Work in Progress Paper
to the 23rd IMP Conference in Manchester, 2007

Combining and Controlling Resources in Networks
Resource Interactions in a Biotech Network Spanning Science and Business from Uppsala to Stanford

Enrico Baraldi, Uppsala University
enrico.baraldi@fek.uu.se

Torkel Strömsten, Stockholm School of Economics
torkel.stromsten@hhs.se

ABSTRACT

This paper discusses the control dimension in how resources are combined in order to create economic value of *scientific knowledge* in industrial networks. The paper presents a case study on how the economic value of biotech science from Uppsala and Stanford universities emerged as it was combined with several other technical, social and economic resources found in a complex network. The purpose of the study is to analyze the interactions involving business actors and scientists, with a specific focus on the *control* issues. The original scientific discovery was developed at the Department of Genetics & Pathology at Uppsala University, Sweden. It was then combined with other innovations at Stanford University, California, and under the influence and control of venture capital these innovations were exploited within a newly founded company, ParAllele.

We analyze the resources that are created, combined and controlled in the network around these scientific discoveries and the company hosting them. This analysis shows how the value of science emerges when the innovations become embedded in a multidimensional resource network including scientific, technical, social and economic elements. We also see the actors involved in *developing* and *trading* the various scientific ideas, as well as the actors essential for *producing* and *using* the innovation, that is, when it needs to find a market. Our discussion emphasizes how the involved actors apply various types of controls on resources in order to add economic value to the scientific discovery. Forms of control that bothentail mobilizing other actors *and* preventing actions in the emerging network appear to be of primary importance.

Keywords: Resources, networks, control, commercialization

Introduction: resource interaction in industrial networks

In a network setting, with interactions spanning firms' boundaries, several actors try to influence and control each other. Håkansson (1987 p. 15) wrote that "The actor's main aim is supposed to be to increase its *control* in the network (italics added). In that struggle the actors are using their experience and knowledge of the network as well as their relationships with others in order to improve their position. They are networking." Thus, even if there is a strong actor in the network (e.g., an owner or a key customer), there are always other actors with objectives and interests that try to influence the direction of development, when it comes to what products should be bought and sold, how facilities should be used, what competences should reside within an organizational unit and finally, what relationships should be develop or terminated. Looked upon in this way, control becomes not only an intra- or inter-organizational issue, but also a network issue, whereby actors design and use their own and others' control systems in order to maneuver in the network. A key issue becomes therefore: how is control exerted in an interactive setting, where actors are embedded in networks of relationships?

In October 2005 ParAllele, a small biotech firm located in South San Francisco, was acquired by a major biotech tool producer, Affymetrix, for $121 million. ParAllele had up to then been a success story, being developed in just a few years, based on research undertaken at Uppsala University, Sweden, and Stanford University, California. The processes of "embedding" a new technology or product (Baraldi & Strömsten 2006) is what made us interested in the case of ParAllele: how did the technology around the firm develop? Why and how did the company end up the way it did? When we started digging into the story, it became apparent that several actors had been intermittently involved over time, all with different interests, sometimes aligned and sometimes conflicting. But most actors seemed to be happy with the ending. As we looked into this process, the complex pattern of managing resources became of great interest, and especially how the different actors tried to control the development and use of critical resources in order to manoeuvre the process in the wanted direction.

In this paper we will explore the role of *control* in the embedding of scientific knowledge: what role did the different control strategies play and how did they evolve? In addition, how did the different control systems residing within the actors interact with each other, and following from that: how were they influenced by different interests and logics, which sometimes co-evolved and sometimes were conflicting?

To increase our understanding of the role of control in innovation processes in networks, we will draw on the IMP tradition and more specifically on a model presented in Håkansson & Waluszewski (2002) which highlights resource use and development, the so called "4-Resources" model. We will also draw upon recent research on control from an interorganisational perspective (eg Håkansson & Lind 2004). These different but complementary perspectives will allow us to analyze the organizational and physical resources that intervened in the innovation process stretching from the first paper on Padlock probes published on *Science* (Nilsson et al. 1994) to the acquisition of ParAllele by Affymetrix.

Theory: combining and controlling resources in networks

Governance is about the relationship between ownership and management in organizations. Different types of ownership influence the organizational life of firms: *who* makes the decision to make investments, *what* types of investments are made and *how* are returns from investments distributed (O' Sullivan 2000, p. 394). In a network, all firms or organizations are governed by a specific (or several) logics. Given that firms interact, different types of governance structures or systems interact

and influence each other, just in the way resources are developed and used. The governance of a firm therefore influences too the interactions between firms, also in innovative new ventures (e.g., Lazonik & O'Sullivan 2002). For example, the financial boundaries (Johansson & Östman 1992) that an owner gives to the firm affect the firm's organization and strategic decisions. For example, new ventures rely much on external competence and production capacity. This partly depends on the availability of such competences (especially for production) in their external network. But such reliance depends much on the financial structure and goals of the new venture, which might force it to rely to a greater extent on partnerships or business relationships. Then, the business unit might develop competences in those areas prioritized by its newly established relationships, which in turn depend on its governance situation. For instance, as building production facilities is often not seen as a core competence in new ventures, these firms often develop

relationships with firms specializing in developing and manufacturing production facilities, for example original equipment manufacturers (OEM).

Taking governance to a more hands-on level, different governance structures lead to different organizational control systems. For all firms, including new ventures, *control systems* are important to ensure that their objectives or those of their owners are fulfilled (Davila 2004 and Davila et al 2003, Granlund & Taiplenmääki 2003). The traditional view of control is to influence the behavior of individuals within an organization (Merchant 1985) in order to reach organizational objectives. This can be done through control systems, which according to Merchant (1985, 1998, Emmanuel et al 1990) are composed of three mechanisms: personnel, action and result based controls.

*Results control*s (Emmanuel et al 1990, p 112) refer to the desirable results that an organization aims for. "Results controls" are achieved in three steps: (1) defining dimensions and standards of performance; (2) measuring performance and comparing with standards; (3) rewarding the results that reach the standard.

*Action control*s (Ibid, p 112-113) ensure that individuals within an organization perform actions that are desirable, or prevent them from performing undesirable actions. There are three types of "action controls": (1) behavioral constraints, that is, some actions are made impossible to perform, by putting looks at doors etc.; (2) pre-action review, that is, actions are observed and corrections are made; (3) action accountability, whereby a firm identifies limits of acceptable behaviors.

*Personnel control*s (Ibid p. 113) include two basic forms: self control and social control, with the latter exploiting the pressure of groups to make deviant individuals conform to group norms and culture. Personnel selection and training are also part of personnel controls, in order to "get the right people" in place.

However, controlling behaviors in a system open to external interactions like networks, entails caveats: when resources are heterogeneous and combined over organizations' legal boundaries, control becomes more a matter of not only steering their behavior, but also *mobilizing* actors or coalitions of actors. Further, for some firms there are of great interest to prevent certain resources to be combined. Thus, finding control mechanisms that prevent this is also of great importance.

The industrial network perspective helps us to frame the nature of techno-economic interaction and development, while at the same time it stresses the existing economic, technical and industrial structures that do play a role in the embedding of science and in the "extraction" of economic value from it. Within the IMP tradition, Håkansson & Waluszewski (2002) develop a model that emphases the *resource* dimension of the earlier ARA model (Håkansson 1987, Håkansson & Johanson, 1992, Håkansson & Snehota 1995), where actors are defined by the activities they perform and the resources they use and control. In the "4-Resources" model, resources are classified as either organizational/social, namely organizational units and business relationships, or technical/physical, namely products and facilities. The four resources presented in Håkansson & Waluszewski (2002) are part of different interaction processes: *organizational units* engage in *cooperation* activities; *business relationships* are used in *networking* activities; *products* are parts of *buying-selling* activities; and lastly *facilities* are involved in *producing-using* activities. These four types of activities interact and therefore influence each other.

The same control mechanisms reviewed above (Merchant 1985, 1998, Emmanuel et al 1990) can be applied in an inter-organizational or network setting and related to the three concepts that the ARA-model is built up from, actors, activities and resources. "Personnel controls" correspond to the "actor dimension" of the ARA model: it is in fact about selecting counterparts and aligning their behavior with the goals of the focal firm. However, even if goal congruence might an important goal in itself (Dekker 2004), "goal conflicts" can be something that drives development and processes. "Action controls" correspond to the "activity dimension" of the ARA model: in fact, certain activities can be supported through formal or informal incentives, which can instead counteract the performance of other activities. But, there are also possibilities to prevent the performance of certain activities, by withholding critical resources. Lastly, "result controls" correspond to the "resource dimension", whereby the combinations of resources are evaluated against pre-set standards and objectives. However, as there is hard to have full knowledge about what certain resource combinations will lead to, there is also hard to have

pre-set standards for this. In these cases, proxies or standards of what is "good" performance seem to be important.

Then, control in a network context refers to all tools employed by actors to influence their and other's use of resources and performance of activities. Further, control certainly embraces also the actor dimension, as all actors try to control other actors while being exposed to other's attempts to control them. All firms in a network have more or less formal control systems, which actors employ to make other actors behave in ways that fit their objectives and strategies.

As this paper focuses on the resource dimension of an industrial network, control can be seen as the intentions *to orient the combinations of products, facilities, organizational units and relationships* towards the objectives pre-set by actors (both for the resources they control directly and for those they control indirectly). In doing this, firms try to identify interdependencies between resources and to exploit them through the design and use of control systems. For example, Håkansson & Lind (2004) show that in the relationship between the Swedish telecom equipment supplier Ericsson and its customer Telia some Ericsson managers were rewarded not only depending on the products sold, but also on how their products were used by Telia. A firm embedded in a network of relationships (Håkansson & Snehota 1995) might therefore design control mechanisms that make other organizations and their individuals act in the best interest of the focal organization.[1]

Attempts to control the combining of resources are constantly ongoing in networks. Actors try to highlight features of some resources in order to make other firms adapt to these features, and to "build them in" in their facilities, products, organizations and consequently in their business relationships. How does this happen? Understanding how control works in a network setting is about being able to "read" intentions that are built upon internal and inter-organizational control systems. What "action controls" are relevant for a certain actor in the network that we want to mobilize in relation to a certain product, facility or relationship? And what actions do we want to prevent, by whom? What types of "personnel controls" would induce that actor to adapt to our resources, start using our products, buying capacity in our facilities etc.? And finally, what types of "result controls" are applied by critical counterparts in a way that might affect the use of our products or the facilities of major customers? Our discussion will present the different types of controls (action, personnel and result) applied by several actors in the ParAllele case in order to affect the combinations of resources that led to embedding a scientific discovery in an industrial network.

The case of ParAllele Biosciences

In the following we present a case study that illustrates the commercialisation of scientific knowledge. We show how several actors tried to influence the development process and the way the innovation of materialized. The real-life case unfolded as we were collecting empirical material, almost in "real time". The first interview was conducted soon after the founding of ParAllele in 2001. Then, interviews with other key players involved in the innovation were conducted in different moments of the development process. These interviews covered the science behind the innovation, the technology that ParAllele was developing and the market opportunities that were progressively moulded. The selection of this case illustrates the network embeddedness of a commercialisation process, how goals sometimes are in harmony but also in conflict, how different logics at different times are prevalent. We interviewed 7 individuals for the study, some of which several times, for a total of 15 interviews. Further we consulted specialized trade journals, the WWW, scientific journals in order to increase our knowledge about the studied phenomenon. We used several empirical sources as a way to triangulate the story of ParAllele, so that multiple sources have been given a voice in order to identify opposing views of the

[1] But there are naturally obstacles to having external actors acting in the interest of another. Firstly, there might be *lack of direction* by the focal organization: therefore, and even despite potential gains for other firms, missing information or communication hinders actions in the interest of a focal firm. *Lack of motivation* is a second possible obstacle: without incentives to interact in a certain way with a focal firm the other organizations will not do it. Finally, *lack of abilities* is a third obstacle that includes two dimensions: lack of general competences and lack of cooperation skills (including knowing how to share knowledge or experiences with other organizations). The lack of abilities can depend in turn on internal control systems that give little or no incentives to individuals to share information and knowledge with other actors in the network (Emmanuel et al 1990, p. 110).

process. The more our understanding of the empirical material has increased, the more the sense of linearity has disappeared, revealing a greater complexity, which we believe is the true essence of this phenomenon. However, we present the case following the chronological order of events, from the first thoughts of starting a company around the innovations from Uppsala University and Stanford, until the firm ParAllele is acquired by Affymetrix.

Science and business

Ulf Landegren is one of Sweden's most well-known researchers within the genetics field. As a post doc he spent five years at Caltech, where he worked with world-renown geneticist Lee Hood and developed the "oligonucleotide ligation assay" (OLA), a genetic analysis method still widely used today to test cystic fibrosis. In 1989, Landegren moved home to Uppsala University, at the Department for Genetic and Pathology (GenPat); but soon realized that the economic resources were limited if compared to Caltech. During the early 1990s Landegren started working as a consultant for Pharmacia Biotech, a large biotech equipment supplier located in Uppsala. One of the methods Landegren worked on for Pharmacia was a further development of the OLA technology. This method builds on that the two ends of synthetic DNA strands hybridize to DNA molecules close to each other. If this is done correctly, the ends can be joined enzymatically, converting the probes into DNA circles. The fact that there are two DNA segments that must fit increases the *specificity* of the test: "It is just like when there are two keys that have to be turned around in order to open a safety vault", Landegren explains. When the ends of the probes are joined, the probes are converted to circles of DNA, wound around, and thus linked to the target DNA molecule, and hence the name of the technology: "Padlock probes".

In 1994 Landegren and his Phd student Mats Nilsson first patented the Padlock probe technology and then published a paper in the prestigious journal *Science*. Even if the development of Padlocks can be traced back to Caltech and OLA, the modification made by Landegren and Nilsson in Uppsala, although small, had important consequences. The Padlock method needs only *one* synthetic DNA string. Instead, a technique that uses two separate recognition probes, such as the PCR method, makes it difficult to look at several genetic sequences in the same reaction, since the large number of recognition probes tends to cross react and give rise to false reaction products. This was a problem that the modified OLA method, the Padlock probe, could solve. In fact, this method made it possible to run many analyses *in parallel*. Whereas the PCR method can run 10 or so analyses simultaneously, Padlocks opened the possibility to run 10,000 analyses, with good results. This certainly would save *time*, *costs* and *sample material* – all increasingly important parameters in genetic research.

In fact, while the mapping of the human genome was being completed, it appeared relevant to go deeper into the genomic material of single individuals, in order to identify that 5% of DNA responsible for all diversity in humans as for physical appearance, risk to develop diseases and reaction to pharmaceuticals. Understanding which variations in a person's genome caused a specific disease or an adverse reaction to a drug would require getting very deep into each of the 3.2 billion nucleic bases composing the human genome, in order to identify the so called "Single Nucleotide Polymorphisms" (SNPs), that is, the individual differences in the sequence of single nucleic bases. Clearly, this endeavour would require high measurement capacity, efficiency, sensitivity (i.e., how much genetic material is needed for running an analysis), and precision.

Landegren and his team continued to publish articles on the use of padlocks probes for genetic analysis. The Swedish team had also been trying since the mid 1990s to utilize the padlock probes to analyse simultaneously multiple SNP in DNA samples on a single array. This is a method called "multiplexing". However the researchers at GenPat were proceeding slowly in their attempts to scale up the analytical power of padlocks probes, mainly due to the lack of resources. In 1998, Mats Nilsson and Ulf Landegren had a meeting with Mostafa Ronaghi, a post-doc from the Swedish Royal Institute of Technology, and told him about their research on padlocks and their ideas to use multiplexing in combination with padlocks: "We were very open towards him, in fact we believed that he wanted to come and work for us as a post doc or to start to cooperate and perhaps we were a little bit too open about our work".

Mostafa Ronaghi had been doing research in biochemistry and genetics in Sweden for almost a decade, but he moved to Stanford University in 1999. Trained enzymologist, his specialization was the development of chemistry-based method for DNA sequencing and analysis. Landegren and Nilsson's padlocks promised the advantages of high-throughput, precision and sensitivity, however Ronaghi thought this would be possible only if the padlock innovation was further developed. Further developing the padlock probe method into a viable tool for large-scale and efficient genotyping was, in particular, something that Ronaghi immediately started working on at Stanford Genome Technology

Centre (SGTC). More precisely, reliability and high-throughput required the padlock method to achieve repeatability and measuring accuracy, while being run *in parallel*: in other words, Ronaghi was looking for a way to achieve "multiplexing", that is, the possibility to analyse simultaneously many DNA sequences in a sample. SGTC should prove to be a perfect environment to add this multiplexing capability.

Starting the journey towards ParAllele

Founded in 1993, SGTC is a large laboratory employing about 50 researchers under the leadership of Professor Ron Davis. Although related to the Biochemistry Department of Stanford University, SGTC mostly deals with applied research and the development of *methods and technologie*s supporting research in the Life Sciences.

Soon after his arrival at SGTC Ronaghi suggested, in November 1999, four of his colleagues to start a company to develop and commercialize a method for high-throughput genotyping relying on the padlock probe idea. These four colleagues, Paul Hardenbol (molecular biologist), Maneesh Jain (optical physicist), Eugeni Namsaraev (chemist) and Tom Willis (astronomer and geneticist), were thrilled by Ronaghi's proposal to enter into business, while working on a breakthrough technology that could also help their scientific careers. All five researchers agreed to quit their other current projects and to focus on Ronaghi's proposal. These individuals all had the necessary common knowledge base to understand what this technology was about, but they especially had a very valuable set of *complementary* competences. This research team not only seemed technically capable of achieving the consistency and precision in large scale DNA analysis lying at the ground of multiplexing, but all five individuals had experience of starting up companies based on their research and shared a basic understanding of the market potential for the technology they were developing.

In late 1999, the team at SGTC started working on introducing the multiplexing functionality in the original padlock probe. Multiplex analysis means *looking simultaneously at more than one DNA sequence in a sample*. Multiplexing would not only allow much faster DNA analyses (precisely those required to detect and map SNPs), but also dramatically reducing the analysis costs in terms of the consumption of plastic tubes and of such reagents as enzymes. For these reasons, multiplexing would add a commercial potential to padlocks, by addressing concrete and widespread needs in public and private research labs. A growing market (that of genetic diversity analysis, which in turn was expected to cater on the needs of such new fields as *personalized medicine*) stood therefore open for the technology that the SGTC team was about to start developing. Consequently, the five scientists were since an early stage explicitly aiming at creating a company – the soon-to-be ParAllele – dedicated to exploiting commercially this new technology.

Adding multiplexing to Padlocks: "MIP"

Padlocks are certainly an important new method for the biotech community, but taken alone, without multiplexing, they provided a limited commercial value. It was instead the addition of multiplexing to padlocks that opened for exciting technical applications, with great commercial value. In order to perform multiplexing, the SGTC researchers partly had to chemically *re-engineer* the padlock probe, which was originally fit for analysing only one DNA sequence per time. This required equipping the padlock probes with a lot of new features: these probes are very difficult to create, but the SGTC team was able to develop a robust method to obtain them inexpensively. Already after the first three months of development, by early 2000, Ronaghi and his colleagues, through the Stanford Office of Technology Licensing (SOTL), filed for a patent, whereby they combined padlocks with multiplexing. But in order to have a complete method, the SGTC team had to further improve the multiplexed padlock probe by developing another technique for chemically enhancing its *sensitivity* of detection (a technology on which the five scientist file a patent through the SOTL too).

It would take longer for this step, but the complete technology for multiplex genetic analysis with padlock probes was practically ready by 2001: its official name was MIP, that is, "Molecular Inversion Probe". Figure 1 relates the three pieces of technology, two of which were patented by SOTL and one, the original padlock method, by Landegren and Nilsson.

INSERT FIGURE 1 HERE

Venture capital and IPR negotiations

Even before founding their company, the five Stanford scientists had come in close contact with the Swiss venture capitalist Index Venture. Francesco De Rubertis, a geneticist employed by Index, saw the technical and commercial potential of MIP and started providing business advice to the five inventors. Considering that MIP was practically ready, Index went even further and in April 2001 provided "seed funding" to the newly founded ParAllele. In this way, Index became an early partner strongly motivated to help ParAllele through successive rounds of financing. Seed funding was provided on very informal basis, only on the promise of receiving a better price than any other VC on ParAllele's shares in an envisaged first round of financing. The team decided to locate ParAllele's office in South San Francisco, near many other biotech firms and potential customers

Before investing money into ParAllele, however, Index raised the IPR issue that MIP was dependent on the Padlock technology (see figure 1) patented by Landegren and Nilsson. It was clear that this patent was necessary in order to commercialize MIP through ParAllele and especially in order to collect further venture capital. No VC firm would invest in the company without a valuable and safe patent portfolio. Index was therefore ready to support the five SGTC scientists in the negotiations with the Swedish professor.

In 2000 Landegren was approached by the SGTC team in 2000, at an important Biotech conference at Cold Spring Harbour, USA. The five SGTC inventors had presented him with the idea of using the Padlock technology together with tag arrays (the key idea behind multiplexing). According to Landegren, the basic point in their message was: "Do you want to compete or do you want to collaborate". Landegren was not totally happy over this development, since he had hoped that the Uppsala group could continue to work undisturbed on Padlocks, and improve the technology by themselves and maybe later commercialize it. However, SGTC seemed to be at an advantage. The GenPat Group at Uppsala University included 10 people and fewer financial resources compared to SGTC and only one doctoral student could work fulltime on the project of multiplexing padlocks. Moreover, such essential materials as industrial tag micro-arrays were not available at the GenPat lab: the group relied on home-made micro-arrays, but this gave unsatisfactory results and caused considerable delays. By converse, in their search for a multiplexing and sensitivity enhancing method, the SGTC team could rely on a strong group composed only of post-docs with strong and complementary expertise. Moreover, SGTC was a world-renown micro-arrays centre, with close cooperation with this industry leader Affymetrix and a chief, Ron Davis, boasting extensive experience in this field.

Even if Landegren was aware of the importance of padlocks, he had been unable to exploit it commercially in Sweden. One reason was that the formal rights on his invention were held by Pharmacia Biotech, the Uppsala-based firm for which he developed padlocks. But this firm showed no interest in exploiting it, while making through its lack of interest other Swedish firms uninterested in this method. Things would change only in 2000, when British Amersham took over Pharmacia Biotech and many molecular biology projects were set aside, whereby Landegren was granted the rights for his padlocks. However, in 2001 the SGTC team had gained more momentum than the GenPat group in Uppsala: as Mats Nilsson puts it, "They had achieved much more than us. I don't think we would have convinced many with our results so far at that time".

At this point, the negotiations with Landegren and Nilsson to obtain the license for the Padlocks technology became increasingly intensive. Index Venture took part in several meetings arguing that, since the Padlocks technology alone would not sustain a company, the best thing to do for Landegren and Nilsson was to license the technology to ParAllele. While the Swedish researcher were not so anxious about doing so, they eventually accepted: in exchange of granting the use of their padlock patent through a licensing agreement earning periodic royalties, Nilsson and Landegren obtained positions in the firm's advisory board and equity shares of ParAllele. At the same time the agreement included a clause requiring them to disclose to ParAllele any future developments on the Padlocks technology.

More interplay with venture capitalists and influence on ParAllele's market plans

In the business plans they used to attract financiers, ParAllele's founders had presented their expected market, as the technical application area including solutions for mapping genetic diversity. Broadly defined as the "SNP market", this area seemed to be very promising in terms of growth, and needed more cost-effective solutions for genotyping. In early 2001, the founders started looking more concretely at the existing competitors and at the likely market size (roughly assessed at $500 million).

From a user's perspective, it appeared evident that any new SNP genotyping technique should address the problem of high costs in performing massive high-throughput analysis and the scarcity of a key process material for labs such as human DNA tissue. And the MIP method appeared as very well fit to address both of these pressing problems.

Index Venture partly affected the business model envisaged by ParAllele's founders: instead of providing a service platform for a mere for-service fee, Index suggested to create *also* a *proprietary kit*, where the technical platform could be embedded. This required having software and electronic components perfectly functioning before any product release. At the same time, Index explicitly requested that other VC firms located closer to ParAllele were involved in the following stages, because Index could not handle from Switzerland the process of assisting and supervising the start-up, also with daily and routine problems, including interviewing job candidates.

ParAllele's founders approached then 10 VC firms deemed to have enough technical competence and interest in the SNP market. When two of these, Abingworth and Versant, jointly presented an offer together with Index, this was accepted: this deal brought $7.5 million to ParAllele and was completed in October 2001. Now ParAllele had on board three VC firms with high competence and several start-up investments in the biotech field, and Abingworth and Versant had offices located just few kilometres from ParAllele's premises.

At this stage, once most technical development problems had been solved, it was still unclear how the solution would be framed towards a market, or what *type of users* the MIP technology should target. In short, there was a solution but ParAllele had still to figure out how exactly it could address user needs and make money on it, that is, its "business model" was still partly undefined. As mentioned, Index Venture played an important role in framing these issues, but when Abingworth and Versant entered the scene, ParAllele's business model changed several times. Versant pushed even stronger for ParAllele to go for something that would have an intellectual property, so that the firm would have a value in itself. This meant that a service model (whereby customers would send tests to ParAllele) was definitely abandoned. On the other hand, developing a complex instrument was seen as too risky, demanding a large organisation with sales representatives, technical support etc. Instead, the solution chosen became a *reagent kit* and *software*. Moreover, ParAllele and the VCs evaluated the option to embed the MIP reagents on chips (known as "micro-arrays") that could be read by existing equipment: this stimulated discussions on how dependent ParAllele would become on chip reader-makers, such as Affymetrix. The fact that the director of SGTC Ron Davis had cooperated with Affymetrix was bringing ParAllele closer to this major supplier of complementary technology. However, this would make ParAllele vulnerable by being so strongly related to a major partner. On the other hand, this could be positive, as ParAllele's product would find an important supporter and distributor to final users.

Important ideas in developing this business model came from what was happening in the genotyping field, where ParAllele's MIP technology was a very *late entrant*. Being perfected in 2001, MIP came to birth almost a decade after the first genotyping techniques and ParAllele was the last entrant in a field already occupied by a dozen firms (e.g., Luminex, ABI, Illumina, Sequenom, Perlegen, Third Wave). But being late gave the possibility to see the other technologies at work, even use some of them, and identify their shortcomings, such as the huge DNA sample consumption required by some methods. This allowed the MIP group to address such problems and solve some of them. It also led to recognise the importance of providing *high sensitivity* to reduce tissue consumption and a method *without* an expensive machine. By contrast, most competing methods required equipment costing alone up to $2 million: instead the MIP method was to be hardware-independent.

On the basis of these experiences and under the influence of VCs, a business model emerged based on a method and a set of reagents embedded in a *micro-array* usable on any of the already existing large machines. In fact, Index's original suggestion to create a kit and a concrete product embedding MIP became concretized when ParAllele closed a deal with Affymetrix, who started producing both standard and customized micro-arrays including the reagents to perform the MIP analysis. VC firms also pushed towards providing highly qualified *services* within close *collaborations* with large pharmaceutical firms. Moreover, VC firms induced a more precise definition of ParAllele's target market: clearly identified technical needs were specified, also to distinguish ParAllele from competitors. It appeared that the value of the MIP technology could be best exploited in two segments: *SNP genotyping* (the analysis of *already identified* SNPs) and *SNP detection* (the search and discovery of new, *previously unmapped* SNPs). The two selected segments were expected to be worth $500 million. ParAllele divided its potential customers into two categories:

(a) “high-end”: 20 large labs at government sites, big pharmas and a few genotyping contractors, all characterized by daily needs up to 500,000 genotype analyses;

(b) the “low-end”: up to 2,000 smaller labs, with daily needs as low as 50 analysis.

ParAllele chose to focus primarily on the large-scale-reactions market, requiring 1,000 or more analysis per time, leaving aside momentarily clinical diagnostics, which needs one analysis per time. Thus, ParAllele’s target customers became (1) those very few large research labs that conduct genetic mapping to localize the genes responsible for a disease (e.g., the Sanger Center in Cambridge or the Centre National de Genotyping in Paris), and (2) big pharmaceutical firms that try to characterise genetic variations that affects how individuals react to a certain drug.

In fact, the first goals that VC firms set for ParAllele were (1) to get the technology working, thus eliminating the so called “technology risk” and (2) to develop relationships with two key players within the SNP field, in order to become accepted by the research community. In general, venture capitalists made the founders market driven: not to develop “a Ferrari for the African market”, as one of the founders put it. Instead, “they wanted us to have reasonable goals…and then to develop what was really needed”. To start with, the investors were monitoring their investment tightly, with monthly meetings and follow up on the objectives and milestones. During these meetings objectives were discussed, including financial goals. VCs had clear financial goal for ParAllele: the first year ParAllele had the goal to sell for $1 million, the second year for $4 million, and the third year for $8 million.

ParAllele develops business relationships

Before acquiring customers and sales ParAllele was in even greater need to acquire legitimacy. An important in this direction was taken in October 2002, when ParAllele received from NHGRI (National Human Genome Research Institute) a large grant ($37 million divided among 10 labs) for cooperating with Baylor College of Medicine on the advanced HapMap project. The project aimed to develop a public catalog of the genetic variations among diverse human populations associated to such diseases as asthma or cancer. Another important relationship developed within the HapMap project was with a researcher from Yale. The collaboration with these major universities was particularly important because they also acted as a beta-customer, testing and helping further develop the MIP technology. Subsequently other important potential customers were contacted and they accepted to test the MIP method under the supervision and in cooperation with ParAllele’s personnel. Some eventually decided to purchase the method: this opened the door for establishing continuous relationships with customers for the supply of reagents and consumables to be used during SNP genotyping.

In fact, in July 2003, ParAllele obtained the first high-profile collaboration with a large pharmaceutical firm, Merck, who funded a large study based on MIP. Shortly after, in September 2003, ParAllele started with another big pharma, Roche, a project to investigate the genetic variation behind Type 2 diabetes: while ParAllele provided its MIP platform, Roche financed the study and provided clinical DNA samples for the analysis. Even if VC firms were not actively involved in recruiting ParAllele’s customers or partners, still they contributed to create “goodwill” around ParAllele, by presentations and informal talks with the big pharma’s executives in their contact network. This helped create interest and good reputation around ParAllele, which favoured obtaining actual cooperation contracts with the above customers/partners. Moreover, VC firms offered advice on which specific customer to contact (especially Merck) and which particular person one should talk with to “enter” a customer.

Another important relationship was developed with Agilent, a micro-array producer. ParAllele’s goal in developing this relationship was avoiding to be perceived as a sole-Affymetrix partner, without any other technology relationships. This was also communicated clearly to Affymetrix: ParAllele “did not want to be in Affymetrix’s hands” and they “always showed Affymetrix people that the product worked well with Agilent’s technology, so they would not feel so secure on” ParAllele. However, the relationship with Affymetrix proved pivotal for the survival of ParAllele’s technology. During this time, Illumina developed a technology for high-throughput genotyping similar to MIP: as one founder put it, “Then it was good that we had a relationship with Affymetrix. We only had $7 million on our bank account, and Illumna had something like $200 million”. Figure 2 shows the network in which ParAllele and its core technology MIP are embedded, a network which also grew together with the emerging company.

Affymetrix acquires ParAllele

ParAllele and Affymetrix had started to collaborate in 2002 in more formal ways. Affymetrix started then selling ParAllele’s product together with their DNA chip-reader. As stressed by one of the founders, “Affymetrix was lacking molecular technologies and this *(MIP)* was exactly what they were

looking for". Meanwhile, ParAllele's revenues were developing according to plan: in 2002 the firm had revenues for $800,000, in 2003 for $3 million, and in 2004 for $7 million. Even if the targets set by VCs were not matched perfectly, still ParAllele proved that its technology was not only a scientific success (with publications in prestigious journals), but that it also cleared "the test of the market". Therefore, ParAllele had no problem in attracting more capital in a new financing round in 2003, which brought $22.5 million to ParAllele and involved also the VC firm Mohr Davidow.

In the meantime, Affymetrix had conducted an analysis for their business and estimated that half of their revenue in 2008 would come from DNA analysis. But they needed products that would fulfil their objectives to grow in this large market, and ParAllele was part of this plan. In February 2005 Affymetrix and ParAllele started to discuss an acquisition and an offer was presented for the major owners. In this process the VC firms played an important role. They had pushed ParAllele not to rely only on Affymetrix, but also to develop a business relationship with Agilent. This proved to be of great importance when it came to negotiate the price for the firm: "They wanted us to talk to both Affymetrix and Agilent…otherwise the valuation of the firm would have been very different". The negotiations started in the spring 2005. ParAllele's owners asked for $200 million, a price that was not accepted by Affymetrix. However, Affymetrix made another offer and suggested that ParAllele and Perlegen (a spin-off from Affymetrix) would merge and go public through an IPO. But this offer was not considered as interesting by ParAllele. In the end, Affymetrix acquired ParAllele for $121 million. "Ulf Landegren commented the acquisition. "It feels nice that the technology has proven to be so successful, and one could hardly have found a better buyer (Affymetrix), where it can be commercialized in large scale" (press release Uppsala university).

Discussion and some latest developments

The case shows how Uppsala University's original scientific discovery of padlock probes progressively increases its economic value after being combined with several other resources: new competence, technologies and products from SGTC, venture capital and business relationships with scientific partners (Baylor and Yale), customers (big pharmas such as Merck and Roche) and technology partners/distributors (Affymetrix and Agilent). During this process, different actors strived to influence the development and application areas of MIP by trying to get priority for their ideas and interests in the network emerging around the original scientific innovation. This is done using control systems, their own and others.

The GenPat group and Ulf Landegren first tried to exploit Pharmacia Biotech in order to commercialise the very idea of genetic analysis via padlock probes. Initially this corresponds to the interests of Pharmacia, but then its internal control system orients the focus of Pharmacia's R&D units far away from the proposals of Landegren and to projects better fitting the company's strategy. Pharmacia's merger with Amersham is in a way favourable to Landegren, as he receives back the rights to commercialise the padlock probes on his own. On the other hand, Mostafa Ronaghi, whom the GenPat group almost recruited, gets immediately excited over the technical and commercial potential of padlocks. And once Ronaghi presents these ideas to the SGTC people, they also realize that padlocks must be combined with other technologies and knowledge to have a stronger commercial value. SGTC people are those who control the largest research-related resources and thus gain a lead in the race to commercialise padlocks. Moreover, this lead grants them some external control also on Uppsala GenPat group: SGTC people make their Swedish counterparts realize that there is really no point in proceeding without including SGTC in their ideas on commercialising padlocks.

Venture capitalists, represented first by Index, then by Versant and Abingworth, finally by Mohr Dawidow, have a clear agenda and want to mould every resource which is connected to their investment in ParAllele, and therefore can affect its value. They have opinions and goals on *how* ParAllele should conduct business, with *whom* and in *why*. By strongly influencing the product features, the choice of customers, and the organisation and employees of ParAllele, VCs have a more direct control on the firm. VCs clearly employ all forms of controls reviewed in the theoretical section. For example "result controls" are applied to set the main features of ParAllele's offering (a reagent kit with software, but not an expensive machine) or to achieve more traditional revenue objectives. VC apply instead "personnel controls" not only in having a say on all major recruitments of ParAllele, but also in pushing for cooperation with well-known actors such as a Yale researcher or in suggesting to develop relationships with two alternative technology partners (both Affymetrix and Agilent). In addition, VCs exploit "action controls" in defining *how* ParAllele should conduct its business, that is, its "business model": it will be about selling a reagent kit to perform large genotyping tasks. This is done, taking the users control systems and accounting into consideration.

Incidentally, the use of these forms of controls induced ParAllele to focus on certain features of padlock probes. But this left open the possibility for Ulf Landegren and Mats Nilsson to set up another company, Olink, which owned the rights on using padlocks in different applications than MIP, excluded from the patents granted to ParAllele. Olink is thus a spin-off from the research conducted by Landegren and Nilsson, but also *indirectly* from ParAllele (as Landegren and Nilsson actually tried to sell the proximity ligation method that Olink is built around to ParAllele). The controls applied by VCs therefore bring back into the picture the GenPat group: for some applications of their original discovery, now Landegren and Nilsson cannot be controlled by ParAllele via the first licensing agreement and, if necessary, they will need to be influenced and mobilized in new ways by ParAllele or by its VCs. Here patents and licensing agreements acted as "action controls": they define who and how is permitted to conduct certain activities on the knowledge included in the patent.

At the start of our story Landegren and Nilsson owned the patents for most application areas of padlocks: this gave them some possibility to control the SGTC group. But despite them granting parts of their rights to ParAllele and loosing some control, they still kept some room to manoeuvre thanks to their exclusive rights on certain other applications of padlocks. This position became even more favourable, when Affymetrix wanted to acquire ParAllele. In fact, Affymetrix wanted to strengthen and secure ParAllele's patent portfolio and offered to purchase the patents still held by Olink: as these patents had limited for Olink business, they were sold to self-finance the first years of development of a different product related to the GenPat group research.

By being included in Affymetrix's micro-arrays, ParAllele's technology MIP became more embedded in an industrial system of producers and users. Having distributors and actual customers made ParAllele different from many other start-ups that try to get investors only on the basis of "expectations" of future sales. After interacting with the Uppsala researchers and acquiring the commercial rights to exploit their research, in the end, ParAllele became itself object of an acquisition. Some of the founders, including the Swedish ones, actually think that there were no choices of pursuing ParAllele as an independent unit in the long-run. Selling ParAllele seems to have been the choice of most involved owners, from the founders to, especially, venture capitalists.

But why doing it? and why selling just to Affymetrix? The financial incentives for the founders provide some explanation to this: the SGTC researchers were all relatively young promising researchers who could see their technology being pursued further by a large and successful company. Moreover, ParAllele had already very close ties with Affymetrix: their products were in Affymetrix's "catalogue" SGTC's director Ron Davis had a stake in Affymetrix technology and pushed in this direction. At the same time, the investments required to be an independent firm would probably be substantial and involve a fair share of risk. The VC firms that had invested from the beginning (Index, Versant and Abingworth) reckoned they could made a healthy return and backed this exit possibility. Mohr Dawidow could "only" double their investment and for sure they had hoped for more.

At first sight, Agilent seems to have been only "exploited" by ParAllele to push up its own price for Affymetrix: in fact, Agilent represented a serious alternative for ParAllele and their relationship created competition for Affymetrix, thereby increasing ParAllele's share price. However, Agilent also benefited from the relationship: firstly, it obliged Agilent's competitor Affymetrix to pay a higher price; secondly, Agilent gained important new technical knowledge thorough the relationship with ParAllele; thirdly, the fact that the MIP kit can be read with both Agilent and Affymetrix's chip readers will hopefully be beneficial to Affymetrix in the future. Figure 3 presents summarily the various types of controls employed by the above actors in order to affect the resources that were combined around the MIP technology.

Concluding remarks

The case of ParAllele and our discussion shows both a process of resource combination that increased the progressively the economic value of a scientific discovery and the efforts of several actors to control for own advantages the outcome of this process. This implies that there were clearly conflicts not only between the control logics of different actors (e.g., scientists Vs venture capitalists Vs existing technology companies), but also within each of the logics (e.g., between the GenPat scientists and the SGTC scientists or between Agilent and Affymetrix). These conflicts are due to how the different goals of the involved actors and to their different ways of viewing and evaluating the value of the specific resources.

If we return to the earlier moments in this process a "key episode" was the first meeting between Ronaghi and the padlock inventors Landegren and Nilsson. In that moment, Landegren and Nilsson's interest was to recruit a colleague for GenPat: therefore they freely communicated and informed

Ronaghi in an attempt to control him so that he would found it attractive to join the research group in Uppsala. However, Ronaghi as it turned out, had a different interest and perspective: his agenda was in the end not to join GenPat, but to discuss research he found interesting. This was a turning point where an attempt to control another actor by unveiling key information turned into a motivator for a different type of behavior than expected. However, if Landegren and Nilsson's attempt to convince Ronaghi had worked, the padlock idea might have been commercialized in Uppsala, or not at all.

To conclude, it is important to stress that for a development process to proceed until science becomes embedded in an industrial network, it is not always a matter of creating "alignment" or "goal congruency" at network level. This might sometimes, and in certain specific development moments, be important and a goal pursued by some actors. However, as the ParAllele story shows, it could be useful to keep different interests and forms of controls alive, as pursuing own interests might lead actors in directions beneficial for some other parties and for the focal technology.

References

Baraldi, E., & Strömsten, T., 2006, Embedding and utilizing low weight: Value creation and resource configuration in the networks around IKEA' lack table and Holmen's newsprint. *IMP Journal*, 1, p. 52-97.

Davila, T., 2004, An exploratory study on the emergence of management control systems: formalizing human resources in small growing firms. *Accounting Organizations and Society*, 30, 223-248.

Davila, T., Foster, G., Gupta, M., 2003, Venture Capital and the Growth of Start-up Firms. Journal of Business Venturing. 18, 689-708.

Dekker, H.C., 2004, Control of inter-organizational relationships: Evidence on appropriation concerns and coordination requirements. *Accounting Organizations and Society*, 29, p. 27-49.

Emmanuel, C., Otley, D., Merchant, K., 1990, *Accounting for management control*. Chapman & Hall, London.

Håkansson, H., 1987, *Industrial Technological Development. A Network Approach*. Croom Helm, London

Håkansson, H., & Snehota, I. (eds.), 1995, *Developing Relationships in Business Networks*, Routledge: London.

Håkansson, H., & Johanson, J., 1992, A model of Industrial Networks. In Axelsson, B. & Easton, G., *Industrial networks: A new view of reality*. Routledge, London.

Håkansson, H., & Waluszewski, A., 2002, *Managing Technological Development. IKEA, the environment and technology*, Routledge: London.

Håkansson, H., & Lind, J., 2004, Accounting and Network Coordination. *Accounting Organizations and Society*, 29, 51-72.

Johansson, S-E & Östman. L., 1992, *Accounting Theory. Integrating Behaviour and Measurement*. Pitman Publishing, London.

Lazonik, W., O´Sullivan, M., 2002, Maximizing Shareholder Value. A New Ideology for Corporote Governance. Economy and Society, Volume 29, Number 1, February, 13-35.

Merchant, K., 1985, *Control in Business Organizations*. Pitman, Boston.

Merchant, K., 1998, Modern Management Control Systems, Texts and Cases. Prentice-Hall, Upper Saddle River, NJ.

Nilsson, M., et al., 1994, Padlock probes: circularizing oligonucleotides for localized DNA detection, *Science*, Vol. 265, pp. 2085-2088.

O' Sullivan, M., 2000, The innovative enterprise and corporate governance. *Cambridge Journal of Economics*, 24, 393-416.

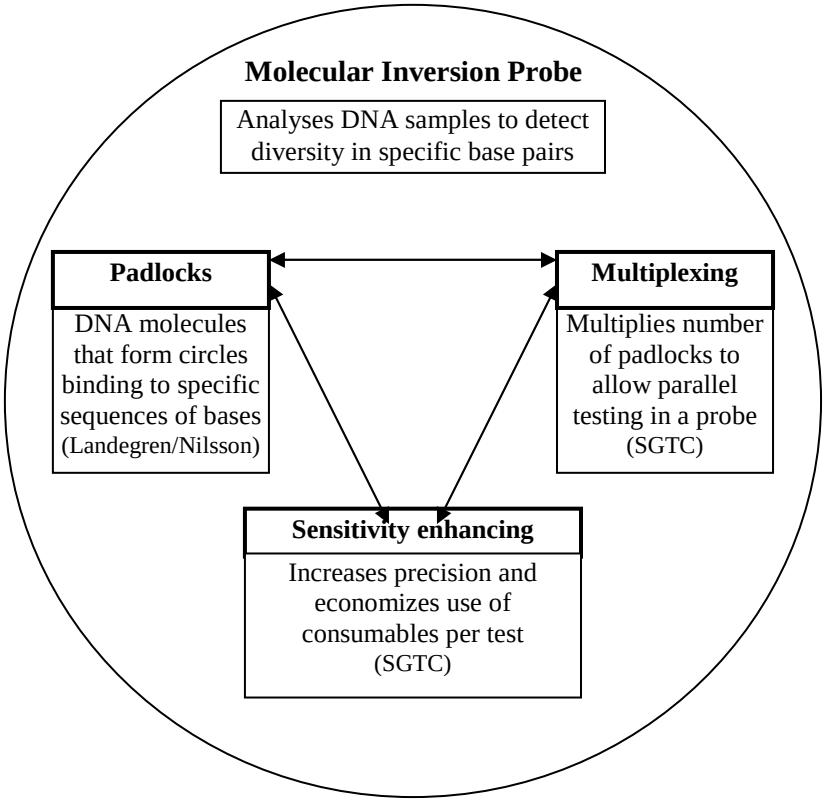

Figure 1: The MIP technology and the three methods that compose it

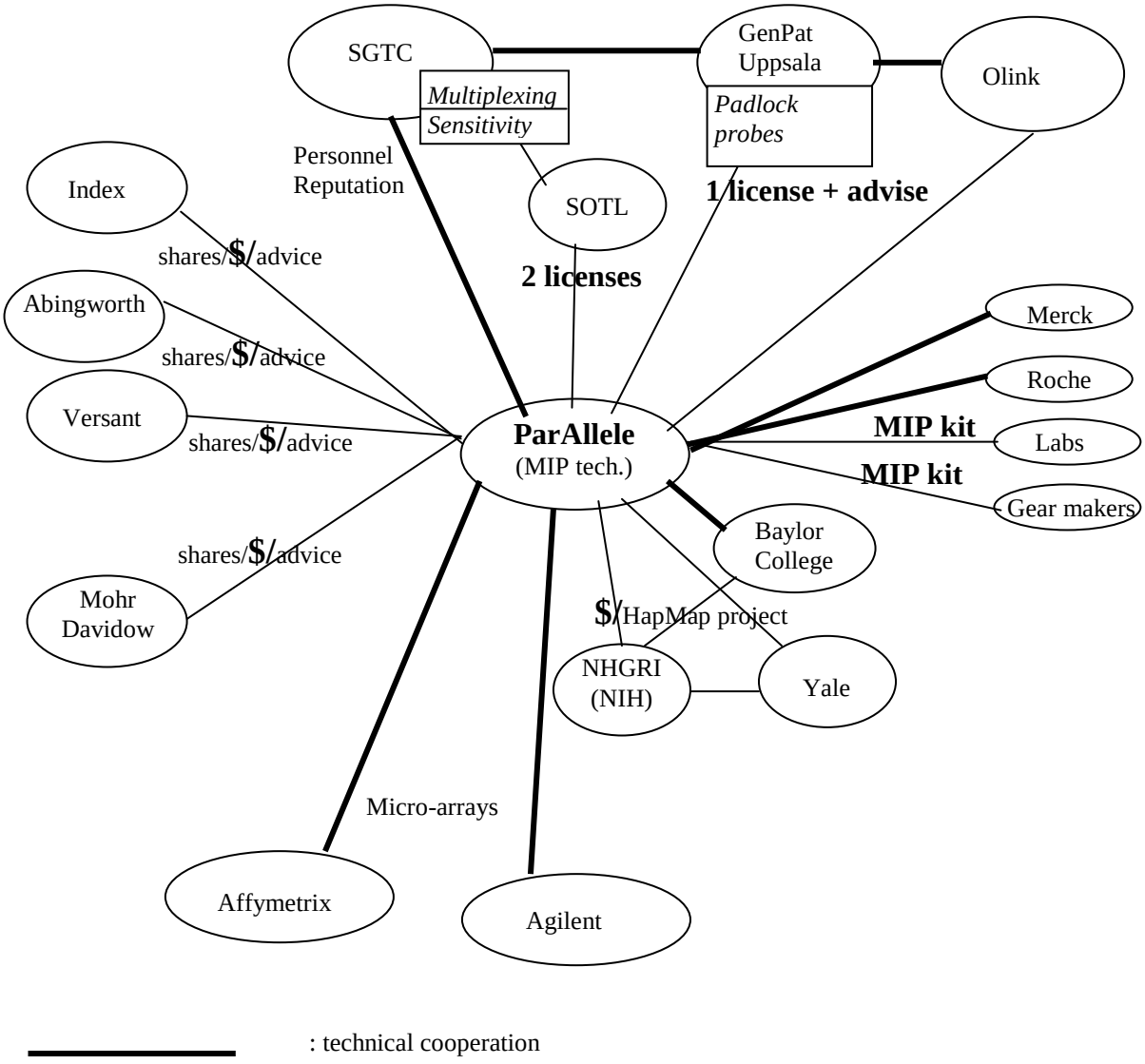

Figure 2: The network emerging around ParAllele and the MIP technology

	Result controls	Action controls	Personnel controls
GenPat (Landegren & Nilsson)	Scientific standards and publications (to attract Ronaghi and SGTC attention)	Patents on padlocks, partial and total out-licensing	Engaging Pharmacia (?), involving Ronaghi (?), interacting with SGTC, creating Olink
Pharmacia Biotech	Fit with overall R&D strategy	Patents on padlocks	Engaging-disengaging Landegren
SGTC	Scientific standards, publications, and achieved MIP functionalities (to impress GenPat)	Informal science & technology development project on MIP	Forming five person-team, involving Landegren & Nilsson
ParAllele	Financial performance, product quality, scientific publications (reputation), future outlook as an independent Vs acquired company	In-licensed patents (to control GenPat), high-profile collaboration projects (to test MIP and build legitimacy)	Own personnel recruits, inclusion of co-founder, selecting VC investors, involving key science/tech. partners for reputation or to avoid overdependence
Index	Strengthened IPRs, ParAllele's financial performance and product offering's key features, price of ParAllele shares	ParAllele's business model definition ("sell a kit for large-scale genotyping")	Involving other VC firms, involving reference customers for reputation
Versant, Abingworth	ParAllele's financial performance and product offering's key features, price of ParAllele shares	ParAllele's business model definition, periodic meetings and reviews	Monitoring ParAllele's recruitments, orienting towards big pharma executives, engaging both Affymetrix and Agilent
Affymetrix	Technical fit of MIP with own technology, MIP's market potential, secured ParAllele's patent portfolio, acquisition price	ParAllele and Olink's patents, acquiring ownership control	Intermediating towards major customers, bringing ParAllele farther from Agilent, suggesting merger with Perlegen
Agilent	Technical fit of MIP with own technology, acquisition price paid by a competitor (Affymetrix)	Joint tests and sales with ParAllele	Intermediating towards certain customers, distracting ParAllele from Affymetrix
Olink (Landegren & Nilsson)	Holes in ParAllele's patent portfolio, price paid for out-licensed patents	Residual owned patents on padlocks	Getting involved in Affymetrix's acquisition of ParAllele

Figure 3: The forms of controls employed by various actors on the resources related to MIP