Reconsidering the Mode 2 and the Triple Helix: A Critical Comment Based on a Case Study

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This paper takes a critical stand towards the Mode-2 thesis and the Triple-Helix model as schemes to describe the association of university research with applied motives and commercial and industrial actors. By drawing from a case study of a plant-biotechnology research group, which transformed into a start-up company, the paper suggests that using these models as conceptual frameworks in the empirical analysis may run the risk of glossing over some vital conceptual insights. The first instance where more focused attention should be given is the analytic distinction between theoretical, methodological and applied dimensions of a local research program. By appreciating it, a central source of dynamic that formed the ground for the commercialization of the group's research results is preserved. The second deficiency is that neither the Mode 2 nor the Triple Helix pays close enough attention to the problems and contradictions that come into the world as university research results are commercialized. In this respect, three problem areas are addressed: 1) the ownership of intellectual property rights, 2) the industrial collaboration and the difficulties of transferring the research results to the market, and 3) the failed attempt of creating a hybrid community between the research group and the spin-off company. Also these should be given a more central role in the models since they seem to be vital challenges for researchers-entrepreneurs as they move from academic to industrial focus.

Keywords: Mode 2, Triple Helix, empirical analysis

This paper takes a critical stand on two recent theoretical schemes – the Mode-2 knowledge production (Gibbons *et al.*, 1994; Nowotny *et al.*, 2001) and the Triple-Helix model (Etzkowitz & Leydes–dorff, 2000) – as a means to describe the association of university research with applied concerns as well as commercial and industrial activities. This is done by taking, as a case, a study of a plant-biotechnology research group, which operated in a major Finnish university (Tuunainen, 2001; 2002a; b). During a ten-year period of time, which started from the group's establishment in 1990, the original, practice-oriented research agenda became gradually linked with business activities with the end-result being the metamorphosis of the group into a university start-up company. By using this case as a source of conceptual insight, the paper puts forth the claim that both the Mode-2 thesis and the Triple-Helix model, if applied as frameworks in the empirical analysis, fall short of giving sufficient enough attention to two vital characteristics of the case example.

The first of these relates to the nature of the group's research agenda as an instance of what Stokes (1997) has called "use-oriented basic research". That is, research which combines fundamental understanding of a phenomenon with its potential use in society. In this regard, especially the Mode-2 thesis fails to make an analytic distinction between, and appreciate interconnection of, the theoretical, methodological and applied dimensions of the studied research agenda. Because of this it also misses a central source of dynamic that prepared the ground for the commercialization of the group's research results. Second, the models do not pay enough attention to the problems and contradictions that emerge when research results are commercialized and transferred into the market. With relation to this, three specific problem areas will be addressed and discussed. These include: 1) the ownership of intellectual property rights at the university, 2) the industrial collaboration and the difficulties of transferring the research results to the market, and 3) the attempt to create a hybrid community of the research group and the spin-off company in a university department. In connection with these, both of the schemes seem to embody too optimistic a view concerning the passage from the academic to the corporate world.

The Mode-2 Knowledge Production Thesis and the Triple-Helix Model

Contextualization of Knowledge in Mode-2 Knowledge Production

In several of their writings, Michael Gibbons, Helga Nowotny, Peter Scott and others have put forward a radical thesis according to which we are currently witnessing an appearance of a new mode of knowledge production called Mode 2 (Gibbons, 2000; Gibbons *et al.*, 1994; Nowotny *et al.*, 2001). According to the argument, this emergent mode is trans-disciplinary, organizationally non-hierarchical, socially accountable, and reflexive. The research is carried out in "the context of application", that is, with societal needs having direct impact on the knowledge production from the early stages of investigative projects. By contrast, the earlier mode of knowledge production, Mode 1, designates reliable academic knowledge produced within autonomous disciplinary contexts. In this sort of research there was only a little direct linkage between research and social application, thus, boundaries between universities and industries were not blurred and academics were quite autonomous in terms of choosing their research topics and problems (Gibbons *et al.*, 1994). Despite the general shift from Mode-1 to Mode-2 there is not, however, any clear historical demarcation line where the former ceased and the latter started. Instead, the change has been gradual and, at present, both modes are said to coexist (Gibbons *et al.*, 1994: 9, 14).

One of the key concepts used by the authors to account for the shift from Mode-1 to Mode-2 science is "contextualization of knowledge", which ascribes to the mutual interpenetration of scientific knowledge and its social contexts. The relationship between science and society has become reflexive, meaning not only that science "speaks to society", as has always happened, but "society now speaks back to science". In the simplest terms, this "reverse communication" is what the authors mean when they speak about contextualization of knowledge production (Nowotny *et al.*, 2001: 50). According to them, the contextualisation has slowly crept into the very core of science while some parts of science have simultaneously oriented outwards. This has taken place via various mechanisms, such as more intensive university–industry relations, national R&D programs, or increasing consulting by academics. These developments indicate that knowledge production occurs currently within open and shifting boundaries, taking place in the context of application and being organized around a particular useful purpose. Gibbons and others call this imperative of usefulness and state that it is present in knowledge production from the beginning (Gibbons *et al.*, 1994: 4).

The contextualization of knowledge also pertains to the institutional structure of university, hence, great interaction between scientists, other knowledge producers and users. The demarcation between universities and other kinds of organizations, such as industrial enterprises, has eroded and university scientists have become more responsive to the needs of industry. Therefore, universities have become "stretched" institutions encountering competitive and even contradictory functions, such as production of scientific knowledge and responsibility to satisfy mass education demands (Gibbons *et al.*, 1994: 70-89; Nowotny *et al.*, 2001: 79-94). These different social and scientific roles may also be mutually sustaining. For example, "hybrid institutions", such as small and medium-sized high-technology companies have developed. According to the authors, these firms play a decisive role in increasing the contacts between universities and industries (Gibbons *et al.*, 1994: 137-138, 144). There has also been growth in what the authors call "programmatic research", that is, research emphasizing dissemination of results and reaching out to potential users (Nowotny *et al.*, 2001: 79-94). Biotechnology, in particular, is a field of study where these developments have been most prominent. In that area, the traditional separation between university and industry has broken down: university-based scientists not only routinely move into entrepreneurial roles as part of their self-understanding as researchers but governments worldwide encourage academics to team up with outside firms or, alternatively, to start up their own companies (Nowotny *et al.*, 2001: 60).

The Triple Helix: Interaction Between University, Industry and Government

An alternative, but closely related perspective on the changing nature of knowledge production has been proposed by Henry Etzkowitz and Loet Leydesdorff. While the Mode-2 thesis underlined the de-institutionalization of the current mode of knowledge production, the Triple-Helix model suggests that universities are taking up a new mission of contributing to economic development. This trend captured by the term "entrepreneurial university" is closely associated with another change appearing at the structural level of nation states: interlinking of institutional spheres of the university, industry and government (Martin & Etzkowitz, 2000).[1]

As a widely held metaphor, the discussion around the Triple-Helix model has been grounded on empirical case studies. Based on these results, Etzkowitz and Leydesdorff have suggested that there is not a single model of the Triple-Helix relations but in fact three different configurations (Etzkowitz & Leydesdorff, 2000; Leydesdorff & Etzkowitz, 1998). In the first of them – Triple Helix I, which is found in the former Soviet Union and East Europe – the nation state encompasses the university and industry and directs their mutual relationships. The second configuration – Triple Helix II exemplified by Sweden – consists of separate institutional spheres with strong borders and highly circumscribed relations among them. Finally, the third variant of the model – Triple Helix III – denotes a knowledge infrastructure made up of overlapping institutions that take the roles of each other and produce hybrid organizations. In this variant sought for in most of the countries, the "objective is to realize an innovative environment consisting of university spin-off firms, tri-lateral initiatives for knowledge based economic development, and strategic alliances among firms…, government laboratories, and academic research groups" (Etzkowitz & Leydesdorff, 2000: 112).

When an internal transformation of one of these helices – the university – is considered the Triple-Helix model becomes parallel to the Mode-2 knowledge production. As articulated by the authors, each of the helices takes roles of others. This is to say, for instance, that universities emphasize entrepreneurial tasks, such as creating companies, while industrial enterprises take on academic dimension of sharing knowledge and training employees (Etzkowitz *et al.*, 1998). With reference to the university institution in particular, "the third mission" of economic development has emerged to supplement the earlier missions of research and teaching. It involves direct contributions to industry and is related to the increase of cooperative initiatives of the academia and industry: "Just as companies seek new ways to collaborate with academic research groups, so universities want to expand their role in economic development of their region" (Etzkowitz & Leydesdorff, 1998: 204). Different forms of organizations have been created to materialize that pursuit, such as university patenting-licensing offices, spin-off firms, business incubators and science parks. Indeed, the economic logic is strengthening within universities, consequently boosting the commercialization of knowledge and aspirations to become "an entrepreneurial university" (Etzkowitz, In press).

According to Etzkowitzs (2002: 121), the emergence of the entrepreneurial university seems to be irresistible and an unavoidable development: it "is not so much a matter of evolution, the capture and retention of change events, but of an internal dynamic working itself out." Such a dynamic is currently evident, for instance, at the level of research practice: by putting forth the notion of "an entrepreneurial science" Etzkowitz wants to draw attention to the simultaneous presence of theoretical, methodological and commercial dimensions of research as well as highlight the integration of academic investigation with corporate activity (Etzkowitz, 1998: 826-827). In the future, this tendency will become even stronger; "the University of the Future" will be a business incubator entirely, that is, technology transfer and incubation of new firms will convert from happenstance into a permanent activity, taking place in each and every department. Even controversial activities of the contemporary university – academic research, higher education and societal service – do not hinder this development as the university incorporates these functions and reconciles their apparently contradictory objectives (Etzkowitz, 2002: 127). In effect, various kinds of problems are just symptoms of the changing role of the organization. These will disappear as the new type of university takes hold: "the 'opposing' norms and orientations are reinterpreted, emphasizing harmony rather than disharmony, mutual reinforcement rather than detraction from each goal" (Etzkowitz, In press).

The Ambiguous Nature of the Mode-2 and Triple-Helix Models

Clearly, as brought out by some commentators (Audétat, 2001; Krücken, 2002; Shinn, 1999; Weingart, 1997), the Mode-2 thesis and the Triple-Helix model are important attempts to come to grips with many recent phenomena concerning university research, its societal application and the broader institutional framework within which universities currently operate. For instance, they draw attention to the practicality of research, to the direct collaboration between university research groups and industrial enterprises as well as to the emergence of hybrid modes of activity. It might well be that some of these, such as the extensiveness and the diversity of university–industry networks, are signs of something new coming up, that is, cues for fundamental changes taking place in some high-technology industries with respect to particular fields of science (e.g., biotechnology and information technology). In this respect, Geiger's (1988: 341-342) study of the university–industry relationships in American universities since the 1920s proves revealing. According to him, the excitement about industrial involvement with the university research[2] should not be received with a *déjà-vu* attitude but we should, instead, appreciate the distinctive nature of the current situation: First, industry is willing to make huge, long-term contractual commitments supporting university research. Second, universities are apparently eager to seek out these contracts. Third, there is a whole diversity of new arrangements that have been worked out by universities to facilitate technology transfer. Fourth, some of these have obviously been facilitated by governmental bodies.

Many commentators have also directed substantial and hard criticism toward the Mode-2 thesis and the Triple-

Helix model. First of all, Weingart (1997) as well as Etzkowitz and Leydesdorff (2000) have maintained that the Mode-2 thesis overstates the change science is undergoing while simultaneously dismissing relevant earlier literature and empirical evidence. In their view, the Mode-2 type of research is not new at all but has, in fact, always existed. On the other hand, all the three authors admit that changes are, in fact, taking place in science. Interestingly, the conclusions seem to converge. Much in a similar vein as Etzkowitz in his Triple-Helix model, Weingart (1997: 607) states: "the transfer time from basic research to technologies has been reduced to such an extent that the institutional distinction between the context of basic (academic) research and the (non-academic) context of application has become obsolete in organizational terms". Interestingly enough, Weingart restricts these changes to a fairly small sector of the scientific enterprise, that is, biotechnology and information technology while Etzkowitz is willing to subsume all the sciences and all the types of universities under the one and the same general schema.

Second, some commentators have expressed their concerns about the very nature of the two models. For instance, Shinn (1999: 153) has considered the theoretical ambiguity of the Triple-Helix model and its problematic relationship to the empirical evidence. Although he holds that Etzkowitz's project has yielded interesting empirical data, he is concerned about its theoretical status: it is unclear so far. Thus, in his point of view, it remains to be seen whether Etzkowitz and others are able to develop their concept into a model having "well defined descriptive and analytic elements", or whether it is going to remain an evocative metaphor only (see also Leydesdorff & Etzkowitz, 1998).

Third, it has been suggested that the discourses related to the models look like they were direct affiliates to the language of science and technology policy and neo-liberal political agenda (Häyrinen-Alestalo, 1999; Shinn, 1999; Weingart, 1997). As noted by Weingart (1997: 608), the lack of adequate empirical evidence concerning the fundamental change of knowledge production makes the Mode-2 thesis looks like "a normative program rather than an empirical analysis". According to Krücken (2002: 128-129; see also Krücken, in press), then, we should be aware of taking the current rhetoric of change at face value, because scientific institutions seem to be much more resistant to transformation than presented by the models. Therefore, he asks whether the argument by Novotny, Scott and Gibbons (Nowotny *et al.*, 2001) is really intended as a serious sociological analysis or if it is just a thought-provoking essay.

Fourth, as discussed by Fuller (1998) and Shinn (1999), Gibbons and others speak about the Mode-2 science as if it had only remote, if any, affiliation to the traditional university organization. If academic research merges with business and other forms of societal activity, its distinctive character as an epistemic enterprise seems to vanish. The picture displayed looks, thus, as if Mode-2 science occurred "in a totally de-institutionalized, fluid, and amorphous environment", which is hardly the case. On the contrary, as Shinn (1999: 151-152) notes, the model disparages the salience of the university institution and scientific disciplines. Nonetheless, these should be acknowledged as the production of scientific knowledge is being addressed.

In consequence, although the Mode-2 knowledge production thesis and the Triple-Helix model really seem to demonstrate that something new is taking place with respect to the relationship between science and society, they also remain highly problematical and controversial. Thus, instead of adopting either of them as conceptual frameworks at face value, I shall make an attempt to evaluate their accuracy and possible usefulness through the case study. The analysis, which I shall summarize, will pull together central strands of my previous articles (Tuunainen, 2001; 2002a; b). While so doing, I shall make an attempt to follow the advice given by Michael Lynch. Drawing from an ethnomethodological standpoint, he argues that instead of putting one's faith in the application of foundational general theories in describing and evaluating specific domains of practice, we should, rather, make the empirical world under investigation the primary – but not the sole – source of our theoretical insight (Lynch, 1999). Equally, I shall use my case example as a possible source of theoretical insight as to examine what the schemes described and discussed may either ignore or bypass too straightforwardly. I shall come up with two particular points of view that, in my opinion, deserve more focused attention. These are: 1) the indivisibility of theoretical, methodological and applied in the course of work of local research groups and 2) the contradictions and problems related to the various ways of commercializing the research results.

Indivisibility of Theoretical, Methodological and Applied in the Research Group's Agenda

The studied research group worked in an applied field of agricultural science in a major Finnish university. Starting its work at the turn of the 1990s, the group concentrated on examining and managing biological hazards in potato production created by viruses. This research was keenly founded on the fact that, in potato, viruses can reduce yields up to 80% (Mäki-Valkama & Valkonen, 1999: 494). Later, the research topics expanded to include, among others, insect resistance in various crop plants, cold tolerance in the potato and oat improvement by using biotechnological methods. In the very beginning, the potato virus resistance was, however, the main object of the research; the group was set both to create better understanding of the potato's virus resistance trait and to combat with viruses by creating a virus-resistant potato:

> A major part of this project is, therefore, to investigate the mechanism(s) of virus resistance in *S. brevidens* [a wild potato], both because of its intrinsic scientific interest and because a (…) source of broad-spectrum virus resistance would be of practical value to breeding and/or genetic engineering of potatoes for resistance (Pehu, 1989).

In addressing the virus resistance in the potato, two specific experimental approaches were used. First, between 1990-96, the natural virus resistance trait was investigated in a wild potato species combined with several attempts of transferring that trait to the cultivated potato gene pool. Second, between 1993-96, a novel genetic-engineering approach was developed by virtue of which the potato-virus genome could be used as a source of virus resistance. While the previous strategy was extremely complex and, in fact, non-productive from the applied point of view, the use of the latter, which partially evolved from the former, proved a success: A virus-resistant cultivated potato was developed by introducing a viral gene into the genome of the Finnish potato cultivar, Pito. Subsequently, the research continued in both scientific and commercial contexts. First, the genetically engineered virus resistance in the potato was theoretically interesting and, thus, its mechanism became the topic for further investigation. Second, the virus resistance effect was potentially useful in agricultural-industrial production, so, it was patented. Along with the methods of its creation, it was also subjected to further development in collaboration with a Danish plant-breeding company.

Clearly, the group's research agenda combined theoretical and methodological concerns with applied agricultural objectives. That is, the studies related to the wild potato's virus resistance simultaneously sought 1) to create the cultivated virus-resistant potato to be used in agricultural production, 2) to develop appropriate cell and molecular-biological research materials, tools and methods to be used in its production, and 3) to theoretically understand the biology of the virus-resistance mechanism in the wild potato species. In practice, these three distinctive concerns depended on each other in various ways during the research practice. For instance, when starting the work, the researchers did not know which genes in the genome of the wild potato caused the resistance effect; these had to be localized first. Therefore, the initial stages of the object construction involved producing new knowledge. This was accomplished by, first, creating suitable plant material by hybridizing the virus-resistant wild potato and the virus-susceptible cultivated potato, and second, by using these potato hybrids as tools for localizing the DNA fragments that contained the resistance genes. In this research, elaborate cell and molecular biological techniques were developed and utilized. The application object was addressed, finally, in the third phase of the experimentation. It consisted of the realization of the virus-resistant potato by transferring the localized and isolated DNA fragments to the cultivated potato.

The research related to the wild potato was pursued jointly in collaboration with multiple other research groups. These included partners working in universities in the United States of America, as well as groups located at governmental agricultural research institutes both in Finland and abroad. Each of these partners had specific tasks to perform in the joint experimentations (also Callon, 1980; Miettinen, 1998). Unfortunately, the experimental setup failed; making use of the wild potato's genes in creating the resistant potato variety proved too difficult. Although the group was not able to materialize the virus-resistant potato by using the genes of the wild potato, the research proved advantageous in terms of creating new knowledge: it provided further evidence for the group's hypothesis according to which the resistance to viruses in the wild potato was related to the restricted virus movement in the host plant. Additionally, as the important resistance trait was described in greater detail, the wild potato became a suitable model plant for further studies on the virus movement in plants.

With respect to the second major experimental approach (the use of the viral gene to induce resistance), the research proved advantageous. As already mentioned, the group succeeded in creating the virus-resistant potato by introducing the viral gene into the genome of the Finnish potato cultivar, Pito. As such, the genetic-engineering method was novel. In practice, it was materialized as a result of two early developments, the first being the gradual accumulation of a whole variety of molecular biological tools and methods within the group between 1990-93. The second was hearing about a new, non-published research result from Cornell University via informal communication channels. On that basis, the group decided, impulsively, to set up an experiment to transfer the viral gene into the Pito potato. In the transgenic potatoes so created, an unusual virus-resistance effect[3] emerged. Soon after, scientific examination concerning its mechanism as well as an attempt to make use of it industrially began.

The theoretical, methodological and applied concerns were apparent also in the research making use of the second experimental strategy. Indeed, such a blend of objectives seems to be important, if not foundational to several fields of investigation. Previous analyses that have drawn attention to such an orientation range from agricultural science (Gieryn, 1999; Kimmelman, 1992; Kleinman, 1998) to pharmaceutical research (Webster, 1994), aerosol physics (Saari & Miettinen, 2001) and industrial biotechnology (Miettinen, 1998). Although this sort of "use-oriented basic research" (Stokes, 1997) or "impure science" (Gaudillière & Löwy, 1998) is part and parcel of the scientific endeavor, the fact that local research agendas address simultaneously theoretical problems, produce instrumentalities and strive for useful applications should not be obscured by way of adopting indistinct analytic language. This is what may happen if one starts speaking about "contextualized knowledge" or "Mode-2 science". Such a vocabulary too easily glosses over these fundamental dimensions of research, a distinction better appreciated by "the entrepreneurial science", as discussed by Etzkowitz (Etzkowitz, 1998: 826-827). Thus, from my point of view, the difference between the theoretical, the methodological and the applied should be given a sharp articulation: they are analytically distinct but practically closely interconnected dimensions of the one and the same dynamic research activity. By so doing, conceptual tools for addressing the complex relationship between scientific knowledge and its technological use can be preserved (de Solla Price, 1984b; Miettinen, 1998; Saari & Miettinen, 2001).

Commercializing the Research Results: Three Problem Areas Encountered by the Research Group

The research agenda discussed in the previous section formed the basis for the group to become entangled with a whole variety of new research topics. This development was initiated right after the virus-resistant Pito potato was created: the learning and developing plant genetic-engineering methods formed a basis, which could be used to address a wide range of problems of agricultural production, such as managing biological hazards created by insects or improving the quality of oil crops as animal feed. Thus, learning the technology and accumulating the related tools opened the door for the diversification of the research agenda and commercialization of the research results. In this section, I shall exemplify the various mechanisms through which the commercialization took place. These included: 1) patenting research results with the university, 2) collaborating with industrial enterprises and, finally, 3) hybridizing the academic work with an emergent activity of the spin-off company. Of course, these three mechanisms took place in dissimilar institutional settings and gave rise to divergent problems, hence, the need for their differential treatment.

Patenting: Dissension Regarding the Ownership of Intellectual Property Rights

The first mechanism to commercialize the products created by the studied research group was patenting. As Gaudillière and Löwy (1998: 298) have noted, the passage from science to industrial application is often mediated by patent laws. Although patenting, as such, is far from a simple, straightforward conversion of research results into a legally protected format (Hughes, 2001; Myers, 1995; Packer & Webster, 1996), it can, nonetheless, be effectively used to manage the application of scientific research results and know-how for commercial and industrial ends. In addition, patenting has been reported having significant implications for the scientific practices as accomplished within universities (Mackenzie *et al.*, 1990). Of the various forms of such implications, I shall later discuss the initiation of industrial collaboration and the establishment of the start-up company.

Despite the built-in use orientation of the group's research agenda, researchers did not seek to patent their results from the very beginning but the idea evolved gradually and coincidentally. The group filed its first patent in 1993; the invention protected was the virus-resistant transgenic potato. The idea to patent was not discovered by the group members themselves but emerged in result of contact made by a local university licensing office, which had only recently started its operation in the form of a company. In consequence of the patent officer's encouragement, the virus-resistant Pito potato and the method of its production were protected through the office, which covered all the costs of the patenting as well. In this stage, the group did not consider commercialization of the results too seriously. Instead, the move was made, in the words of the group leader, "in a half-humorous vein". Soon after, the commercial bent started to gather momentum: Along with the arrival of a new researcher, the proprietary interest strengthened. In the context of the insect-resistance studies, the group began to have stronger concern as to whether or not the research was innovative enough, that is, if it could be patented in the future.

Subsequently, several patents were filed. Although forming an initial vehicle for transferring research results from the academic setting to the commercial domain, patenting proved also a contested issue at the university. The group encountered two intractable problems both of which were closely associated with the confusion on ownership of intellectual property rights (IPRs). In the first instance, the issue was about who has the juridical right to patent the results of the project concerning biotechnological oat improvement, the university or the researchers-inventors. The debate was associated with the proposed alteration of the governmental IPR policy according to which the property rights for university research might be transferred from individual academics to the university institution (Opetusministeriö, 1998). A similar kind of a move – strengthening of the university's role in the commercialization process – had already been made in the United States of America (Lee, 1994). In Europe, then, the university IPR policies have been more confused and scientists have frequently ignored them (Harvey, 1996; Tupasela, 2001). In the examined case, the group leader persisted that the inventors had the legal right to patent the result. The university lawyers, on the other hand, maintained that the university expected the group to transfer the IPRs to the university. The clash of viewpoints proved profound, and the participants were stranded by the juridical dispute for an extended period of time.

The second strife concerning the IPRs was a direct derivative of the establishment of the group's spin-off company in 1998. As noted earlier by Kesan (2000) and Hughes (2001), critical to success of new biotechnology ventures is their patent portfolio: in order to attract investors and fund research and development activities, a firm needs to have ability to generate and protect its intellectual property. Once the group's firm was founded, the researchers and the investors wanted to have as large a patent portfolio for the embryonic company as possible, that is, all the group's previous patents. The group had, however, given the IPRs of two of its early patents – the virus-resistant potato and the genetic transformation of the turnip rape – to the university's patenting and licensing office. Although these had not yet created any revenue, the licensing office was unwilling to restore the IPRs to the researchers. Also in this case, there was a deadlock in the negotiations for a long period of time. Finally, after the office's managing director changed, the problem was solved for the best interest of both: concerning the first patent (the virus-resistant potato) a mutually beneficial marketing agreement was achieved while the second (genetic transformation of the turnip rape) was left into the file of the licensing office non-commercialized.

In summary, patenting represented the group's first direct connection to the commercial exploitation of the research results, thus, serving as an important stage in its developmental course from an academic research community to the start-up company. The case also documented the complexity surrounding the intellectual property rights system at the university. Despite the government's encouragement of universities and researchers to patent, the interaction between the participants became extremely troublesome up to the point, which prevented everybody from utilizing the innovation. As stated by Rahm (1994: 269) and exemplified by the case, such conflicts emerge especially as university researchers themselves move from academic settings toward a more industrial focus. Consequently, the commercialization of research results seems to be heavy with contradictions rather than being a relatively straightforward process, something that easily comes across with respect to the Mode-2 knowledge production and the Triple-Helix model.

Industrial Collaboration: An Attempt to Transfer the Innovation to the Market

Gaudillière and Löwy (1998: 298) observe that there is a close association between patents and industrial collaboration networks of scientists. This is due to the fact that further development of marketable commodities is often based on the knowledge, technologies and skills of the very same scientists who originally created the patented research results. It has also been suggested that industrial collaboration represents a new form of organization of research and development, "which no longer fits neatly within the boundaries of a firm or public-sector research laboratory, and produces research that can no longer be classified easily as academic and industrial, or basic and applied" (Walsh, 1998: 320). Such collaboration, which creates, for instance, marketable products, publications, patents and PhD theses as outputs has also been said to have an important role in the development of local research agendas (Webster, 1994) and even in the formation of the entire biotechnology industry (Blumenthal *et al.*, 1986a).

In the studied case example, the patenting of the research results set the scene for more established research and development accomplished by the group and its industrial partners. As seen from the point of view of the group's research topics, the industrial collaboration continued the research that was associated with the development and patenting of the virus-resistant Pito potato: it provided the group with an opportunity to launch an attempt of materializing the presumed use and exchange-value of the result. It also facilitated the future emergence of the start-up company and provided data that supported the group's academic research, hence, the complex and constitutive role of the industrial collaboration from the point of view of the group's developmental trajectory.

The emergence of the group's industrial network was promoted by national science and technology policy and linked with it changing from an academic funding agency to an applied R&D sponsor. Until 1997, the group had received most of its funding from purely academic sources, mostly from the Academy of Finland. Due to the financial hardship, it decided, however, to shift from the Academy to near-market R&D funding provided by the National Technology Agency, Tekes. This money had more strings attached to it. As a precondition, Tekes stipulated that industrial collaboration had to be involved in projects it was going to finance. So, the group began seeking suitable partners. Industrial collaboration included an interesting option for further research as well: a possibility of experimenting with the already created virus-resistance effect by using multiple new commercial potato varieties.

At first, the group had three potential partners. These included: 1) a plant-breeding unit operating under the auspices of the Finnish governmental research institute, 2) a Dutch plant-breeding company and 3) a Danish breeding firm. After negotiation, it appeared that the Finnish and the Dutch partners were not interested in the joint research, for different reasons. On the Finnish side, the reasons were economic: although potentially useful, the markets for transgenic potato in Finland were considered too small, so the breeding organization did not want to invest any money into the project. Another reason was that Finnish potato-seed producers, clients of the breeding organization, remained non-committed to the virus-resistant potato. Because plant diseases are major reasons for farmers to buy new, healthy seed each year, with more tolerant potatoes, farmers would not renew their seed as frequently as before. On the Dutch partner's side, the situation was more straightforward: the company had recently subscribed to an exclusive agreement, which specified that all of its biotechnological R&D should be done in collaboration with an American company, Monsanto. Thus, the embryonic collaboration with the Finnish group was brought to an end.

Nonetheless, the Danish company,[4] which had recently intensified its biotechnology activities wanted to take advantage of collaborating with the studied group. More specifically, as a result of its involvement in a Danish seed-potato firm, it had launched a brand-new program focusing on biotechnological development of genetically-modified potato varieties (Plant Industrial Platform, 1999). For these reasons, the joint research and development was started in 1997. For the Finnish group, the Danish company proved a good partner. As noted by the leader, it had the necessary competence on plant genetic transformation, interest in the work accomplished by the group and plant-breeder's rights for the entire downstream process through which the virus-resistant transgenic potatoes could be transferred from the laboratory into the market.

Altogether, the research, which involved investigation of the virus resistance in potato and developing commercial potato varieties with an enhanced resistance trait, went ahead with three related projects: First, the questions concerning the biological mechanism of the virus resistance in the transgenic Pito potato were addressed by a doctoral student of the Finnish group. Second, the breeding company and the studied group jointly applied the patented invention to increase the virus resistance of the Danish commercial potatoes, that is, they sought to replicate the created resistance effect in new potato varieties. Third, as a supplement to the second project, two post-doctoral researchers on the Finnish side worked to further expand the genetic-engineering method so that it would enhance resistance to a broad spectrum of potato-infecting viruses. Some parts of this work were also accomplished in cooperation with the scientists of the Danish firm.

In summary, the use-oriented basic research on the potato virus resistance continued to exist despite the applied part of it becaming entangled with the industrial collaboration. The theoretical questions were addressed by the group within the scientific community while the further development of the genetic-engineering methods and the creation of commercially viable products took place in cooperation with the industrial partner (also Saari & Miettinen, 2001). These undertakings were also interconnected: The applied work contributed to the understanding of the virus-resistance mechanism by way of providing more data to support the hypothesis according to which the biological mechanism of the resistance phenomenon was the one known as a post-transcriptional gene silencing. Thus, the point made earlier by Kesan (2000) proved felicitous: "In biotechnology, it is also true that applied research augments the knowledge of basic science. For instance, when an applied research project is carried out, scientists often gain a better understanding of the underlying principles moderating desired chemical or physical relations."

The industrial researcher also found out that if two particular gene sequences were integrated in a certain way in a transgenic potato they tended to produce specific molecules that acted as signals to initiate the silencing mechanism. This observation was applicable in practical breeding work: modifying plants to produce such signaling molecules would trigger the silencing mechanism and the respective resistance effect in them. Consequently, the industrial-oriented research made a double contribution: it was useful both in fundamental research and applied breeding work.

Successful as it was, the joint work by the partners came to an end before the commercial potential of the research was fully materialized. This event exceeds analytical scope of industrial collaboration networks and directs attention to what scholars have called the public understanding of science. More specifically, it draws attention to the fact that, during the late 1990s, widespread public distrust to genetically modified foodstuffs and crops increased in Europe (Gaskell *et al.*, 2000). The trend has been said to have begun after "the watershed events of 1996-97", that is, after the imports of Monsanto's Roundup Ready soybeans and presentation of Dolly the sheep (Bauer, 2002; Dahinden, 2002; Gutteling, 2002). The public controversy also forced the once hot field of research and development to cool off as the moratorium was imposed on commercial releases of genetically-modified crops in Europe (Hodgson, 2000b). As reported by the Science magazine, the European plant-biotechnology industry simultaneously began to scale down its research programs as well as its collaboration with academic groups (Frank, 2000). With specific reference to the studied case, the commercially applicable virus-resistant potato never reached the market. This was due to the fact that the Danish company quite suddenly ended its potato-biotechnology program once and for all. In the summer of 1999, when majority of people expressed pessimism about biotechnology in Europe (Gutteling, 2002), it abandoned its research and development on the genetically modified virus-resistant potato (Hodgson, 2000a). The fact that the studied network was also discontinued at this stage reveals the fragility of the university–industry collaboration in the face of public opinion and market conditions.

Boundary Work as Means to Separate the Research Group-Firm Hybrid Entity

An important mechanism of commercializing academic research results especially in the field of biotechnology has been the university spin-off company (Kenney, 1986; Orsenigo, 1989). As described by Walsh (1998: 313), these companies are set up by scientists to exploit the results of their public sector research, and often founders of such firms leave the academia entirely. Nonetheless, that is not always the case. As acknowledged by the Mode-2 and the Triple-Helix models (Etzkowitz, 1998; In press; Etzkowitz *et al.*, 2000; Gibbons *et al.*, 1994: 137-138, 144) and discussed by Fransman (2001) with respect to Dolly the sheep, the so-called hybrid institutions may emerge. These are institutions and companies that carry the features of a university and for-profit firm and, according to Fransman, play an important role in science-based industries. In the examined case, such a hybrid community combining the academic research group and the emergent spin-off company was formed in 1998 with an aim of pursuing both academic research and commercial development all at once. During the course of such an effort, which lasted for two years (1999-2000), an interesting aspect came strongly forward: the contentious border between academic work by the scientists and their private business enterprise. As such, this occurrence might be understood as a specific instance of boundary work. With respect to Gieryn's (1999) earlier conceptualization, boundary work in this case was not a matter of demarcating science from non-science but, rather, a set of local bureaucratic procedures through which the university administrators sought to maintain a fine line between the two parts of the hybrid entity, the academic activity and the private business (see also Rabinow, 1999; Rappert & Webster, 1997).

The group's decision of forming a company of its own was grounded on multiple motives including, among others, the researchers' aspiration to transfer the research results from laboratory to the practical use and the group's dissatisfaction with the local working environment within the faculty it was located at. The governmental bodies also had their role to play. As noted above, the National Technology Agency, Tekes, wanted to support the development of commercially viable products and called for industrial collaboration as a precondition for the funding of the group's research. Another governmental agency, the Finnish National Fund for Research and Development, Sitra, sought to create new companies out of the university research and enabled the group to found the firm by providing the necessary capital investment.

Despite the company's foundation, the group did not want to cease its academic research. Some of the doctoral students were still in the midst of their dissertation projects, and the group leader sought to pursue both academic research and commercial application simultaneously. As a result, a mixed community, or a hybrid of the research group and the company emerged: the group leader and three doctoral students became shareholders of the new company while maintaining their positions as faculty members. Once the firm started its operation, in the early 1999, the public research was accomplished in the very same laboratory under the auspices at the university as the firm's commercial development. This situation continued to persist for a period of nearly two years, until the group finally decided to cease its academic work and separate itself entirely from the university.

Nonetheless, the existence of the research group–firm hybrid entity became a contested issue in the university department it was working in. Although economic development and commercialization of the research results were considered issues of great importance in the university policy, no clear-cut rules and regulations existed in relation to managing start-up companies at departments. Instead, determining the conditions for the business activity became an issue of a heated battle between the group leader and those in administrative positions. When thematized from the point of view of administrative boundary work, the following topics can be identified: 1) the bureaucratic accountability of the professor to administrators, 2) the confusion concerning the loaned research materials and instruments, and, finally, 3) the social and spatial separation of the research group-firm hybrid entity by way of drafting a formal contract. I shall, next, discuss each of these, respectively.

The university administrators wanted to make sure that there existed a fine line between the hybrid community's academic work and its commercial projects. They also wanted to secure that the group leader performed her teaching duties in the department diligently. Thus, administrative reports and plans concerning the group leader's allocation of working time were called for; the administrators believed, indeed, that she was neglecting her duties as a university professor. The group leader, then, had a different point of view. She was perplexed and irritated by these requests for accounts that questioned her academic freedom. Moreover, she regarded the start-up company as an entirely private issue with no other relationship to the university, except a temporary rental of laboratory space. She also held that she had done excellent work in accomplishing her departmental duties, teaching and research.

Besides the group leader's teaching performance, there emerged confusion about the ownership of university property as well. When transferring to work in its new laboratory in the university's business incubator building, the group took along some research materials and instruments it had acquired by using public research grants. The issue was whether it really had the proper right to do so. Despite a loan contract agreed by the department chairman and the company's chief executive officer, a serious conflict over the instruments and materials ensued. Not wanting to raise any further complications the company's chief executive pursued a quick resolution. Some items were given back immediately while others were loaned for a short period of time.

Contemporaneously, the group left the department and associated with the university's biotechnology research institute operating in the local science park. In connection with this association, an agreement of collaboration was drafted between the hybrid community and the institute. In the contract, a resolution to the fuzzy university–industry boundary was sought. This took place by abandoning the hybrid roles of researchers-entrepreneurs and defining separate locations for academic research and commercial development. In addition, the finances of the research group were subjected to close scrutiny by the chief of administration at the institute. Although not thoroughly disconnecting the academic projects from the company, these measures provided a temporary resolution of the acute boundary problem.

The group's combining academic work with private business activity provides an apt example to raise a general question about whether or not hybridization of academic activity and private business is feasible within the university organization, a topic of central interest in both Mode-2 and Triple-Helix models. Both of these schemes state that such hybridization is a key characteristic of the contemporary mode of knowledge production. The results of the studied case point to a rather different direction, however: it seems that hybridization of academic work and business is extremely difficult giving rise to serious problems. Some of these were associated with practically managing the multiple functions of the university, that is, academic research, higher education and economic development. Some others were related to proprietary issues or the use of public research funds for private purposes.

Thus, it seems quite evident that the public and private activities do not neatly fit together as matters of daily organizational life at universities. As organizations, universities seem to be historically specific kinds of institutions that adapt to changing political trends to some degree, while simultaneously protecting their public characteristic (Krücken, in press). Despite the abundance of the talk about new hybrid modes of activity, traditional universities seem not to want to fuse with other forms of societal activities at will. Accordingly, the examined case example suggests, alongside the study by Rappert and Webster (1997; Rappert *et al.*, 1999), that a hybrid community is, perhaps, more likely a passing phase in becoming an independent company than a permanent option for research groups to work across the university–industry boundary, at least in the confines of the traditional public university. If that proves to be the case in other instances as well, it might create a need to reformulate the overarching arguments put forth by both the Mode-2 and the Triple-Helix models.

Discussion

With respect to the characteristics of the Mode-2 thesis and the Triple-Helix model one could easily consider the examined case an exemplar of the new kind of knowledge production taking place in the context of evolving linkages between university research, governmental funding and industrial application. Further, as emphasized by both of the schemes, a hybrid mode of activity emerged at the interface between the university activity and private business. Nonetheless, I did not choose to use either, the Mode 2 or the Triple Helix, as my conceptual framework to understand the examined case. My reason was simple: I thought that these schemes were too inclusive, vague and debated to provide a firm and justified frame of reference to be directly applied in the empirical analysis. For that reason, I took my case example as a source of possible theoretical insight. In this respect, two particular points of view that have a bearing on both the Mode-2 thesis and the Triple-Helix model were taken up: 1) the indivisibility of theoretical, methodological and applied in the local research agenda and 2) the contradictions and problems related to the different ways of commercializing the studied group's research results.

First, when addressing the plant-biotechnological research pursued by the group I spoke about the "use-oriented basic research" (Stokes, 1997), that is, research where understanding of a phenomenon is closely linked with its potential use in society. As the analysis showed, this concept did not wholly display the important characteristics of the investigated research. Thus, I also spoke about the theoretical, methodological and applied as distinct analytical dimensions of the one and the same research program and maintained that they were practically indivisible. I also argued that especially the Mode-2 model neglected this distinction subsuming it under indistinct analytic vocabulary. In my opinion, this is a serious drawback since these dimensions account for a central source of dynamic in the course of work of a local research activity: in the studied case this was evident in a sense that their interplay in time formed a basis on the grounds of which commercializable research results emerged, industrial collaboration began and the spin-off company was founded. In connection with the Triple Helix, then, the notion of "the entrepreneurial science" proved more accurate as it made a remark on these.

Second, I examined how the research program became gradually entangled with commercial and industrial activities. In this respect, three problem areas were addressed. These included: 1) the ownership of intellectual property rights at the university, 2) the industrial collaboration and the difficulties of transferring the research results to the market, and 3) the attempt to create a hybrid community of the research group and the spin-off company. Concerning each of these, I displayed serious problems and contradictions as to how the research results were commercialized. First, there was a serious confusion about the intellectual property rights policy within the university and as to who owned the group's inventions. Second, with respect to the consumers' reluctance to use agri-biotechnological products, the fragility of the university–industry collaboration was illustrated.

Third, the unfeasibility of the hybrid entity constituted by the academic research group and the spin-off company was displayed. These fundamental and multiple controversies make the straightforwardness of commercialization of research results questionable at least with respect to the traditional, public-funded universities. As regards the Mode-2 and the Triple-Helix models – or, in fact, any relevant theory of addressing similar topics – this contradictory nature of commercialization is something that should be better appreciated. Otherwise, the accurate contact of the models with the phenomena they want to describe and understand becomes severely endangered.

What then, is valuable in these models, as they currently exist? Substantive answers are hard to give: there is still a need to study relevant concrete processes that address various dimensions of the science–society interaction and, more importantly, to connect or contrast the results so achieved with the central claims of the Mode-2 and the Triple-Helix models. It is only through constant critical discussion concerning the models and through on-going efforts of applying them that their strengths and weaknesses become recognized. One response to the question is, however, quite evident. As Krücken (2002: 130) points out these schemes are valuable in that they provoke thinking and may inspire further research about the topics they address. As general schemes of meaning that seek to capture the nature of an era and to define an epoch (Bogen & Lynch, 1996: 272; Noro, 2000), they might also prove heuristically useful especially to the science and technology policymakers. In this respect, however, their practicality is damaged by the lack of serious attention to the contradictions and problems encountered as scientific research get commercialized.

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Notes

1 Interestingly, as regards to the Mode-2 thesis, Etzkowitz and Leydesdorff seek intensive interaction. Nevertheless, they consider their model more fundamental than that of Mode 2. They state, for instance, that the Triple Helix explains observable reorganization in the university–industry–government relations and provides, thus, "a model at the level of social structure for the explanation of Mode 2 as an historically emerging structure" (Etzkowitz & Leydesdorff, 2000: 118).

2 Within the field of science studies, there is an abundance of literature concerning the university – industry research relationships in biotechnology alone (e.g., Blumenthal *et al.*, 1986a; Blumenthal *et al.*, 1986b; Busch *et al.*, 1991; Curry & Kenney, 1990; Dill, 1995; Faulkner, 1994; Kenney, 1986; Krimsky *et al.*, 1991; Lee, 1998; Miettinen, 1998; Ronit, 1997; Webster, 1994).

3 Hacking (1983: ch. 13) made a useful distinction between phenomena and effects. According to him, phenomena refer to events that can be recorded or revealed by the observer who does not intervene in the world. Effects, on the other hand, result from active interventions to the nature by scientists. In this sense, they are created. See also de Solla Price (de Solla Price, 1984a).

4 The Danish firm was a shareholding company controlled by nearly five thousand seed growers through a limited liability co-operative. It was one of the world's leading clover and grass-seed producer, also developing and marketing several other crop plants. In 1999-2000 the company's turnover was one billion Danish krones and 85 % of its production was exported. It employed 416 people approximately 70 of which were involved in research and development.

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