Estimating business value of academic research outcomes: towards a multi-dimensional approach

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Abstract: As academic entrepreneurship develops, questions of business valuation of research become more important. Therefore, there is a need to develop methods for value assessment of academic research. Conventional business valuation models for technology are usually financially oriented and will only disclose its economic value. However, this under specifies the value of university-industry transactions. The value of an invention not only depends on economic value but also on strategic, cultural or social value added to the applicant of the invention: usually a company. We introduce gross business value, being a function over time of these four dimensions of value and propose to position this gross business value of an academic technological invention within a three-dimensional model, with the research value creation process on the X-axis, the type of research on the Y-axis and its contribution to the applicant's four types of capitals at the Z-axis.

Keywords: entrepreneurship; technology transfer; business valuation methods; research value chain.

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1 Introduction

Academic research is basically oriented at creation of new scientific knowledge. The current rewards structure for academics is oriented at reputations based on open dissemination of new findings and ideas which are openly discussed in a well-functioning review system (e.g., Stephan and Levin, 1996). However from a societal point of view the application of this new knowledge in society is one of the main contributions of university to society. In this context the creation of business value out of academic processes, such as academic entrepreneurship, becomes an important issue (e.g., Shane, 2004; Etzkowitz, 2003). The roles of universities traditionally focusing on research and teaching (their 1st and 2nd mission respectively), is complemented by increased participation and embeddedness in societal economic and social developments, e.g., resulting in the development of much stronger ties between universities and other sectors, such as hospitals, industries and governments laboratories (Godin and Gingras, 2000; Haour, 2005). Developing this so called 3rd mission of universities, i.e., academic entrepreneurship, questions of business valuation of research become more important triggering a need to developing more adequate methods for value assessment of academic research. This is the central theme of this publication.

The 'value' of academic results is traditionally being regarded as an economic issue, in which the economic value of research outcomes is determined using economic business valuation models based on business development scenario's. Conventional business valuation models exist, such as cost-based models, market-based models (income-based models, option-based models) and integrated models, combining both technology and monetary valuation models (for an overview see Leloux and Groen, 2007). However, the predictive financial scenarios of such models depend on the input into these models, which is merely based on rather rough estimations of the technology's expected added value in its market. Furthermore, these models are used in a transaction mode which, as is shown in marketing research, leads to underestimation of value generated over time of the relation between the knowledge producer and user (Hakansson, 1987, 1989; Hakansson and Snehota, 1995; Hakansson and Sharma, 1996; Narver and Slater, 1990; Ulaga and Eggert, 2006).

Due to these limitations of existing business valuation methods, we believe that alternative methods of business valuation of academic research are needed having a much broader avenue than the traditional monetary business valuation methods. Such alternative business valuation methods should be able to more accurately define the *gross benefit* of a given scientific invention or technology to an applicant of this novel technology. In this article we will introduce a novel approach towards such an alternative business valuation model, which is embedded in social systems theory. Our approach is as follows. Starting at the university as a science and technology producer, we will first describe the research value chain and the technology transfer process. Then we introduce a stepwise research value creation process with its different steps. Consecutively, we adopt a social system theory based on an entrepreneurship-in-networks perspective and present a concise review of related literature. The implications of this approach for an alternative business valuation model of academic research are then discussed. As an illustration, we will then comment on the valuation of academic research results that are licensed to an applicant/company. And finally, we will introduce the novel multi-dimensional valuation model.

2 Research value creating process

2.1 The research value chain

In a research value chain, (scientific) information is transmitted from basic (i.e., fundamental research: fundamental development of knowledge leading to insights in principles in a discipline or topical area) research to applied research (research oriented at the development of an artifact which can fulfill a certain function), from applied research to development and from development to production. Although the distinction between basis and applied research is notoriously vague (Niiniluoto, 1993) and can be distinguished on a bibliometric basis (Godin, 1996; Ranga et al., 2003), basic research can also be seen as *curiosity-driven* and *technology-push*, and applied research as *designed to answer specific questions*, i.e., *market-driven* and *market-pull* (Llewellyn Smith, 1997). The distance to (market) applications may be much larger for inventions embedded in basic research than those originating from applied research, having developed organical links with industry. However, basic research might also result in principles which are much broader applicable then more specific applied research, generating a larger long term potential for value creation. Thereby, it could add to the strategic flexibility of firms (Volberda, 1996; Groen, 2002a, 2002b). Inventions from basic research might also be regarded as being instrumental or services in applied research themes. Within an academic context, basic and applied science preferably occur whereas at industries, applied and developmental science mostly occur.

2.2 Technology transfer

Value creation out of academic research (research valuation, academic entrepreneurship) is traditionally being envisaged as a technology transfer mechanism: the transfer of academic research results and the associated intellectual property rights to an applicant outside the academic context, e.g., an organisation or private company which will develop and sell final products and services in exchange for royalties and often, the funding of further academic research (Bertha, 1996). The research value creating process, encompassing an effective technology transfer between a university and a company (e.g., a spin-off company or an external company) requires an appropriate fit between the donating (i.e., the academic inventor-entrepreneur as a technology provider) and receiving parties (i.e., the applicant/company) at the technical level at least. This is horizontal transfer of technology: it occurs when technology used in one place, organisation or context is transferred and used in another place, organisation or context (Mansfield, 1975). Or, more specifically: horizontal technology transfer as a shift of ideas from the science base (universities, research organisations, governmental laboratories) and their uptake by industry for incorporation into a development phase, resulting in improved products, processes and services. Conventional technology transfer models imply linear technology-market interaction issues, involving an owner of technology (the university), the technology itself and an applicant/buyer of technology (a company). The technology-market interaction occurs either through a technology-push or market-pull mode; the first might be the most obvious. So traditionally this transfer is seen as a momentary transaction with relatively clearly defined value parameters. More realistically than this linear interaction model, the technology-market interaction process may be depicted as an interactive process, in which industrial needs and research

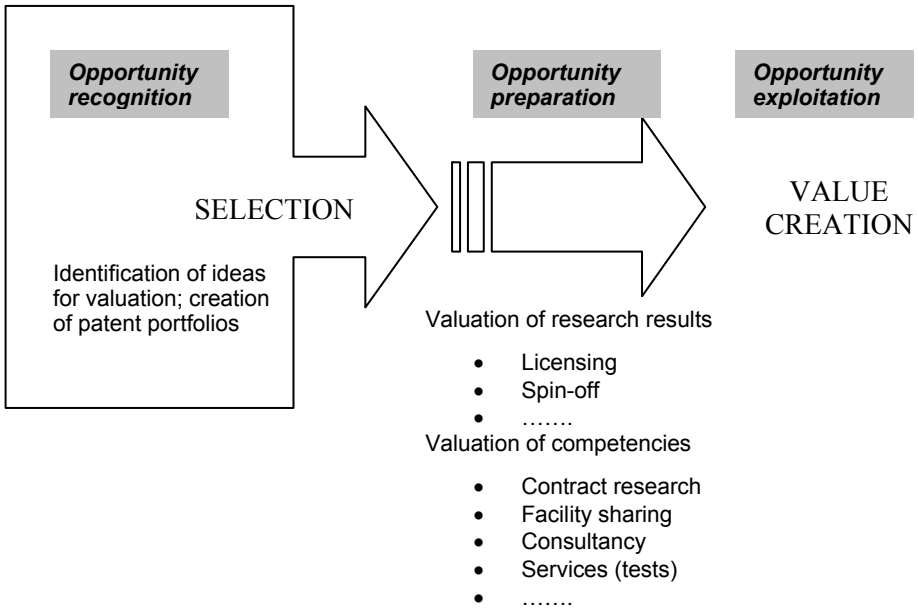
processes are brought in line over time in a relational pattern and that will lead to novel research topics (Leonard-Barton, 1988; Etzkowitz et al., 2000). In technology transfer, the transfer of competencies, such as information transfer, services (e.g., tests), consulting and contract research and the transfer of research results, e.g., by licensing of (patented) know-how and spin-off creation have been distinguished (DeBackere and Vleugels, 2005). In this paper we will only focus on the transfer of academic research results from a university to an applicant/company. The exploitation of the developed scientific knowledge or technology mainly occurs through (business) connections between the academic researchers and market organisations (companies, spin-offs; Jones-Evans et al., 1999; Klofsten and Jones-Evans, 2000; Meyer et al., 2003, Meyer, 2006a, 2006b). Our model will especially be useful for the creation of such business relations and more specifically the negotiation between the university and the market organisation leading to a valuation of the research outcome.

2.3 The entrepreneurial process of value creation

In order to investigate these issues in more detail, an entrepreneurship-in-networks perspective on the academic entrepreneurship phenomenon is adopted. Entrepreneurship is regarded as the process in which actors interact so that opportunities are recognised, preparatory steps are taken in such a way that the recognised opportunity can be exploited and leads to the creation of value (Shane and Venkataraman, 2000, 2001; Singh, 2001).

In the following we assume that there is an academic inventor-entrepreneur seeking economic value of his/her research outcomes i.e., technological inventions. Note that in most entrepreneurship literature the assumption is that a new firm (e.g., a spin-off from a university) is created in such a process. However, following our step-wise research valuation process in Figure 1, we also add the situation that an applicant, i.e., an already existing firm or organisation not connected to the university adopts the research outcome, e.g., by setting up a research collaboration with the academic inventor or by licensing the (patented) technology invented by the academic researcher(s) to create value in its own existing processes.

Figure 1 A stepwise research valuation process



2.3.1 First step: the opportunity recognition process (OR)

In the entrepreneurship-in-networks perspective, the first step in our research valuation process may be regarded as an opportunity recognition process (OR). Several authors including Long and McMullan (1984); Bhave (1994); Koning, (1999) and Puhakka (2002) have modelled the opportunity recognition process in general. In our situation, the essence of the opportunity recognition process is that the inventor-entrepreneur develops an initial idea how his technological invention may create value into a viable business opportunity. First, the technological invention may occur through a combination of scientific fields, presumably guided by scientific discussions with academic colleague researchers. The scientific fields that are combined might be horizontally (i.e., multidisciplinary) related to each other or vertically: creating a fundamental-applied research value chain. Second, some non-technical related issues of the technological invention, i.e., business-related perspectives, may be identified by networking with other professionals within or outside the university, such as technology transfer professionals within a university technology transfer offices, (external) technology transfer or business consultants, (scientific) colleagues working in other (industrial) areas or others, such as trusted friends or family. According to Koning (1999) and Bloodgood et al. (1996), the initial idea may be found through scanning the environment and interaction with multiple weak ties or as a result of a chance discovery. This information is analysed, the idea takes shape and the academic entrepreneur may begin to recognise the value of the idea and decide it is worth being pursued. In this process, creativity, intrinsic motivation, management experience, the amount of social interaction and commitment to relationships seem to be important (Puhakka, 2002). Baron (2006) pleads for a pattern recognition perspective in the opportunity recognition phase, as inventors-entrepreneur

seem to use cognitive frameworks they possess to connect the dots between changes in technology, demographics, markets, government policies and other factors, which events or trends suggest ideas for new products or services, that can potentially serve the basis for a new venture.

The opportunity recognition process may occur either at the individual researcher level or the academic institutional level or both. Universities may actively contribute to an entrepreneurial attitude of scientists by increased entrepreneurial professionalism, e.g., by eliminating hampering mechanisms in technology transfer, or the set-up of a technology transfer interface providing services to inventors-entrepreneurs (Etzkowitz, 1998), such as active scouting for ideas, creating and maintaining patent portfolio's, attracting subsidies and grants for research projects, playing an active role in the set-up and maintenance of scientific, institutional and business networks and providing legal and business development services.

At a given point during the opportunity recognition process, it must be decided whether the business opportunity is sufficiently developed and whether or not it will actually be exploited. Attainable resources and perceived market needs of one or several potential buyers will have to be matched to the (perceived) technical features of the invention, before deciding whether or not and how to exploit this opportunity. In the latter case, the inventor-entrepreneur alone or assisted by an inventor-entrepreneurial team start(s) to prepare the exploitation (opportunity preparation process, the second step of our research valuation process).

2.3.2 The second step: the preparation of the opportunity

During the second step, the preparation of exploitation of the opportunity, the business opportunity is translated into a specific concrete business concept, at least composed of strategic, technological and market issues. The business concept incorporates all ingredients, necessary to enable the exchange of the technology or scientific invention to the market and comprises e.g., a proper description of the invention, its technological features, uniqueness and its application potential, as well as a concise analysis of its market applications, its competitive technological position, potential (business) partners for further (co-)development/exploitation as well as worst case and best case economic scenario's. In our analysis, we distinguish at least three different exploitation opportunities: contract research collaboration with a business partner, licensing-out of a patented technological invention or spin-off creation.

One of the most important steps in this process is the development of a resource base, consisting of *creative capacity*, *transfer capacity*, *infrastructure capacity*, *human resources* and *financial resources* (Brush et al., 2001). In all three different exploitation opportunities: contract research collaboration, licensing-out or spin-off creation, this resource base is immanent, but different. *Creative capacity* enables to further developing the technological invention within a more applied, pre-competitive or near-market domain, resulting in a technology development plan. In contract research collaboration (which may also be a part of a licensing scenario) such a technology development plan is the key capacity of the resource base, whereas in spin-off creation it may only be an essential step at the start. *Transfer capacity* aims at reducing demand-side rigidities and favour the application of the technological invention, resulting in a business development plan. Business developmental efforts, being a part of this transfer capacity, may be important in all exploitation opportunities. *Infrastructure capacity*, e.g., the availability of

research and testing facilities, or (business) incubators, results in prototype development or demonstrations of feasibility. Part of the infrastructure capacity may be located at the developing partner in contract research and licensing collaborations. *Human resources*, e.g., entrepreneurial training of inventor, resulting in entrepreneurial skills of the inventor. The entrepreneurial attitude of the scientist, which may be low (inventor-entrepreneur model), favouring research and licensing collaborations or high (surrogate-entrepreneur model), favouring spin-off creation (Radosevich, 1995). Finally, '*financial resources'* are needed to apply for and maintain a patent, or to facilitate a business development process. In spin-off creation, high investments may be needed.

In this opportunity preparation phase, there is a need for criteria and guidelines to select a proper exploitation strategy. At its basis lies the need for a reliable business valuation method.

2.3.3 The third step: the opportunity exploitation phase

In the third step, the opportunity exploitation phase, value creation should finally be effectuated. But what would be the definition of 'value'? From the viewpoint of the academic researcher it can be monetary value: increased financial governmental and/or industrial funding for contract research collaborations, lumpsum payments and royalties for licenses and investor's money in spin-off new ventures. From the viewpoint of an applicant/company interested in the novel technology, the exploitation of the opportunity may lead to the creation of marketable products or services showing an added benefit to customers. For this applicant/company, the opportunity exploitation phase may be regarded as an investment, which is expected to generate profit in the long turn. So for the applicant/company of the novel technology, 'value' will be different than for the academic inventor-entrepreneur.

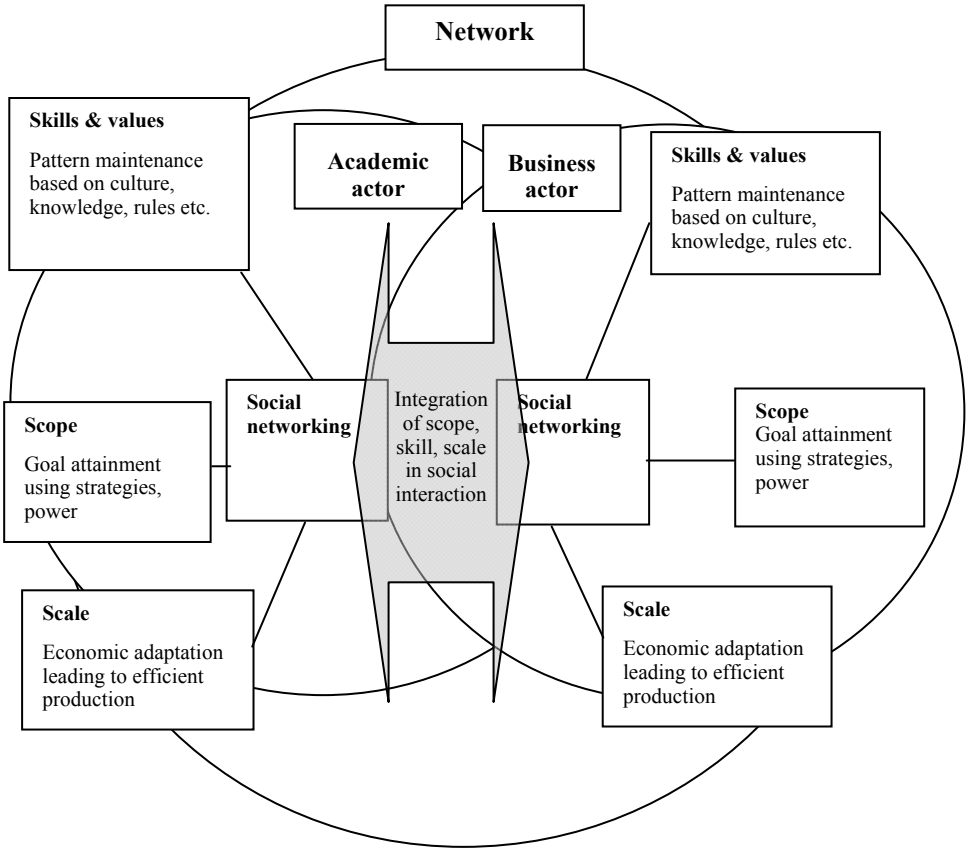
At any point during the exploitation process, the inventor-entrepreneur may realise if an appropriate resource (technology, human resources, facilities, money) base to exploit the opportunity is viable or not. Likewise, the applicant/company may experience that the demand for the product or service may turn out to be insufficient for profitable exploitation. In these cases, the business concept may be revised or even abandoned (Herron and Sapienza, 1992).

3 A social system perspective

Although our model of the entrepreneurial process is opportunity-based, the inventor-entrepreneur(ial team) is the driving force throughout the process. The inventor-entrepreneur(ial team) initiates and directs the process from an (original) idea to the exchange with the market (Van der Veen and Wakkee, 2004). Yet, the inventor-entrepreneur(ial team) is not an independent actor. As stated before, we regard the inventor-entrepreneur(ial team) as being embedded in a social context, which needs to interact with other actors to exchange information and resources to exploit the opportunity and create value. Recognising that this is a process with multiple-actors and multiple levels of aggregation, where actors interact and construct new technologies into new business, we adopt a theoretical model (Groen et al., 2002a, 2002b; Rip and Groen, 2001) which is inspired by functionalistic social system theory (i.e., Parsons, 1964). The fundamentals of this approach are that entrepreneurs strive for goal attainment; develop

new action patterns in existing culturally shared patterns of behaviour; strive for continuous optimalisation of rewards which leads to more effective and/or efficient processes; and integrate their actions in (direct and indirect) interaction with other actors. A four dimensional space describes the entrepreneur's development. For each of the dimensions the entrepreneur accrues capital: *strategic capital* (e.g., power, authority) for goal attainment, *cultural capital* (Bourdieu, 1979) as relates to connections in cultural patterns such as value and norm systems, and also to knowledge necessary to maintain (or change) the patterns of behaviour; *economic capital* relating to money and last but not least: *social capital* which relates to the network connections an actor direct or indirectly can access (Burt, 1992, 1987).

Figure 2 4S-model



Based on the above social system theory, the inventor-entrepreneur(ial team) needs to develop the four types of capital: strategic, economic, cultural (human and organisational) and social capital up to a certain 'minimum' level (Groen, 2005) for a successful exploitation of the opportunity. The inventor-entrepreneur(ial team) needs to develop a strategy to develop its knowledge and enter the market (*strategic capital*), identify and mobilise financial resources and develop a business model (*economic capital*), find the necessary human and organisational resources, including the knowledge and technology resources (*cultural capital*). Important in all these activities is the network (*social capital*). Dependent on the inventor-entrepreneur(ial team)'s position in the network, the activities are channelled and facilitated but also constrained and inhibited (Dubini and Aldrich, 1991; Carsrud and Johnson, 1989; Hoang and Antoncic, 2003). Throughout the entrepreneurial process of research value creation, the inventor-entrepreneur(ial team) interacts with many actors (the network) within and outside the university, activating different parts of this network at different stages to exchange and accumulate the capitals (and resources) seeking power, knowledge, finance, networks) necessary to pursue the opportunity.

This generic model, as depicted in Figure 2 is applied on the entrepreneurial process, and can be used to analyse the pursuit of opportunities in all contexts.

4 The research value creating process in a social system perspective

In our model, we assume that the technology transfer of academic inventions may occur according to the value chain: basic science-applied science within the university context towards the developmental research phase outside the academic context, i.e., at an applicant (a company/spin-off outside the academic context). These three types of research within both an academic environment (basic and applied) as well as outside the academic environment (i.e., at the applicant, e.g., within a company/spin-off: developmental research phase) can have outcomes which may have different values in the applicant or market domain. Within the context of our social system theory (opportunity recognition, opportunity preparation, opportunity exploitation) we can systematically analyse the value creation process using the four dimensional model of entrepreneurial processes: strategic, cultural, economic and social capital (refer to Table 1, Groen et al., 2002a, 2002b; Groen, 2005; Kirwan et al., 2006).

Table 1 Capitals

Strategic →	Value added to strategic position of applicant
Cultural →	Value added to knowledge position of applicant
Economic →	Value added to cost reduction or turnover of applicant
Social →	Value added to network position of applicant

The results of this analysis are illustrated in Table 2. It is obvious that all these four capitals are spread throughout all phases and both research development types.

Table 2 Issues in the research valuation processes at the technology provider/university (basic research, applied research) and at the applicant/company (developmental research)

Research value creation process	*Basic*	*Applied*	*Development*
Opportunity recognition	Publication or patent? (C)	Patent position/patent portfolio creation(C)	Active scouting of technologies with market potential (S, N)
	Inventors' reward (C, E)	Inventors reward (C, E)	Market-based and product-based technological development (S, C)
	Scientific peer review (C, N)	Business concept (S)	
	Academic culture (C)		
Opportunity preparation	Positioning of invention within the technology-market value chain (S)	Demolab feasibility study (C)	Spin-offs formation (S)
	Identification of co-development partner (S, N)	Business model(S)	Entrepreneurship (C)
	Grant application (E)	Market data (C, N)	Investors, venture capitalists (E)
		Product-market-combinations (S)	
Opportunity exploitation	Creation of technological concept (C)	Commercial network (N)	Incubator (laboratoria, offices, administration, science park, business park) (C)
	Scientific and industrial networks (N)	Business development process (S)	Production, commercialisation and management (S)
	External communication (science, society, education) (C, N)	Financial valuation of technology (E)	
		Research collaborations with industry (grant application) (E, N)	
		Licensing scenario's (S)	

Note: C = cultural capital, S = strategic capital; E = economic capital; N = social/network capital

4.1 The value of research: four capitals

We will now explain a few examples of how these types of capitals add to the value of research outcomes, not only from the viewpoint of the academic researcher-entrepreneur (basic, applied) but also from the viewpoint of the applicant/company (developmental phase).

Cultural Capital refers to the things people have, including both objectified/material culture and embodied cultural capital (i.e., knowledge) and habitus, which refers to things people do (Devine-Eller, 2005). The academic cultural capital favours basic scientific knowledge, scientific publications and a studious attitude, but not entrepreneurial behaviour or economic motives. As an inventor-entrepreneur needs to connect dots between science and business in the opportunity recognition phase (Baron, 2006) and basic scientists are especially focused on the science part of this, opportunity exploitation in basis research will be less economic and business oriented than e.g., opportunity exploitation in applied research or in developmental research, being more orientated at problem-solving and having a smaller distance to market. So cultural hurdles towards academic entrepreneurship may exist especially in basic research. However, special instruments, such as inventor's rewards or fees may reduce these cultural hurdles. On the contrary, the increasing business-like culture and knowledge of business processes, business development and marketing in applied and developmental research will favour entrepreneurship.

Due to this smaller distance science-to-market, the *social/network capital* will be more diversified (i.e., science networks, industrial networks) in applied science or in developmental research professionals, in comparison with more basic-research oriented professionals, being mostly embedded within the scientific community. For instance, co-development partners in basic research are expected to be other basic research scientists, probably active in a horizontally-related disciplinary field, leading to joint scientific publications or scientific grant applications. In applied research and developmental research, co-development partners may additionally be industrial R&D groups, leading to industry-university collaborations, R&D contract research or licensing scenarios.

The increase of *economic capital* is of interest to all fields of research; in a basic research setting the money comes mainly from public and governmental (i.e., national funds, international funds such as EC or NIH) and science-promoting organisations whereas in organisations focusing more on applied research types, such as contract research organisations, industrial funds are additionally involved as well.

The increase of *strategic capital* in basic research must be envisaged in the context of research strategy (i.e., curiosity-driven knowledge development), whereas strategic capital in applied and developmental research may additionally deal with the positioning and added value of technology within a business chain and potentially also perceived customer-benefits of the technological invention.

5 Business valuation in a licensing process

Having described the research value creation process in some detail, we will now focus on the business valuation of an academic research outcome in a licensing-out scenario. To assess the value of the academic invention for the applicant/company, we start at

defining the changes in its four types of capital due to this technology transfer case. Briefly spoken: value creation by technology transfer may thus occur at the strategic level, adding to the strategic position (*strategic capital*) of the applicant/company; it may occur on the cultural level, adding value to the knowledge base of the applicant/company (*cultural capital*); it may add value at the *economic level*, e.g., to a cost reduction of processing costs or, alternatively, generating additional profit to the applicant/company (economic capital) and finally add value to the business or scientific network position of the applicant/company (*social capital*). In many cases, the ultimate value or *gross business* value to be created at the applicant/company by technology transfer will be a cumulative effect of several different values, being based on the four capitals.

5.1 Strategic capital

For the applicant/company licensing a novel technology, improvement of its *strategic capital* is an important driver. The applicant will seek a contribution of the licensed academic invention for its business potential. Improvement of market and/or competitive position adds to strategic capital. However, also when its own business is not improved, but threatening developments at competitors can be blocked by the ownership of this intellectual property adds to strategic capital.

The most potential occur when the licensed invention is characterised as *a disruptive innovation* (Schumpeter, 1934; Bower and Christensen, 1995), ultimately making existing technologies obsolete and creating new markets with more value providing business concepts, processes or infrastructure. Alternatively, the licensed invention may be a sustaining innovation, strengthening the current strategic position of the company, by adding additional market potential in a similar market segment.

Integrating this ‘disruptiveness concept’ with our research valuation approach (refer to Table 2), opens up questions about the relationship between disruptiveness or sustainability of an innovation and the type of research it stems from: basic, applied and developmental. We expect the disruptive innovations to be more closely related to basic research whereas the sustainable innovations might be more closely related to applied or developmental types of research. Note that the social/network capital will be important also in disruptive innovations (see below). Other strategic issues in our research valuation approach, adding to the strategic capital of the applicant/company would encompass various business-concept related topics occurring through the opportunity preparation and opportunity exploitation phases, such as the positioning of the invention within the technology-market value chain, and the development of licensing scenario’s.

5.2 Cultural capital

Improvement of the *cultural capital*, such as the technology base of the applicant/company about to invest in the novel patented invention occurs like a quantum jump if the invention is a *radical innovation.* A radical innovation has been defined as a non-linear and discontinuous innovation. A radical innovation may be a totally new approach, offering a different package of performance attributes. A radical technology can be defined in terms of competence change (e.g., the technological distance to a preceding generation, the distance to a common scientific field, a substitution or complementation to the existing technology), as a physical product or process change (e.g., a new component, a new subsystem, complete redesign or a new product class) or

changes in the price/performance level; Ehrnberg, 1995. The radicalness of innovations refers to the extent an innovation is based on a substantially new technology relative to existing practice (Govindarajan and Kopalle, 2006). Note that this novel technology may be the result of one of the three types of science: basic, applied and developmental, but maybe mostly derived from basic research. Developmental risks may be high, especially if the market distance as is the case in basic research is high and the technological developmental trajectory may be sporadic and discontinuous.

An incremental innovation on the other hand (e.g., maybe more in applied or developmental research) will have a less revolutionary impact on the technology base and cultural capital of the company. Patented inventions may thus be described using both technological (i.e., radical innovations) and market-based (i.e., disruptive innovations) dimensions. Positioning the licensed *invention*, either a novel technical or technological product or process, as a result from a research process or project at a position somewhere on the continuum that goes from incremental/sustaining innovations to radical/disruptive innovations, has implications for either the strategic or cultural capital of the buying company!

The implications of the technology providers' (university) cultural capital for the cultural capital of the technology absorber (applicant/company) are not straightforward (Polt et al., 2003). The absorptive capacity of the applicant/absorber depends on various factors, e.g., in-house R&D, qualification of employees, technology skills, innovation management capabilities). However, improving the cultural capital of the technology provider especially in the opportunity recognition phase (basic and applied science), for instance by enlarging relevant academic-business networks stimulating thus knowledge spillovers via informal contacts and social interaction between academic researchers and potential applicants, may improve technology transfer and thus finally the cultural capital of the applicant/company.

5.3 Economic capital

Improvement of the *economic capital* of the applicant/company may occur if the novel technology either results in novel marketed products, an increased market share, improved competitive position and concomitant additional profits, or in cost-reduction of its conventional production processes. In the case of a co-development between the technology provider (university) and the applicant/company on the invention to be licensed which receives additional funding by e.g., a grant of subsidy, the technology provider may also add to the economic capital of the applicant/company. This may occur in both opportunity preparation and opportunity exploitation phase, for basic and applied research. The economic capital of the applicant/company may also be improved if the financial terms and conditions in the licensing contract are relatively favourable to the applicant/company.

However, the investments of the applicant/company in novel technology development, especially in a radical technology or even a disruptive technology can be substantial and may cause a serious burden to the applicant/company, which will only be taken if the expected profit will outrage these investments. As a matter of fact, private sector profits result only from developing effective businesses with market-driven products and robust markets and not just technology. The willingness of private parties to invest in novel technology increases as the cash flow risk-based discount rates increases during the business development process of a novel technology. During the so-called

valley of death, between technology creation at the university and early commercialisation at an applicant/company, investors are scarce (Murphy and Edwards, 2003).

5.4 Social capital

Improvement of the *social capital* of the applicant/company about to invest in the novel patented invention might occur also. Among the reasons companies have to set-up collaborations with universities are access to the scientific community for recent knowledge and human resources (recruitment) as well as prestige (Caloghirou et al, 2004). This may be especially the case in the opportunity exploitation phase of basic and applied research.

In the case of technology transfer of a disruptive technology, an impetus in social capital of the applicant/company may occur (Ferrary, 2003). When one considers the time to market, which is often long, combined with ongoing technology development at the applicant, the building of lasting relations between academic and business actors seem to be fruitful. However, the Granovetter (1973, 1982) thesis of the role of weak or strong ties is also here of importance. Strong ties are necessary in ongoing research and development or new product development, but the amount of new information in marginal contacts tends to get lower. Weak ties on the other hand deliver often high degrees of newness, but this type of information is also most difficult to absorb. Another form of social capital deals with positional issues. The contact with the university often leads to contacts elsewhere in the academic world. In research on global start ups, it is shown that this positional effect leads to brokerage between network partners all over the world (Kirwan et al., 2006). Of course the other side of the relation is that the firm offers brokerage relations for the academics to the market. As stated above the value is really created in the market place. This makes clear that mutual dependencies are likely to exist, leading to the impetus to collaborate.

6 A novel multi-dimensional business valuation model

In this work, we have analysed technology transfer issues in a research value chain, composed of basic-applied-developmental research at two different contexts respectively (basic and applied at a technology provider/university and developmental at an applicant/company context respectively) within a multi-dimensional framework, pointing at four capitals: strategic capital, social capital, economic capital and cultural capital. We have discussed how a successful technology transfer operation may contribute to these four types of capital of an applicant/company. How can we use this to define the value of an academic research outcome?

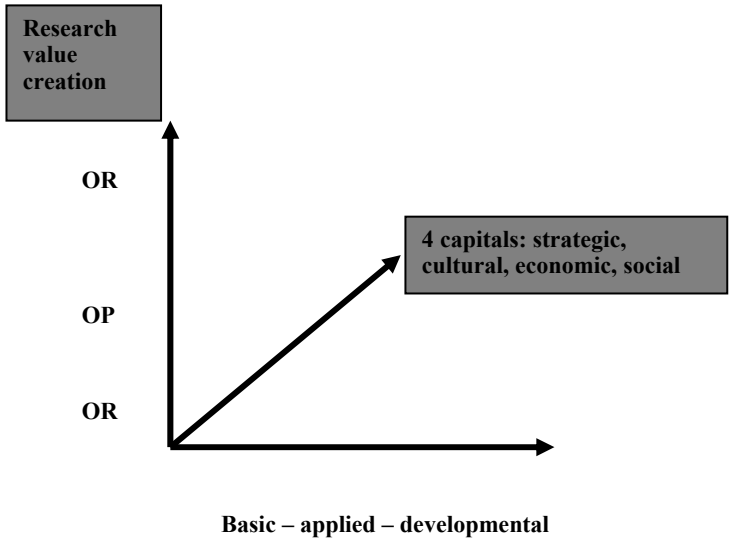
In the literature, a new two-dimensional method for technology valuation was published, incorporating both a technological and monetary valuation step (Park and Park, 2004). The technological step was performed by rating some technological performance indicators, composing a correcting factor out of this rating process which was consecutively used to adapt a business-oriented economic valuation outcome.

In our model, we would introduce a so-called *gross business value* of a given technological academic invention, based upon the multi-dimensional input of the various dimensions influencing the value of the invention to the eye of the applicant/company.

We propose to illustrate the research valuation process within a multi-dimensional model of at least three dimensions, i.e. the type of research on the X-axis, the research value creation process on the Y-axis and its contribution to the four capitals on the Z-axis.

Any novel invented technology could be positioned within this model, as it would be situated within a research value chain, e.g., within basic science (X-axis); it would also be either within an OR, OP or OE-phase (Y-axis), e.g., in an OR-phase and it would additionally add to different extents to the four capitals of the applicant/company (Z-axis), e.g., as a disruptive, radical technology, with an expected high profitability/investment ratio and opening up unknown (scientific networks) for the company. Such an invention would be of much greater *gross business value* to the company than an alternate case: for example an invention in applied science, in an OR-phase, a continuous, incremental innovation, a limited profitability/investment ratio and no relevant novel networks accessible. Various scenarios can be analysed and discussed using this approach. The relative impact of all dimensions could be rated numerically, using new scoring methods to be developed and the output of the scoring models added and then used as a correction factor on economic valuations.

Figure 3 Multi-dimensional model of research valuation



7 Conclusions

In this paper, we have developed a novel multi-dimensional approach to research valuation and introduced *gross business value* as the 'value' of an invention not only depending on costs and profitability (economic capital) but also on strategic, cultural or social value added to the applicant of this invention. We propose to position the *gross business value* of an academic technological invention within a three-dimensional model, with the research type on the X-axis, the research value creation process on the Y-axis and its contribution to the applicant/company's four types of capitals at the Z-axis.

This model may contribute to achieving a broader and more systematic business valuation model for research outcomes.

This multi-dimensional approach is very contrasting against conventional business valuation financial scenarios for technology, but it may be a novel and interesting addition. To further develop this model, we would propose to set-up the following research agenda. The first step would be to develop adequate scoring models within this model and investigate the relative contribution of all respective dimensions (capitals, stages in the research value creation process and research type) to the gross business value. The second step would be to empirically assess the various dimensions related to the gross business value of some selected case studies, being representative for specific fields and stages of research (basic, applied) and developmental status. Finally, based on the conclusions drawn from the previous work, novel tools to define the gross business value of a given technological invention should be developed suitable for practical application by technology transfer officers and other professionals in the field.

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