positive sanction (incentives)	persuasion (influence)	inducement (money)
negative sanction	activation of commitments (commitment)	deterrence (power)

Table 1 presents the types of behaviour and concomitant currencies of exchange (in brackets). To be able to compare different relationships established between the researcher and his societal environment we translate the types of behaviour of these partners to these currencies. A currency of deterrence is power. For example in a relationship between the researcher and his environment, the environment has power to e.g. terminate a research contract (negative sanction) and therefore to affect the situation of the researcher. A currency for persuasion is influence. To influence others, a partner uses his prestige, reputation. The higher the reputation of the person, the easier to persuade others.

The researcher influences his societal environment when he offers (positive sanction) to create a new scientific product, e.g. a new theory that will supersede an existing one (effecting intentions of the users). When the partner in a relationship wants to induce the other he uses money. Money is not always 'money' in the literal sense. Money has no value in itself; it is rather a symbol for value. It can be a symbolic capital like information or a physical product which is being exchanged. It can be any scalable added value. Another way to get one partner to comply with demand is to commit him to the system of values and norms of the other partner. The researcher being a part of his research environment is committed to comply his research with high scientific standards, as discussed by Merton in his normative structure of science (Merton, 1973). In a relationship with his environment, the researcher engages his environment to values and norms of the research environment, to a different extent in different relationships.

5. The balance in currencies of exchange

The exchange of currencies between actors on whatever level of aggregation results in a dynamic equilibrium. In principle, there are always four currencies exchanged by the partners within a social system, thus in a strategic relationship. The difference

between relationships is in the balance in sanctioning on the one hand and in being dependent on the other hand. On balance, the partner who sanctions the other in a relationship has a stronger flow of currency; the one who is dependent has a weaker flow. This can be applied to all four types of behaviour and therefore to all four currencies of exchange used by partners. In studying relationships we are investigating this balance in the currencies as this balance indicates the positioning and behaviour of the researcher in his environment.

Moreover, we analyse the flow of currencies in relationship between the researcher and his societal environment, not relations between the currencies. Therefore we look at the currencies separately.

As mentioned above, currencies of exchange indicate the position in both organisational autonomy and strategic interdependence. These dimensions are measured on ordinal scale ranging from 0 to total organisational autonomy or strategic interdependence, assuming transitivity and with the range determined by research under study. A position of high strategic interdependence means that the partners share resources (therefore a position of high strategic interdependence). This being the case, money and commitment are being exchanged. A position of low strategic interdependence means that money and commitment are not exchanged directly. If there is a relation established then organisational autonomy can be measured. The difference between the modes of strategic positioning is then in the difference in balance of currencies exchanged by the partners. High organisational autonomy in terms of currencies means that the researcher can sanction his societal environment. Low organisational autonomy means that the researcher is dependent on his societal environment in the relationship.

In mode0 there is no exchange between researcher and societal environment. The position of organisational autonomy and of strategic interdependence is low by definition. This means that there is virtually no strategic relationship and therefore there are no dependent partners. Therefore this mode will not further be taken into consideration

In mode1 there is a position of high organisational autonomy combined with a position of low strategic interdependence. Therefore there is no direct flow of currencies of exchange between these two parties. However, there are money and commitment exchanged indirectly. In mode1 the research institute of the researcher and external institutions exchange money. These institutions do not directly connect money with research tasks and do not influence research directions (e.g. lump sum financing of universities). In such a situation, the researcher is accountable not to his societal environment but to his research environment, meaning that he has to comply with the norms of this research environment. He has to produce knowledge according to agreed standards without being constrained to specific, externally set research goals. Furthermore, the researcher in mode1 does not produce knowledge that can be applied directly and can so influence his societal environment. As mentioned before the

difference between the modes is in the balance of the use of sanctions. In mode1, on balance, there is a stronger flow of power and influence from the researcher. The researcher makes use of power and influence only within his research environment. In the mode1 situation, the researcher does not sanction his societal environment but only his research environment and vice versa.

Mode2 is characterised by a position of low organisational autonomy combined with a position of high strategic interdependence. Thus, there is an exchange of currencies between the researcher and his societal environment. In such a relationship the environment sanctions the researcher. The researcher is accountable to his environment which is able to set specific research goals for the researcher. His societal environment will ask the researcher to deliver a specific commitment dedicated to a specific research task. This does not necessarily comply with high scientific standards, but must comply with the demand of his environment. Furthermore, next to setting research goals the environment influences the researcher and his research. The environment has also power in the mode2 relationship. On balance, there is a stronger flow of power and influence from his societal environment than from the researcher. The research directions proposed by the environment can hardly be influenced and researchers have to match their own directions of research.

In mode3 the balance in power and influence is positive for the researcher. In a mode3 relationship both the researcher and his societal environment are strong enough to sanction each other even if they differ in competences. On balance, there is a stronger flow of power and influence from the researcher than from his environment. The most important characteristic of the research entrepreneur is that he influences research management and directions including research goals in such a way that he creates demand for scientific results he wants to deliver. The research entrepreneur influences his environment by creating demand for the scientific products he produces. Even being an equal partner in the collaboration the research entrepreneur is still accountable to his societal environment, but to a certain, negotiated degree. This degree depends on how much of autonomy he accepts to give up as quid pro quo for reaching his goals. Moreover, the exchanged commitment in the mode3 relationship is more general than in the mode2 relationship as it deals with more general issues such as e.g. ethical issues such as genetically modified food or cloning (van Steendam, et al. 2006) as will be seen below. Commitment is then not connected to specific research tasks and the researcher himself directs deliverables.

6. First empirical results

To test the feasibility of the model of strategic positioning presented in this paper, a study on the MESA+ Institute for Nanotechnology was executed. The research question addressed in this particular study is: *What mode of strategic position does the researcher establish in a relationship with his societal environment?*

As mentioned before a strategic relationship is defined as a deliberate and established collaboration in which one partner sanctions the other who depends on him. One of the possibilities to observe sanctions is to analyse formal documents such as contracts. Contracts are seen as expressions of desired intentions and desired situations. They in fact show the positions the partners want to establish with respect to each other and the needs of the partners that had to be resolved explicitly to establish the relationship. According to the model of strategic positioning, we look at sanctions in order to assess the use of currencies of exchange and then to determine the mode of a position. Therefore, in the empirical study we carried out content analysis of contracts of research projects at MESA+. Contracts are usually dealing in the majority of their content with standard issues, but focusing on the non-standard, unique issues gives insight to what has been the core of the negotiation and therefore indicates the positioning of the researcher in a relationship.

Contracts show the variety of collaborations the researcher has. The researcher can establish different relationships with different partners. In different relationships he can position himself differently and accepts a different balance in the exchange of currencies. This can even be the case with the same partner but in separate research projects. The added value in the project may well differ in different relationships.

The societal environment of MESA+ is represented by NWO (Dutch National Science Foundation), STW (Technology Foundation), Senter (an agency of the Dutch Ministry of Economic Affairs for implementing policies on: innovation, energy and climate and environment and spatial planning), FOM (Research foundation related to NWO), the European Commission (framework programmes), and industry. The sample to obtain preliminary findings consists of 5 contracts signed with: STW, Senter, two with the EC, and one with a company.

These contracts were studied to analyse clauses indicating the presence of observables for strategic interdependence and organisational autonomy. More specifically, clauses dealing with sharing resources with the environment including research funds, research facilities, scientific information and scientific products, collaboration were examined to find potential sanctions that would indicate strategic interdependence. Clauses about management and organisation of the project and research were examined to find indications for organisational autonomy. These clauses are being evaluated in terms of the use of currencies of exchange.

A four-step analysis was applied. The first step is to assess if there is a sufficient position in strategic interdependence in terms of resources and capabilities being exchanged. The second step is to assess a position in organisational autonomy which partner sanctions the other affecting his intentions and/or situation. The third step is to decide which currencies are being exchanged between the partners. The fourth step is to decide which of the modes of positioning is predominantly represented in the contract.

Some preliminary results are highlighted in an example of the relationship between MESA+ and industry as described in a contract with a company. This contract shows positive and negative sanctioning by the contract company, as presented in the table 2. The researcher appears to sanction only negatively.

Table 2. The exchange of currencies between MESA+ and a company (IN 00301).

	intention	situation
positive sanction	influence	money • company
negative sanction	commitment • company • researcher	power • company

The company sanctions positively (offers payment) changing the situation of MESA+ (organisational aspects of research): "(company) wishes to engage the university in the carrying out of a certain study in this field; and the university is willing to arrange for such a study to be carried out". This citation indicates the use of money by the partners with a stronger flow of money from the company.

The company sanctions negatively MESA+ (can terminate the contract) and in fact can change the situation of MESA+ (organisational aspects of research): *"(company) shall not unreasonably withhold its consent to the publication of (company) information and/or results pursuant to clause (..), but may request the university to delete certain (company) information and/or results or to delay publication for a period (...)"*. This example shows the use of power with a stronger flow of this currency from the company.

The company again appears to negatively sanction MESA+ which is intentionally dependent (wants to publish) on the company: "(company) recognises that the research associate and the supervisors may wish to publish some or all of the results, together with any relevant (company) information, as a paper within the university or in the open literature. Before any such publication the university shall arrange for the paper to be passed to (company) for examination and comment". At the same time, the researcher can sanction negatively the company affecting its intentions if he wants to publish the scientific results. This exchange of sanctions shows that the balance in terms of commitment is in equilibrium between the partners.

The analysis of this relationship shows that the partners both possess resources, *"the university possesses expertise in a field".* The company has financial resources and information that can be used in the research and exchange them (money and commitment). It can be concluded that they are highly strategically interdependent. The use of positive and negative sanctions by the company shows that the researcher is dependent. On the other hand, he can also sanction the company. However, on balance there is a stronger flow of power, money and commitment from the company. The

position in organisational autonomy is not very high for the researcher. We can conclude that this collaboration with this specific company is not mode1, and is more mode2 than mode3. Collaboration with other companies may well yield different relationship depending on the specific arrangements made.

The next example shows the relationship between MESA+ and the European Union under the 6th Framework Programme. According to this contract, MESA+ builds a Network of Excellence together with other research universities and institutes. The results of the analysis on this contract are shown in the table 3.

Table 3. The exchange of currencies between MESA+ and the EU (NoE 01302).

	intention	situation
positive sanction	influence • researcher	money • societal environment • researcher • researcher in relationship with the collaborators
negative sanction	commitment • societal environment • researcher	power • researcher in relationship with the collaborators • societal environment

A few citations will be presented to illustrate table 3 and our way of analysing this contract. The researcher can sanction positively his environment offering new scientific products and business units which will disseminate these products and he tries to change the societal intentions by creating a demand on its products: *"knowledge generated and spread through (the network) is expected to lead to the development of marketable new technologies, processes, tools and devices that will in turn have great impact on science, industry and society"*, and *"special attention is paid to the formation of business cases and to the establishment of an integrated European curriculum for life sciences related nanotechnology"*. This example indicates a positive balance of influence for the researcher.

The EU by offering research funding (positive sanction) changes the situation of the researcher. At the same time, MESA+ offers to change the position of European research in nanotechnology (positive sanction): *"we aim to leverage the potential and existing quality of some of the best groups in nanotechnology that Europe has to offer, in order to create opportunities for Europe to become leading in one of the relevant areas within nanotechnology"*. In this case, the EU exchanges money.

The EU requires special treatment of animals used in experiment: "two members of the (network) will face ethical issues in the sources of cell and animals used in all parts of the proposed work …" (this limitation to the research method to be applied is specified in the contract). Requiring this, the EU sanctions negatively the researcher and

can affect the researcher's intentions. This combination of the two dimensions shows the use of activation of commitment by the EU.

MESA+ is obliged by the EU to deliver progress reports otherwise it can lose its reputation and it can change organisational aspects of research (situation): *"the project co-ordinator MESA+ will organise an annual assessment meeting (…) with all parties and the Commission's representative(s)"*, and *"final versions will be proved before the end of each year for the assessment review by the European Commission"*. In this case, the EU exchanges power.

The analysis of the relationship between MESA+ and the EU shows that the partners exchange money and commitment. This means, according to the model of strategic positioning that the partners are strategically interdependent. Furthermore, both partners can sanction one another. On balance, there is a stronger flow of influence, money, power, and commitment from the researcher. This indicates that the researcher is highly autonomous. On the base of this analysis we can then conclude that this collaboration is predominantly mode3. These results are consistent with the EU charter on the FP6 according to which the FP6 supports the researcher to be autonomous in strategically managing research, i.e. choosing the directions of the research (The Sixth Framework Programme in brief, 2002, http://ec.europa.eu/research/fp6). It supports the researcher to behave as the research entrepreneur that should result in "a durable restructuring and reshaping of the way research is carried out in Europe in a given area" (http://ec.europa.eu/research/fp6).

7. Summary and conclusions

In this paper the concept of strategic positioning is being applied to the relationship between researcher and environment. On the basis of this concept, a new, analytical model of this relationship of the researcher is developed. The model is built on the assumption that the researcher has goals and to achieve these goals he positions himself in his societal environment. The second assumption is that he establishes a relationship with this environment when positioning, and such a relationship is seen as a strategic alliance, joint venture, merger or an acquisition. The model results in different modes of strategic positioning. These modes depend on the researcher's choices and on his goals. The model is able to deal with the researcher at different levels of aggregation ranging from individual researcher to research institute or research at large.

Next to the modes well-known from the literature, mode1 – ivory tower and mode2 – strategic research, the model predicts a new mode3 – the researcher entrepreneur. The research entrepreneur, as distinct from the other modes, is highly autonomous and at the same time fully intertwined with his environment. This additional mode of strategic positioning is claimed to be the answer to the need, as articulated by Gibbons, for a new social contract between research and its societal environment requiring research to "enter the agora and participate fully in the production of socially robust

knowledge" (1999). To paraphrase Gibbons (1999), the research entrepreneur speaks to his societal environment and this environment not only speaks back but also listens to the researcher as he directs his environment.

The model of strategic positioning can be used as an instrument for the analysis of the position of the researcher working in the research enterprise. This model can also serve as an instrument for strategy development by the researcher as it takes the view of the researcher interacting with his societal environment. In distinction to research policy approaches, the model analyses the choices of researchers and their institutes as reactions to changes of policies and developments in the environment such as social and technological change and change in the policy of the government. In this context, it allows the researcher to translate research policies into his behaviour and to analyse if these policies are relevant and what they indeed mean for the researcher. At the same time, the model allows the societal environment to analyse the positioning of the researcher. This allows the environment to develop appropriate strategies or policies in its interaction with the researcher.

Policy studies take a different view on the relationship between the researcher and his environment. Policy studies generally start from the environment, being in this case the government imposing restrictions on research goals and on the heterogeneous distribution of resources to which the researcher has to react. As stated, in our model it is the researcher who develops strategies to influence his dynamic environment. These restrictions can be certain research programmes financing only application driven research or restrictions on doing certain research such as ethical issues mentioned before. The model of strategic positioning can predict the new mode3: the research entrepreneur as it combines an inside-out approach in developing strategies with an outside-in approach in developing strategies and setting policies.

In this paper we present the results from the preliminary study of contracts that MESA+ closed with its partners. These results show that the researcher establishes in his negotiations different strategic positions in different relationships with different partners. The position depends on the strategic goals of the partners and on how much of the resources the partners are willing to share and how much autonomy is necessary to retain in order to attain each partner's goals. MESA+ in its relationship with the EU positions itself more as the research entrepreneur and at the same time, in its relationship with a company positions itself more as the mode2 researcher. This is an example of a relationship of two strong partners who are strategically interdependent on each other resulting in a joint goal and an exchange of resources to attain this goal, and at the same time, the researcher is autonomous enough to influence his societal environment and the EU as its representative. This relationship is typical mode3. On the other hand, MESA+ can be dependent on a partner such as a company who wants the researcher to deliver a solution to a set of certain research goals only. This relationship is a typical mode2 relationship.

These empirical findings confirm the feasibility of the proposed analytical model; the model is feasible to create observables for the different modes of strategic positioning of the researcher. Further research focused on predicting the performance of research tasks e.g. the acquisition of scientific information by the researcher as determined by strategic positioning will be reported in future. Other research based on the presented model may deal with studies on the researcher's career or the research institute's performance and sustainability.

Contracts are not the only method confirming the feasibility of the model. Contracts are used because they report objectively on intentions, situation and potential sanctions at the moment of the negotiation. Another method that will be applied in our research is the method of structured and in-depth interviews. Interviews will collect information additional to the information obtained in the contract analysis. However, in order this model to be tested it requires further development. This development will lead to expanding the model to a predictive model.

The relationship between the researcher and his environment resulting in joint research projects has been seen as a strategic alliance, joint venture, merger or an acquisition. The two dimensions organisational autonomy and strategic interdependence analysed in this paper are the relevant dimensions to look at these relationships at different levels of aggregation. As we have shown in this paper these dimensions are equally relevant to look at the relationship between researcher and societal environment. The model not only predicts the well-known modes of strategic positioning of mode1 and mode2, but predicts next to these well known modes, a new mode3 – the research entrepreneur.

The model is able to predict positions in organisational autonomy and strategic interdependence that the researcher most probably is likely to accept given his goals. Therefore it is able to predict the mode of strategic positioning the researcher decides to establish, under the assumption that the researcher behaves like a rational actor and given ceteris paribus conditions.

The researcher will in the long term strive to achieve a position of highest possible organisational autonomy and lowest possible strategic interdependence. Along the path to achieve this desired strategic position the researcher may encounter the need to compromise on positioning in mode2 or in mode3. But at the end of the day mode2 and mode3 will only be intermediate positions necessary to attain the desired mode1 position.

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Chapter 2: Strategic positioning of the researcher in his societal environment and its role in the production of scientific knowledge*

Kasia Zalewska - Kurek, Peter A.T.M. Geurts & Hans E. Roosendaal

The production of scientific knowledge is often described in terms of mode1 and mode2. The strategic positioning model, presented here, adds a new mode3 – the research entrepreneur. This mode3 emerges from the fact that we take into account the inside-out view on the production of knowledge next to the usual outside-in view. The model is based on the two dimensions of strategic interdependence and organisational autonomy and it allows analysing the sharing of resources between the researcher and his societal environment and the governance of these partners in the production of knowledge.

This article delivers a further conceptual development of the positioning model introduced earlier.

A study of research contracts of the MESA+ Institute for Nanotechnology at the University of Twente shows that the model is feasible in creating observables and therefore can be applied in further research.

In general, the model can be applied by researchers and research institutes in developing strategies and by the environment in developing research policies.

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1. The research environment

The production of scientific knowledge is currently a broadly discussed topic (see e.g. Special Issue of British Management Journal, 2001; the Academy of Management Journal, 2001; Special Issue of Research Policy, 2006; Organisation Studies workshop: The Generation and Use of Academic Knowledge about Organisations, 2007). Not only because scientific knowledge is crucial for the development of science but also because of the great interest of society in scientific knowledge. Researchers therefore try to find a balance in the future role of science and society in the production of knowledge (e.g. Godin & Gingras, 2000).

The approaches to the research organisation known from the literature such as 'the new production of knowledge' (Gibbons et al., 1994), 'post-normal science' (Funtowicz & Ravetz, 1993) and 'the triple helix' (Etzkowitz & Leydesdorff, 1997) describe the emerging influence of society on the knowledge produced in research. Recently they were reviewed by Hessels & Van Lente (2008) who also raise a need for an empirical study of the notions of mode1 and mode2 (see also Godin, 1998). These approaches, in particular the approaches of mode1 and mode2 taken by various researchers, take the outside-in view on the production of knowledge. This is a view of how the production of knowledge changes at the overall level and what consequences it has on the society. In this paper we make use of a model that applies the concept of strategic positioning to analyse the relationship between the researcher and his societal environment (Kurek et al., 2007) and present an empirical application of this model. This model does not only take the outside-in view represented in the abovementioned policy studies but also the inside-out view. This inside-out view is the view of the researcher with articulated strategic goals positioning himself and his research in his societal environment in order to attain these goals. With the researcher we mean an actor at different levels of aggregation: research at large, the research institute, the research group, the individual researcher. The positioning model enables an analysis of strategic positioning at different levels.

This article in an extension of the paper published in *Science & Public Policy* in 2007 (Kurek et al.). In that article we introduced the positioning model resulting in a continuum of modes in which 4 typical modes of strategic positioning can be distinguished. In this article we postulate that this model and the modes can be relevant in analysing different conditions under which scientific knowledge is produced. Additionally, we present a further conceptual development of the model as well as operationalisation of the model in order to be able to test the model empirically. This model is used in this paper to analyse the production of scientific knowledge from the angle of the relationship between the researcher and the society.

The production of scientific knowledge always requires a specific organisation and management at both individual and institutional levels. Such an organisation includes e.g. knowledgeable human resources, size of research teams (Carayol & Matt, 2004; Louis et al., 2004), network of collaborators, (e.g. Crespi & Geuna, 2008), and time spent

on research and teaching (Fox, 1992). Furthermore, such an organisation produces settings in which researchers can perform scientific research. These settings include e.g. a transparent system of sharing research results made public as scientific information.

The starting point of the discussion here is the researcher claiming intellectual property in the competitive research environment (Merton, 1957; Hagstrom, 1965, 1974) as he strives for recognition in his environment. This recognition increases the researcher's power in competing for heterogeneously distributed resources (Garcia & Sanz-Menendez, 2005) and thus in the researcher's positioning. This is because society is more likely to share resources with recognised researchers, as they seem to be more credible and productive. Furthermore, the researcher having a high reputation is able to direct this society, more specifically his societal environment being the entire world outside the researcher including e.g. another researcher, government as well as industry.

As already mentioned before, scientific research is nowadays of interest not only to researchers but also to their societal environment. This societal environment plays one of the major roles in setting research policies and research directions. By setting the research directions this environment has an impact on the scientific knowledge production. At the same time, the researcher will influence research policies and directions (Kurek et al., 2007).

The impact of the environment has been studied e.g. by Knorr-Cetina (1981), Gibbons et al. (1994), Ziman (1994), Wilts (2000), Laudel (2006), and Swan et al, (2007). All of them claim that the production of knowledge is affected by the relationship between the researcher and his societal environment imposing conditions on research. In this paper, this impact will be analysed in terms of boundary conditions that result from the negotiation between the researcher and his societal environment on research conditions such as restrictions on which research results can be made public, or which scientific products to produce.

A relationship established between the researcher and his societal environment determines the production of scientific knowledge in terms of choices the researcher has to make such as e.g. the choice of research goals, as well as in terms of sharing governance in a research project (Wilts, 2000). Like in any relationship between organisations, a main parameter determining this relationship is the strategic positioning of the researcher in his societal environment. Like any organisation, the researcher positions himself in a relationship in order to attain his goals of which the main goal is to produce scientific knowledge. Choices made in the production of knowledge, concerning e.g. the directions of research, the acquisition of and matching of resources offered by his societal environment, result in a position observed in the relationship between the researcher and his environment.

The relationship between the researcher and his environment is considered here as a (temporary) strategic alliance, joint venture, merger or an acquisition between partners. To analyse such relationships the model of strategic positioning uses the

dimensions of organisational autonomy, i.e. governing the directions of research, and strategic interdependence, i.e. sharing heterogeneously distributed strategic resources like time, knowledge, skills, research facilities and funds (Haspeslagh & Jemison, 1991). Applying these two dimensions the model of strategic positioning results in a typology of four combinations of positions in these dimensions. These are modes of strategic positioning: the well-known modes such as mode1 and mode2, and in the new modes: mode3 – the research entrepreneur and mode0 (Kurek et al., 2007). In this paper we discuss how the production of knowledge varies in these modes. Next to the analysis, we will report results from a study conducted in a research environment specifically selected for its high competitiveness, i.e. the fast developing domain of Nanoscience, more precisely, the case of the MESA+ Institute for Nanotechnology at the University of Twente.

2. Strategic positioning of the researcher

To produce scientific knowledge the researcher establishes at his discretion a strategic relationship with his societal environment. These partners, depending on how they are dependent on each other, may be intertwined or completely separated, but for the purpose of analysis we talk about two distinct actors in such a relationship: the researcher and representatives of the environment, e.g. science foundations, governments, various funding agencies, companies, etc. These partners, seen as actors who share joint goals, make the decision of entering into a collaboration because without each other's resources they would not be able to deliver the desired knowledge. They negotiate conditions under which scientific knowledge will be produced. These conditions include issues of strategic interdependence and organisational autonomy.

The researcher at different levels of aggregation can interact with various representatives of the societal environment. An individual researcher or research group e.g. establishes a strategic relationship, next to the hierarchical relationship, with his employer in the same way as with other partners funding research. With different partners in various relationships he may well position himself differently. Both the employer and funding agencies expect profit from the research they participate in, not necessarily in economical terms. But they vary in resources shared and the extent to which they direct research and impose restrictions on the researcher. The employer or a company wants to direct research and expects in general more short-term profits. Funding agencies such as EU, national science foundations, etc. intend to have scientific products delivered that will result in a long-term profit. The researcher operates also in a research environment consisting of researchers judging the scientific quality and relevance of the researcher's scientific work (Whitley, 1984). Whenever there are resources deliberately shared in order to produce scientific knowledge, there is a relationship between researchers from the research environment that can be analysed with the model of positioning. The positioning model enables analysing various relationships, also internal relationships between researchers from the same research

group. In this article, however, we do not focus on the internal organisation of research groups but on how to analyse such an organisation at various levels of aggregation.

In the relationship the researcher decides to give up governing research to a certain degree in exchange of sharing resources to a certain degree. The model of positioning dealing with the relationship and those abovementioned conditions was extensively analysed and argued (Kurek et al., 2007). The main assumption is that the relationship between the researcher and his environment is seen as a strategic alliance of two organisations. The model, built on the dimensions of organisational autonomy and strategic interdependence, predicts a continuum of modes broadly characterised by the four mentioned modes of positioning. These modes vary in the character of integration of the researcher with his environment (types of integration between two organisations are described in Haspeslagh & Jemison, 1991). The mode1 researcher positions himself as highly autonomous. For the attainment of the researcher's goals it is not necessary for him to integrate with his environment and to share other resources than financial resources. This is a relationship of two separate organisations. Contrary to mode1, in mode3 it is necessary for the researcher to integrate with his environment. The research entrepreneur is fully intertwined with his environment as they share resources. At the same time, the researcher is highly autonomous in governing his research. The relationship between the research entrepreneur and his societal environment then has a more symbiotic character. There have always been research entrepreneurs throughout history. The existence of the research entrepreneur is of course not new. What is new is the approach to systematically analyse the production of knowledge leading to the observation of the phenomenon of the research entrepreneur next to the phenomena of mode1 and mode2.

The research entrepreneur is an entrepreneur in research and is distinct to the academic entrepreneur broadly described in the literature (e.g. Louis, 1989; Balazs, 1996; Leydesdorff & Etzkowitz, 1998). The differences between these two concepts are discussed in Kurek et al. (2007).

In mode2 there is also a necessity for the researcher to integrate with his environment. The researcher is accountable to his societal environment that asks the researcher to deliver on its demand. The mode2 researcher has thus less autonomy than the mode3 researcher; the researcher is almost amalgamated with his environment. In mode0 the necessity for the researcher to integrate with his environment is low. There is no alliance and the environment serves just as a bank providing funds for research. Mode0 is irrelevant for the present research environment, and is only mentioned here for reason of consistency.

In the literature there are several descriptions of specific types of knowledge production delivered by several researchers (e.g. Whitley, 1984; Stokes, 1997; Huff, 2000; Wilts, 2000; Huff & Huff, 2001; Starkey, 2001). The model of Whitley (1984) analyses various types of the organisation of scientific fields in terms of 'mutual dependence: functional and strategic', in which 'reputational autonomy', as he names it,

is a contextual factor affecting the degree of mutual dependence, and 'task uncertainty' to analyse relationships between researchers. These dimensions are specifications of the dimensions of the model of positioning because if restricted to the research environment proper, organisational autonomy and strategic interdependence would reduce to reputational autonomy and mutual dependence. Thus, these dimensions can be used in operationalising the dimensions of organisational autonomy and strategic interdependence. Reputational autonomy is thus a specific aspect of organisational autonomy as 'control over skills and competence standard' because next to controlling skills and standards organisational autonomy includes the overall control over research, i.e. setting research goals and directing research. Mutual dependence is the dependency of one researcher on contributions from other researchers. In this respect it is a specific aspect of strategic interdependence as it addresses a joint effort in doing research by sharing heterogeneous resources but it limits these resources to knowledge and skills only.

Another specification of the model of positioning is based on the two variables 'relations with economic and political actors' and the 'internal decision-making procedures' (Wilts, 2000). With this model relations between the research organisation and research practice are analysed. The variable of 'relations with economic and political actors' refers to the dependency of the researcher on financial resources and this variable as such is an aspect of strategic interdependence. The difference is that strategic interdependence is not restricted to research funds but broadens to other resources such as time, knowledge, skills and research facilities. Wilts' model results in three types of research organisations: knowledge seekers, service providers and research contractors. These organisations are subsets of our modes of positioning. Knowledge seekers are subsets of mode1 as they are not dependent on research funds research provided by the environment and therefore do not depend on goals set by this environment. Service providers are a special case of mode2 researchers because they are strongly dependent on research funds and their research goals are determined by the environment. Research contractors are subsets of the research entrepreneur who relies on external funding but influences their own research goals. An important difference between the model of Wilts and the model of strategic positioning, however, is that we assume that the researcher is driven by his goals and dynamically shapes the organisation of his research distinctively in various relationships with different partners. Furthermore, the dimensions of strategic interdependence and organisational autonomy are meant to be explanatory dimensions of the production of knowledge.

In order to produce scientific knowledge as a result of a joint research project this project and the joint effort have to be managed and organised. All managerial and organisational activities that add to creating scientific products define collaboration. This being the case, collaboration integrates production of knowledge, strategic interdependence and organisational autonomy into a system. Collaboration of research includes managing financial and human resources and research facilities of the research enterprise as well as managing exchange of scientific knowledge between the partners.

The abovementioned properties of the relationship, i.e. production of scientific knowledge, strategic interdependence, organisational autonomy and collaboration are seen here as functions of a social system performed by the partners in the relationship (as proposed by Parsons, 1962, 1964). These functions are interrelated with each other, while at the same time remaining distinct. The possible relations between these functions in the system can be presented in the tetrahedron as in Figure 1 (Geurts & Roosendaal, 2001).

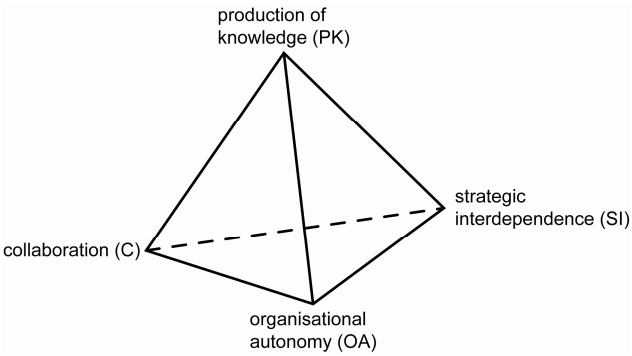

Figure 1. The strategic relationship of the researcher in his societal environment.

As shown in this tetrahedron, the production of knowledge is the dependent variable. Strategic interdependence, organisational autonomy and collaboration as independent variables have a direct link to the production of (as indicated by arrows in the tetrahedron).

The relations, both direct and indirect, between the functions result in a number of combinations of modes of positioning. Analysing possible indirect relations we assume that collaboration means that there is strategic interdependence, i.e. there are resources shared that have to be managed. A high degree of strategic interdependence leads to a high collaboration. A low degree of strategic interdependence leads to a low degree of collaboration. Thus, a position of low strategic interdependence together with a position of high collaboration is not possible, because if there is no exchange of resources there is no need for managing them.

From all possible combinations of relations between the functions, only four combinations meet the above conditions. These combinations lead then to four possible modes of positioning and can be formalised as:

- $\uparrow$ PK = PK (C $\downarrow$ + OA $\downarrow$ + SI $\downarrow$) mode0
- $\uparrow$ PK = PK (C $\downarrow$ + OA $\uparrow$ + SI $\downarrow$) mode1
- $\uparrow$ PK = PK (C $\uparrow$ + OA $\downarrow$ + SI $\uparrow$) mode2
- $\uparrow$ PK = PK (C $\uparrow$ + OA $\uparrow$ + SI $\uparrow$) mode3

(upward arrows indicate a high degree, downward arrows a low degree)

This assumption implies that all other possibilities lead to low or no production of knowledge.

The researcher, in whatever mode he positions himself, always produces scientific knowledge. This knowledge is produced in various research settings which affect the type of the final product of scientific research, e.g. mode1 leads to more curiosity driven results, whereas mode2 leads to more application driven results. These research settings, regarding e.g. directing research and research goals appearing in distinctive modes of positioning, can be analysed with the energy spent by the researcher on management and organisation of research measured in a system consisting of the researcher and his societal environment. As we take the inside-out view combined with the outside-in view on the production of scientific knowledge we analyse the effort the researcher makes in his relation to his societal environment. As in atomic physics, there is a ground state representing the least but not zero energy that the researcher has to spend to produce scientific knowledge.

The concept of the ground state in atomic physics implies that a system will always return to this state. The analogue in the model of positioning is that the researcher will return to his ground state, as a result of his goals, as he will strive to maximise his organisational autonomy and to minimise his strategic interdependence (see e.g. Greenberg, 2007; Swan, 2007). The energy is defined as time accompanied by knowledge, skills, research facilities and funds that are used by the researcher in performing the research and managerial tasks resulting in a certain output. The researcher wants to conserve his resources and use them on research and the research management and organisation only, whereas additional energy is required for the positioning in his societal environment. Striving towards his goals, the state to which the researcher will return is mode1. The energy that the researcher in mode1 spends on creating scientific knowledge is spent on research, research management and organisation only. The researcher spends additional energy if the attainment of his goals so requires. He spends this energy on strategic management and/or on supplying on the demand of his societal environment. This energy results from the research settings that are a consequence of restrictions imposed on research by the environment in the relationship with this environment. The energy can be expressed in currencies of exchange that will be introduced in the next section. Producing scientific knowledge in collaboration with the societal environment always requires extra time to comply and to adjust research goals and directions to those proposed by the environment. The acquisition of resources has an impact on knowledge production by "consuming applicants' and reviewers' time and money, which would otherwise be available for research" (Knorr-Cetina, 1981; Chubin & Hackett, 1990; Lederman, 1993; Horrobin, 1996; Wessely, 1998; Laudel, 2006). This acquisition requires also extra energy as the researcher has to make an "effort in gathering information about the rules of the funding agency and 'learning the game'" (Laudel, 2006), and on communication with the environment. An example of extra energy required from the researcher is from the Framework Programmes of the European Union. The EU requires collaborative

research projects only. The researcher therefore has to find research partners from both his research and societal environment and manage such a collaborative research organisation (Eichinger, 2007). Furthermore, joint research projects require "negotiation, coordination and integration of heterogeneous types of knowledge, values and interests" (Maasen & Lieven, 2006). Because of this extra energy, the researcher will only invest in collaboration with his societal environment, will accept strategic interdependence to a certain degree, and will give up organisational autonomy to a certain degree, if this collaboration enables attaining his goals. The societal environment expects benefits from research in which it invests such as an applicable product. The environment can also invest in research without this objective of a scientific product. The scientific knowledge is then used by others for further scrutiny and for adjusting to possible application. An example of such a situation is cosmology that is curiosity driven and has spin offs in application driven domains, e.g. nuclear instrumentation for medical applications.

The energy that the researcher spends on research in mode1 results in scientific products directed by the researcher. He does not take into account societal needs and demands when setting his research goals and produces curiosity driven scientific products, reliable knowledge (Ziman, 1991) as research goals are set by the researcher himself (Wilts, 2000) and it is being certified and accepted or rejected by the research environment. It means that such a product complies with scientific standards of the research environment and results of research are not necessarily meant to be of societal relevance. Mode1 does not mean that the researcher does not communicate his research results. It means that the environment does not directly influence his scientific products.

The researcher spends more energy on producing knowledge in collaborative research with his societal environment. He accepts restrictions on research that affect his scientific product and the process in which it is produced. In these so-called excited states the researcher accepts restrictions of his societal environment. This means that he agrees to produce a scientific product that is application driven (Wilts, 2000). Therefore, in mode0, mode2 and mode3 scientific products are more application-driven, and more socially robust than in mode1 (Novotny et al. 2001).

As mentioned before, the research entrepreneur spends additional energy on managing his relationship with his environment and on adjusting to some restrictions on the production of scientific knowledge imposed by his environment in this relationship. The research entrepreneur autonomously determines the directions of research and sets research goals. The research entrepreneur, like a business entrepreneur, creates demand for his scientific products and influences his societal environment; at the same time his environment articulates its intentions that they can jointly produce new products. He influences scientific products by setting goals that determine scientific information acquired and used, and the methodology used. Results of the mode3 scientific knowledge production are meant to add to the development of scientific domain but can be also applied.

In mode2 more resources required from the researcher have to be used on research and research management as well as on management of the relationship with the societal environment and supplying on the societal demand. The production of scientific knowledge in mode2 is directed by the societal environment. The mode2 researcher accepts more restrictions on research than the research entrepreneur as he accepts research goals proposed by his environment and fits them into his research agenda. This means that the researcher accounts for the demand of his societal environment like e.g. in consultancy and research outsourced by a financial partner if this partner demands particular studies to be carried out and the researcher complies (Gibbons et al, 1994, Ziman, 1994). The researcher listens to the environment and fulfils societal needs. With the societal need we mean a need that is explicitly expressed in the relationship by the societal environment.

These above modes are illustrated in the figure below (Figure 2).

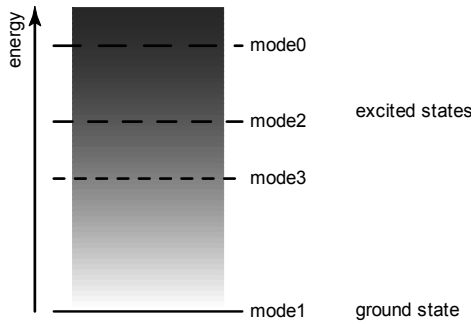

Figure 2. Ground state of strategic positioning.

The additional energy required from the system is spent by the researcher e.g. on translating scientific knowledge to knowledge that can be used by his societal environment. Results delivered by researchers from various scientific domains may differ, for example nanotechnology researchers deliver tangible products that can be used. Social sciences researchers such as management or organisational studies researchers export scientific knowledge and skills to organisations to be used in practice. However, this knowledge translation seems to be a problem and as a result social sciences researchers do not establish relationships with their societal environment as often as they wish (Starkey et al., 2001).

The adjustment of scientific knowledge to practice causes the main difference in the energy spent on the production of knowledge between mode3 and mode2. In mode3 the adjustment concerns both partners: the researcher and his societal environment whereas in mode2 it is the researcher who has to adjust knowledge and intentions to intentions of the environment.

Having added the energy in research and the organisation and management of research to the model of positioning, this model can now be formalised as:

$$\uparrow PK = PK (C, OA, SI, E_n),$$

where n represents a mode.

As we have introduced the ground state $E_g = E_1$ we can reduce this equation to:

$$\uparrow PK = PK (C, OA, SI, E_n - E_g).$$

3. How to observe strategic positioning?

We can observe the positions and identify conditions and restrictions on the production of knowledge in the exchange between the researcher and his societal environment in a relationship. The researcher producing scientific knowledge makes choices that are being affected by his environment. By analysing the relationship between the researcher and his environment we can, in principle, measure how these choices are being influenced by his environment.

The exchange is based on the negotiation of intentions and situations between the researcher and his environment. The negotiation process ends with an agreement that is an expression of intentions and situations of the actors including potential positive and negative sanctions that could be used in case the actors deviate from situations and intentions they agreed upon. The agreement is then the enactment of the negotiation. The choices the actors make afterwards are executed in terms of positive or negative sanctions included in such an agreement. The choices of the researcher result in a position in organisational autonomy and strategic interdependence that he accepts in a specific relationship in a contract or agreement. We can then observe positions in organisational autonomy and strategic interdependence in potential sanctions on which the actors have agreed.

Intentions of the researcher and his societal environment are presented in table 1. These intentions are systematically assigned to each function of strategic positioning. The list restricts to main issues being negotiated with the societal environment, e.g. what those partners expect regarding the production of knowledge, sharing resources and collaborating, and governing research (see also: Good Scientific Practice, 2002; The Netherlands Code of Conduct for Scientific Practice, 2005).The situation of the partner (the researcher or his societal environment) refers to all organisational aspects of a research project (mainly possession of resources or lack of such resources)

Table 1. Intentions of the researcher and his societal environment

	researcher	societal environment

production of knowledge	• to deliver research results that will be reported and justified
	• to add to existing theories
	• to disseminate research results in
	  ○ scientific publication
	  ○ presentation
	  ○ internal research reports
	• to independently choose a medium for dissemination of research results
	• to produce a curiosity driven scientific product
	• to be recognised as an author of research results
		• to get research results delivered
		• to obtain new solutions (more cost effective, more efficient) to existing applications
		• to disseminate research results in
		  ○ research reports
		  ○ patents
		  ○ business units
		• to direct a choice of medium in which results will be disseminated
		• to get an applicable scientific product produced
		• to be recognised as a contributor to research

strategic interdependence	• to acquire strategic resources (financial, knowledge from the societal environment, research facilities, to acquire human resources without an involvement of the environment)	• to share strategic resources (financial, knowledge with the researcher, research facilities if available, to be involved in acquisition of human resources)
organisational autonomy	• to set research goals • to direct research • to be accountable to the research environment only • to communicate research results primarily to the research environment • to govern scientific information use and acquisition • to govern methodology applied	• to set research goals • to direct research • to ask the researcher to deliver on demand • to be informed on research results • to govern scientific information use • to govern methodology applied
collaboration	• to organise research • to manage available human resources • to manage possessed financial resources • to manage research facilities • to manage exchange of scientific knowledge with the societal environment	• to direct the organisation of research • to direct managing human resources • to direct managing financial resources • to direct managing research facilities • to direct managing exchange of scientific knowledge with the researcher

Next we analyse how these intentions and the situation are being affected and potentially sanctioned by the partners. To this end, we apply four types of behaviour as proposed by Parsons (1963). These types of behaviour are used by the partners to get the other to comply with their demands.

When the researcher offers (positive sanction) to produce a new scientific product, e.g. a new theory that will supersede an existing one (effecting intentions of the users) he influences his societal environment. When the actor in a relationship wants to induce the other, he exchanges money. Money is not always 'money' in the literal sense; it can for instance be information or a physical product, which is being exchanged. It can be any scalable added value. To meet the terms of an agreement, the actors may also deter one another. When not delivering results as agreed upon, the societal environment may terminate the contract. Another way to get one actor to comply with the demand of the other is to commit him to the system of values and norms of the other actor. The researcher being a part of the research environment is committed to comply his research with high scientific standards, as discussed by Merton in his normative structure of science (Merton, 1973). In a relationship with the environment, the researcher engages the environment to values and norms of the research environment, to a different extent in different relationships.

Table 2. Types of one actor's behaviour towards another actor and currencies of exchange (Parsons, 1963: 44).

	intention	**situation**
positive sanction (incentives)	persuasion (influence)	inducement (money)
negative sanction	activation of commitments (commitment)	deterrence (power)

Table 2 presents the types of behaviour and concomitant currencies of exchange (in brackets). To be able to compare different relationships established between the researcher and his societal environment we translate the types of behaviour of these actors to these currencies.

As the situation of the societal environment refers to organisational aspects of research including the control over resources the researcher can hardly affect the situation of the general societal environment. The researcher can affect the situation of his societal environment differently in various relationships with various representatives of this environment such as the employer, industry or the government. The researcher can affect his employer as well as a company e.g. by producing a scientific product from which the environment can gain reputation or will financially benefit. The researcher can affect the situation of his employer and a company on the short term, whereas funding agencies or the EU can be affected only in the long term. This is because for a small-medium enterprise financing a research project is usually a

bigger investment than for the European Union having a larger research budget. Having invested in research, the situation of such an enterprise is much more affected by the created scientific product than is the situation of the EU. Other representatives of the societal environment are potential buyers/users of scientific products. These potential users do not enter the relationship and do not directly finance research. They can purchase scientific products. Such products will not affect their situation but can affect their intentions, e.g. nuclear energy or bio fuel that raise controversy and discussions whether they should be applied at all.

Table 3. Potential sanctions by the researcher and his societal environment.

	researcher	societal environment

Positive sanctions	• offering scientific knowledge
	  ○ scientific product
	  ○ scientific services
	  ○ commercial product
	• offering strategic resources (human, knowledge, research facilities)
	• contribution of the societal environment will be mentioned in agreed media
		• offering scientific knowledge
		  ○ recognition
		  ○ rewards
		  ○ patents
		• offering strategic resources (human, financial, knowledge internalised by the societal environment, research facilities)
		• encouraging certain behaviour, e.g. dissemination of research results

Negative sanctions	• refuse to conduct specific research • refuse to produce demanded scientific knowledge • refuse to disseminate research results • refuse to disseminate research results in a manner proposed/ medium chosen by the societal environment • disseminate research results without acceptance of the societal environment • terminate contract • refuse to conduct research if not universal • the researcher may acquire strategic resources from another representative of the societal environment in next research • disagreement	• refuse to finance specific research • control of research and management activities • obstruction on disseminating research results • omit dissemination of research results • ask to delete certain information from a publication • terminate a contract • ask to conduct research compatible with ethical and political correctness • stop financing in future (if reputation is lost) • disagreement

The societal environment using negative sanctions can change the situation of the researcher in the sense that he will have to look for another financial source. By a positive sanction the environment encourages the researcher to conduct specific research.

The potential sanctions that the partners may use in the relationship are specified in table 3.

The observable difference between the modes of positioning is in the balance of the sanctioning of intentions and situations. The actors exchange currencies to various degrees. These dynamics are indicated by sanctioning the other actor. In the balance, the actor sanctioning the other has a stronger flow of currency than the dependent actor. This asymmetry in the balance in the exchange of currencies is well visible in the excited states of positioning.

In the ground state (mode1) there is no external exchange between the researcher and his societal environment. There is no direct flow of currencies of exchange between these two partners; therefore there is no sanctioning from the environment. The research institute of the researcher and external institutions exchange financial resources only. These institutions do not directly connect money with research tasks and do not influence research directions (e.g. lump sum financing universities).In such a situation, the researcher is not accountable to his societal environment but only to his research environment, meaning that he has to comply with the norms of the research environment. The production of knowledge results in this case in a theory driven scientific product as discussed before. The researcher has to produce scientific knowledge according to agreed standards without being constrained to specific, externally set research goals. Furthermore, it is not the intention of the researcher in mode1 to produce knowledge that can be applied directly and influence his societal environment. The researcher makes use of power and influence only within his research environment. In the mode1 situation, the researcher does not sanction his societal environment but only the research environment and vice versa.

In the excited states the researcher allows his societal environment to sanction intentions (presented in table 1) and situations in exchange for resources from the environment needed to produce knowledge. Given his goals, he accepts spending extra effort in the production of knowledge.

In mode2 production of scientific knowledge is being restricted by the societal environment as the researcher has a position of low organisational autonomy and of high strategic interdependence. There is an exchange of currencies between the researcher and his societal environment. In such a relationship the environment sanctions the researcher. The researcher is accountable to the environment which is able to set specific research goals for the researcher. The societal environment will ask the researcher to deliver a specific commitment dedicated to a specific research task. This does not necessarily have to comply with high scientific standards, but must comply with the demand of the environment. Furthermore, next to setting research

goals the environment influences the researcher and his research. The environment has also power in the mode2 relationship.

In mode3 the researcher is strong enough to sanction his societal environment. The most important characteristic of the research entrepreneur is that he influences research management and directions including research goals in such a way that he creates demand for scientific results he wants to deliver. The research entrepreneur influences the environment by creating demand for the scientific products he produces. Even being an equal partner in the collaboration the research entrepreneur is still accountable to his societal environment, but to a certain, negotiated degree. This degree depends on the degree of autonomy he accepts to give up reaching his goals. Moreover, the exchanged commitment in the mode3 relationship is more general than in the mode2 relationship as it deals with more general issues such as e.g. ethical issues (van Steendam, et al. 2006) as will be seen below. Commitment is then not connected to specific research tasks and the researcher himself directs deliverables. This means that scientific knowledge produced by the researcher is negotiated by both partners but the societal environment does not govern this value.

4. An empirical analysis of research relationships

To explore the feasibility of the model in creating observables, an analysis of the exchange between the researcher and his societal environment is being conducted at the MESA+ Institute for Nanotechnology of the University of Twente (The Netherlands). MESA+ employs over 475 employees including 375 researchers. MESA+ is a multidisciplinary institute collaborating at the national and international level. Internationally MESA+ collaborates with e.g. IMEC (Belgium), Max Planck Institutes (Germany) and Forschungszentrum Karlsruhe (Germany).

The strategic relationships of MESA+ are observed in contracts that the institute entered with its societal environment. Contracts are the enactment of the negotiation on desired intentions, desired situations and potential sanctions (Kurek et al., 2007).

Studying research projects in this specific research environment consists of two steps: one step is contract analysis to be followed by the second step of interviewing researchers (to be reported in a forthcoming paper).

Next to the legal language, contracts contain unique and sufficient information on the relationship between the researcher and his societal environment, in particular on what has to be done and how (Van der Meulen, 1998). The contracts were studied to analyse clauses indicating the presence of observables for the production of scientific knowledge, strategic interdependence, organisational autonomy, and collaboration. Each of these functions is operationalised in terms of intentions of the researcher and his societal environment as listed in table 1. Each of these intentions (as well as the situation of the partners) is being matched with potential sanctions: positive and negative as proposed by one of the partners. Not all of the intentions of both partners

are explicitly stated in the contracts but are implicitly assumed. They can become an issue though and a contract can be terminated.

To illustrate the measurement some interesting aspects of content analysis of the contracts are presented underneath on one example of a relationship of MESA+ and the European Union under the 6th Framework Programme.

As expected, not all of the intentions from the list (table 1) can be found in the contracts of MESA+. Nonetheless, in each contract there are at least a few, and this is sufficient to test the feasibility of the model in creating observables.

Each mode of positioning has a specific combination of strategic interdependence, organisational autonomy and collaboration being variables determining the production of scientific knowledge (being in this model a dependent variable). In each mode the researcher has to accept various restrictions from his societal environment on these variables in order to produce scientific knowledge. This being the case, each of these four variables will be analysed closely and separately to distinguish between these restrictions.

In the exemplary contract between MESA+ and the EU specific research settings are expressed. In particular it is expressed that MESA+ responds to a call for proposals and it offers a new solution to existing applications, which up till now are not sufficient in terms of cost effectiveness and efficiency. This agreement is interpreted as a positive sanction affecting the intentions of the environment. Therefore, it indicates the use of influence by the researcher. This statement also indicates that scientific knowledge will be produced in this relationship. Furthermore, the researcher offers the environment *"to maintain such higher level competitiveness"* (positive sanction) of European research and this will affect the intention of the societal environment who wants to be competitive.

MESA+ affects intentions of its societal environment by proposing this specific solution (positive sanction affecting the situation of MESA+). It can, at the same time, sanction negatively the environment (can refuse doing specific research) if the environment does not agree to this solution trying to affect and change it. This indicates the exchange of commitment by the researcher for money that the EU agrees to invest in the proposed solution. With this potential negative sanction the researcher commits his environment to scientific products he will produce. This commitment is more general as it is MESA+ who decides what solution to produce and the environment agrees on what the researcher proposes. MESA+ offers to *"bridge the gap from 'knowledge production' to 'knowledge use'"* (positive sanction) affecting intentions of its societal environment (indicating an exchange of influence by the researcher). This argument also indicates that the environment affects the intention of the researcher. The researcher has to comply with the restriction of the environment and deliver scientific knowledge that can be applied otherwise the environment will not grant the project (potential negative sanction affecting the intention of the researcher indicating

an exchange of commitment by the EU). The environment commits the researcher to the application of scientific products.

Research results will be disseminated via scientific publications as well as via the web site, the popular scientific press, and via invited European companies *"to lay the foundations of a European network of companies and research institutes that develop, fabricate or apply …*(scientific product at hand)*"* (positive sanction affecting the intentions of the societal environment indicate exchange of influence by the researcher). Furthermore, the environment requires that *"any notice or publication by the contractors about the project, including at a conference or seminar, must specify that the project has received research funding from the Community's Sixth Framework Programme"* otherwise the research project will not be funded (potential negative sanction affecting the situation of the researcher indicating use of power by the EU). The researcher will be recognised as an author as he can use his research results *"the contractors shall use or cause to be used the knowledge arising from the project, which they own, in accordance with their interests"* (negative sanction that can be used if the environment would not agree, affecting the environment's intention). However, *"the contractors shall set out the terms of use in a detailed and verifiable manner, notably in the plan for using and disseminating the knowledge, and in accordance with the provisions of this contract and the Rules for Participation"* (potential negative sanction affecting the intention of the researcher).

The next variable determining the production of scientific knowledge is strategic interdependence. As expressed in the contract, both partners share resources with each other. MESA+ shares *"experience, infrastructure and know-how"* and *"the consortium partners possess between them the wide range of skills and relevant infrastructure"* (positive sanction affecting the intentions of the societal environment) whereas his environment shares financial resources (positive sanction affecting the situation of the researcher). Another indicator of strategic interdependence is the acquisition of human resources by the researcher (positive sanction affecting the intention of the societal environment).

As we assume in this model, the researcher strives to maximise his organisational autonomy. The researcher if accountable to his societal environment, like in this case, has always to provide arguments for his choices in setting research goals and in a choice of research methods.

A deficiency of studying contracts is that we cannot observe the research interests of the researcher and to what extent he has to fit his research interests to research topics proposed by his societal environment. This deficiency will be solved by expanding this study to include interviews and analysing scientific publications (publication records will help to define research interests of researchers involved in analysed research projects). In the analysis we assume that the researcher selects a call for a proposal that will fit his research interests as close as possible as this will require least energy. Hence, he sets a research goal more autonomously.

Measuring a position in organisational autonomy, we see that in this relationship MESA+ defines the methodology that will be applied: *"the overall methodology has the advantage of inherently minimising the risk of project failure"* (positive sanction affecting the intention of the societal environment). The EU sets some restrictions on the methodology in the sense that the researcher tries to prevent a project failure (negative sanction; intentions). But after all, it is the researcher who governs and commits his environment to methodology and to research (potential negative sanction potentially affecting the intentions of the EU and indicating the use of commitment by MESA+).

As mentioned, MESA+ is accountable to the EU as the EU requires reports on the progress of the research. Otherwise the researcher can lose his reputation and this can change the organisational aspects of research (potential negative sanction affecting the situation of the researcher and indicating the use of power by the EU): "*the project co-ordinator MESA+ will organise an annual assessment meeting (…) with all parties and the Commission's representative(s)"*, and *"final versions will be proved before the end of each year for the assessment review by the European Commission"*.

The last, but not the least, function of positioning is collaboration. Activities that the partners perform focus on the organisation and management of the research. According to the contract, the researcher manages and organises the research activities (positive sanction affecting the intentions of the societal environment; and potentially a negative sanction if the researcher refuses to conduct this research thereby affecting the intentions of the societal environment). The project coordinator is chosen by the researcher and named in the contract (potential negative sanction, as mentioned above, affecting the intentions) but the EU has to agree to this coordinator (negative sanction potentially changing the situation of the researcher). The EU requires a specific project management that is standard for all the applicants (a negative sanction potentially affecting the situation of MESA+). The researcher has to establish an international collaboration as a condition for the acquisition of the resources. Project proposals without other research partners are not taken into account by the EU (potential negative sanction affecting the intentions of the researcher as well as his situation). This somewhat limits the researcher striving for independence in research.

The analysis shows that the contract covers almost all of the intentions of both partners. Some of the intentions are not included in the contract indicating that the exchange of currencies has not reached the equilibrium for each of the variables (table 4).

Table 4. The strategic positioning of the researcher as expressed in the exchange of currencies.[♦]

	researcher	societal environment
production of knowledge	• influence • commitment to scientific products	• power • money • commitment to the application of scientific products
strategic interdependence	• influence	• money
organisational autonomy	• influence • commitment to methodology used	• power • commitment to a methodology that will prevent a project failure • commitment to ethical issues
collaboration	• influence • commitment to personnel appointed by the researcher	• power • influence

The balance in exchange of currencies in this contract leads to asymmetrical flows as presented in table 4. This means that this project requires from MESA+ extra effort to produce scientific knowledge. The balance shows that there is a stronger flow of influence and commitment (general commitment for scientific knowledge) for MESA+. This is in line with the goal of MESA+ that is to be an entrepreneurial university. The flow of power and money is stronger for the EU. Both partners had been seen to influence each other. This indicates a relationship of two equal partners. The EU is seen to be engaged in the organisation and management of this research project.

As said, the modes of positioning have specific combinations as results of the model of positioning. Having elaborated the functions of the model it can be concluded that MESA+ has a position of high strategic interdependence (observed stronger flow of influence by the researcher) and high collaboration (observed flow of influence on both parties), and a position of quite high organisational autonomy (not as in the ideal type) in the relationship with the EU. This combination is therefore close to the ideal combination indicating the mode3 of positioning.

$$\uparrow PK = PK\ (\uparrow C, \uparrow OA, \uparrow SI, E_3 - E_g)$$

♦ The exchange between MESA+ and the EU (STRP 01303)

In this particular contract MESA+ is positioned slightly above mode3 (see Figure 3) on the scheme of energy required from the researcher to produce scientific knowledge. The energy required from the researcher is much lower than in mode2 but somewhat higher than in mode3.

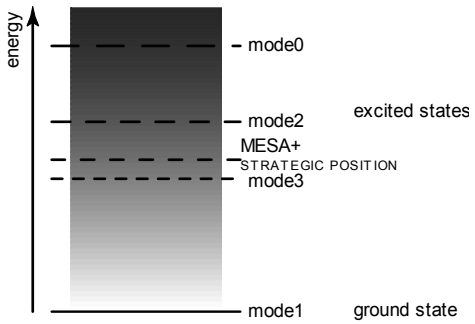

Figure 3. The energy levels for MESA+.

A similar analysis was done for other contracts of MESA+. An example of a relationship with a company shows that there is also an asymmetrical balance of power, money and commitment for the company. In this case, the position of MESA+ was not very high in organisational autonomy and collaboration. We can conclude that this particular relationship is closer to mode2 than to mode3.

For the purpose of this paper and for testing the observables it is in our opinion sufficient to present this extended analysis of just one contract. Furthermore, even research contracts with the European Union while standardised to a certain extent are a solid indication of what currencies are exchanged between the researcher and the EU.

5. Some policy implications

The above analysis of the positioning of MESA+ is an empirical application of the model of strategic positioning. In general, this model can be applied by the researcher at various levels of aggregation to the organisation of research. For an individual researcher an application is developing a strategy to achieve his research goals. This researcher being aware of his goals is able to recognise what resources he needs to achieve these goals. This allows him to become aware of opportunities in acquiring resources. The proposed model will increase such awareness.

A research institute or university may well apply the model for developing a 'corporate' strategy. A university needs to position itself to be sustainable. She has to gain competitive advantage over other institutes and universities to attract excellent researchers, teachers and students. Just like any organisation, if a university wants to position herself she should define her goals and communicate them to the outside world – her societal environment as well as to her scientific and other staff. To develop a strategy she has to recognise her resources and acquire new ones if needed. An example of a strategic relationship between universities is a consortium of universities known as

ECIU (European Consortium of Innovative Universities). This consortium of 11 universities was established to strengthen the position of those universities on the market of higher education. This collaboration results in e.g. joint research and educational projects. For example, to attract students the consortium establishes joint master programmes. These programmes enable students to study at various ECIU universities with full recognition of grades respected by all the ECIU partners. Given such a goal, universities have to decide on the degree of organisational autonomy and strategic interdependence they need to have to attain this goal.

Another application of the model of strategic positioning is to the situation and changes in the university landscape that we are currently observing in Germany as well as in other countries. German universities, due to new law regulations, are in transition towards more autonomous research & teaching units, towards universities as described by Clark (2001). These universities are becoming self-governing in setting their research and teaching agenda, and deciding about the quality of its research and educational products. At the same time, they are encouraged to compete for resources in their environment, i.e. to be more entrepreneurial. The model of strategic positioning can serve in this case as an analytical instrument for a diagnosis of the current position of a university. Given such an analysis, a university can make use of it to attain its goals by making choices regarding what degree of organisational autonomy she needs to have and what resources she wants to share with which partners.

As for policy makers this model offers an understanding and awareness of the researcher's choices, intentions and situation. It also allows policy makers to analyse strategies of universities and research institutes. This will improve decisions about the allocation of resources and in developing appropriate research policies. It is shown above that comprehensive strategies and research policies can be developed only by applying both the inside-out and the outside-in view. Not understanding the researcher's choices, intentions and situation can lead to misunderstanding between partners implementing research programmes and policies and researchers. An example is the case of the policy initiative of the Genetics Knowledge Parks implemented in 2002 in the UK (Swan, 2007). The government set a mode2 research programme but did not consider the intentions of researchers. Therefore, the programme failed as researchers positioned themselves in mode1 (Swan, 2007).

Summarising, appropriate policies should focus on a few general aspects. Such aspects are considered in the relationship of two organisations. This relationship can be considered as some sort of integration of the two organisations (Haspeslagh, Jemison, 1991).

If the goal of the societal environment in a relationship is to accumulate knowledge without being specific on what kind of knowledge and to learn from it, the researcher should be left in the ivory tower. In this mode1 policy the researcher should be left entirely autonomous in setting research goals as the project leader in this relationship.

The environment is there to support the production of knowledge and defend its commitment to the scientific standards of the researcher.

In a mode2 policy, the environment wants to define research goals and tasks specific for this temporary integrative relationship. The environment needs to make its intentions and expectations clear towards the researcher. The management and organisation of research are then influenced by the environment, e.g. in acquiring human resources, directing research, and sharing knowledge. And it is the environment that leads the research project in this relationship. The researcher adapts 'best practices', proposed by his environment, e.g. in research methods or reporting research results to the environment. The environment strengthens the original complementarity between the researcher and his environment.

A mode3 policy is of a more symbiotic character. In this policy the environment makes use of knowledge produced by the researcher. The difference between a mode2 policy and a mode3 policy is that in mode3 the researcher is the leader of the project and sets research goals, directs research, manages and organises it. This policy strives to temporarily amalgamate the researcher and his societal environment for the purpose of the specific research project. The environment adjusts its expectations to the goals proposed by the researcher and his intentions.

6. Conclusions

The strategic positioning of the researcher in his societal environment is analysed here with the aim to get insight how this positioning affects the production of scientific knowledge. To this end, we have developed an analytical model based on the dimensions of strategic interdependence and organisational autonomy of the partners in the relationship (Haspeslagh & Jemison, 1991).This model takes into account next to the outside-in view also the inside-out view focusing on the researcher and his goals in the production of knowledge. Using this model we are able to analyse choices that the researcher makes in the relationship with his societal environment and the temporary integration of the researcher and partners in his societal environment aiming to attain the joint goal of producing scientific knowledge. The model results in four modes of strategic positioning: not only in the well-known modes such as mode1 and mode2 but also in new modes: mode3 – the 'research entrepreneur' and mode0 (Kurek et al., 2007). Mode3 is claimed to be the answer to the need for the researcher to "enter the agora and participate fully in the production of socially robust knowledge" (Gibbons, 1999) as the 'research entrepreneur' speaks to his societal environment and this environment not only speaks back but also listens to the researcher as he directs his environment.

The model has been applied to the case of the MESA+ Institute for Nanotechnology at the University of Twente. On this basis we conclude that the model is feasible in creating observables for the modes of strategic positioning. With the help of this positioning model we are able to deliver a systematic analysis of the production of scientific knowledge.

The confirmed feasibility and suitability of the model allows us to conclude that given the strategic goals of the researcher the model will be able to predict modes of strategic positioning and therefore strategies developed by the researcher to attain his/its researcher strategic goals: ranging from strategies of an individual researcher to strategies of a research institute.

As mentioned above, this model takes both the outside-in view and the inside-out view on the production of knowledge into account. This is the main difference between this strategic positioning model and the known approaches to the production of knowledge such as mode2, Triple Helix, and post-normal science. These latter approaches lead to general descriptions of changes in the societal environment, e.g. in economy, and suggest to adjust research programmes to these changes. This is a consequence of only applying the outside-in view which means that the researcher has to react to such changes. As a consequence these approaches can only result in two strategies of dealing with such changes from the perspective of the environment: the well-known mode1 and mode2. In the mode1 strategy the researcher does not react and in mode2 the researcher has to adjust to changes in the environment. The inside-out view in supplementing this outside-in view results in the third strategy. The inside-out view implies that the researcher, additionally to reacting to changes, can himself induce changes in the societal environment, can influence the partners in this relationship. This combined view is comprehensive enough to analyse how the researcher deals with the external world and to explain why he makes certain choices when producing scientific knowledge. Just assuming a dichotomy of mode1 and mode2, when setting research programmes, cannot lead to an explanation of the behaviour of the researcher. The environment can misinterpret motives and the behaviour of the researcher. The model of strategic positioning allows avoiding such failure and misunderstanding in the implementation of research programmes. In addition, we can define and measure the effort in terms of energy the researcher spends in doing research as well as in managing this research including the acquisition of resources. The energy is measured to assess what it costs the researcher to produce knowledge in different research settings, i.e. in dealing with different restrictions on research. Such an assessment is a prerequisite for developing a strategy. The researcher needs to assess the resources he has, the resources he needs and the costs of acquiring those resources.

Appropriate research programmes and policies matching the intentions of both the researcher and the societal environment finally leading to the growth of scientific knowledge are of interest for both partners. It is relevant in order to develop a strategy to analytically diagnose intentions of both partners and the effort that has to be made to produce knowledge.

To develop research strategies and policies one needs to understand the mechanisms ruling the production of knowledge from both the outside-in and the inside-out perspectives. The model of strategic positioning is shown to allow the partners to make such an analysis and to match strategies and research policies developed respectively by researchers and policy makers. This strategy and policy

development and their matching should lead to the enhancement of the production of scientific knowledge.

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Chapter 3: The impact of the strategic positioning of researchers on their production of knowledge*

Kasia Zalewska-Kurek, Peter A.Th.M. Geurts, Hans E. Roosendaal

In this article the impact of the strategic positioning of the researcher in his research environment on the production of scientific knowledge is tested. The observed production of knowledge is measured by the number of articles published by the researcher and by the number of articles multiplied by the impact factor of the journal.

The strategic positioning is determined by the two dimensions of strategic interdependence, i.e. resources shared, and of organisational autonomy, i.e. governance. Both dimensions are observed in in-depth interviews focusing in particular on how researchers make research results public and how they acquire scientific information.

The model of the strategic positioning of the researcher was tested in interviews of 43 researchers active in nanotechnology, business and public administration. The sample of researchers is stratified along scientific positions and the heterogeneity of scientific domains is maximised.

The interaction model was applied to the data of the empirical study to test the main hypothesis that 'the more the researcher is both interdependent on his colleagues and at the same time autonomous, the more knowledge he produces'. The results confirm this hypothesis. Applying the interaction model results in predictions for the production of knowledge for the abovementioned sample. The results show that the positioning model is able to predict values for the production of knowledge.

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* to be submitted for publication

1. Introduction

The production of knowledge is a strategic issue for both researchers and policy makers. Researchers are interested in increasing their productivity for the benefit of their career, for recognition, and for the growth of their research units. Their research performance is measured a.o. in the publications they produce. Publication records are important for their career in science and for the acquisition of financial resources from the society at large. Policy makers are interested in the productivity of researchers for reasons of allocation of resources (Lee & Bozeman, 2005) when setting research programmes. Nowadays, the European Union has a keen interest in competing at a scientific level with countries outside Europe. Both researchers and policy makers are then interested in conditions stimulating a high scientific productivity.

Researchers studying the organisation of science seek for factors that affect scientific productivity. Up till now, empirical studies show that collaboration enhances scientific productivity (e.g. Lotka, 1926; Price & Beaver, 1966; Zuckerman, 1967; Pao, 1982; Pravdic & Oluic-Vulovic, 1986; Allison & Long, 1990; Lee & Bozeman, 2005) as scientific productivity increases with the number of co-authors and joint research projects (Lee, Bozeman, 2005). This argument is used by policy makers in setting research programmes, e.g. in mode2 research programmes or in programmes set by the European Union for which collaboration at both a national and international level is a requirement.

Studies on the production of knowledge focus on describing the trends in scientific productivity from the angle of the number of co-authors (e.g. Crespi & Geuna, 2008), on characteristics of scientific productivity such as age, rank, status of researchers (Lehman, 1953; Pelz & Andrews, 1966; Cole 1976; Levin & Stephan, 1991, Ramsden, 1994; Lee & Bozeman, 2005), on accumulative advantage of researchers (Allison & Stewart, 1974), on the number of research grants and contracts (Gaughan & Bozeman, 2002, Godin, 2003), on gender and family relations (e.g. Cole & Zuckerman, 1984; Fox & Faver, 1985; Long, 1987), on citizenship (Bozeman & Corley, 2004), on collaboration strategies (Lee & Bozeman 2005), on department effects (incl. research facilities, intellectual stimulation, and motivation) (Allison & Long, 1990), and on the influence of research organisation on scientific production (Carayol & Matt, 2004; Louis et al, 2004).

All of these abovementioned elements, however, do not allow predicting the production of knowledge, whereas in this article we aim to develop and test a model that allows predicting this production. We focus on the organisation of the production of knowledge and on addressing conditions that should be met in a relationship between researchers aiming to produce more knowledge. We deliver a diagnosis of the organisation of the production of knowledge with the use of the model of strategic positioning (Kurek et al., 2007a,b) and report the results of an empirical study answering the research question: *does the strategic positioning of the researcher have an effect on the production of knowledge?*

2. Research environment

The strategic positioning of the researcher is observed in the strategic relationship with his environment (Kurek et al., 2007a). In this article, this environment is restricted to the research environment proper. The research environment is defined as a "self-conscious and self-regulating group of colleagues controlling intellectual innovations based on their power to validate the expertise, and thus mediate careers, of members" (Whitley, 1984). We observe the positioning of individual researchers in their relationships with their own research groups with the use of the model of strategic positioning based on the two dimensions of strategic interdependence (sharing of heterogeneously distributed resources) and organisational autonomy (self-governing in deciding about research) (Kurek et al. 2007a). Sharing expertise, skills, facilities, i.e. all different kinds of resources that add to the production of knowledge are the main reasons for researchers to work together (Beaver & Rosen, 1978). The third dimension in the positioning model is collaboration (management and organisation of sharing resources). As we argued (Kurek et al, 2007b), strategic interdependence and collaboration are aligned, meaning that researchers cannot share resources without managing them and vice versa.

The tetrahedron in figure 1 is used to show all possible relations of the three independent variables with the dependent variable being studied. Arrows indicate the relations that we study in this research.

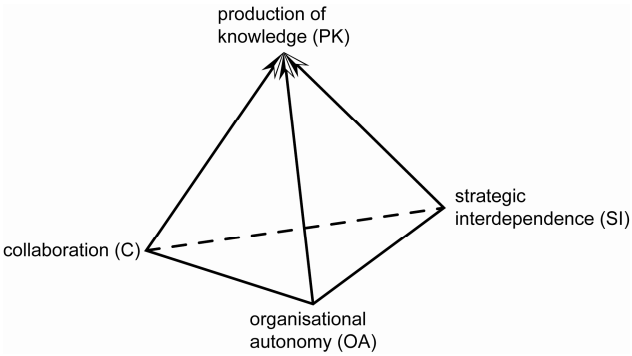

Figure 1. Tetrahedron representing relations between SI, C, OA and PK in the strategic positioning model.

The positioning model results in four modes of positioning[1] built on different necessities for the two dimensions of strategic interdependence (SI) and organisational autonomy (OA). Necessity for SI or OA means that specific degrees of these two dimensions are necessary to attain the researcher's goals. We observe the degree of the

[1] The modes are not discrete but continuous [ibidem].

dimensions but it should be kept in mind that these dimensions should always be interpreted in relation to the goals of the researcher. Mode0 is a combination of low necessity for both strategic interdependence and organisational autonomy, mode1 (ivory tower) is a combination of a low necessity for SI and a high necessity for OA, mode2 of a high necessity for SI and a low necessity for OA, and mode3 – the research entrepreneur is a combination of a high necessity for both SI and OA.

The restrictions to the research environment proper means that the resources that researchers share are limited to such resources as e.g. knowledge, skills, time, and research facilities. To measure the impact of strategic positioning on the production of knowledge we measure strategic decisions concerning the organisation of the production of knowledge including making research results public and acquiring scientific information. Decisions on what to make public, where and when, etc. are strategic in the sense that they have consequences for the position of the researcher in his research and societal environment.

The researcher claims intellectual property (IP) by means of a scientific publication as he strives for a sustainable position in his environment: among his peers and among financing partners. He is avoiding a situation that his competitors will claim similar or the same ideas earlier (Merton, 1957) with the result that he will not be acknowledged as the author or inventor. Claiming intellectual property for his achievements can bring recognition (e.g. "publish or perish" coined by Wilson, 1940; de Solla Price, 1980; Lubans, 1987; Ziman, 1970; Franck, 2002) and reputation if disseminating his ideas in journals having prestige and a high impact factor (Whitley, 1984). Choices that the researcher has to make when deciding on claiming intellectual property regard content – what to publish, co-authors, time – when is it good for positioning purposes to publish and why, what scientific information to use in the article, etc. And what is quite important – where to claim intellectual property. The quality of the peer-review process has consequences for the impact of the claims. The more prestigious the journal, the more strict the peer-review process and the higher quality it has. All these elements are depicted in the tetrahedron below (figure 2) and as such are used in developing a topic list for interviews as will be presented later in the text.

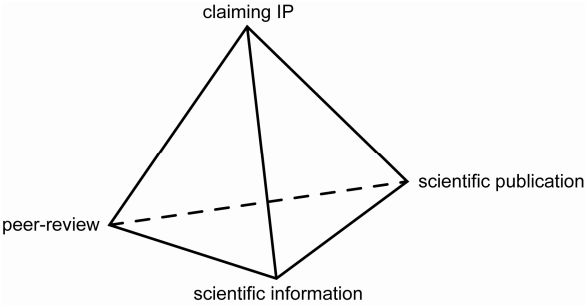

Figure 2. Tetrahedron representing the elements of making research results public as scientific information.

Making research results public as scientific information is a way to share knowledge with the research environment. But in science it is never one-way sharing. The rule *do ut des* applies – researchers always acquire scientific information from their scientific domain. To choose research topics, to check for multiple discoveries or to perform research, researchers have to be aware of the literature available in their scientific domain. We distinguish between the acquisition of information to keep abreast (collecting) or to solve specific information problems (selecting). Each time researchers acquire scientific information they make use of information sources (personalised interfaces). In principle, researchers require scientific information to be relevant, reliable, up-to-date (e.g. Kircz & Roosendaal, 1996). They usually acquire information from their scientific domains defined by journals they read and conferences they attend. In each type of acquisition there are decisions made which are the objects of observation in this study. More specifically, we observe on which interfaces researchers depend in the research process and how they are directed in the acquisition. In the same way like above with making results public, the main elements of collecting or selecting are depicted in the tetrahedron below (figure 3).

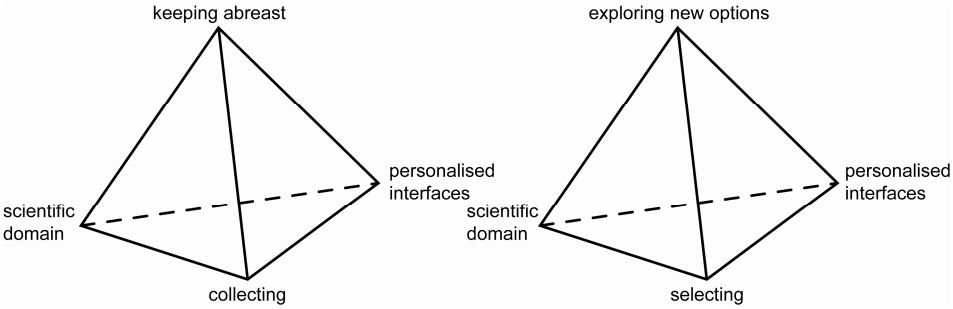

Figure 3. Tetrahedra representing the elements of the acquisition of scientific information when collecting (left hand-side) and selecting (right hand-side) scientific information.

3. Data

The positioning model has been tested in an empirical study conducted at the University of Twente. We interviewed in total 43 researchers: 15 researchers from the IGS (Institute for Governance Studies) institute, 27 researchers from the MESA+ Institute for Nanotechnology, and 1 researcher from the CTIT institute (Centre for Telematics ad Information Technology). Because the latter researcher's behaviour resembles the behaviour and habits of the interviewed MESA+ researchers (except for scientific articles as medium of dissemination as argued later in the text), we include this researcher in the subsample of MESA+.

MESA+ employs 237 fte's in research (2006 University Report). The institute is organised in 6 research programmes called Strategic Research Orientations: BioNanotechnology, Cell-Stress, MesoFluidics, NanoElectronics, NanoFabrication, and

Molecular Photonics. These programmes cover a number of scientific domains including applied physics, chemistry, biology, biochemistry, electrical engineering, and mathematics. These domains are rather homogeneous in terms of publishing behaviour. To give an example of an aspect of the publishing behaviour: most of the MESA+ researchers have Nature or Science as common top journals to which they may submit articles, provided the quality of the articles is commensurate.

MESA+ is chosen for this empirical study for its competitive environment at the national and international level. The institute was used in previous research to analyse the positioning of researchers in their societal environment with the use of research contracts (Kurek et al, 2007a,b).

To extend the sample, researchers of the IGS institute were added. This institute employs 104 fte's to conduct research (2006 University Report). The research within IGS is organised in 6 research programmes: Sustainable innovation, Higher Education and Research in the Knowledge Society, Innovation in construction processes, Innovation in Water Management, Innovation of Governance, and Innovation at the national, sectoral and organisational level. Researchers from scientific domains such as public and business administration including entrepreneurship, marketing, management, economics, law, financial, environmental studies, higher education studies, political science, and sociology participate in these programmes. These domains are less competitive than hard sciences and are sometimes local, e.g. on legal research. They are also quite heterogeneous in terms of tradition and research habits, and researchers do not have common journals in which they could claim intellectual property. Because of these differences in traditions and research habits the heterogeneity in the IGS subsample is large.

Both subsamples are stratified along the positions of the scientists in the two organisations. Generally, the sample covers the whole spectrum of scientific positions ranging from PhD students (MESA+: 6/ IGS: 5), post-doc (5/0), assistant professors (6/4), an associate professor (1/0), and full professors (9/6/CTIT: 1), and managerial positions of group chairmen and scientific directors.

Based on the law of large numbers 43 observations should be sufficient for testing the positioning model under the condition that the population is not too heterogeneous and the number of variables is not exceeding 4 or 5.

Choice of samples

The objective of this study is to empirically test the positioning model (see also Kurek et al 2007). First we concentrated only on MESA+ but as we have seen above, scientific domains at MESA+ are rather homogeneous. Therefore, we added IGS with researchers active in various domains and having different publication habits, e.g. representatives of legal research almost exclusively publish in Dutch scientific journals whereas in public administration there is a mix. The other institute is added not for reasons of comparison of the two institutes but for reasons of generalisation. For the

same reason we have chosen to optimise the variation in scientific domains within the IGS subsample, and of course the scientific positions. Both samples are not necessarily fit for generalisation for the two institutes and are not meant for descriptive conclusions, but are composed in such a way as to allow testing the theoretical model. The samples have no descriptive purposes as such. Throughout this article we will consistently use the terms researchers in the MESA+ sample and the IGS sample or the MESA+ researchers and IGS researchers to describe the used two samples.

Method

The data is gathered from in-depth interviews. This technique was chosen as it allows flexibility in asking questions about decisions researchers make during the process of making research results public and in the acquisition of scientific information. In preparing for interviews, the publication records of the chosen researchers were studied. We have selected three articles of each researcher and used them in the interview. These three articles were in general chosen from a larger pool of publications and the interview focused on decisions regarding the publications, not on the impact of these articles nor on the number of publications at large. These articles were used to probe the researchers about decisions in relation to the functions in table 1. An important criterion for choosing the articles was the variety in co-authorship. We have chosen articles co-authored with researchers from their own research groups and varying in scientific positions, e.g. a full professor publishing with his PhD students or assistant professors. Next, we looked if the chosen researchers published with researchers from other research groups within their institutes or outside their institutes. We then selected such examples. This is applicable as in general researchers are active in their domains but some might have spin-offs in other domains. The selected articles should result from different relationships with different co-authors and indicate an overall position in SI and OA. This was not possible with all researchers, e.g. some of the PhD students always published with the same co-authors. The majority of the articles used was recently published and varied in terms of impact factors and prestige of the journals in which they were published.

Excluding the preparation time each interview took approximately 1-1.5 hours, sometimes even 2 hours. The researchers were asked questions from a topical list of open questions. To develop such a topical list of questions for the interviews each element of making results public and acquisition of scientific information is considered in terms of the main components of a strategy, i.e. strategy development, strategic positioning, strategic choices and strategy into action. Then, each of these components is discussed in terms of strategic positioning: what is shared, which decision is made, why and how the sharing is organised, who shares resources, who makes decisions and when are resources shared, and when are decisions made. This detailed analysis gives us a comprehensive framework for the interviews and for interpreting the interviews' outcomes. The main questions on each function are presented in table 1.

Table 1. The main interview topics.

function	Operationalisation
claiming IP	why do researchers claim intellectual property (IP)?
scientific publication	who does decide how and when researchers claim IP?
scientific information	who does decide what information is chosen and how?
peer review	how researchers are involved in the peer-review process; is it a source of information?
keeping abreast	do researchers need to keep abreast?
personalised interfaces	what are information sources? Which and when
collecting	overview of scientific domain?
scientific domain	how defined? journals, conferences, and other media?
exploring new options	situations for new options?
personalised interfaces	what are information sources? Which and when?
selecting	how do researchers solve information problems?
scientific domain	defined by journals, conferences, and other media in which researcher make results of their research public

Researchers in answering these open questions gave usually multiple answers that are relevant for a number of their relationships with their colleagues. To arrive at an answer indicating an overall position of a researcher in all of his relationships in a specific aspect of organisational autonomy or strategic interdependence we built constructs combining the relevant answers. Firstly, the separate answers were interpreted as indicating a low, medium or high degree of organisational autonomy (OA) or strategic interdependence (SI) were loaded to a scale ranging from 0 to 1. These results were then compounded and normalised. Next, these constructs were used in statistical analysis.

4. The measurement of the production of knowledge

The dependent variable in the positioning model is the production of knowledge. The production of knowledge is defined in this study in terms of the scientific products a researcher produces. We measure the output of the individual researchers interviewed.

The most frequently used indicator of scientific productivity is the number of articles published in peer-reviewed scientific journals (e.g. Cole & Cole, 1967[2]; Liebert,

[2] Cole & Cole measure correlations of the number of publications with the quality of these publications. The quality was measured by the number of citation to researchers work. Based

1976; Ramsden, 1994; Louis et al., 2004; Lee & Bozeman, 2005). The scientific journal is the most popular medium for claiming intellectual property by researchers (Meadows, 1998, pp: 160-161). It is also used in assessing the performance of researchers in universities and research institutes. This is also relevant for the interviewed researchers. Making research results public in scientific journals is common practice in hard sciences. It is slightly less common in social sciences and humanities (here books are more important: Meadows, 1998, p: 161), and it is not common in computer sciences. Computer sciences researchers claim that they make their results public in conference proceedings because this gives them a shorter throughput of the peer-review process and higher visibility in their domain. The production of knowledge of the computer sciences researcher in the sample is here measured by the record of articles in published peer-reviewed conference proceedings.

The production of knowledge is measured here both in terms of:

- quantity of articles published in scientific journals per year;
- quantity of articles published in a scientific journal per year weighted by the quality of the journal in which the researcher publishes measured by impact factor of this journal: $\Sigma = n_m * IF_m$ (m being the journal).

We measure the production of knowledge in the period of 5 years preceding the interview, where the unit of time is 1 year. To be more specific: beginning of 2003 – end of 2007. We decided to analyse the publication records of more than one year to take into account fluctuations in the annual productivity of the researchers.

Some of the researchers in the sample worked less than 5 years as such. To compare their production of knowledge with the production of knowledge of more experienced researchers we normalised the number of journal articles on the number of years worked during 2003-2007 as a researcher.

We asked the researchers for motives to publish by asking the question *why do you publish?* (function: claiming IP in table 1) From the answers of the researchers three main motives emerge: external pressure, knowledge sharing and recognition. These motives were usually combined in the researchers' answers. 40% of the interviewed researchers answered (see figure 4) that they publish because of two reasons. Firstly, they want to share knowledge, secondly, they publish under external pressure because being member of a group, or as a researcher in general they are expected to publish, or to show that public money is spent well, etc. The motive of sharing knowledge is perceived by some of the respondents as a sort of 'idealistic' reason. Some even said verbatim 'idealistic'. It was often a first answer given to this question followed by

on such correlations they create a typology of 4 types of physicists that they later used for the recognition study. Lee & Bozeman (2005) measure the productivity by two measures, a simple count of publications and a fractional count in which co-authored papers are divided by the number of co-authors.

external pressure or recognition. From these reactions we conclude that this motive of sharing knowledge is a sort of cliché. A sizable part of the sample (27%) said that they publish because they want to share knowledge, gain recognition in their scientific domain and because of the external pressure mentioned above. 10% of the interviewed researchers publish because they want to be recognised as authors of their discoveries and want to share knowledge.

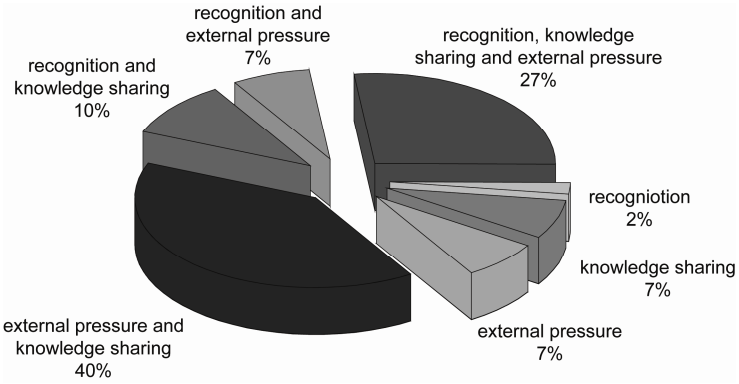

Figure 4. Motives for making research results public.

Publication records of the interviewed researchers from the MESA+ and IGS samples are gathered from the database of the university. However, this database is incomplete. There is a lack of data about publications of those researchers who were not appointed at the UT in the studied period. To gather this data we have explored external databases such as Scopus and ISI Web of Science and used the websites of the researchers.

Other measures of scientific productivity

Another measure for scientific output retrieved from the literature is the number of patents (Dietz & Bozeman, 2005) or the number of research projects the researcher has acquired funds for (or is involved in). Neither of these indicators is used in this study. The number of patents refers to strategic relationships with the societal environment and we restrict our research to the research environment proper. Instead of counting research projects of an individual researcher, we measure time that he spends on research, on organising research and on strategic management as will be explained later.

Some authors add to the quantity of publications the number of refereed professional presentations (Louis et al., 2004). We decided not to include presentations in our measurements for two reasons. Firstly, because of difficulties in measuring the quality of conference papers as they are not always peer-reviewed and there is no ranking of conferences (except for a few 'must be' type of conferences in each scientific domain). Secondly, because some of the researchers are invited to give talks that very often resemble lectures about general ideas developed within a research group rather

than present new scientific discoveries. Such presentations are more oriented towards promoting the ideas generated in the research group.

For the same reason we decided not to include books. Books are less reliable sources than scientific journal articles because they are not always peer-reviewed. And even if they are, we do not have insight into the quality of the peer-review process. We provisionally checked the productivity of the researchers in writing books and on this basis we can preliminary conclude that researchers not productive in terms of published articles are not more productive in writing books either. Adding books would not make a big difference in the distribution of the production of knowledge. And it is the distribution of the production of knowledge that is being used in the test, not the absolute level of production.

The habits regarding making results public are different for different scientific disciplines resulting in the fact that the production of knowledge cannot be measured on an absolute scale. Therefore, the samples constitute two separate observations that are analysed independently. The researchers in business and public administration tend to publish more books or book chapters than scientific journal articles. It is clear from the analysis of the production of knowledge of the studied researchers that the researchers from the IGS sample produce less journal articles than the researchers from the MESA+ sample (see figure 5). Most of the studied MESA+ researchers produce from 1 to 5 articles per year, 40% from the sample produces more than 5 articles per year, whereas 20% produces more than 15 articles per year, and the observed maximum is 22 articles a year. The researchers of the MESA+ sample publish on average with 5-6 co-authors.

The number of articles produced by the studied social researchers of IGS is lower, as anticipated. The observed maximum number for them is 6 articles per year. The majority of the interviewed social researchers produces about 1 or 2 articles per year. The researchers of the IGS sample publish on average with 1.5 co-authors. Official indicators, as reported in the 2006 Annual University Report, report the ratio of refereed publications per researcher. For MESA+ this is 1.6 and for IGS 2.3. We, however, decided not to correct the numbers of articles by the number of co-authors as it is of no importance for general positioning[3].

[3] Consequently, we should then correct the number of articles also for support staff and financial investments in research, etc., which are not of interest for this study. We should ask for other researchers or support staff contributing to research but not listed as co-authors. This is another difference between MESA+ and IGS. MESA+ researchers having any input are most of the time listed as co-authors, whereas at IGS they are mentioned in acknowledgements.

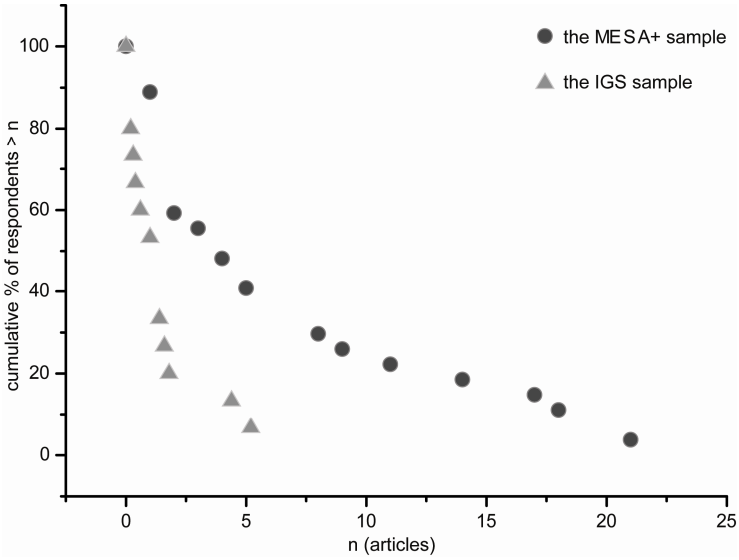

Figure 5. The cumulative distribution of respondents having published n articles or more.

The distributions of the production of knowledge for both samples show an exponential decay and both almost fit Lotka's law: about 60% of the researchers in the sample publishes about one article a year.

The measure of the number of articles*impact factor (PKIF) shows even more clearly that the performance of the researchers from these two samples has to be analysed separately. The social sciences researchers in the sample rarely publish in journals listed by ISI, only 2% publishes in journals with impact factors. The rest either publishes in non-listed international journals or chooses Dutch scientific or professional journals. The main reason given is that their science is rather local, applying e.g. to the political situation in the Netherlands, and is not publishable in international journals.

The production of knowledge of about 70% of the researchers of the MESA+ sample is between 1 and 20 (see figure 6). This means that the majority produces articles in journals with quite a high impact factor. A few researchers scored between 60 and 80 meaning that they produce both quite a high number of articles and publish them in journals with a high impact factor. These results should not be surprising because the majority of the interviewed MESA+ researchers said that their main criterion of choosing journals for submitting articles is the impact factor.

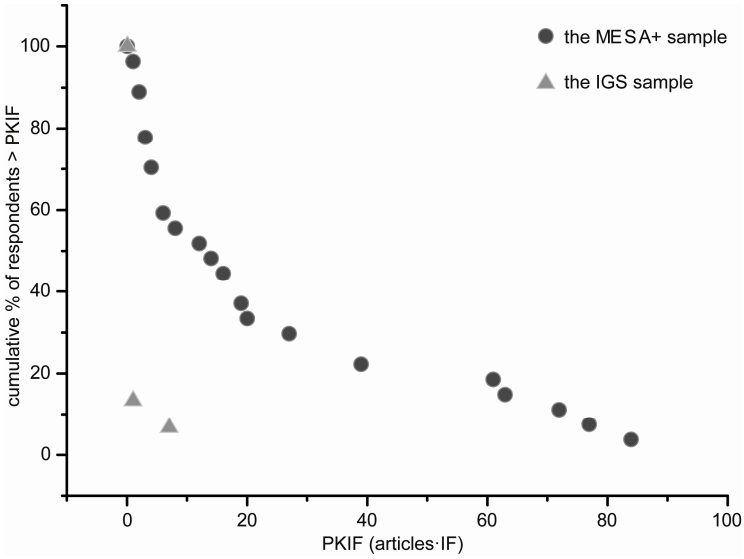

Figure 6. The cumulative distribution of respondents having produced the number of articles* impact factor (PKIF) or more.

5. The measurement of strategic interdependence

The positioning model aims at explaining the production of knowledge with the two dimensions of strategic interdependence and organisational autonomy. Strategic interdependence is being measured for both the societal environment (Kurek et al., 2007a) and for its specification: the research environment. As the environment is limited here to the research environment proper, we focus our analysis mainly on the resources exchanged in research groups in the process of making research results public and in the acquisition of scientific information between researchers. For the purpose of this analysis the research group is not considered as the societal environment of the researcher.

The degree of strategic interdependence is measured in:

- dependence on colleagues in writing articles
- dependence on information sources in acquiring scientific information

Dependence in writing

We asked the researchers: *Why did you publish with these scientists? What was their contribution to these articles?* (function: scientific publication in table 1) Researchers working with others share resources in research. The intellectual property they claim together results from the joint effort. Therefore they are usually dependent on colleagues. To differentiate the degrees of strategic interdependence we look into the writing process but we do not focus on the specific resources that are exchanged, e.g. what is the nature of comments, whose comments and suggestions are used, whose

input to research is larger, etc. The researchers answering questions on the writing process indicated what their input to the exemplary articles was and how other co-authors contributed. Researchers writing their articles without any help of other researchers are less dependent on others than researchers who do not write the articles which they co-author. They often answered that they are involved in a discussion on an outline and a final draft. Researchers writing an article usually spend more energy on it than researchers who comment on manuscripts. Researchers publishing alone without any other researcher are evidently independent of others.

Some researchers are not directly involved in the writing process but provide facilities and acquire financial resources for research. Their input is then connected with the research process but not with making research results public itself. They are highly dependent on researchers they publish together with, being usually the scientific staff of their research group. Researchers who do not write articles and whose contributions are limited to commenting on drafts without correcting them are more dependent on their co-authors than researchers who correct and re-write drafts of articles. The latter takes usually more time, knowledge and skills to perform.

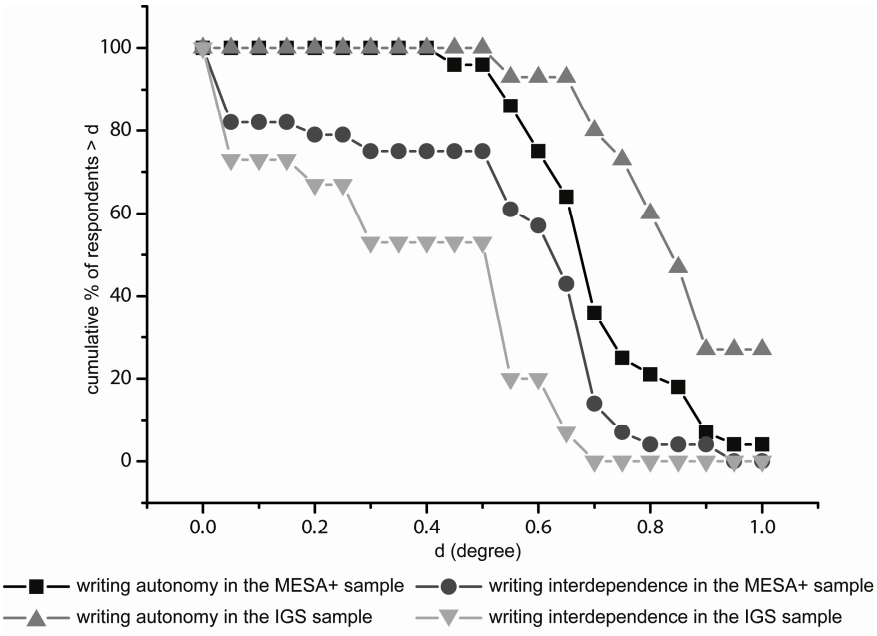

Figure 7. The cumulative distribution of respondents having writing autonomy or interdependence higher than the degree d of SI or OA (lines are drawn to guide the eye).

The results are consistently presented in this article as the cumulative distribution of the percentage of respondents having an autonomy or interdependence higher than a specific degree (see figure 7). The X-axis represents the degrees of writing autonomy or

writing interdependence. The researchers in the MESA+ sample are in general both highly autonomous and interdependent. The researchers in the IGS sample show a higher degree of autonomy and a lower degree of interdependence (see figure 7). The autonomy will be discussed later on.

Dependence on information sources in acquiring scientific information

The degree of strategic interdependence is also measured in the acquisition of scientific information. But the way we analyse strategic interdependence when acquiring information differs from the way we analyse strategic interdependence in making research results public. Whereas making results public is, with some exceptions, a joint effort, the acquisition of information is an individual activity. It does not mean, however, that a researcher acquires information in isolation from his colleagues. But in this case, other researchers are sources of information for a researcher. The degree of strategic interdependence is measured in personalised interfaces which are the sources that a researcher uses to acquire scientific information. Personalised interfaces are means in attaining research goals in the research process.

To identify on what information sources the researchers rely we asked them *How do you learn about new developments in your field?* (function personalised interfaces and collecting in table 1) The researchers who answered that they learn about new developments from *the Internet, various databases, by scanning or reading scientific or professional journals, from the articles sent by editors for a review* show a low degree of interdependence. They do not depend on their colleagues but rather do desk search. Involving other researchers, indicated by such answers as: *at conferences, meetings with other researchers, from mailing groups, from my students, colleagues, from my collaborators,* increases the degree of dependence because the researchers rely on the information communicated and selected by other people.

The same argument applies to all measurements of interdependence in the acquisition of scientific information. One of such measurements is the dependence on information sources when choosing experiments. This measurement applies to researchers who are engaged in doing pure research: experiments, developing research models, etc. Researchers with a low degree of interdependence use the Internet, databases to choose their experiments. The degree increases with the use of colleagues, supervisors, mailing groups, doing what is already done in the group or discussing their research models with other parties such as companies.

Another question indicating the degree of interdependence on information sources is the question *Why do you attend conferences?* (function: keeping abreast, collecting in table 1). The researchers attending scientific conferences to *present their work,* or *because they are invited* are not dependent on this research environment in acquiring information. They do not use conferences as sources of information.

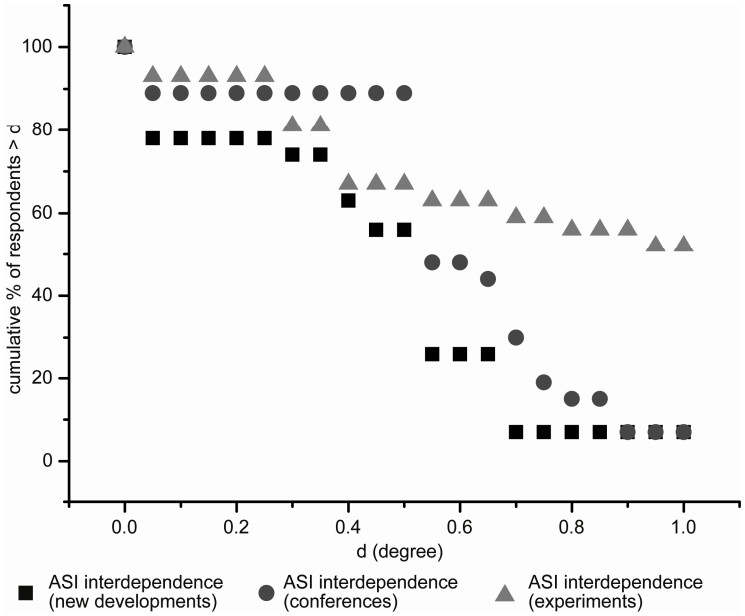

Figure 8. The cumulative distribution of the MESA+ respondents having interdependence in the acquisition of scientific information (ASI) higher than d.

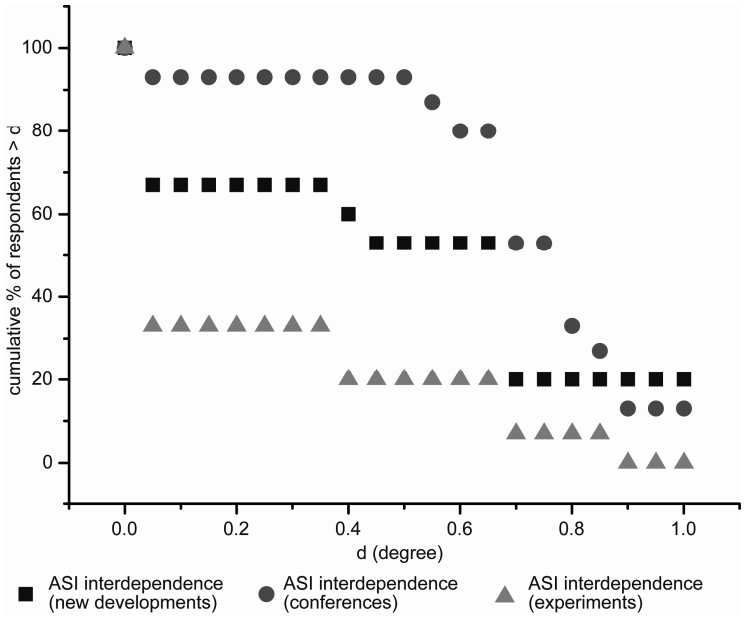

Figure 9. The cumulative distribution of the IGS respondents having interdependence in the acquisition of scientific information (ASI) higher than d.

Answers such as: *I attend conferences to establish collaborations, to be inspired, to look for people to hire*, do not indicate this either, although these answers show that the researchers go to conferences to meet people but not necessarily to acquire scientific information from them. The high degree of dependence is indicated by such answers as: *meet and talk to people, get an overview of what is happening, discuss problems, quality check*.

The distribution of the degrees of interdependence in the acquisition of scientific information among the researchers of the MESA+ sample show that most of them depend on their colleagues from their research groups or scientific domain (figure 8). The researchers of the IGS sample do not seem to rely on their colleagues in the acquisition of scientific information as strongly as their colleagues from MESA+ (figure 9).

6. The measurement of organisational autonomy

The another variable that we assume in the model of strategic positioning to explain the production of knowledge is organisational autonomy. In the literature autonomy of researchers is defined as "freedom from influence of the environment", external pressure e.g. in formulating tasks (Dill, 1958) or "autonomy to control sufficient resources" (Collin: in Whitley, 1984, p.12-13), or "self-governing in deciding about research, research goals and directions" (Kurek et al., 2007a). The degree of autonomy "depends on strategic choices to such factors as location, markets to be served or products to be made" (Aharoni et al., 1978). Organisational autonomy understood as self-governing includes all decisions in research, e.g. setting research goals, acquisition of research funds, decision on with whom to collaborate, on what resources from whom to acquire, and decisions with regard to making research results public and acquiring of scientific information.

Organisational autonomy is observed in the four currencies of exchange discussed by Kurek et al, (2007a,b). A researcher exchanging power, influence, commitment or money has a high degree of autonomy. The more currencies a researcher exchanges, the higher the degree of autonomy. The idea of the currencies of exchange is based on positive and negative sanctions affecting intentions and the situation of the partners in an interaction. In the strategic relationship established to produce knowledge between the researcher and his research environment positive sanctions are e.g. suggesting what to include in an article, editing or commenting on articles, advising on research, etc., and negative sanctions are e.g. refusing to work together, disagreeing or even withdrawing a co-authorship. Negotiations on the process of making results public, acquisition of scientific information, and the production of knowledge result in decisions. With the aim to observe potential sanctions and currencies we ask the researchers about these decisions.

The necessity for the autonomy of the researcher in a relationship with his research environment is lower than if working in isolation. The researcher entering any

organisation of knowledge, e.g. university, research institute or research group gives up his organisational autonomy to a certain extent. Or otherwise stated, he gives up certain aspects of his autonomy. For example when he agrees to deliver scientific products, or to comply with specific regulations, or when agreeing on a specific research programme. But the researcher has a choice to agree or not to agree to certain decisions as well as he can make decisions on his own to an agreed extent and can sanction his research environment. We assume that researchers have in general a high degree of organisational autonomy. However, in order to be able to observe differences between researchers we look at specific decisions they make in the production of knowledge. These decisions are being observed in:

- deciding what to write in articles (function: scientific information in table 1)
- deciding where to submit the article (function: scientific publication in table 1)
- deciding when the work can be published (function: scientific publication in table 1)
- deciding which relevant articles to include in articles (function: scientific information)
- acquiring scientific information (functions: personalised interfaces, exploring new options, selecting in table 1)
- deciding on research goals.

Autonomy in writing

Writing an article is a process in which the author decides on how to communicate the obtained research results to his audience. He decides on the line of argument, on how to present the content, what to include and why. These decisions indicate a degree of writing autonomy. We assess the degree of autonomy based on the currencies that researchers exchange when writing an article. Researchers have a high degree of autonomy if they exchange influence and power. We can observe such an exchange when writing an article if a researcher suggests the content and gives arguments why he chooses certain theories, experiments, etc. (positive sanction). Therefore, the primary author has a high degree of autonomy because he suggests what to include. Those authors who only comment on drafts have a lower degree of autonomy because they do not shape the text to such an extent as the primary author. They might give suggestions but such suggestions are secondary to the original text. But those authors who edit or re-write articles have a high degree of autonomy because they change the text (have influence on it). Researchers who discuss the content and the line of argument upfront and then write have a medium degree of autonomy even though they write the decisions are made jointly. Also a medium degree of autonomy have those researchers who make decisions jointly and those who are not involved in the entire process but only at the beginning and at the end meaning that they are involved mainly in general discussions not going much into details.

Autonomy in deciding where, when and what to publish

Researchers making decisions where to submit articles or suggesting a journal have a high degree of autonomy. They exchange power (negative sanction) or influence (positive sanction). If such a decision is jointly made (if there is no indication who made a decision, suggestions are split over co-authors), or is made by other co-authors the degree of autonomy is low. These researchers rely on decisions made by their co-authors.

The same argument applies to autonomy in deciding when the work is ready to be published and choosing relevant articles to be included in the article. The measure of quality assessment was not included in the original list of questions for the interviews. But answers given by some of the researchers show that the assessment of the quality of work is an important element in the decision making process in research and therefore, it should be taken into account. In the research process junior researchers learn how to judge when their work is good enough for submission, and to which journals they can submit it. These are elements of gaining experience. Researchers whose co-authors or supervisors assess the quality and decide when they should publish have a low degree of autonomy as they do not decide on their own. A researcher who decides or suggests exchanges power or influence towards his co-authors. Joint decisions mean a medium degree of autonomy. Low degrees have those researchers who do not make decisions on their own when to start writing and submitting articles.

When making research results public, a researcher does not only claim intellectual property to his own discoveries but also acknowledges the work of other researchers. He positions his work within a scientific domain by showing the relevance of his work in comparison to research results of others. The use of scientific information available in the scientific domain is used here to measure the degree of autonomy. We asked the question *who is responsible for references in an article.* A researcher has a low degree of autonomy if he is not responsible for references in the article, i.e. if he does not write an article. He does not make the decision what to include. A medium degree of autonomy has a researcher who makes such a decision together with his co-authors. He is not fully autonomous but has some influence on a decision. It's clear that a researcher who either suggests or decides on his own has a high degree of autonomy.

The distributions for the autonomy in deciding when, where and what to publish are presented in figure 10 and 11.

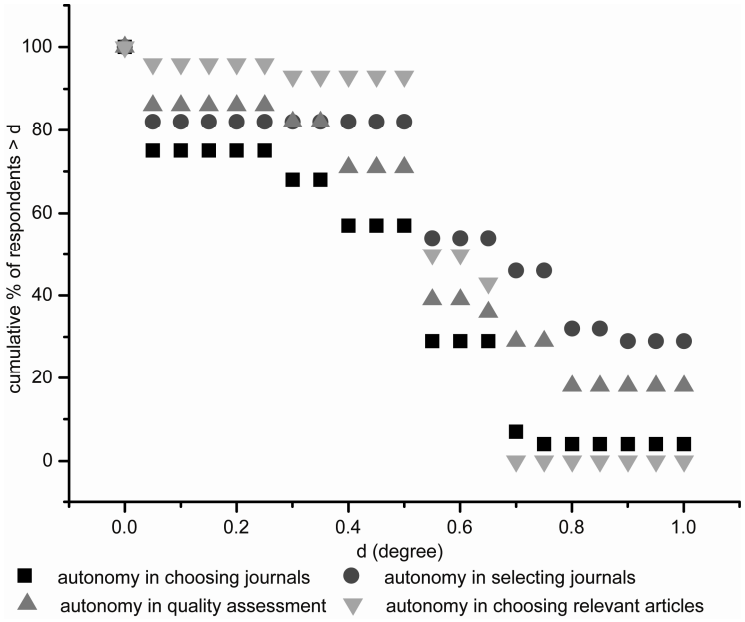

Figure 10. The cumulative distribution of the MESA+ respondents having autonomy higher than d.

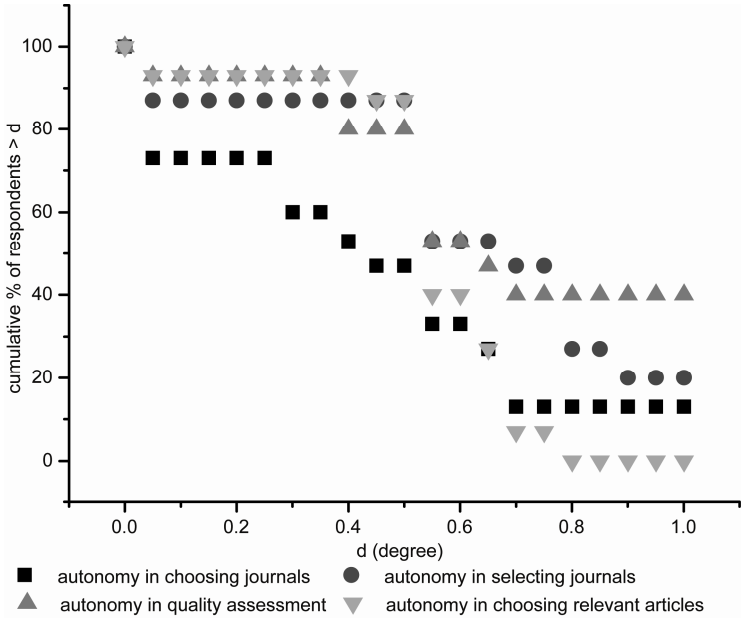

Figure 11. The cumulative distribution of the IGS respondents having autonomy higher than d.

Acquiring scientific information

Next to measuring decisions made when making research results public, we measure decisions made when acquiring scientific information. The acquisition of resources in research regards also the acquisition of scientific knowledge needed to conduct research.

Decisions are measured in answers to the question: When your students meet problems in their research and they ask you for help and if you don't know an answer do you try to find it out? How do you do this? A researcher who is influenced by his students has in such a situation a low degree of autonomy. He is influenced if he searches for specific information himself when a student suggests that a specific problem is to be solved. If a researcher refers students to contact specific researchers or to acquire specific literature he has a high degree of autonomy because he does not search for himself. He influences the students' acquisition of information.

Another measurement is checking for publications. Researchers were asked 'if you come up with an idea how to solve your research problem, experiments, etc., do you make sure that something similar was not yet published?' A researcher who does not have to check if something similar was published because his co-author does this (first authors, students) is not autonomous in selecting. It's his co-author or student who is responsible and influences this. If a researcher checks if there is indeed something similar published he is considered highly autonomous in this aspect of selecting scientific information.

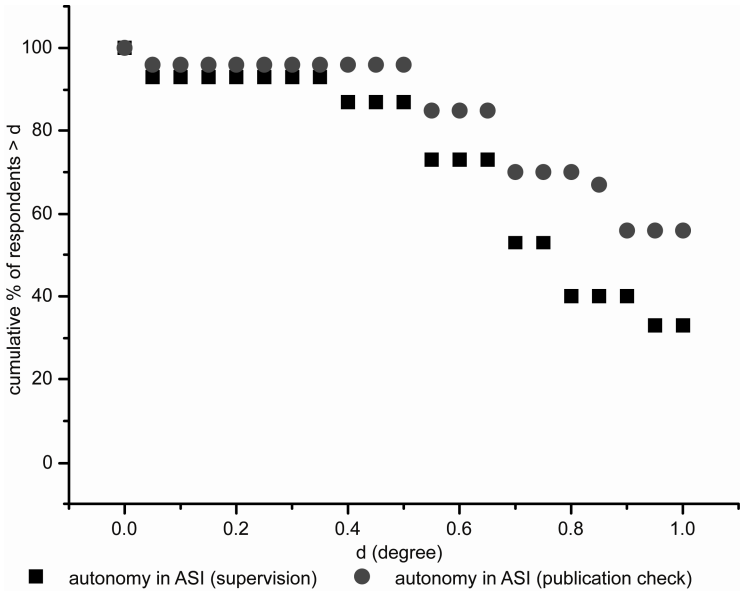

Figure 12. The cumulative distribution of the MESA+ respondents having autonomy when acquiring scientific information (ASI) higher than d.

The majority of the researchers in both the IGS sample and MESA+ sample are highly autonomous when acquiring scientific information (figure 12 and 13). For the IGS sample the distribution of the autonomy when acquiring scientific information (ASI autonomy) does not show any differentiation

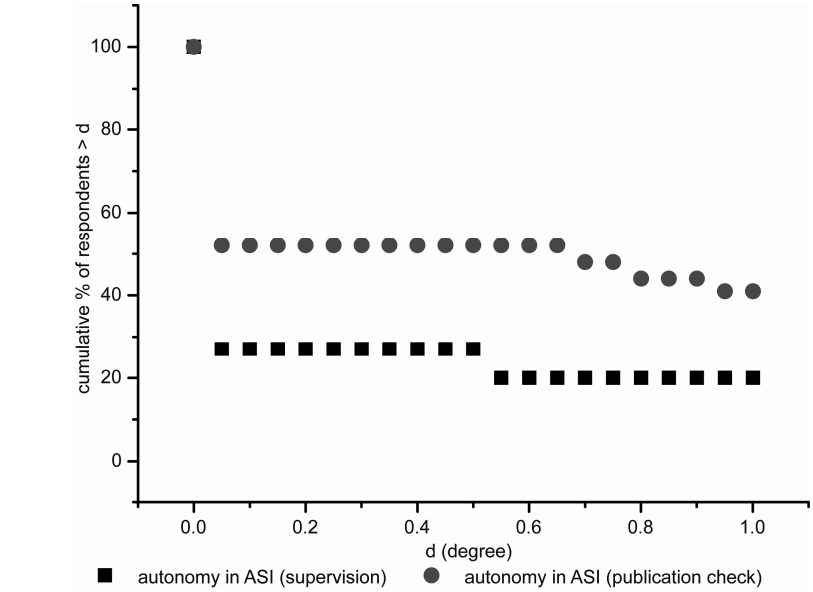

Figure 13. The cumulative distribution of the IGS respondents having autonomy when acquiring scientific information (ASI) higher than d.

Choosing research goals

We also measure to what extent researchers set research goals autonomously. To do so we asked the researchers if they write project proposals and for whom. The researchers who write proposals, or give ideas and steer the writing for members of their groups or strategic research orientations have influence or power on setting research goals. They decide in what direction research groups or research orientations should go. They are highly autonomous with respect to setting research directions. The researchers writing proposals for individual projects not involving any other researchers, and researchers commenting on proposals of others, have less influence on the direction of research for their groups and have a medium degree of autonomy. Researchers who do not write proposals at all are assigned a low degree of autonomy.

In figure 14 we see that most of the researchers from both samples set research goals for individual projects or write project proposals. About 35% of the interviewed researchers in the MESA+ sample, about 20% of the researchers in the IGS sample set research goals for their groups or direct research orientations.

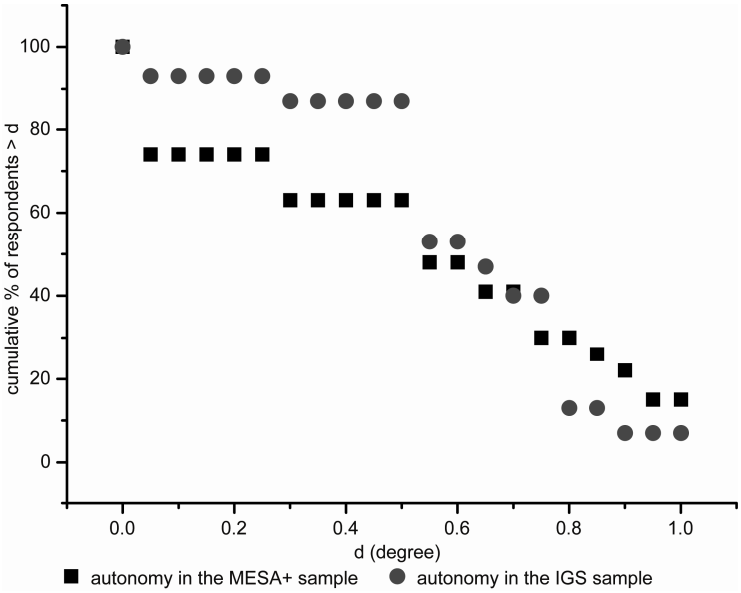

Figure 14. The cumulative distribution of respondents having autonomy in setting research goals higher than d.

7. Testing the main hypotheses

The main hypotheses tested here are derived from the positioning model (Kurek et. al, 2007a, b). These hypotheses concern relations between the production of knowledge (dependent variable), strategic interdependence and organisational autonomy (both independent variables). In the model we assume that a researcher with a high degree of interdependence and a high degree of autonomy will produce more knowledge than a researcher with a lower degree of both variables. The main hypothesis is presented in the following equation:

$$H1: \uparrow PK = PK\ (SI \uparrow + OA \uparrow).$$

This above equation presents mode3 – the research entrepreneur. Other feasible combinations of strategic interdependence (SI) and organisational autonomy (OA) result in mode0 = SI $\downarrow$ + OA$\downarrow$; mode1 = SI $\downarrow$ + OA$\uparrow$; and in mode2 = SI $\uparrow$ + OA$\downarrow$. The modes are presented in figure 15.

We assume that researchers in these three latter combinations produce relatively less knowledge than they would produce if positioned as research entrepreneur.

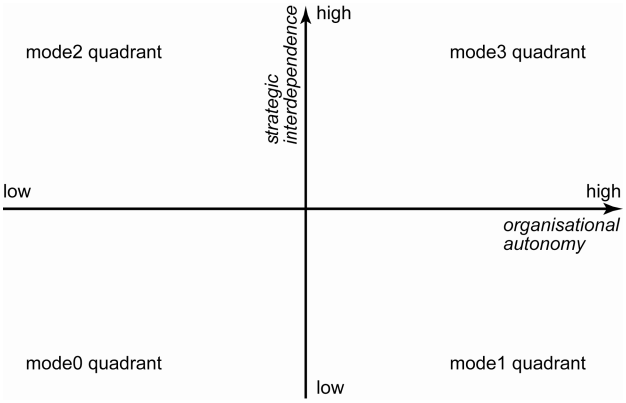

Figure 15. The continuum of modes of strategic positioning.

A further second hypothesis is that mode2 researchers produce less knowledge than mode3 researchers but more than mode1 researchers, whereas mode1 researchers have a larger production than mode0 researchers, or:

$$H2: PK_3 > PK_2 > PK_1 > PK_0$$

To test these hypotheses we first computed the overall degrees of SI and OA in making research results public and the acquisition of scientific information. The degree of SI was computed as the mean of the partial positions in dependence on colleagues in writing articles, dependence in acquiring scientific information. The degree of OA was computed as the mean of autonomy in choosing journals, writing autonomy, autonomy in assessing when the work can be submitted for a publication, autonomy in selecting journals for publication, autonomy in choosing references, autonomy in the acquisition of scientific information.

Figures 16 and 17 present the observed distributions of SI or OA. The statistics show that the interviewed researchers have on average a rather high degree of autonomy (80% of the interviewed researchers in the MESA+ sample and about 90% of the researchers in the IGS sample) in making research results public and acquiring scientific information. No extreme values 0 or 1 are observed for either dimension. As to be seen in figure 16 the MESA+ researchers are highly autonomous and highly interdependent. The gap between the autonomy and interdependence curves is larger for the IGS sample (Δ=0.267) than for the MESA+ sample (Δ=0.054). This gap will be indicative for the modes of strategic positioning and the production of knowledge.

Figures 16 and 17 present also the mean values (μ) of SI or OA and the standard deviations (σ) of these values. These values for μ are measured in the cumulative distributions for SI and OA (figures 16 or 17) at 50% by fitting the cumulative distributions by a normal distribution, as expressed in R^2 (figures 16 and 17). The standard deviation indicates the spread in the average value in the sample.

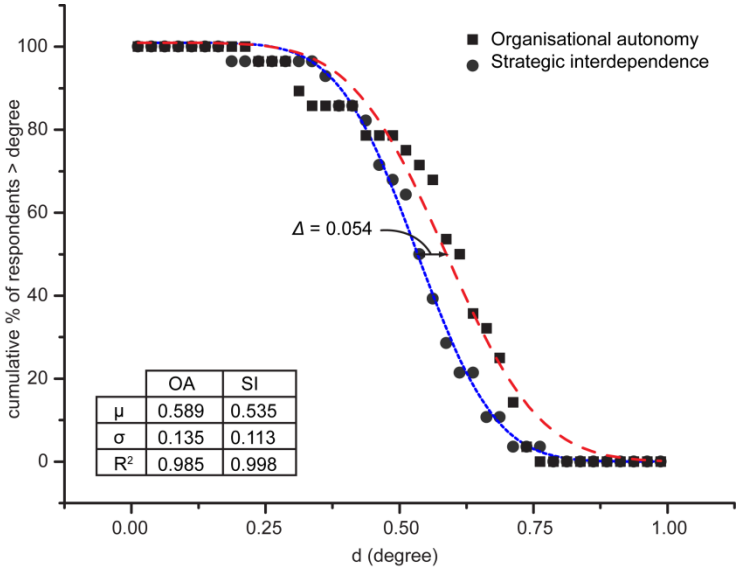

Figure 16. The cumulative distribution of the MESA+ respondents having SI and OA higher than degree.

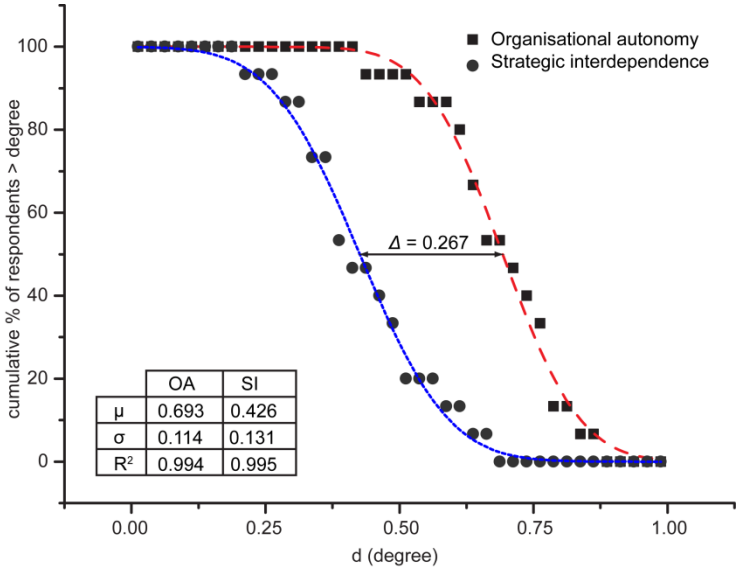

Figure 17. The cumulative distribution of the IGS respondents having SI and OA higher than degree.

These observed distributions of SI and OA are commensurate with the distribution of the modes in the two samples. As most of the researchers in the MESA+ sample are generally highly autonomous and interdependent (56%), they position themselves in mode3 as research entrepreneurs (figure 18). 22% of the researcher is highly

autonomous but lowly interdependent and this is mode1. The minority positions himself in mode2 (11%) or mode0 (11%).

These presented modes should be seen as mode spaces rather than as discrete modes. For the purpose of presenting the modes on this pie chart (figures 18 and 19) we make a distinction between 4 mode spaces as shown on figure 15.

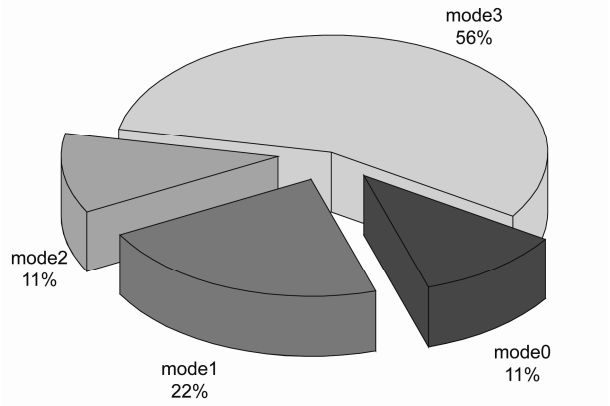

Figure 18. The distribution of the modes in the MESA+ sample.

In the IGS sample we find more mode1 (66%) than mode3 (27%) researchers (figure 19). The researchers are highly autonomous but rarely work together with other researchers when making research results public or with the societal environment.

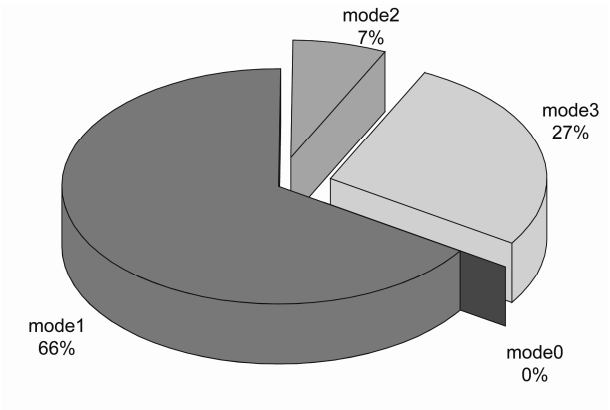

Figure 19. The distribution of the modes in the IGS sample.

These pie charts illustrate a discrete representation of the distributions over the modes. The full distributions over the continuous modes are presented in figures 20 and 21.

To analyse the results from the interviews for each of the two samples we perform a linear regression analysis on the two dependent variables of the normalised number of

articles or PKIF and the two independent variables of strategic interdependence and organisational autonomy (overall degrees). We begin with constructing a simple regression model assuming a linear relation between the dependent variable of PK and two independent variables of SI and OA. This model is expressed in the following equation:

$$PK = a_0 + a_1SI + a_2OA + e,$$

with

- a_0: the intercept
- a_1:the slope of the independent variable SI;
- a_2: the slope of the independent variable OA;
- e: the error term.

The unstandardised coefficients resulting from this model (for the MESA+ sample: a_1 =4.86, a_2 =17.75, for the IGS sample: a_1 = 2.67, a_2 =-1.13 in table 2) show the expected effect on the production of knowledge as assumed in the positioning model. The model explains 19% of the variance for the MESA+ sample (R^2=0.19) and 8% for the IGS sample (R^2=0.08).

The IGS sample shows a negative effect of autonomy on the production of knowledge.

Interdependence is seen as a precondition towards autonomy – if there is no relationship at all, there is no need to consider autonomy. No relationship means that there are no resources shared, not even financial resources. Autonomy is relevant only if there is a simultaneous necessity for strategic interdependence.

The distribution of the observed production of knowledge for the MESA+ sample is presented in figure 20 and for the IGS sample in figure 21. The figures visualise the differences in the production of knowledge in the different modes of positioning. The circles indicate the production of knowledge per researcher observed in the sample. The larger the circles, the larger the production. We see that the researchers positioned in mode3 and mode1 are the most productive in both institutes. The shaded areas in figure 20 and 21 show the average degrees of both SI and OA and their spread for each sample as calculated in the model. For the MESA+ sample this area is located predominantly in mode3 and extends into mode1, slightly grasping the mode0 and mode2 spaces. For the IGS sample the average value and its variance are located predominantly in mode1 and extend into the mode3 space.

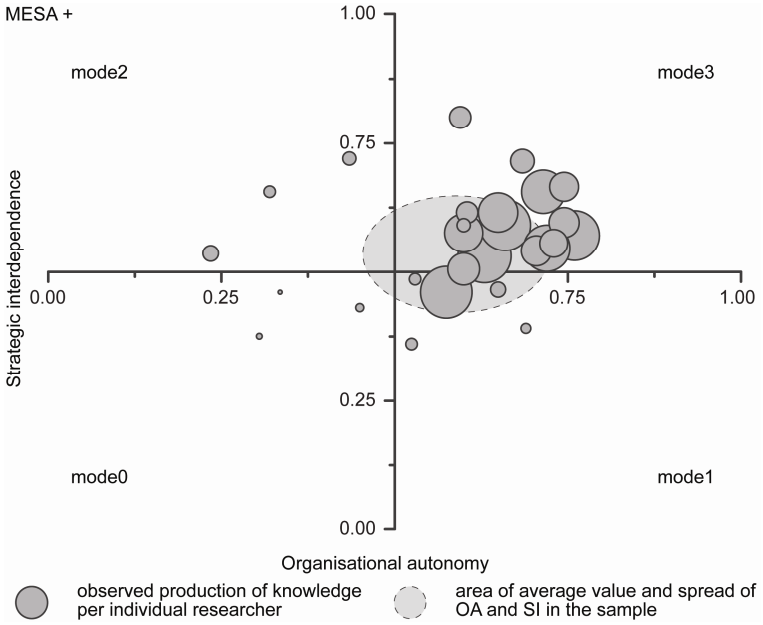

Figure 20. The observed production of knowledge for the modes of strategic positioning and the average value of both SI and OA and their spread in the MESA+ sample.

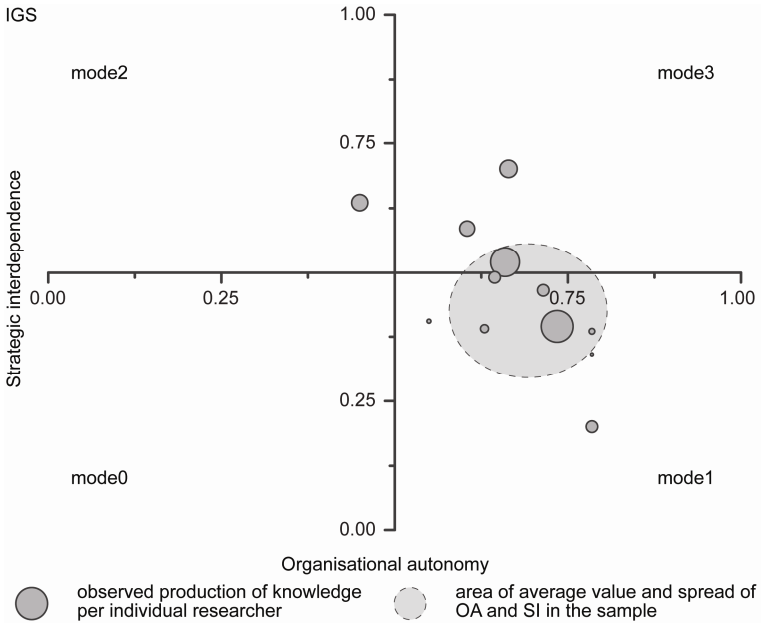

Figure 21. The observed production of knowledge for the modes of strategic positioning and the average value of both SI and OA and their spread in the IGS sample.

To test the positioning model in giving predicted values for the production of knowledge under different degrees of interdependence and autonomy we make use of an interaction model. The use of interaction models is a common way to test causal claims in scientific models (Wright, 1976; Brambor et al. 2006). We test if the conditional nature of the main hypotheses, as we assume in the model, is not intuitional, i.e. if indeed SI and OA cause the growth of the production of knowledge. This can be done by adding an interaction factor to the linear regression analysis of the causal claim. Here such an interaction variable is SI*OA. Usually, such an interaction variable is a dichotomous variable that equals one when the assumed condition is met, and zero otherwise. However, in this case we cannot use a dichotomous variable because the modes are continuous. In using a dichotomous variable we should have to make the modes discrete. The production of knowledge (PK), SI and OA are however all continuous variables. The regression analysis was run for these variables to test the two hypotheses derived from the positioning model and formulated above. The first hypothesis is then formulated as:

$$H1: \uparrow PK = PK (SI \uparrow + OA \uparrow), \text{ or in words:}$$

The more the researcher is both strategically dependent on his colleagues and autonomous in making research results public and in the acquisition of scientific information, the more knowledge he produces.

The second hypothesis concerns the relations between the differences in the production in different modes:

$$H2: PK_3 > PK_2 > PK_1 > PK_0$$

The production of knowledge is larger in mode3 than in mode2, the production of knowledge in mode2 is larger than in mode1 and in mode1 > mode0.

The interaction model is expressed in the following equation:

$$PK = b_0 + b_1SI + b_2OA + b_3(SI*OA) + e,$$

with

- b0: the intercept;
- b1: the slope of the independent variable SI;
- b2:the slope of the independent variable OA;
- b3: the slope of the interaction variable (SI*OA);
- e: the error term.

Table 2 presents the unstandardised coefficients[4] for both samples resulting from the interaction model. The coefficients for the multiplicative interaction models cannot be interpreted in the standard way like in a standard linear regression model, like the average effect of a change on SI and OA (Brambor, 2006). The coefficients cannot be

[4] For a discussion on the use of unstandardised coefficients see: Wright, 1976.

considered separately. To interpret the results the above equation is specified for all four modes of positioning. The results are predicted values of the dependent variable (table 2 and figure 20 and 21).

Table 2. Results of the interaction model analysis for the number of articles and the predicted values of PK in the four modes.

	MESA+ sample	IGS sample
coefficients	b_0=0.41	b_0=3.00
	b_1=-9.92	b_1= -1.68
	b_2=4.23	b_2= -4.07
	b_3=25.30	b_3= 6.15
R^2	0.19	0.09
Adjusted R^2	0.09	-0.16
Std. error of estimation	6.08	1.68
predicted values of PK		
mode0 (0.25; 0.25)	0.57	1.95
mode1 (0.25; 0.75)	5.85	0.68
mode2 (0.75; 0.25)	-1.23	1.88
mode3 (0.75; 0.75)	10.37	2.14

As argued, the positioning model is a continuum allowing the calculation of predicted values for the production of knowledge for any combination of values for SI and OA ranging from 0 to 1. To illustrate the predicted values of the production of knowledge under different conditions of strategic interdependence and organisational autonomy we present two types of graphs.

The first type of the graphs is a contour plot. The contour lines in figure 22 indicate the number of articles that the researchers in the MESA+ sample would produce assuming specific combinations of SI and OA. Legends on the right sides of the graphs present the scale of grey indicating the number of articles. For the MESA+ sample the predicted production increases with the increase of the degrees of both SI and OA, i.e. is the highest for extreme degrees of mode3 (about 20 articles per year). The researchers in the MESA+ sample would thus be most productive if positioned in mode3. The predicted value for the production of knowledge turns out to be negative in mode2 for the MESA+ sample. This is interpreted as a non-feasible mode, because a negative

production is not possible, and therefore this cannot but lead to an exit strategy from scientific research[5].

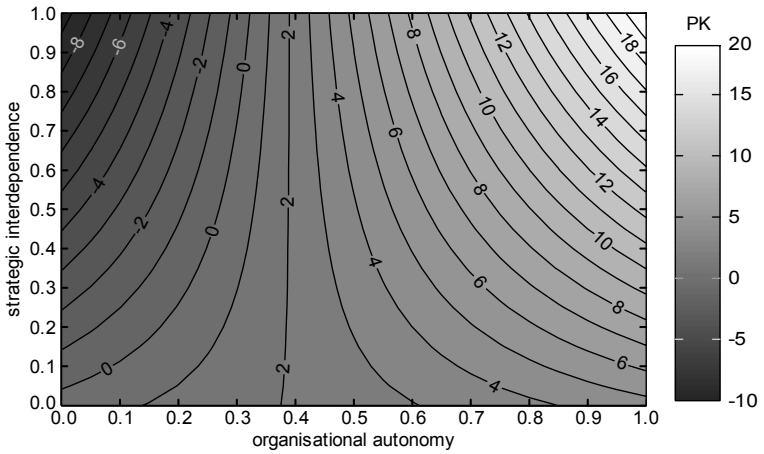

Figure 22. The predicted production of knowledge for MESA+ under various combinations of strategic interdependence and organisational autonomy.

It is in principle possible to calculate the predicted values of the production of knowledge for the IGS sample for any degree of SI ad OA. The results of the interaction model for IGS are reported in table 2. However, because the data for IGS is highly scattered as there is a small number of observations we have chosen not to report the predicted production of knowledge. There is too little information to draw firm conclusions on the predicted production for the sample and also to show improvements to the simple linear model.

The second type of graph that we use to represent the results is a three-dimensional graph showing the same results but from a different perspective (see figure 23). The X-axis represents the organisational autonomy, the Y-axis the strategic interdependence, and the Z-axis the production of knowledge. The figure clearly illustrates that a high degree of SI coupled to a high degree of OA leads to a preferred position for a high production of knowledge.

[5] It might be that researchers in this position will produce more consulting type of products. Speculating on the information we got from the interviewees from MESA+, sometimes researchers include in the co-authorship some of the technicians at MESA+. These technicians delivering on the demand of researchers are highly dependent on the researchers and at the same time less autonomous (even though they might suggest solutions, they are supposed to comply with already set research goals).

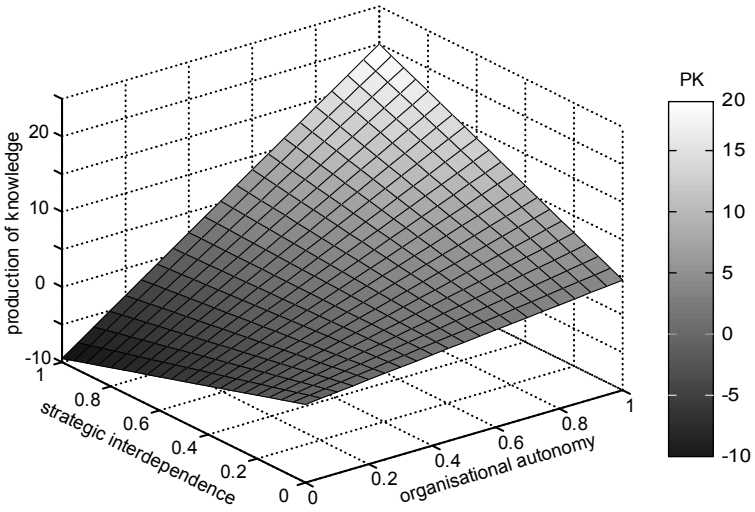

Figure 23. Three-dimensional representation of the predicted values of production of knowledge in various combinations of SI and OA for the MESA+ sample.

The results of the interaction model for both samples confirm the conditional nature of the main hypothesis tested here. Thus we can conclude that a researcher who is both highly dependent on his colleagues and highly autonomous in making research results public and in acquiring scientific information is more productive.

The H2 hypothesis, however, has to be rejected as researchers would produce in both samples more knowledge in mode1 than in mode2. This allows us to conclude that a high degree of autonomy adds to the production of knowledge. And if there is a high degree of interdependence it adds even more significantly.

The second dependent variable of the production of knowledge as measured by the number of articles multiplied by impact factor shows a similar pattern.

For the IGS sample the results are too scattered to establish a firm linear relationship. Therefore, we can neither confirm nor refute the linear model for the results in the IGS sample. But, even if the IGS results are scattered, the results do not contradict the general pattern and the data allow us to conclude that the mechanisms in the two samples are commensurate.

8. Discussion and conclusions

The production of knowledge is analysed in this article using the model of strategic positioning based on the dimensions of strategic interdependence and organisational autonomy. The model was tested in an empirical study conducted with two samples of researchers of the MESA+ Institute for Nanotechnology and the IGS Institute for Governance Studies, both located at the University of Twente. The results obtained in the interviews with the researchers from these institutes confirm that the model is

feasible: next to creating clear observables for the modes of strategic positioning (Kurek et al., 2007a, b), it is able to predict the production of knowledge.

In comparison to other studies on scientific productivity mentioned in this article (e.g. Lehman, 1953; Pelz & Andrews, 1966; Cole 1976; Cole & Zuckerman, 1984; Fox & Faver, 1985; Long, 1987; Levin & Stephan, 1991; Gaughan & Bozeman, 2002; Godin, 2003; Bozeman & Corley, 2004; Lee & Bozeman 2005; Crespi & Geuna, 2008), we claim that these results give more insight in the conditions under which knowledge is produced. Consequently these conditions should be considered when establishing collaborations with other researchers as they present a diagnosis of the performance of researchers in producing knowledge. This diagnosis shows that the strategic positioning of the researcher has an effect on their productivity. Different combinations of the degrees of both strategic interdependence and organisational autonomy result in a difference in the production of knowledge for each different sample. It has been confirmed in the analysis for both samples that the more the researcher in positioning himself is both interdependent and autonomous, the higher his knowledge production will be.

Figures 5 and 6 show the production of knowledge in the two samples. The data show clear differences between the two samples, as anticipated. Thus we have created two samples sufficiently different and allowing scrutinising the positioning model. It can be concluded that given these differences the positioning model can be applied to both samples leading to significant differences observed in strategic interdependence (SI) and organisational autonomy (OA) and explaining the mechanisms for the observed production of knowledge. This leads us to assume that the mechanisms in the model could well be applied more generally, i.e. also in other domains that were not the object of this study.

The data for the IGS sample suffer from more scattering than the data for the MESA+ sample. This is due to the fact that the sample is smaller than the sample for MESA+, combined with a larger heterogeneity in scientific domains and therefore in publishing habits. Nonetheless, the results for both samples allow us to observe significant differences in autonomy and interdependence and consequently knowledge production as outlined above.

If we look closer at the relations between the dependent variable, the production of knowledge, and the independent variables, the strategic interdependence and organisational autonomy, we see differences in the distributions of the two independent variables and in consequence the distribution of modes of strategic positioning. The researchers in the MESA+ sample are in general more dependent on their colleagues when making research results public and acquiring scientific information. About 80% of the researchers in the sample is highly interdependent, whereas only 40% of the interviewed researchers in the IGS sample is highly dependent on their colleagues. The researchers in the MESA+ sample work with a higher number of co-authors than the

researchers in the IGS sample. This can be well explained by the necessity for sharing resources of others in experimental sciences (Beaver & Rosen, 1978).

An interesting observation is that the gap between the distributions of SI and OA, as seen above, is rather large for the IGS sample (0.267) and smaller for the MESA+ sample (0.054). Relating the observed production of knowledge (for both samples) and the predicted values of the production of knowledge for the MESA+ sample as shown in figures 22 and 23 to this gap results in the assumption that to ensure a higher productivity research management could stimulate closing the gap by increasing the interdependence between researchers. A significant result of this study is that in order to be highly productive researchers need to share resources with other researchers - interaction in science is crucial. And this result is shown to be independent of the absolute level of production.

Because of the large scatter of the data for IGS we do not report the predicted values of the production of knowledge as this might lead to incorrect conclusions. The scatter and the small number of observations do not allow us to draw conclusions on the predicted production.

The gaps between the distributions of SI and OA should be considered when developing strategies, and polices for a research group or research institute. Closing the gap is then a challenge for the management of such a research group or institute. As the combination of high necessity for both interdependence and autonomy results in higher productivity a research group or institute is well advised to stimulate the strategic interdependence between researchers in combination with a reasonably high degree of autonomy of the individual researchers.

On the basis of the diagnosis of the scientific productivity it is possible to draw conclusions that may be of relevance for policy makers. The model can well serve as a tool in setting research programmes as it gives insight on which settings could and should be created by research managers or policy makers, given the specific domains and organisational conditions. The model can be used for strategy development of research groups or institutes as it predicts the degree of necessity for both strategic interdependence and organisational autonomy the researchers need in order to attain the chosen strategic goals. It shows how to position researchers in their research environment to enhance the productivity in line with the goals of the group or institute.

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Part II

Chapter 4: The use of business models for scientific publishing in the production of knowledge*

Kasia Zalewska - Kurek, Peter A.T.M. Geurts & Hans E. Roosendaal

The goal of any business model for scientific publishing in the research environment should be to serve researchers in the production of knowledge. Sharing of scientific information is seen as a prerequisite for this production. A publishing business model organises the conditions under which scientific information, i.e. information reporting research results, is being shared. As the focus is on the production of knowledge, this article addresses primarily the conditions set by the research environment on a business model next to commercial conditions. Main elements in any business model are the strategic positioning of researchers in their societal environment and competition in the research environment.

It will be shown that publishing business models can be analysed in terms of two main parameters: availability and selection of scientific information.

Different degrees of availability and selection lead to different business models for scientific publishing in which availability and selection can in principle be provided by various suppliers such as a university or a commercial publisher.

* to be submitted for publication

1. Business models in the research environment

Business models for scientific publishing draw more and more attention in the discussion on the future of scientific communication. Scientific communication has developed very fast in the last decade. This was caused by e.g. new information technology such as the Internet that improved formal and informal communication among researchers (e.g. Meadows, 1998; Geurts & Roosendaal, 2001; Roosendaal, Geurts & Van der Vet, 2001; Meho L.I. & Tibbo H.R., 2003; Tenopir et al., 2003). Apart from that, the knowledge society has commenced a new dialogue with science. Society is interested in scientific development and potential applications of the research results. Thus, scientific communication flows both within the research environment and from the research environment to the societal environment and vice versa. As will be discussed in this paper, both of these flows are of interest for any business model for scientific publishing.

In this article the premise is that such business models should be commensurate with the research environment serving the production of knowledge. Like any general business model it should create value in its environment (Chesbrough, Rosenbloom, 2002). A business model is then defined as a sustainable organisation for creating value in a specific environment. For a given setting specific conditions are then to be applied. A publishing business model organises and manages scientific information in setting conditions for the use of this information in scientific research activities. Scientific information is defined here as information reporting research results. Serving the production of knowledge is only possible if such a business model supports researchers as main stakeholders (users) in these business models in undertaking research. This makes the understanding of the mechanisms of scientific communication a requirement in developing publishing business models. Following the argument that scientific communication and information are the core of research (Meadows, 1998), the roles of scientific information, in particular sharing of scientific information, will be discussed before dealing with business models.

In this article we analyse publishing business models from the point of view of the researcher. The starting point is that scientific information is an integral part of research. In reporting research results scientific information should not be considered a final product, as would be the case for most products, but an intermediary product accepted by the scientific community as being worthy of further scientific effort and scrutiny (Popper, 1963). Therefore, scientific information is produced in scientific research and adds value to existing scientific knowledge only if it is shared, i.e. made public. Sharing information is in line with scientific ethos according to which science should be universal implying that nobody should in principle be excluded from it. According to Merton, scientific knowledge is common property and thus has to be shared otherwise it does not exist (1973). Researchers accountable to their research environment make public their research results as scientific information. They do so by

means of scientific reports such as journal publications, books, scientific presentations, etc. These research results can then be falsified in future research (Popper, 1934).

Summarising, from the researcher's point of view any business model for scientific publishing should have as core value proposition the sharing of scientific information. It may be noted that this definition of sharing does not imply that the information is for free, or that can be no commercial interests neither on the part of the researcher nor on the part of other stakeholders. As authors, researchers want to be recognised in the research environment. This requires availability of the information. At the same time as readers, they want to be able to effectively and efficiently select scientific information and to stay up-to-date with scientific developments. For researchers, scientific information should thus be available to serve them in their role not only as authors but also as readers. The acquisition of scientific information is then determined by the availability of the information and the ability of researchers to select this information. We need then to analyse the two aspects of scientific publishing: making research results public as scientific information and acquiring this scientific information. These aspects should therefore be accounted for in publishing business models.

As business models for scientific publishing manage scientific information they should fulfil the above mentioned conditions of availability and selection of scientific information. It will be shown that availability and selection are the main parameters of any business model for scientific publishing, albeit not in all models with equal weight. As the acquisition of scientific information is important for research, this acquisition should be enabled by services accounted for in business models for scientific publishing. To this end, an analysis of conditions under which scientific research is being performed is required. The efficacy and efficiency of the acquisition of scientific information has to be optimised to allow effective use of this information.

The main parameters availability and selection will be applied to a set of business models including the known publishing models such as the subscription model and the open access model. The subscription model focuses primarily on selection. This model was lately discredited because of the 'serials crisis' (Battin, 1982; Tinerella, 1999). In this serials crisis price increases by publishers lead to cancellations of journal subscriptions leading in turn to further price increases and so on, causing in the end, reduced accessibility of scientific information resulting in limited availability. A response to this crisis and to the resulting limited availability is the *Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities* (2003) that postulates general access to scientific information.

2. Strategic positioning

As mentioned, the strategic positioning of researchers should be accounted for in business models for scientific publishing. In this section we analyse this positioning and its function in the research environment regarding scientific publishing.

Researchers are considered part of a research enterprise which is defined as either individual researchers or groups of researchers performing activities contributing to scientific research. These activities include research activities and organisational activities embedded in the societal environment of such an enterprise.

Researchers position themselves and their research in the societal environment in order to achieve their strategic, long term goals. The main strategic goal of researchers is to produce scientific knowledge. Research, and therefore scientific information that is being used in research, is a means to attain this goal. In producing knowledge, researchers have to make choices to share with external sources heterogeneously distributed strategic resources, such as research facilities like knowledge, skills, time, instrumentation and funds (Laudel, 2006). Such choices are an integral part of a strategy leading to a specific strategic position of researchers given their specific goals. The choices of researchers concern the acquisition of resources from the societal environment, and their matching.

Researchers position themselves in a continuum of strategic positions span by four modes of strategic positioning: mode0, mode1, mode2 or mode3 (Kurek, et al., 2007). These different modes result from different positions of researchers in the dimensions of organisational autonomy (defined as self-governing in deciding about the directions of research in a competitive environment, including setting goals) and of strategic interdependence (defined as deliberate sharing of heterogeneously distributed strategic resources) (Haspeslagh, Jemison, 1991). Degrees to which researchers give up their autonomy and accept strategic interdependence lead to different conditions on these two dimensions (Kurek et al., 2007). These conditions determine the production of research results and the activities required for this production: making research results public as scientific information and acquiring scientific information. Specific conditions on organisational autonomy result in different research goals and different scientific products such as e.g. scientific publications, patents, scientific products. These specific conditions may e.g. cause a delay in scientific publishing, retention of some research results or even cancellation of a publication.

In mode1, there are no specific conditions on organisational autonomy by the societal environment. Sharing of resources is limited to financing research only. Researchers claim intellectual property by making research results public in scientific journals or at scientific conferences, etc. They are autonomous in deciding about what, when and with whom to publish. The mode1 researchers strive for long term recognition in the research environment. The driver to publish is not to earn reputation in the societal environment, as they do not need to acquire strategic resources from this environment.

In mode2, researchers are less autonomous and less independent. There are specific conditions on organisational autonomy. The societal environment may ask researchers to delay a publication or even to retain certain scientific results that are considered as confidential and should not be disseminated. This does not restrain researchers from

making results public in scientific journals. The societal environment may, however, influence types of scientific products and claims. They might lead to commercial products to which intellectual property is claimed in patents. To this end, delays might amongst other be related to the process of patenting of scientific products initiated by the societal environment.

The mode3 researchers, the research entrepreneurs, seize the opportunity to autonomously determine the strategic directions of research including research goals. The specific conditions on organisational autonomy are much smaller than for researchers in mode2. Researchers are though accountable to their societal environment. The environment may ask them to patent and market their research results. The difference between the mode2 researcher and the research entrepreneur is that the research entrepreneur does not accept the societal environment to unduly delay a publication or retain scientific results unless agreed upfront. The delays are only caused, similar as in mode2, by organisational aspects influencing the publication process such as e.g. the patenting process.

Mode0 is mentioned here for reasons of consistency only. As there is no relationship with the societal environment at all in mode0, this mode is irrelevant (Kurek, et al, 2007) for the discussion on business models for scientific publishing. Therefore, this mode will not be discussed any further.

Also in terms of acquiring strategic resources the strategic positioning of researchers is connected with claiming intellectual property. Researchers make use of their reputation and recognition in the research environment to acquire or match strategic resources. Researchers successful in the research environment and having a good reputation earned by top level publications, invited speeches, etc., have a strategic advantage over their colleagues and competitors and therefore greater chances to collaborate with the societal environment. That is because researchers are judged on their scientific developments, "often grant funding depends largely on the quality and quantity of previous publications" (Yoxen in: McCain 1991, p.262). Reputation in the research environment helps researchers in negotiations on conditions on organisational autonomy and strategic interdependence. The more reputable the researchers, the higher position in these two dimensions they can negotiate, depending on their strategic goals. Researchers having high positions in their research environment are more likely to be invited to develop and deliver scientific products that they propose.

The reputation of researchers is built on their position in the research environment on claiming intellectual property and productivity, and thus credibility of the claims.

3. Competition within the research environment

Scientific information, like information for any business organisation, creates competitive advantage for the research enterprise as researchers use the acquired information in producing scientific knowledge. Competitive advantage achieved by means of scientific information enhances the influence of researchers not only in their

research environment but also leads to a better strategic position in the societal environment.

Competition in the research environment was studied by a number of researchers. One of the first contributors to this subject is Merton (1957) stating that the increasing number of scientists and the popularity of particular scientific domains cause clustering of research areas into a limited number, and may lead to multiple discoveries. He illustrates his argument by the pursuance to priority of discovery with examples of conflicts over priority between Newton and Hook, and between Newton and Leibniz. Since Merton, many other researchers significantly contributed to this subject (e.g. Gaston 1970, 1971, 1973; Hagstrom, 1965, 1974; Collins, 1968; McCain, 1991, Atkinson, 1998). Hagstrom confirmed Merton's discovery of competition in research. According to his study in physics and biology, over 60% of his respondents were faced at least once with the fact that somebody else published a solution for a research problem they were working on.

Other research results delivered by researchers from 14 countries in 1992-93 also confirm the influence of competition in the research environment. These results show the importance of publishing research results for competitive purposes, in particular for tenure. Researchers from Israel (81%), Germany (78%), Sweden (58%), Australia (64%), and US (75%) agreed that "it's difficult for a person to achieve tenure if he/she doesn't publish" (Altbach, 1996).

Gaining competitive advantage will also result in a number of rewards. Firstly, research results made public as scientific information produced by researchers if accepted by the research environment, contribute to scientific knowledge. Secondly, the research environment offers recognised researchers e.g. scientific position, tenure, research projects, being asked to review scientific papers, grant proposals, being a member of an editorial board, member of programme committees of international conferences, invited talks at the international level, visiting fellowships (Laudel, 2006, p.491), and/or various consultancy opportunities both in research and in the societal environment. Recognition and reputation help researchers to acquire strategic resources from the societal environment, as argued above.

Scientific information in terms of competition

In this competition, scientific information plays a major role. Although, as discussed above, scientific information from the researcher's point of view should be common property and should in principle be shared, this is not always done for competitive reasons. Campbell et al. (2000, p.310) indicate that some researchers in academic medicine withhold data from their younger colleagues not having an established reputation, as well as from researchers commercialising their knowledge or publishing, in their opinion, too many papers. Other research conducted by Ceci (1988) reports on secretive behaviour among university researchers who do not share data before claiming intellectual property by publishing or patenting. Researchers are not willing to

share their research results before claiming the property as they are afraid of plagiarism or commercial abuse (Barnes, 1987; Campbell et al, 2002). Needless to say, sharing scientific information is important for the development of scientific knowledge and for minimising duplication of each others' research (Campbell & Blumenthal, 2002).

Roosendaal and Geurts (2001) and later Campbell and Blumenthal (2002) state that exchange of information is essential for the integrity of science. Research is only valid if it can be repeated and published research results are only valid if reproducible and not falsified by other researchers. Applied research methods should be transparent for the research environment. This means that others may request materials and data used in particular research. Withholding data precludes the quality control. Campbell et al. (2000) discover in their research on geneticists that secrecy and withholding data preclude confirming published research.

Secrecy, however, might be concomitant with research funded by the societal environment e.g. by industry (Wadman, 1996). This leads to specific conditions on the organisational autonomy. Such conditions, as seen before, are often conditions required by industry that information produced in joint research is kept confidential or the publication is delayed.

Summarising, competition is a driver for scientific publishing. Competition drives researchers to create new research results and to make these results public.

4. Business models for scientific publishing

Up to this point, two aspects of the research environment determining necessary conditions for scientific information and for the researchers' behaviour regarding scientific information and scientific communication have been discussed: the strategic positioning of the researcher in the societal environment and competition in the research environment. The reason to discuss these aspects here is the abovementioned premise that business models for scientific publishing should serve researchers in the production of knowledge.

Based on this premise, we will discuss in this section which aspects of the business models can serve researchers in producing knowledge. Such business models should serve both elements of scientific publishing: making scientific results public and acquiring scientific information.

Serving researchers in making research results public as scientific information and in acquiring scientific information demand sharing scientific information. Business models should then enable this sharing. This sharing of information requires the availability of scientific information as a necessary condition for making the results public and the power of selection by the researcher as a necessary condition for acquiring scientific information. Availability and selection are thus the parameters of a publishing business model that characterise the necessary conditions for scientific information and thus the role of information in the research environment. These parameters are generally valid for all publishing business models. Availability of

scientific information is thus a requisite for conducting research and helps researchers to earn recognition. The second parameter is selection by the researcher who has to acquire scientific information for the purposes as abovementioned. Selection is defined as the ability of researchers to select information that is relevant, up to date and acquired in an effective and efficient manner. Power of selection by researchers is an important aspect of the acquisition of scientific information due to the time limitation on research. Next to research, researchers also have to spend time on operational management (including supervision, writing scientific publications), education and the strategic management of relationships with the societal environment, limiting the time window for acquiring and reading scientific information. Improving efficacy and efficiency of the acquisition is in the interest of researchers, as it will allow saving their time they can use purely on research.

A business model is defined as the organisation of property (Kurek, et al., 2006). This organisation extends to the property, to the various owners, and to services to these owners. Therefore, we analyse the researcher as owner of the property and his or her actions focused around claiming intellectual property and the instruments protecting this property. Researchers will strive for maximum availability of scientific information and maximum power of selection, therefore any business model for scientific publishing should provide appropriate services to fulfil these necessary conditions for availability and selection.

Following Chesbrough & Rosenbloom in their general discussion on business models (2002) any business model for scientific publishing should:

- articulate a value proposition. In scientific publishing business models the main value proposition should be: making research results public and sharing these in the research environment,
- clearly define the market segment, i.e. the audience to which the scientific products are addressed,
- reflect the strategic position of researchers, as analysed before,
- identify the value chain of the research environment, and position of the value proposition in this value chain,
- reflect researchers' competitive strategy, and
- identify cost structure and profit potential.

Like stated before, any business model for scientific publishing should create value in the environment in which researchers operate. This includes added value for the research enterprise and commercial value for the research institution or intermediary acting as publisher. Publishing can or perhaps should be outsourced by scientific communities to external partners, e.g. to commercial publishers, as organising publishing is not a core scientific task. It is then required for the benefit of science that this external publisher enables sharing scientific information.

To improve sharing scientific information instruments protecting researchers have to be developed in a publishing business model. Such instruments are the intellectual property rights. Researchers claim the property by making this statement public, i.e. by publishing, the alternative being that the research results they produce will never exist. Research claims should be protected in the competitive research environment otherwise researchers will be not willing to share scientific information for fear of plagiarism and commercial abuse (as seen: Barnes 1987; Ceci, 1988; Campbell et al. 2000; Campbell & Blumenthal, 2002). In this case, a business model is the enactment of the negotiation between researcher and publisher (taking responsibility for exploitation rights transferred by researchers (Kurek, et al., 2006)) on the protection of intellectual property.

The acquisition of scientific information

As stated, business models for scientific publishing should also serve researchers in the acquisition of scientific information. This means that these business models should take into account that the acquisition of scientific information is largely determined by strategic positioning and competition.

Scientific information has to be available, up to date, relevant, and retrievable. It is recognised in the study of Tenopir and King (2000) that researchers among other activities spend on average 100-150 hours per year (depending on the scientific domain) on acquiring the information required for their research. This is a sizable fraction (5-10%) of the researcher's working year. Moreover, research is always done under some time pressure; either there is a deadline for a conference paper, or a presentation, or a report for the societal environment, etc. Researchers want to acquire scientific information effectively and efficiently. Therefore, they require services that will optimise the acquisition effort.

The way in which competition in the research environment determines the acquisition of scientific information is twofold. A lack of relevant and available scientific information that has to be acquired and scrutinised by researchers can lead to a crisis, to some discontinuity in research. This crisis situation can further result in a reduced strategic position of researchers in the environment and finally in losing their reputation or the chance to acquire strategic resources. Scientific information is therefore requisite for gaining and for retaining competitive advantage.

Second, competition determines the manner in which researchers acquire scientific information. Next to daily acquisition such as e.g. browsing the Internet and scientific journals, journal tables of content alerts, abstracting and indexing services, references in other articles, scientific communication with collaborators, etc. (e.g. Brown, 1999;Tenopir, King, 2000; Davis, 2004;), researchers acquire the information by searching what their competitors recently have discovered. Researchers must "monitor and anticipate what competitors ... intend" (Yoxon, 1988 as cited in: McCain, 1991). This is an aspect of the power of selection by researchers in their attempt to follow closely

most recent publications of researchers working in the same scientific domain to avoid multiple discoveries.

The efficiency of the acquisition of scientific information can be improved by improving the power of selection by researchers. This power can be enhanced by pre-selection provided by e.g. specific services to disclose the information effectively and efficiently. Researchers do then require 'basic' services making certified, i.e. peer reviewed, scientific information generally available. These basic services will of course include selection tools naturally based on the structure of scientific information.

This peer review is essential for the research environment and therefore core to any business model for scientific publishing. By 'branding' their contribution peer review serves researchers striving for recognition in the research environment. Peer review also serves researchers doing research, especially junior researchers, including students, in selecting the information as they are able to choose between different brands. In this way, peer review supports the power of selection of researchers and is important for the acquisition of scientific information.

Peer review serves the reputation of researchers. Researchers competing for recognition do not want to publish in low quality journals and hardly want to refer to such journals. Such journals may lose the audience and revenue stream (e.g. Prosser, 2005). Therefore, peer review should be a basic service offered by any business model for scientific publishing.

Peer review may be weakened in the open access model as argued by Prosser (2005). According to Prosser, such a weakness could consist of a lower reliability of the peer review process if researchers pay for their publication. For the same reason of reliability the university acting as publisher cannot manage the certification of research results of its own employees (Roosendaal, 2004).

Criteria for a business model for scientific publishing

The above analysis of the use of business models for scientific publishing in the research environment and its main aspects allows us to develop specific criteria for such a business model. First of all, such a model should create value in research, i.e. stimulate the production of knowledge. Such a business model can also create commercial value for the commercial publisher or the university acting as publisher, but this commercial value should be commensurate with the sharing of scientific information. Researchers need access to this information to be able to use it in the production of knowledge. Last but not least, the business model should be sustainable.

Serving researchers also means that a publishing business model accounts for the conditions determining how researchers are conducting research. This means that this model accounts for the different modes of strategic positioning in which different types of scientific information is being required, acquired and produced. This results in a different behaviour in scientific publishing as discussed above. A publishing business model should then account for competition within the research environment which, as

argued, affects the researchers' choices, requirements, and the necessary conditions for scientific information. The model should account for the two main aspects of scientific publishing: making scientific results public and acquiring scientific information.

Furthermore, as a publishing business model should serve researchers in producing knowledge it should serve them in claiming intellectual property and acquiring scientific information by providing a proper balance between availability of scientific information and selection by researchers. Such a balance increases the researchers' ability to acquire and select relevant scientific information and therefore, to gain competitive advantage. As argued in this paper, availability of scientific information is required by researchers for their daily research practice and their functioning in the environment. Researchers require availability of and accessibility to scientific information anyhow, anywhere and anytime. This means that the information should be universally accessible. The acquisition of scientific information also depends on the power of selection by researchers. This power of selection, if additionally enhanced by various services supplied by a publisher, gives researchers additional competitive advantage in terms of improved access to relevant and up to date information acquired at the right time.

Availability determined by the basic services of peer review and basic selection based on the structure of scientific information such as e.g. editorial lists or journal titles, and enhanced power of selection determined by added value services, are in principle two distinct services. These two distinct services can be provided by two separate suppliers: one responsible for wide availability of scientific information and one responsible for the enhanced power of selection by researchers.

A publishing business model can allow different combinations of availability and power of selection. This leads to a suite of different business models for scientific publishing in which availability and selection can in principle be provided by different combinations of suppliers.

In this way responsibilities and costs for availability can be kept separate from responsibilities and costs for selection. These models allow researchers acquiring selected information and selecting services for which they want to pay additionally.

Separating these costs benefits researchers. Paying for basic services in combination with added value services provided by one supplier makes the publishing and the acquisition quite expensive and leads to increase the competitive difference between large and small research institutes. Having different options by paying separately for chosen services encourages researchers to publish/acquire scientific information in/from a medium providing such an option.

In these models, researchers claiming the property only pay for the basic services of availability and peer review. Furthermore, researchers acquiring information can buy services according to their current needs determined by their strategic and competitive

position. Different types of scientific information and different situations may well require different added value services.

A solution for such business models could be a federated network of repositories (Roosendaal, 2004). Such a network would provide availability of scientific information and in this way fulfil researchers' need for recognition and access to relevant scientific information. It could also cut the costs for availability and additional services from different sources for researchers acquiring scientific information as well as the costs for claiming the property for researchers. Intellectual property and the protection of the author's moral rights have been seen to be an important element of a business model (Kurek et al., 2006). Repositories will only be successful if they are willing to warrant these moral rights of the authors. As an example, the Dutch repository DARENET does not fulfil this condition.

An example of combining the costs for availability and selection is the known subscription model. The subscription model provides limited availability of scientific information as access to the information is restricted by a subscription fee. This subscription fee is usually being paid by the research environment via the library. A library has limited financial resources and therefore has to make choices what scientific information to buy. This is not the choice of individual researchers. This limited availability is the clear weakness of this model from the viewpoint of the researcher. On the other hand, the power of selection by researchers is enhanced by the publisher offering additional services such as e.g. abstracting and indexing, sophisticated search software, appropriate metadata, alerting systems, mailing lists, etc. additionally to the basic services including peer review (Kurek et al., 2006) which are being paid by the researcher acquiring scientific information via a subscription fee.

The open access model as an alternative publishing model can also be analysed in terms of availability and selection. The general goal of open access is to provide general availability. There are some variations in open access models but the basic principle is that the researcher as author in claiming intellectual property pays for the publication. This enables sharing scientific information as this information is available and accessible anywhere and anytime. This means in practice that researchers are not dependent on the choice of a library. Nowadays, technology also allows open access journals offering most of the abovementioned selection services. A clear weakness of this model is that there is no real incentive to enhance the power of selection of the reader.

Combining the costs for these two parameters of availability and selection results thus always in a weaknesses in one of the two main parameters. We see that neither the subscription model nor the open access model does entirely fulfil the necessary conditions for general availability and power of selection. Each of these models focuses too much on one parameter.

Restricted availability and accessibility gives larger and strategically resourceful research institutes competitive advantage over smaller institutes or groups or

individual researchers. This means that some researchers are excluded from scientific results. This is not in line with the Mertonian ethos of science. Therefore, the open access model has been seen in the last decade as more acceptable with the research habitat, more suitable to the necessary conditions for scientific information because it provides a free flow of scientific information (see e.g. Serials Review: Special Issue on Open Access, 2004). The open access model seems then to be more acceptable than the subscription model as it complies with the competitive goals of researchers in claiming intellectual property and in acquiring information but still has the weakness that the power of selection may be less advanced.

From the above discussion, we see that a model providing full basic services combined with optional added value services fits the necessary conditions for scientific information better than the subscription model or the open access model. It should therefore be considered in the future development of scientific communication.

5. Conclusions

The goal of business models for scientific publishing in the research environment is to serve researchers in producing scientific knowledge. This means serving researchers in scientific publishing, in particular in making scientific results public and in acquiring scientific information.

We have analysed the research environment and the researchers' behaviour regarding scientific information as being determined by conditions created by this environment. We have also identified the necessary conditions on scientific information in meeting the requirements of researchers. These necessary conditions have been analysed in terms of two main parameters for business models for scientific publishing: availability and selection. Availability of scientific information, as a necessary condition for making scientific results public, has been argued to be prerequisite for conducting scientific research. Selection, as a necessary condition for acquiring scientific information, has been argued to depend on the reader's ability of assessing the relevance and the quality of the information for his work. These two main parameters can be met to different degrees. Researchers require then to make scientific information public, widely available and to deliver services increasing the efficacy and efficiency of the acquisition of scientific information. Researchers strive to minimise costs spent on the acquisition in terms of time and money.

The acquisition of scientific information is, as argued in this paper, influenced by competition in the research environment. This has consequences for the manner researchers acquire certain scientific information, e.g. by monitoring recent developments of their competitors.

These abovementioned aspects should be accounted for a publishing business model as they set criteria for such models.

The main conclusion of this article is that different degrees of availability and selection lead to different business models for scientific publishing in which availability

and selection can in principle be provided by different combinations of suppliers. Providing general availability and enhancing the power of selection by researchers leads to a suite of business models providing different options for added value services. In these models researchers claiming the property pay for the basic services of availability and peer review whereas researchers acquiring scientific information only pay for those added value services they choose to use.

Combining the costs for availability and selection is provided by business models that we know from the literature, i.e. the subscription model and the open access model. The subscription model has been seen to lead to enhanced power of selection by researchers but on the downside to limited availability of scientific information. Focusing on general availability leads in principle to the open access model. The weakness of this model, however, is that it has no real incentive to enhance the power of selection by researchers.

It is important to point out that different business models for scientific publishing allow making results public in a different way for different combinations of the two parameters and result in different modes of acquiring scientific information. Therefore, if such a model aims at serving researchers it should account for a combination of availability and selection that will be optimal for them.

As seen from the above discussion, it is then required for a publishing business model to focus on the two parameters in a combined way but at the same time keeping the costs separate. Such a model should in this case provide as basic service peer review. Peer review cannot be considered an added value service and as such should be accounted for by any publishing business model. Next to this, such a model should provide optional added value services that will meet requirements for selection by the researcher. These added value services are e.g. abstracting and indexing, sophisticated search software, appropriate metadata, alerting systems, mailing lists, etc. enhancing the power of selection by researchers.

Summarising, any business model for scientific publishing should serve researchers by providing wide availability of scientific information. A publishing business model should provide the basic services of availability and peer review and can offer optional added value services further enhancing the power of selection of researchers. It should serve researchers in attaining their strategic goals in their environment. Therefore, it has to fulfil the basic premise that scientific information is to be shared and used in the production of knowledge with the aim to enhance this production.

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Chapter 5: The split between availability and selection. Business models for scientific information, and the scientific process?*

Kasia Kurek, Peter A. Th. M. Geurts and Hans E. Roosendaal

The Berlin declaration on Open Access to Knowledge in the Sciences and Humanities has resulted in a strong impetus in the discussion on business models, and in particular the model of open access. A business model is defined as just the organisation of property. Consequently, business models for scientific information are discussed on the premise that any such business model should primarily produce added value for the scientific process next to commercial value for the research institution or intermediary acting as publisher. Furthermore, any business model should be sustainable. Scientific information is thus considered an integral part of the scientific process. It is not an end product but an intermediary product subject to scientific scrutiny. The final goal is to integrate the information into the scientific process. To this end, scientific information should be widely available for selection by the user as common property.

Two basic business models emerge: one with the focus on added value as selection by the user known as the 'subscription model'; and another one with the focus on wide availability known as the 'open access' model.

Both in the subscription model as in the open access model it is the scientific community that invests. In the subscription model scientific information is more considered as external to the scientific process in a consumer type model, while in the open access model scientific information is more seen as internal, as necessary acquisition costs for the scientific process. In the subscription model there is less incentive for broad availability of information whereas in the open access model there is less incentive to develop and maintain added value services to facilitate the selection by the reader. The organisation of property is a condition sine qua non. Although common property, the information is owned by the author claiming this property by the act of publication. Core to this claim

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of property is peer review being therefore core to any business model. The author is interested in protecting his moral rights against plagiarism; the publisher is interested in protecting the added value against commercial abuse. It is suggested that open access repositories could boost if repository management would guarantee protection of the moral rights of the author. In this way, the protection to the two main infringements could be split over different stakeholders. This would also allow separating the responsibility for availability coupled with peer review as a basic service from added value services coupled to selection at an optional charge.

In the end, any business model has to fulfil the basic idea that scientific information is not there just for the record as a commodity, but is there to be used in research and teaching: scientific information has no value in itself.

1. Introduction

The *Berlin declaration on Open Access to Knowledge in the Sciences and Humanities* (2003) has resulted in a strong impetus in the development of and the discussion on business models, and in particular the model of open access. Open access is not new. We may wonder why open access is especially now again in the picture. This may be due to the fact that open access seems with respect to habits and ethics more acceptable for the scientific community than the subscription model. The open access model values the production of scientific output more as intrinsic acquisition costs of the scientific process. Furthermore, the present Internet technology allows more advanced applications of the open access model than in the past. Against this background, this article will discuss options for business models for scientific publishing.

Before dealing with any business model we need to address the position of scientific information in the scientific process, and the conditions authors and readers do expect with respect to scientific information and its business model.

Following a brief introduction to these issues the paper will discuss the vision guiding scientific information, report on some pertinent developments in scientific information, report some relevant research data on the use of digital services in the Netherlands, will discuss some pertinent issues related to intellectual property before turning to business models and an outlook on market developments.

Some remarks on the position of scientific information in the scientific process seem appropriate as these are related to the use of scientific information. In this paper the view is taken that scientific information is an integral part of the scientific process. Merton (1973) extensively describes this scientific process and this description is still largely valid, albeit that Gibbons et al. (1994) and Ziman (1994) have made important contributions since then. For this discussion it is relevant to realise that science should be universal implying that nobody should be excluded from the scientific process and that scientific knowledge is common property or otherwise does not exist. Scientific information is not an end product. It is an intermediary product accepted by the scientific community as being worthy of further scientific effort and scrutiny (Popper, 1972a). The information must therefore be shared and thus must be available and it should be possible to 'falsify', using the original terminology of Popper, the knowledge in the future scientific process (Popper, 1972b). The author no doubt has a vested interest that this contribution to the scientific process is of such quality that the author wants it to be subjected to scientific scrutiny. Summarising, the primary purpose of scientific information and knowledge is to create value in the scientific process.

In looking at the market and business models we should thus keep in mind that scientific information is an integral part of the scientific process and that scientific publishing should serve the primary processes in science: research and teaching. Both primary processes need appropriate management information coupled to the research and teaching information. For science, the primary objective of scientific information is

to make use of the information for scientific purposes as outlined above and this means integration of this information into the everyday scientific working processes. This is the purpose that repositories among others will serve; they are not primarily built to generate direct revenue from this information. Integration of scientific information into the scientific process means that scientific information can be merged, mingled, manipulated and used in new or existing settings like e.g. worldwide collaboratives or collaboratories. Also in this sense scientific information and knowledge is common property or else loses its proper function. Next to sharing these results with the scientific community to be subjected to scientific scrutiny, these results will also be used in innovative change. In this way science will serve society and industry and vice versa will researchers be driven by innovation goals. To that end universities or research institutes should have the right to exploit the findings of their employees in a competitive environment and this implies the full use of these findings under conditions to be determined by these universities and the scientific community. The alternative would be that scientific information is only there for the record, and this would erode its value.

This article will discuss business models for scientific publishing on the premise that these business models will only be successful if they meet the following conditions:

- they should allow value creation for the scientific process;
- any model must cope with the natural growth of scientific information that is a result of scientific progress and is essential for the scientific process.
- they should allow commercial value creation;
- publishing will be outsourced by the academic community to external partners if and only if this outsourcing results in additional value creation for the scientific process. Value creation in this context may mean e.g. efficacy or efficiency of the sharing of scientific information, etc.

2. Developments of the scientific information market

The scientific information market has developed over a period of more than 300 years characterised by a steady growth of information. This market was faced by an almost disruptive technology, the Internet technology, promising new options of sharing scientific information that are more commensurate to the scientific habits as discussed above. In particular over the past 10 years this Internet development has resulted in considerable changes in the scientific information world. It is among others for this reason that universities and publishers have both invested in technological innovation.

With respect to publishers these investments have forced an ongoing clustering of publishers resulting in ever fewer publishers, with each of the remaining publishers controlling an expanding market share of published papers. This development has strengthened the strategic position of the publishers and as a consequence their negotiation positions vis a vis the scientific world, i.e. the universities. This

development is contrary to the expectations at the outset of the development of Internet; Internet was initially seen as a major instrument to empower authors and readers, and consequentially the universities.

What kind of strategies will universities develop and implement to their benefit? Only if science can build a strong position and will be a strong partner in the value chain, will it be possible to create a transparent market, i.e. based on comprehensive information for all stakeholders. Just complaining about high prices is simply not sufficient. In many countries universities now create 'repositories of information' with the aim to integrate the information required for research, education and the management thereof in an in-house system to make the scientific process more effective and efficient. These repositories also give them opportunities for public relations activities as needed nowadays in an era of growing worldwide competition between universities. And not least, the development of repositories also provides universities with the opportunity to strengthen their joint position in the value chain versus the other stakeholders, in particular the publishers. Indeed, these repositories of information allow universities to make scientific information widely available. This feels as scientific production coming back home to the alma mater.

The creation of e-science makes the above discussion on strategies related to the value chain of scientific information even more relevant. E-science essentially means the sharing of scientific information in a federated network of research and higher education institutions. E-science means a further step towards the goal of full availability of scientific results, comprising also the primary results and other pertinent data, and thus a further step towards full integration of information into the scientific process. This development is probably even more important for the smaller and medium sized institutions. It is key to them to fully participate in research that is nowadays organised in a more and more programmatic approach in a national or international setting. Only when firmly embedded in e-science these institutions may be able to effectively and efficiently participate in projects of that scale.

E-science means sharing of information at all levels in the scientific process, at the informal and formal level. Next to this demand for general availability, the demand for power of selection remains and this means a demand for services provided by other service providers as publishers and other intermediaries.

In summary: *'authors want to publish more, readers want to read less'* (Roosendaal, Geurts, 1997), is equally if not even more valid in the future than in the past. It states that in scientific information the author, after claiming intellectual property for the work, wants wide exposure for this work, and the reader wants for reasons of efficacy and efficiency to have the power to select him/herself the information relevant for his/her work. This selection depends on the reader's ability of assessing the relevance and the quality of the information for his work. It also states that author and reader are both end-users. The author might even be considered the principal end-user. Availability and selection are thus the relevant parameters in creating added value and

therefore crucial parameters for any business model, where availability evidently is a prerequisite to selection. As expressed in the title of this paper and as will be expanded upon below, availability and selection may well each lead to separate and sometimes even opposite requirements on business models of scientific information.

In a previous paper (Roosendaal et al., 2005) the following vision for scientific information was identified:

"The scientific information market will in future be based on a federated network of repositories of scientific information that conform to open standards, and an accommodating architecture that allows users the easiest and fastest possible access to information in all of these repositories.

The information available by such a network will not only comprise of scientific information material, but also of management information relating to this information.

The market is the scientific community. This federated network will be an open and global network."

This vision is not new; the language is just adjusted to the present technological opportunities. The vision describes the general desire and need of the users for full availability of scientific information. The overall aim is to share the information in the interest of the progress of science and in the interest of the author and the reader. This desire and need are of all times, and independent of technical, business or other considerations. The creation of the scientific journal in 1665 can be seen as an early expression of this vision[1], the idea being that a worldwide communication vehicle for all science was needed and created as soon as technology allowed it.

Next to demands on general availability and effective and efficient selection, this vision states that users of scientific content will always strive to integrated access to information in a particular domain and will demand that the information can be seamlessly searched irrespective of the mode of access.

3. Growth of scientific information and its consequences

On a worldwide scale, scientific information is growing at about 5% on an annual basis and has already been growing at roughly this rate for a period of several centuries. Such growth is well-known as exponential growth and results in a doubling of the worldwide annual scientific output every 10-15 years. This growth has primarily been the result of a growth in the number of scientists worldwide; on balance the productivity per scientist has not changed much (Price, 1986). Scarceness of the available human resources will exhaust this growth in a natural way. Growth in scientific output can then only be the result of an increase in efficacy and efficiency in the scientific process. This efficacy and efficiency in the process depends on the efficacy

[1] See the archives of the Royal Society, Bodleian Library, Oxford.

and efficiency of the information transfer, i.e. of the scientific information system. An effective and efficient scientific process is in turn indispensable for innovation and our modern society is nowadays particularly dependent on the success of innovation.

This growth of scientific information has given rise to a debate on 'information overload', suggesting exorbitant growth of information. As we have seen this 'information overload' is the result of the steady growth of scientific output as witnessed already for centuries and as is needed to sustain scientific progress. Slower than exponential growth will lead to diminishing returns hampering the rate of scientific progress. The solution to this 'information overload' is evidently not to hamper scientific progress with the only objective to reduce the availability of information, but to find ways to deal more effectively and efficiently with this ever-growing pile of information. If we want to sustain or enhance the rate of scientific progress or innovation, this calls for continuous innovation of the power of selection by the reader. Selection is, as we have seen before, dependent on the reader's ability of assessing the relevance and the quality of the information for his work. Steady enhancement of the selection options is the right response to the steady growth of scientific information. Technology can and will help us here in providing an instrument for the reader to effectively and efficiently manage the selection process.

The volume of available information will therefore continue to grow and as a consequence the costs for availability will continue to grow in some more or less commensurate way. This means roughly a doubling in annual costs every 10 years or so for availability only, irrespective of other factors such as costs arising from additional added value, profits or inflation. Other issues to be considered in relation to availability are that dated information may not always be available in digital sources or simply not generally available while not visible, such as with some grey and black information. This autonomous growth of scientific information has resulted in more and more journals to cover the expansion in research areas and existing journals have grown in volume. This makes them more expensive as part of the costs of journals is related to the volume of articles. The overall system will become more expensive if we want all this growing information to be widely available for science.

More and more expensive journals result in cancellations of these journals as libraries cannot afford to subscribe anymore due to budget ceilings. This in turn results in loss of revenues for the publishers and in return these publishers raise prices additionally to compensate for this loss. This process has launched a pricing and cancellation spiral, and is known as the 'serials' crisis'[2]. This serials crisis endangered

[2] This serials' crisis commenced in the 1970's as a consequence of growth in scientific publications and journals volume, decreasing libraries' budgets, inflation, space constraints (Battin, 1982). Moreover the dollar devaluation and increasing subscription costs of scientific journals contributed to this phenomenon. Subscription costs have started to raise continuously already in 1963. That caused the cancellation of scientific journals by libraries on the basis of

and still endangers the full availability of information. As stated above the author wants wide exposure for this work, while the reader wants (pre)selection. Wide exposure means wide availability of information and availability in turn is a prerequisite to selection. Availability is thus a basic service in the interest of the author. Sharing of information is an indispensable function in the scientific process.

Selection can be viewed much more as an added value in the interest of the reader and readers may well have different demands to this added value. These considerations result in different requirements for availability and selection on the business model of scientific information. The demand for full availability of scientific information and concomitant power of selection drive change in the system. Availability is crucial to empower the users of scientific information, and such empowerment is a necessary condition for integration into the everyday working processes of the scientists.

4. An illustration of recent developments

A limited experiment on the enhancement of the availability of scientific journals has been carried out in the Netherlands in 2003/2004. The Dutch university libraries and the Royal Library, the publishers Elsevier and Kluwer Academic, and 'Surf ICT in research', jointly carried out this research as part of agreements that allowed the university libraries to offer their users access to complete journal collections in electronic form, e.g. from ScienceDirect and Kluwer Online (Report of the steering group, 2004). In this way full availability to the users for at least these journal collections was realised and this is a condition for comparative research.

As the cooperation with the publishers allowed access to the log files of the journals a study was made of the number of articles downloaded from the publisher platforms. In October 2001 the users downloaded on average 1 in 14 articles of these databases, in October 2003 this number had increased by more than 30% to an average of 1 in 10. This increase can be attributed to the fact that articles can comfortably be downloaded by the reader, but some part of this increase will be the result of multiple downloads.

The number of downloads per journal varies substantially, from just a few downloads per month to more than a thousand downloads per month. From the figure below we see that 20% of the journals do cover about 80% of the downloads, 40% of the journals is good for more than 90% and 60% of the journals even for more than 95% of the downloads. This download behaviour follows nicely the '80/20' rule or the 'Pareto' distribution as was to be expected.[3]

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use by scientists and the cancellation of multiple subscriptions (Tinerella, 1999). Publishers started to compensate this attrition of revenues in the journal price finally resulting in an avalanche of price increases: the serials' crisis was born.

[3] The law was first presented in details in V. Pareto 'Cours d'economie politique', 1897, 2: 299-345.

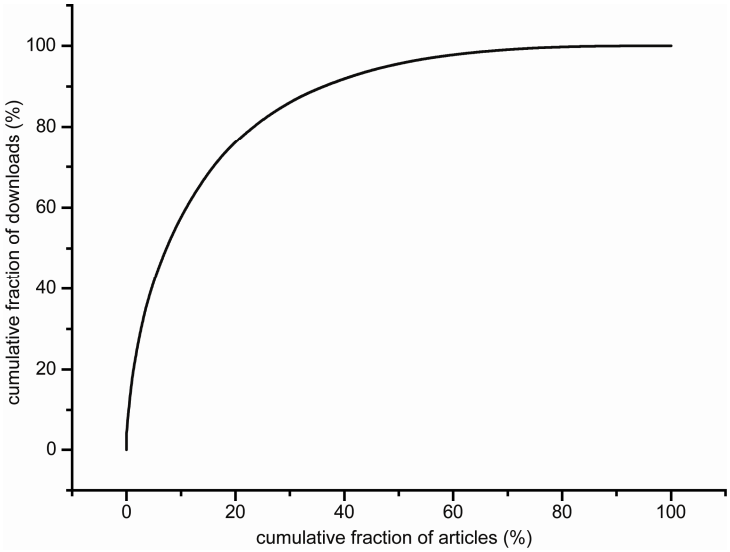

Figure 1. The cumulative fraction of downloads per article (%).

An interesting observation is that according to a sample of interviewed scientists electronic journals do offer additional advantages for performing interdisciplinary research: the comfort at which one can inspect many different articles, e.g. by using specific search terms, allows scientists to find yet unknown sources and new angles that were not evident before. Research is also expected to speed up as the required information from disparate sources can be collected and integrated much faster. This will be an impetus to a more effective and efficient information system as it allows a stronger integration over different disciplines. Again, full availability is required for enabling this.

Overall, this research confirms the relevance of full availability and concomitant power of selection. Scientists appreciate full availability as the most important property of electronic journals: journals must be available at any desired moment and it should be possible to consult them at the working place and from home, via the university network. In the eyes of the scientists access to scientific information by the desktop has become the rule. Availability of scientific information is taken for granted.

This experiment confirms that availability and selection are the crucial parameters for any business model. Experiments focusing on the balance between availability and selection with the aim to optimise this balance could be worthwhile.

5. Issues of intellectual property

Availability and selection are seen to be crucial parameters in the scientific information market as the market of sharing scientific information, of sharing of intellectual property. The organisation of property is evidently a *conditio sine qua non* in

any business model in any market. As noted in the Introduction intellectual property is at the nucleus of the scientific process. In this chapter we will touch upon those issues of intellectual property that are strongly interrelated to the scientific process. We will not touch upon the issue from a legal point of view but take the view that law should follow society, in this case the scientific world.

As discussed above, scientific knowledge is common property or otherwise does not exist. For the scientist, scientific information is not an end product but an intermediary product. The information is to be shared. Again, the primary purpose of scientific information and knowledge is that it will be used in the scientific process. To this end, the information must be generally available. Scientific information also requires added value e.g. specific services to disclose the information effectively and efficiently. These added values are not common property and can be owned on a proprietary basis by service providers such as universities and publishers.

Scientific knowledge while being common property is nonetheless owned by the author. The author claims the property of the 'invention' by publishing this 'invention'. The author retains always the rights to the personal expression and this personal expression is protected. The author retains the 'moral rights'. These moral rights are the paternity and the integrity rights. The author can transfer the exploitation rights, integrally or partially, to a third party, be this a university operating as an institutional repository, a university publisher, a non-commercial or a commercial publisher. In exchange to these exploitation rights the service provider provides added value in terms of services leading to among others visibility of the work of the author and protection of the moral rights of the author.

Whatever the business model the author, as we have seen above, claims the intellectual property to the work by publishing this work. Publishing in an acknowledged medium of publication, be this an institutional repository, a book, a journal or any other accessible medium is for the author the only way of claiming this intellectual property. Moral rights are part of the copyright and the author will retain these moral rights in perpetuity. Which commercial or exploitation rights are exactly transferred is just a matter of negotiation between the author and the publisher. If the information is published on the university's repository, the university can also support or even act on behalf of the author in negotiating the further exploitation rights for the work.

A common infringement of these moral rights is plagiarism; a common infringement of the exploitation rights is commercial abuse of the information. Plagiarism is of direct relevance to the author as it affects the paternity and integrity rights of the author and it is here that the author needs protection. Commercial abuse is not an issue directly relevant to the author as the author is primarily interested that the work will be available to the scientific community, but instead highly relevant to the publisher. It is therefore in principle possible to split these different responsibilities. The above argument means that the protection to these two main infringements does not need to

be in one hand, but could easily be split over different stakeholders. The university, possibly as the employer of the author or if the work is published on the university's repository, might just as well guarantee protection against plagiarism; in fact the university has to guarantee this if the repository is freely accessible. The publisher could take responsibility for the commercial abuse, as this is in the publisher's interest. Needless to state that the university can also be the publisher.

6. Business models for scientific information

We have seen that the scientific process demands that scientific information must be widely available, and in perpetuity. This is generally valid, but it is in particular valid for information that has been accepted for publication in scientific journals after having been subjected to the peer review process. Within the general condition that any business model for scientific information should be commensurate with the scientific process the above leads to the following basic requirements for any business model:

- the model should account for wide availability anyhow, anywhere and anytime,
- the model should account for the power of selection by the reader. This power of selection should ever continue to advance with technology;
- the model should be commensurate with the specific demands on intellectual property inherent to the scientific process.

Two prototypical models emerge:

- the emphasis on selection leads to the subscription model;
- the emphasis on availability leads to the 'open access' model.

Here we use the concepts of availability and selection as introduced before. Selection is the selection as done by the reader and does not include selection of information on scientific and/or editorial criteria, such as peer review. Peer review is coupled to availability as it is the determinant of which information is worthy of being published. In other words which information qualifies as scientific information or as scientific knowledge being worthy of further scientific effort and scrutiny, and thus as common property?

In the widely used business model, the subscription model, it is the library that pays on behalf of the researcher as reader. The basic idea is that the overriding added value for which is paid is the power of selection by the reader. The model aspires to maximum availability which is then bounded by selection. Selection is in this way used as an ordering principle to create this bounded availability. Limited availability adds to this. Selection as ordering principle was no doubt relevant with printed journals as here selection is to a large extent based on title choice. With electronic information, digital searching means searching over more than one title and over different products with the concomitant result that one can and will find new sources and new angles. This makes the journal title less important as a selection tool, albeit that the journal and thus its title will remain important to the reader for the scientific and editorial policies it

represents. As such the journal title represents the flavour of the journal, the title is the brand. The subscription model puts the total financial responsibility and burden, for selection and availability, on the reader. The challenge for the subscription model is to create a higher or even full availability at an affordable price.

The discussion about the business models can be illustrated using the value chain. Figure 2 presents the chain of added values in the subscription model. The essence of the subscription model is that the acquisition, thus first selection of scientific information precedes its dissemination.

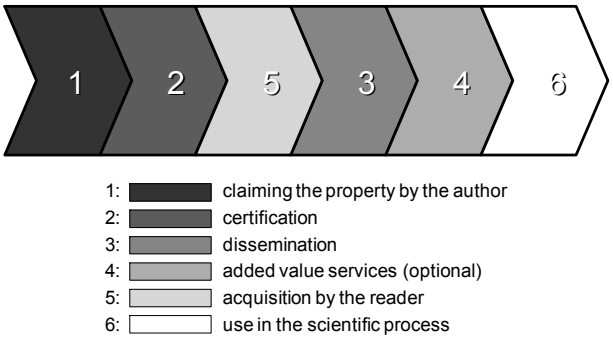

Figure 2. The subscription model.

As we have seen, the costs for availability will continue to increase in the foreseeable future, as there will be no end to the steady growth of worldwide scientific output. And indeed, such an end is not desirable from the point of view of the scientific process.

An alternative to the subscription model is the 'open access' model. In this model availability is the overriding added value for which is paid. Basically, it means that the authors pay a one-time lump sum for the publication and perpetual availability of their work, and the journals will be freely accessible for the readers. But at the end of the day, it is always the scientific community that pays for the publication, in the subscription model the reader channel is used via library funds and in this open access model the author channel via research funds. This open access model is not new, but recently reintroduced as a possible new solution. A premise to the open access model is that authors can dispose of funds to cover these costs, be this directly or via the institution in the form of a publication budget. This may require a transfer of funds from the library budget to a publication budget. This is in principle possible as the library budget would be freed from subscription responsibilities.

Not for long, most American journals used to have a somewhat similar system of 'page charges': authors paid to cover the fixed costs connected to a publication. In this model, the variable costs were covered by subscription costs paid by the reader. However, pressure of mainly non-American authors forced many journals to abandon this system largely or partially in the seventies as these authors could not afford these

page charges. In some research areas, such as economics, review charges are being levied as separate payment covering the costs of the reviewing process. In this way, the costs for the reviewing process are made independent from the revenues from subscriptions. However, the reviewing process is still coupled to the submission of an article to a journal as scientific and editorial frame of reference.

Technology allows any institution to make scientific information available via repositories of information. The university can also support or even act on behalf of the author in negotiating the exploitation rights for the work. Scientific quality control by peer review next to power of selection is then a clear separate added value for which independent segmentation or branding, e.g. by journal titles or other editorially controlled scientific information collections, is vital.

While it remains to be seen if authors will accept the model of 'open access' and if this model will prove to reduce total costs, this model has one clear weakness: there is no real incentive to warrant an optimal power of selection for the reader. Optimal power of selection means that its continuous innovation using the latest technology will be guaranteed in future. Open access is commensurate with the intrinsic scientific demand for availability. Alternatively, the subscription model is seen to be strong with respect to selection but weak on availability.

The 'open access' model is presented in figure 3. The basic idea of the open access model is that scientific information is available for the reader who acquires the information either with or without added value services (e.g. sophisticated search software, appropriate metadata, alerting systems, mailing lists, etc.).

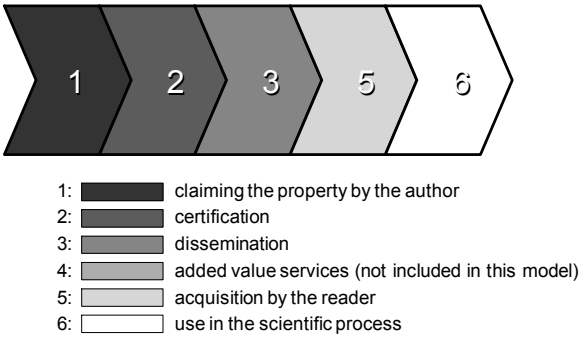

Figure 3. The open access model.

Combination of these two basic elements of availability and selection in one hand is seen to result in a painful split: either there will be problems with full availability or problems with less effective and efficient power of selection for the reader.

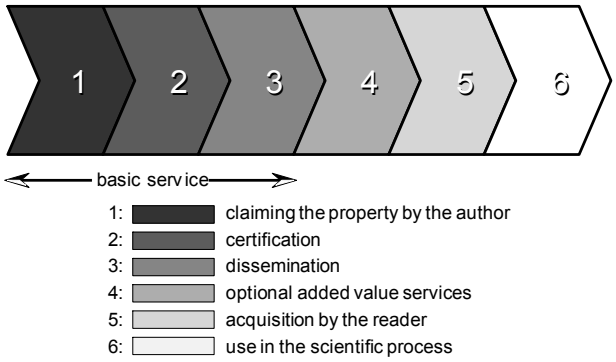

Figure 4. An optional model with added value services.

This leads to a business model as presented in figure 4 comprising of a basic, no frills service of sheer availability coupled with peer review as the major value proposition required and with optional value added services as the reader might desire. This model is further discussed in the conclusions below.

7. Conclusions and outlook

Would it then not be desirable to separate the costs and pricing for availability from the costs and pricing for selection? From a business point of view this is not new. There are nowadays many examples where services are being separated from the infrastructure needed to provide these services, such as the Internet and the providers, the UK and Dutch trains and railway systems, etc.

Following the above arguments on the different aspects of availability and selection as core added values of scientific information and the different roles they therefore play in the business model it follows to consider, at least from a theoretical point of view, two separate suppliers: one for availability and a second for the selection by the reader. These suppliers can be both universities and publishers. This is even more interesting as we have seen that availability and power of selection represent different types of added value. Availability can be seen as a basic need directly coupled to the notion that scientific information is common property whereas power of selection can be seen as a proprietary added value that needs be tailored to the desires of the reader.

Peer review can be seen as a separate added value and as seen above is strongly coupled to availability. It will in principle be possible to make the costs for peer review a clear transparent, and possibly non-remunerable, part of the availability costs. In connection to this notion of peer review being a separate added value in the process it may be noted that peer review is a scientific process carried out by scientists as a scientific duty and is not an added value provided by the publisher. Peer review is a service to the author and it is an added value for the reader when assessing the relevancy of the information. Although, as it is sometimes claimed, peer review may not

always be required in scientific disciplines such as e.g. physics or chemistry, peer review is definitely needed when uncertainty is high, e.g. in interdisciplinary studies. Publishers play an important role in assisting in this process of peer review, but the key players are the editors of a journal and the referees. Peer review results in the scientific conditions under which the paper can be published in a certain editorial collection such as a journal. If these conditions require the author to rewrite the paper it is still the author deciding to do so in order to claim the 'invention'. By this act, the author then creates a new personal expression superseding the previous one that thereby cedes to exist, or rather has never existed. It is this negotiation with the scientific community that has brought the author to take this decision, and such a decision is an integral part of the scientific process.

Market segmentation with independent pricing for both forms of added value of availability and power of selection can increase the transparency of the market. Enhancing the transparency in the market requires strong partners and we have seen that universities, albeit somewhat hesitantly, are nowadays strengthening their strategic position by building repositories and investing in e-science. This development allows universities to assume a key role in providing the availability of scientific information. A transparent market also requires transparency for all stakeholders in cash flows, tariffs, revenues and all, also hidden, costs. As a first step to support this development proactively and to bring the investments in repositories and e-science to fruition the cash flows between research, education and information within the university will have to be transparent. Such a development seems, however, still far away.

More generally, further developing the digital scientific information market requires developing and testing new value chains different from the present ones, and consequently new business and distribution models. A prerequisite for the acceptance of new models is that they provide sustainable solutions.

Sustainability requires that a new value chain for the scientific information market should be jointly developed between universities and the other partners like publishers and other service providers. A new value chain should be able to support a variety of value chains for the information market representing different organisational, legal and business models. The individual stakeholders will need this flexibility to effectively compete with their information products. This process has begun with the experimentation of new license models, but these models can only be considered as a beginning of a long process still ahead of us.

In considering new business models it remains important to realise what was stated before: scientific information is an integral part of the scientific process and scientific publishing should serve the primary processes in science: research and teaching. The primary objective of scientific information is to make use of the information for scientific purposes in everyday scientific working processes. Scientific information and knowledge is common property or else it loses its function. The latter would mean that

scientific information is only there for the record, and this would erode its value. But at the end of the day scientific information has no value in itself, but is there to serve in teaching, and research and development.

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Summary

The focus of this dissertation is on the organisation and management of scientific research. Scientific research aims to produce knowledge. The main research question answered in this thesis is 'What conditions regarding research and the organisation of research do serve the researcher in the production of knowledge?' This question is answered by analysing the production of knowledge by a researcher or research group from the angle of the strategic positioning of this researcher in the environment. To this end, we developed a model analysing this strategic positioning in the relationship of the researcher. This strategic relationship is established to attain the goals of the researcher and it is expressed in the negotiated and agreed relationship between the researcher and his environment. Furthermore, this relationship, like any other relationship, is seen as a (temporary) strategic alliance, joint venture, merger or even an acquisition between two partners. The environment of the researcher that we have in mind is the societal environment and its representatives such as government, funding agencies, industry, etc., and also other researchers, research groups or research institutes bound in joint research projects or programmes.

The positioning model contains two dimensions to characterise the relationship: the organisational autonomy and the strategic interdependence of each of the partners in the relationship. This model can be applied to any relationship, i.e. irrespective of the nature of this relationship, between two or more partners because there is always an exchange of resources and partners always have some degree of organisational autonomy that can be measured in the relationship at hand.

Strategic interdependence is defined as the deliberate sharing of heterogeneously distributed resources such as e.g. knowledge, skills, time, research facilities, and funds between the partners in order to achieve a joint goal. Strategic interdependence is thus a necessary but not sufficient condition for an effective collaboration, meaning that close collaboration goes hand in hand with a position of high strategic interdependence, and vice versa. Organisational autonomy of the researcher is defined as self-governing in deciding about the directions of research, including setting goals, in which scientific knowledge is being produced and scientific information is being used. A high position in organisational autonomy allows actors to make autonomous strategic decisions regarding setting goals and establishing how to attain these goals. Depending on the strategic goals of the researcher, he needs specific degrees of strategic interdependence and organisational autonomy. These degrees of the two dimensions are not the degrees desired by the researcher but the degrees necessary to attain the agreed research goals.

The overriding result of the model is that it leads to a continuum of modes in which we can distinguish four characteristic or typical modes of strategic positioning: the well-known mode1, also known in the literature as the ivory tower, and mode2, also known as strategic research, and the newly introduced mode0 and mode3. Mode3 is

called the research entrepreneur. Each mode is a specific combination of a low or high necessity for strategic interdependence and organisational autonomy.

In mode1 researchers are producing knowledge without the intervention of the societal environment. The mode1 researcher positions himself as highly autonomous. For the attainment of the researcher's goals it is not necessary for him to integrate with his environment and to share other resources than financial resources. This is a relationship of two separate organisations. In mode2 there is a necessity for the researcher to integrate with his environment. The researcher is accountable to his societal environment that asks the researcher to deliver on its demand. The mode2 researcher is directed by his environment as he has a low necessity for autonomy. The researcher matches his research goals to existing research programmes based on the demand of the societal environment. The mode2 researcher listens to the environment and fulfils the demanded societal needs.

Next to these well-known modes, the model enables observing mode0 and mode3. Mode0 is a combination of low necessity for both interdependence and autonomy. In mode0 it is not necessary for the researcher to establish a strategic relationship with the societal environment to attain his goals. Nor is it neither necessary to be highly autonomous. This mode resembles a sort of holding construction between two or more organisations, as we also know in industry. In mode0 the researcher is connected to his environment only financially, he works on his own and he complies with the goal set by the environment.

Mode3 – the research entrepreneur is shown to be the most autonomous and at the same time most interdependent researcher in all of the modes of positioning. This means that he sets research goals and directs research being at the same time intertwined with his environment. The relationship between the research entrepreneur and his environment has a symbiotic character. The existence of the research entrepreneur is of course not new. What is new is the approach to systematically analyse the production of knowledge leading to the observation of the phenomenon of the research entrepreneur next to the phenomena of mode1 and mode2.

The research entrepreneur is proposed as an answer to the need for the researcher to "enter the agora and participate fully in the production of socially robust knowledge" explicitly raised by Gibbons. The research entrepreneur interacts with the societal environment in such a way that "he speaks to the environment and the environment speaks back to him". The research entrepreneur "speaks to the environment" by developing, like a business entrepreneur, appropriate strategies to create demand for his scientific products, in this way influencing his societal environment. In this context, he influences strategies and policies developed by his environment. The environment "speaks back to him" by developing appropriate strategies reflecting its interests and accounting for the strategies developed by the researcher, resulting in possible and new research policies. In principle, the researcher can at the same time position himself in

different modes with different partners and in different relationships, and these positions add to his overall position.

The model resulting in the four modes is new as compared to approaches described in the literature such as e.g. mode1 and mode2 or the triple helix because it not only describes these modes but analyses them and predicts them. This is possible as we analyse the production of knowledge from the inside-out view: the view of the researcher articulating strategic goals and positioning himself in his environment in order to attain these goals. We combine this view with the outside-in view: the view of how the production of knowledge changes at the overall level and what consequences it has on the society.

The feasibility of the model in creating observables for different modes of positioning was confirmed in a study of research contracts entered by the researchers of the MESA+ Institute for Nanotechnology at the University of Twente and their societal environment.

With the use of the positioning model we have analysed the production of knowledge under different conditions, i.e. under different combinations of necessities of strategic interdependence and of organisational autonomy, in relationships between researchers and their research environment. Strategic interdependence and organisational autonomy are both measured in two important activities in the research process: in making research results public and in the acquisition of scientific information. Strategic interdependence is measured by the dependence on colleagues in writing articles and by the dependence on information sources in acquiring scientific information. Organisational autonomy is measured in observations on how researchers decide what to write in articles, where to submit the article, when the work can be published, which relevant articles to include in articles, acquire scientific information, and decide on research goals. The production of knowledge is measured by the number of articles published by the researcher and by the number of articles multiplied by the impact factor of the journal.

The model was tested in interviews of 43 researchers active in nanotechnology (the abovementioned MESA+ institute), business and public administration, and social and behavioural sciences including sociology, legal studies, economics, health sciences (the IGS institute). The sample of researchers was stratified along scientific positions and the heterogeneity of scientific domains was maximised. The samples are chosen to test the model and are not meant to be representative for the MESA+ or IGS institute, respectively.

Due to the given difference in the production of knowledge between the researchers of the two samples we were able to test the model of strategic positioning. A significant difference observed is the difference in strategic interdependence (SI) and organisational autonomy (OA) in both samples. The researchers in the MESA+ sample are in general more dependent on their colleagues when making research results public and acquiring scientific information. About 80% of the MESA+ researchers in the

sample is highly interdependent, whereas only 40% of the interviewed researchers in the IGS sample is highly dependent on their colleagues. The researchers in both samples are in general highly autonomous, but the researchers in the IGS sample have in general a slightly higher degree of autonomy than the researchers in the MESA+ sample. Furthermore, the cumulative distributions of SI and OA can each be fitted to a normal distribution allowing determining the difference in the average position of SI and OA for each sample. This difference is called the gap between SI and OA. This gap is rather large for the IGS sample and smaller for the MESA+ sample.

The main hypothesis derived from the positioning model tested in the empirical study is the more the researcher is both interdependent on his colleagues and at the same time autonomous, the more knowledge he produces. The data obtained from interviews was analysed with the use of the interaction model. The results confirm this hypothesis. Thus we can conclude that a researcher who is both highly dependent on his colleagues and highly autonomous in making research results public and in acquiring scientific information is most productive.

Applying the interaction model allows predicting values of the production of knowledge. The result of this analysis is that the researchers in the MESA+ sample would be most productive if positioned in mode3. The predicted value for the production of knowledge turns out to be negative in mode2 for the MESA+ sample. This means that if researchers would be positioned in this mode it cannot but lead to an exit strategy from scientific research because a negative production is impossible.

The data for the IGS sample suffer from more scattering than the data for the MESA+ sample. This is due to the fact that the sample is smaller than the sample for MESA+, combined with a larger heterogeneity in scientific domains and therefore in publishing habits. Nonetheless, the results for both samples allow us to observe significant differences in autonomy and interdependence and consequently knowledge production as outlined above. Because of the large scatter of the data for IGS we do not report the predicted values of the production of knowledge as this might lead to incorrect conclusions. The scatter and the small number of observations do not allow us to draw conclusions on the predicted production.

The gaps between the distributions of SI and OA mentioned above should be considered when developing strategies, and policies for a research group or research institute. Closing the gap is then a challenge for the management of such a research group or institute. As the combination of high necessity for both interdependence and autonomy results in higher productivity a research group or institute is well advised to stimulate the strategic interdependence between researchers in combination with a reasonably high degree of autonomy of the individual researchers.

In this thesis we also discuss business models for scientific information and for scientific publishing. We point out that in developing such business models (and also business models for research groups or research institutes) the strategic positioning of the researcher should be taken into account because, as we argue, any business model

for scientific publishing should serve researchers by providing wide availability of scientific information. A publishing business model should provide the basic services of availability and peer review and can offer optional added value services further enhancing the power of selection of researchers. It should serve researchers in attaining their strategic goals in their environment. Therefore, it has to fulfil the basic premise that scientific information is to be shared and used in the production of knowledge.

Applying the positioning model in developing business models is just one potential application of this model. On the basis of the diagnosis of the production of knowledge under different conditions as delivered in this thesis we can conclude that the positioning model may be of relevance for researchers, research strategists, research managers and policy makers alike. The model can well serve as a tool in setting research programmes as it gives insight into which settings could and should be created by research managers or policy makers, given the specific domains and organisational conditions. The model can be used for strategy development of research groups or institutes as it predicts the degree of necessity for both strategic interdependence and organisational autonomy the researchers need in order to attain chosen strategic goals. It shows how to position researchers in their research environment to enhance the productivity in line with the goals of the group or institute.

Samenvatting

Het onderwerp van deze dissertatie is de organisatie en het management van wetenschappelijk onderzoek. Het primaire doel van wetenschappelijk onderzoek is om kennis te produceren. De onderzoeksvraag waarop dit proefschrift een antwoord geeft, luidt 'welke voorwaarden ten aanzien van onderzoek en de organisatie van dit onderzoek ondersteunen de onderzoeker in het produceren van kennis?'. Deze vraag wordt beantwoord door de kennisproductie van een onderzoeker of onderzoeksgroep te analyseren vanuit de invalshoek van de strategische positionering van deze onderzoeker in zijn omgeving. Hiertoe ontwikkelden we een model dat deze strategische positionering van de onderzoeker ten aanzien van zijn relaties kan analyseren. Uitgangspunt daarbij is dat deze relaties aangegaan zijn om de doelen van de onderzoeker te realiseren en dat deze relaties vervat zijn in een overeenkomst, die tussen de onderzoeker en zijn omgeving onderhandeld is. Tevens worden deze relaties, als alle relaties, gezien als een (tijdelijke) strategische alliantie, joint venture, fusie of zelfs overname waarbij twee of meer partners betroken zijn. We richten ons op de maatschappelijke omgeving van de onderzoeker met zijn vertegenwoordigers als regering, sponsoren, industrie, etc., en ook andere onderzoekers, onderzoeksgroepen of onderzoeksinstituten die deelnemen in gemeenschappelijke onderzoeksprojecten of programma's.

Het model van positionering berust op twee dimensies, die de relaties karakteriseren: de organisatorische autonomie en de strategische onderlinge afhankelijkheid van ieder van de beide partners in deze relaties. Dit model kan in principe toegepast worden op alle vormen van relaties, d.w.z is onafhankelijk van de aard van deze relaties, tussen twee of meer partners aangezien er altijd een uitwisseling van middelen plaatsvindt en deze partners altijd een zekere mate van organisatorische autonomie en strategisch afhankelijkheid hebben die in deze relaties gemeten kunnen worden.

Strategische (onderlinge) afhankelijkheid is gedefinieerd als het bewust delen van onder de partners heterogeen verdeelde middelen, zoals kennis, vaardigheden, tijd, onderzoeksfaciliteiten en fondsen om een gemeenschappelijk doel te bereiken. Strategische afhankelijkheid is dus een noodzakelijke maar niet voldoende voorwaarde voor een effectieve samenwerking, hetgeen betekent dat nauwe samenwerking hand in hand gaat met een positie van hoge strategische afhankelijkheid, en vice versa. Organisatorische autonomie van de onderzoeker is gedefinieerd als zelfbestuur in het beslissen over de richting van onderzoek, inclusief het stellen van doelen, leidend tot productie van wetenschappelijke kennis en daarbij gebruik makend van wetenschappelijke informatie. Hoge organisatorische autonomie staat actoren toe om autonome strategische beslissingen te nemen ten aanzien van het vaststellen van doelen en hoe deze doelen bereikt moeten worden. Deze strategische doelen van een onderzoeker bepalen welke specifieke maten van strategische afhankelijkheid en

organisatorische autonomie de onderzoeker daarvoor nodig heeft. Het gaat hierbij niet om de gewenste mate van één van de twee dimensies maar om de mate van noodzaak van deze dimensie om de overeengekomen doelen te bereiken.

Als algemeen resultaat leidt dit model tot een continuüm van modi waarin we vier karakteristieke of typische modi van strategische positionering kunnen onderkennen: de bekende modus1, ook in de literatuur bekend als de ivoren toren, en modus2, ook bekend als strategisch onderzoek, en de hier geïntroduceerde modus0 en modus3. Modus3 hebben we de onderzoeksondernemer genoemd. Elke modus ontstaat uit een specifieke combinatie van een lage of hoge noodzakelijkheid tot strategische afhankelijkheid en organisatorische autonomie.

In modus1 produceren onderzoekers kennis zonder noemenswaardige tussenkomst van de maatschappelijke omgeving. De onderzoeker in modus1 kiest een positie van hoge autonomie. Om zijn doelen te bereiken is het niet strikt noodzakelijk voor de onderzoeker om te integreren in de omgeving en om andere dan financiële middelen te delen. Deze relatie wordt gekenmerkt als bestaande uit twee gescheiden organisaties. In modus2 is het noodzakelijk voor de onderzoeker om te integreren in de omgeving. De onderzoeker moet rekenschap afleggen aan de maatschappelijke omgeving die de onderzoeker vraagt te leveren. De lage noodzaak tot organisatorische autonomie maakt dat de onderzoeker in modus2 door de omgeving wordt gestuurd. De onderzoeker past zijn onderzoeksdoelen aan aan bestaande onderzoeksprogramma's die door de maatschappelijke omgeving zijn geformuleerd. De onderzoeker in modus2 luistert naar de omgeving en voldoet aan de maatschappelijk gearticuleerde vraag.

Naast deze al bekende modi, maakt het model het mogelijk om modus0 en modus3 waar te nemen. Modus0 is een combinatie van een lage noodzaak tot zowel afhankelijkheid en autonomie. In modus0 bestaat er voor de onderzoeker om zijn doelen te bereiken geen noodzaak strategische relaties aan te knopen met de maatschappelijke omgeving. Het is evenmin noodzakelijk om zeer autonoom te zijn. Deze modus vertegenwoordigt een soort holding constructie tussen twee of meer organisaties, zoals we die in het bedrijfsleven kennen. In modus0 is de enige verbinding van de onderzoeker met de omgeving een financiële, de onderzoeker werkt zelfstandig en binnen de door zijn omgeving gestelde doelen.

Modus3 – de onderzoeksondernemer is aantoonbaar de meest autonome en tegelijkertijd de meest afhankelijke onderzoeker van alle modi van positionering. Dit houdt dat hij onderzoeksdoelen vaststelt en het onderzoek stuurt terwijl hij tegelijkertijd verweven is met zijn omgeving. Deze vorm van relatie tussen de onderzoeksondernemer en de omgeving is van symbiotische aard. Het bestaan van de onderzoeksondernemer is natuurlijk niet iets nieuws. Nieuw is wel de benadering hoe systematisch kennisproductie geanalyseerd kan worden, en dit leidt tot het waarnemen van het verschijnsel van de onderzoeksondernemer naast die van modus1 en modus2.

We zien de onderzoeksondernemer als een antwoord op de vraag gesteld door Gibbons naar een onderzoeker "to enter the agora and participate fully in the

production of socially robust knowledge". De onderzoeksondernemer staat in wisselwerking met de maatschappelijke omgeving op een zodanige wijze dat "he speaks to the environment and the environment speaks back to him". De onderzoeksondernemer "speaks to the environment" door, net als een zakelijke ondernemer, geschikte strategieën te ontwikkelen en op deze wijze zijn maatschappelijke omgeving te beïnvloeden om vraag naar zijn producten te creëren. Op deze wijze beïnvloedt hij de strategieën en het beleid ontwikkeld door deze omgeving. De omgeving "speaks back to him" door het ontwikkelen van geschikte strategieën op basis van haar belangen en rekening houdend met de strategieën ontwikkeld door de onderzoeker met als resultaat een mogelijk en nieuw beleid. De onderzoeker kan zich in principe tegelijkertijd met verschillende partners en in verschillende relaties in verschillende modi positioneren. Deze posities zijn dan een maat voor de globale positie van de onderzoeker.

Dit model resulterend in de vier modi is nieuw in zijn benadering in vergelijking met de benaderingen beschreven in de literatuur als modus1 en modus of als het tripel helix model in die zin dat het niet alleen een beschrijving geeft van deze modi, maar ze ook analyseert en voorspelt. Dit wordt mogelijk gemaakt door het feit dat we de kennisproductie van binnen uit analyseren: vanuit de positie van de onderzoeker die strategische doelen stelt en zich zodanig positioneert dat deze doelen bereikt kunnen worden. Daarbovenop komt dan de analyse van buiten af: vanuit de positie hoe het algemene niveau van de kennisproductie verandert en welke consequenties dit heeft op de maatschappij.

Door het bestuderen van onderzoekscontracten aangegaan door onderzoekers van het MESA+ Instituut voor Nanotechnologie van de Universiteit Twente met de maatschappelijke omgeving kon de haalbaarheid van het model in termen van het creëren van 'observables' voor de verschillende modi van positionering bevestigd worden.

Gebruik makend van het model van positionering hebben we kennisproductie onder verschillende condities, d.w.z. onder verschillende combinaties van noodzaken van strategische afhankelijkheid en organisatorische autonomie, in relaties tussen onderzoekers en hun onderzoeksomgeving geanalyseerd. Strategische afhankelijkheid en organisatorische autonomie worden beide gemeten in twee belangrijke activiteiten in het onderzoeksproces: in het openbaar maken van onderzoeksresultaten en in de acquisitie van wetenschappelijke informatie. Strategische afhankelijkheid wordt gemeten als de afhankelijkheid van collegae in het schrijven van artikelen en als de afhankelijkheid van informatiebronnen in het acquireren van wetenschappelijke informatie. Organisatorische autonomie wordt gemeten door waar te nemen hoe onderzoekers beslissen wat in een artikel te schrijven, waar dit artikel in te dienen voor publicatie, wanneer het gepubliceerd wordt, welke artikelen relevant zijn om vermeld te worden, welke wetenschappelijke informatie geacquireerd wordt en beslissen over de onderzoeksdoelen. De kennisproductie wordt zowel gemeten aan de hand van het

aantal artikelen gepubliceerd door de onderzoeker als aan de hand van ditzelfde aantal, maar dan vermenigvuldigd met de impact factor van het betreffende tijdschrift.

Het model is getoetst aan de hand van interviews met 43 onderzoekers op het gebied van nanotechnologie (het al genoemde MESA+ Instituut), van bedrijfs- en bestuurskunde, en sociale en gedragswetenschappen, waaronder sociologie, rechten, economie, gezondheidswetenschappen (het IGS Instituut). Het sample van onderzoekers is gelaagd opgebouwd naar wetenschappelijke posities, waarbij de heterogeniteit van de wetenschappelijke domeinen gemaximaliseerd is. De samples zijn gekozen om het model te toetsen en hebben niet de intentie representatief te zijn voor het MESA+ of IGS instituut, resp.

Op basis van het gegeven verschil in kennisproductie tussen de onderzoekers in de twee samples waren we in staat het model van positionering te testen. Een significant verschil ligt in de strategische afhankelijkheid (SI) en de organisatorische autonomie (OA) in beide samples. De onderzoekers in het MESA+ sample zijn in het algemeen afhankelijker van hun collegae bij het openbaar maken van de onderzoeksresultaten en het acquireren van wetenschappelijke informatie. Ongeveer 80% van de MESA+ onderzoekers in het sample is in hoge mate afhankelijk, terwijl dit voor slechts 40% van de geïnterviewde onderzoekers in het IGS sample geldt. De onderzoekers in beide samples hebben in het algemeen een hoge mate van autonomie, maar onderzoekers in het IGS sample hebben in het algemeen een iets hogere mate van autonomie dan de onderzoekers in het MESA+ sample. Het is mogelijk de cumulatieve verdelingen van SI en OA te fitten met een normale verdelingsfunctie waardoor het mogelijk is het verschil in de gemiddelde positie van SI en OA voor ieder sample te bepalen. Dit verschil noemen we de ‘gap’ tussen SI en OA. Deze ‘gap’ is nogal groot voor het IGS sample en kleiner voor het MESA+ sample.

De eerste van het model van positionering afgeleide hypothese getoetst in deze empirische studie luidt: ‘des te afhankelijker de onderzoeker is van zijn college en daarbij tegelijkertijd autonoom, des te meer kennis zal hij produceren’. De gegevens verkregen uit de interviews zijn geanalyseerd met behulp van het interactiemodel. De resultaten bevestigen de hypothese. Dit leidt tot de conclusie date en onderzoeker die zowel in hoge mate afhankelijk is van zijn collegae als in hoge mate autonoom is in het openbaar maken van onderzoeksresultaten en het acquireren van wetenschappelijke informatie het productiefst zal zijn.

Door toepassing van het interactiemodel kunnen waarden voor de kennisproductie voorspeld worden, met als resultaat dat de onderzoekers in het MESA+ sample het meest productief zouden zijn, indien gepositioneerd in modus3. De voorspelde waarde blijkt voor het MESA+ sample in modus2negatief te zijn. Dit betekent dat, indien onderzoekers in deze modus gepositioneerd zijn, dit slechts kan leiden tot een exit strategie uit wetenschappelijk onderzoek aangezien een negatieve productie niet tot de mogelijkheden behoort.

De gegevens voor het IGS sample vertonen een veel sterkere strooiing dan de gegevens voor het MESA+ sample. Dit wordt veroorzaakt door het feit dat het sample niet alleen kleiner is dan het MESA+ sample, maar ook een grotere heterogeniteit heeft in wetenschappelijke domeinen en daarmee in publicatiegedrag. Toch laten de resultaten voor beide samples toe om significante verschillen in autonomie en afhankelijkheid waar te nemen en de gevolgen voor de kennisproductie. Vanwege de grote strooiing in de gegevens voor IGS zien we ervan af warden voor de kennisproductie te voorspellen omdat dit tot incorrecte conclusies zou leiden. De strooiing en het geringe aantal waarnemingen laten geen conclusies hierover toe.

De hierboven al genoemde 'gaps' tussen de SI en OA verdelingen vormen een belangrijke overweging bij het ontwikkelen van strategieën en beleid voor een onderzoeksgroep of onderzoeksinstituut. Het sluiten van de 'gap' is dan een uitdaging voor het management van een dergelijke groep of instituut. Omdat de combinatie van een hoge noodzaak tot zowel afhankelijkheid en autonomie resulteert in hogere productiviteit kan men een onderzoeksgroep of –instituut adviseren de strategische afhankelijkheid tussen de onderzoekers te stimuleren, dit in combinatie met een redelijk hoge mate van autonomie van de individuele onderzoekers.

In dit proefschrift worden ook business modellen voor wetenschappelijke informatie en wetenschappelijk uitgeven besproken. In het ontwikkelen van dergelijke business modellen (en dit geldt ook voor business modellen voor onderzoeksgroepen en –instituten) dient de strategische positionering van de onderzoeker in overweging genomen te worden, omdat, zoals we argumenteren, ieder business model voor wetenschappelijk uitgeven de onderzoekers moet ondersteunen door een brede beschikbaarheid van wetenschappelijke informatie te faciliteren. Een business model voor uitgeven moet dan voorzien in basisdiensten op het gebied van beschikbaarheid en peer review en kan optionele diensten van toegevoegde waarde bieden die de mogelijkheid tot selectie door de lezer vergroten. Het moet de onderzoekers dienen in het bereiken van hun strategische doelen binnen hun omgeving. Om dit te bereiken moet het aan de premisse voldoen dat wetenschappelijke informatie er is om gedeeld en gebruikt te worden ten behoeve van kennisproductie.

Het toepassen van het model van positionering in het ontwikkelen van business modellen is slechts één mogelijke toepassing van dit model. Op basis van de diagnose van kennisproductie onder verschillende condities als besproken in dit proefschrift kunnen we concluderen dat het model van positionering relevant kan zijn voor onderzoekers, onderzoeksstrategen, onderzoeksmanagers, en beleidsmakers. Het model kan als instrument dienen in het opzetten van onderzoeksprogramma's omdat het inzicht geeft welke condities managers en beleidsmakers zouden kunnen en moeten creëren, gegeven een specifiek domein en organisatorische condities. Het model kan gebruikt worden voor strategieontwikkeling voor onderzoeksgroepen of –instituten omdat het de mate van noodzaak voor zowel strategische afhankelijkheid als organisatorische autonomie, die onderzoekers nodig hebben om hun gekozen doelen te

bereiken, voorspelt. Het geeft een leidraad om onderzoekers zodanig in hun omgeving te positioneren dat de productiviteit in lijn met de doelen van de groep of het instituut verbeterd kan worden.

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