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A dynamic view on interactions between academic spin-offs and their parent organizations

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ABSTRACT

Literature on academic spin-offs gives evidence of different modes of interaction between spin-offs and their parent and their relative role in different modes of knowledge production. In this article, we examine the development of interactions between academic spin-offs and their parent organizations over a mid- to long-term period (4–15 years), drawing on a series of 25 case studies of spin-off/parent pairs from France and Switzerland. We show that the relational trajectories can be captured by four major dynamic patterns. These patterns range from an early cut-off of interactions in line with a linear model of innovation to sustained interactions supporting joint production of knowledge. Some patterns even include a change in the mode of knowledge production over time. In addition, we identify a number of determinants, internal or external to the pair, affecting the dynamic pattern. We conclude that management of spin-off processes and support policies for academic spin-offs should embrace this dynamic diversity.

1. Introduction

Due to their emblematic quality, academic spin-offs have received increasing attention in various literatures, such as in innovation economics and management, science policy and science studies. Academic spin-offs, that is, firms founded by staff or graduates of academic institutions that exploit research outcomes, are raising high hopes for bridging scientific research and economic exploitation. By this they support the contribution of science to innovation, and ultimately economic and societal welfare. The hopes attached to spin-offs can be related to different assumptions on how technology transfer actually takes place, which in turn is linked to the type, intensity and duration of interactions between the academic spin-off and its parent organization.

Following a 'linear' innovation model (Marquis, 1969), spin-offs are a very effective means for 'transferring' knowledge from the lab into the economy (Rothwell, 1994; Godin, 2006). In this view, one may basically expect a unilateral transfer of a more or less confined set of codified knowledge, epitomized for instance in the transfer of intellectual property rights. This has consequences for the type of interactions we expect to take place between the spin-off and its parent organization. Except for an early incubation phase, there would be no need for further substantial interaction. The second view maintains that knowledge is not so much transferred from academia to industry, but rather co-produced in an interactive process which entails continuous interaction between industry and academia (Etzkowitz and Leydesdorff, 2000). Spin-offs may be seen as palpable candidates for exemplifying this mode of knowledge production. We would then expect rather a continuous exchange of knowledge or a co-production of knowledge, with strong and long lasting interactions between spin-offs and their parent organizations.

These diverging interpretations of the role of spin-offs in technology transfer suggest quite different policy and management implications on how to support academic spin-off processes. The linear knowledge transfer model recommends focusing on the creation phase and setting up incentives for a frictionless separation. In turn, the co-production of knowledge model would propose improving conditions for sustained and mutually beneficial collaborations.

Empirical literature on spin-off processes gives evidence for both models, showing that some firms do cut off their linkage to the parent soon after their foundational act (Autio, 1997; Perez and Sanchez, 2003), whereas others maintain more or less intense interactions with their parent organization long after the creation

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phase (Johansson et al., 2005). Thus, we assume that the two views represent different modes of knowledge production and technology transfer respectively, which may co-exist and ask how these relate to interactions between spin-offs and their parent organizations. More specifically, we ask how long interactions last, to what extent they are actually related to a co-production of knowledge, and if spin-off/parent unit pairs (SPP) fall in one or the other category or rather shift modes over time.

Investigating these questions requires a dynamic and longitudinal perspective on interactions between spin-offs and their parent organizations. We examine how the interactions evolve over the mid- to long-term (4–15 years), which forms of knowledge transfer and joint production of knowledge are taking place, and how the evolvement relates to structural characteristics, processes and events on the side of both partners. In this, we differentiate from other studies that consider similar research questions from the point of view of the spin-off only (Bathelt et al., 2010). Do we observe specific patterns in how interactions and modes of knowledge production evolve? We analyze these questions with a sample of 25 qualitative case studies of French and Swiss SPPs chosen from the domains of information technology, biotechnology and micro/nanotechnology. In so doing, we expect to develop a differentiated understanding of the conditions that shape the relationship between spin-offs and their parent organizations. Our study provides a unique, longitudinal view on the dynamic relationship between research organizations and their academic spin-offs and on the conditions for particular modes of knowledge production. This perspective complements the vast literature, which focuses on the creation phase and the short-term development of academic spin-offs. In so doing, we contribute to a better understanding of what might be appropriate patterns of interaction and how these may be facilitated by institutional frameworks and an adequate management by both partners.

The argument in the paper proceeds as follows: the next section will review literature on spin-offs and science–industry interactions, with regard to conceptual and empirical insights on interactions between spin-offs and their parent organizations, their determinants and dynamics. In the Section 3, we will introduce the methodological approach, our empirical sample and specify the operationalization of the core variables that characterize our case studies. Section 4 analyzes the observed interactions and derives four ideal type dynamic patterns for spin-off/parent organization dynamics. Section 5 discusses a set of variables that affect the dynamic patterns. Section 6 concludes by reflecting on the academic, management and policy implications.

2. Conceptual framework: Spin-off–parent interaction, its determinants and dynamics

2.1. Interactions

Prior research on SPP interactions has demonstrated the broad variety in their types and intensity (Autio, 1994; Johansson et al., 2005; Perez and Sanchez, 2003; Rappert and Webster, 1998; Rappert et al., 1999). Interactions may take the form of highly circumscribed transactions, usually confined to points in time or short periods, such as the transfer, licensing or selling of intellectual property rights, the recruitment of personnel or the selling of products. Furthermore, they may expand over longer periods with regularly occurring interactions, which are related to joint research projects, Ph.D. and master theses, joint publications or the joint use of facilities and instruments. Finally, they may be of a continuous and intense kind, particularly if academic staff holds an operative position within the spin-off or a position as a board member. While these forms of interaction are largely formal, underpinned by a contract or an official agreement, informal interactions such as meetings and discussions take place as well. Informal interactions have been reported to be at least as, or even more, important for technology transfer than formal interactions, be it in their own right by facilitating the exchange of tacit knowledge or as supports to formal interactions by building trust (Autio, 1994; Rappert, 1997). This is in line with findings on more general university–industry interactions (Bekkers and Bodas Freitas, 2008; D'Este and Patel, 2007) and findings on corporate spin-offs (Johansson et al., 2005).

Related to the types and intensity of interactions taking place, spin-offs may fulfill different roles in knowledge production and ultimately innovation, driving technical change (Kirchhoff, 1994). Spin-offs can be seen as very effective means for a predominantly unidirectional, 'linear' transfer of knowledge from science to industry, based largely on highly circumscribed types of interactions such as the transfer of intellectual property rights or transfer of personnel. This type of technology transfer is in line with a view according to which the institutional spheres of academia and industry should be kept rather separate with highly circumscribed relations among the spheres (Etzkowitz and Leydesdorff, 2000). Accordingly, spin-offs are expected to 'emancipate' themselves from the parent organization and move from the academic sphere to the industry sphere rather quickly. In this way, the spin-off is expected to be able to focus on product development and market needs, instead of remaining too much oriented on the academic world (Gilsing et al., 2010). Researchers should thus decide very clearly whether to participate in a spin off or to stay in academia, in order to avoid conflicts of interests (Bekkers et al., 2006; Krimsky, 2006). Otherwise, publicly funded research, i.e., personnel, space and equipment, may be diverted to the support of private profits (Ndonzuau et al., 2002).

According to an innovation model where mutual, interactive exchange and joint learning are at the core of technology 'transfer' (Meyer-Krahmer and Schmoch, 1998; Etzkowitz, 2003; Balconi and Laboranti, 2006), spin-offs can fruitfully engage in intense and sustained interactions with their parent organizations even beyond the creation phase including joint research, joint publications and informal ways of exchange of more or less tacit knowledge. In this model spin-offs may be interpreted as boundary-spanning organizations facilitating knowledge production and innovation, which takes place in overlapping institutional spheres (Etzkowitz and Leydesdorff, 2000; Perez and Sanchez, 2003; Youtie and Shapira, 2008). Relationships between the spin-off firm and its parent organization may therefore be rather intense. This model assumes that in this way science is contextualized with respect to societal or economic needs (Nowotny et al., 2001) and that industry gets an easy access to scientific findings. Spin-offs and their academic parents may even be seen as preferential partners, as they are likely to hold a shared cultural and educational background, a shared stock of tacit knowledge and similar research interests. In line with learning theories, such an overlapping knowledge base has been considered as an important precondition for realizing mutual learning, both for academic and corporate spin-offs and their respective parents (Cohen and Levinthal, 1990; Johansson et al., 2005;Sapienza et al., 2004). Proximity, established personal links and trust relations support additional complementarities (Johansson et al., 2005). On the other hand, long term relationships can lead to growing interdependence, not only as a source of synergies and knowledge creation, but also creating a risk for the firm to become dependent on the knowledge of the parent (Riordan and Williamson, 1985; Parhankangas and Arenius, 2003; Johansson et al., 2005).

As divergent as these models may seem at first glance, literature on spin-offs or science–industry interactions provides

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conceptual and empirical support for both models, and it gives indications on what may account for the variety and changes in patterns of interactions and 'modes' of technology transfer.

Some studies see spin-offs as predominantly motivated by and resulting in commercial benefits (Arza, 2010; D'Este and Perkmann, 2011) and make a clear separation with more interactive forms of science–industry linkages such as joint research. Hence, these studies seem to implicitly pend towards a more linear model of interaction. The assumption of a quick separation from the parent organization or a fading process is supported by studies indicating a general decline of interactions with the parent after creation (Autio, 1997; Perez and Sanchez, 2003). Rothaermel and Thursby (2005) observed a quicker move out of a university incubator and, supposedly, quicker self-reliance for those firms, which entertained weaker linkages with their parent. Other studies observed joint learning processes (Johansson et al., 2005) and sustained interactions between spin-off and parents for all or part of the spin-offs investigated (Rappert, 1997; Mustar et al., 2006; Shinn and Lamy, 2006), in particular if founders keep a position in academia (Johansson et al., 2005). Rappert and Webster (1998) even report on spin-offs seeking interaction at a later stage after operating rather independently for some time.

2.2. Determinants

The observed variety is not so surprising if we consider the various characteristics of a SPP, which may affect the interactions. It has been widely shown that linkages and interactions between public research organizations and industry differ between technology sectors in which different innovation models prevail (Faulkner and Senker, 1994; Meyer-Krahmer and Schmoch, 1998; Rappert and Webster, 1998; Rappert et al., 1999; Schartinger et al., 2002; Salavisa et al., 2012). In a similar vein, the scientific discipline of the academic partner can explain the observed variety in science–industry interactions (Bekkers and Bodas Freitas, 2008). In the case of biotechnology, most authors report particularly strong relations between industry and academia and a particularly high importance of formalized interactions, the spin-offs acting as a channel of technology transfer (Faulkner and Senker, 1994; Cohen et al., 2002; Bekkers et al., 2006; Salavisa et al., 2012). A slightly different view is taken by Gilsing et al. (2011), who expect biotechnology to be a typical example of a science-based regime that interacts less due to a high division of labor between the partners in the innovation process. For the ICT-sector and software industry, linkages with academia are reported to be less essential than for biotechnology and typically of a more informal nature. One explanation is that patents are not as important as in biotechnology or material science (Rappert et al., 1999; Bekkers et al., 2006; Salavisa et al., 2012). The innovation and interaction patterns in nanotechnology have been researched much less. Initial evidence suggests that innovation follows different routes than biotechnology, and that - given the high diversity within the field – variety in the modes of technology transfer can also be expected (Libaers et al., 2006; Genet et al., 2012). As for the types of interactions, both for bio- and nanotechnology, expensive instruments are usually much more important than in information technology, and are therefore more often the reason for maintaining long term interactions (Faulkner and Senker, 1994; Rappert and Webster, 1998; Rappert et al., 1999; Salavisa et al., 2012).

Besides the technology sector, the firm size and the business model have been identified as affecting the intensity and type of interactions between spin-offs and their parents, or science–industry interaction in general. Usually, larger firms, with larger R&D departments, have been found to interact more (Faulkner and Senker, 1994; Cohen et al., 2002). To what extent this is transferable to spin-offs, which seem to interact more than other firms of their size (Cohen et al., 2002) and mostly are rather small anyway, is, however, not fully clear. The business model of the spin-off influences the interactions with the parent as well, for instance if it is focused on consultancy, developing specific technology assets to be commercialized further by others, or regular product development (Stankiewicz, 1994; Rappert and Webster, 1998; Rappert et al., 1999).

The technology sector or discipline a SPP belongs to is likely to remain constant over time. However, when we look at some of the elements advocating for a looser or a closer connection between the spin-off and its parent, such as firm size, business model, potential complementarities and shared research interests, availability of research equipment, personal links and trust, we may expect that these are dynamic variables which may change over time. Hence, the conditions, relative benefits and costs of the relationship for both partners can evolve and trigger a change in its nature and intensity.

The dynamics of spin-off development have been addressed by literature on lifecycle or stage models, highlighting that the size, business model, entrepreneurial team, internal research and development capacities may change over time (Autio, 1994; Clarysse and Moray, 2004; Druilhe and Garnsey, 2004; Vohora et al., 2004; van Geenhuizen and Soetanto, 2009). Some of those report that interactions with the parent organization diminish over time (Autio, 1994), while others observed that also the more advanced spin-offs retained close links (Vohora et al., 2004). However, with regard to our interest in the longer-term dynamics of interactions most of these studies remain silent, due to their focus on the early phases of spin-off development (a couple of years). Further, the literature on firm life cycles, not necessarily dealing with academic spin-offs, but mostly new high-tech firms, considers longer term developments. Phelps et al. (2007), reviewing stage model literature and drawing on Aldrich (1999), conclude that it is hard to find a common pattern and suggest that there is no linear stage model based on some 'organic' logic, but that firm development rather follows an evolutionary dynamic. This evolutionary dynamic is the contingent result of a process of interaction between internal factors and external events. Hence, while a highly dynamic development may be expected, this does not follow easily predictable paths. Rasmussen (2011) found similar evidence of unpredictable events and environmental changes affecting the development of spin-offs in the early phase. This suggests that interactions with the parent organization and the variables affecting them may also develop in hardly predictable ways.

Moreover, not only the spin-off, the parent organization, which may change relevant policies and strategies should also be expected to evolve (Rasmussen and Borch, 2010; Rasmussen, 2011). Even more so, the department or research group the spin-off originated from, which is likely to be the primary partner in interactions (Johansson et al., 2005), may change, for instance with regard to personnel or research agenda. Thus, we should expect an interplay or even interactive dynamics. This suggests that the resulting dynamics of interactions between spin-offs and their parents may be quite complex and hard to predict and thus require an analysis of the actual evolvement of the interactions and its determinants. While the linkages and interactions of academic spin-offs with their parent organizations have been the concern of a number of studies (see above), to our knowledge none of those traces the actual evolvement and its underlying reasons for a broad and diverse set of SPPs. In particular, the study of Johansson et al. (2005) comes closest to our approach, but relies on a set of four spin-offs characterized by sustained interactions over the mid- to long-term, hence seemingly reporting on a specific subset of dynamics. Rothaermel and Thursby (2005) provide a longitudinal

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study over 3 years analyzing the effect of university linkages on spin-off success, but measure only the success and not the linkages in a longitudinal perspective. Finally, Rasmussen (2011) follows the dynamic evolvement of a set of spin-offs, but focuses on the early phase.

The development of the SPP interaction might be influenced not only by characteristics and dynamics relating to the spin-off, the parent or their relationship, but also by external conditions such as the specific characteristics of the national research system and systems of innovation more generally (Lundvall, 2007). Relevant characteristics may be regulations supporting or inhibiting interactions between academic staff and industry, national policies of spin-off support and academic cultures (Konrad and Truffer, 2006; Mustar and Wright, 2010). Finally, relationships are likely to develop differently depending on the basic mission and research orientation of the parent organization. In the German academic system for instance, the Max Planck institutes have for long considered academic spin-offs as a disturbance and supported therefore a linear knowledge transfer model. The Fraunhofer Institutes, along with their mandate to support research and development in industry, have instead developed much more hybrid interaction structures with industry (Knie and Lengwiler, 2008). Divergence in industry linkages has also been reported for different types of academic organizations in France (Mustar and Wright, 2010). Depending on the specific composition of the national research system, differences at the level of types of organizations may even aggregate at the national level.

3. Sampling and operationalization

Our empirical investigation relies on case studies carried out in the context of an international research project (PROKNOW) running from 2006 to 2009, which investigated the impact of the creation and interactions with academic spin-offs on their parent organizations in seven countries (the impact of the creation and interaction with academic spin-offs for the parent organization is discussed in more detail elsewhere, see Konrad et al., 2009). Our analysis is based on a *sample* of case studies of interactions between 25 spin-off firms and the research laboratory they spun off from located in two European countries, Switzerland and France. We considered as *academic spin-offs* all firms exploiting research results, which had been created by the staff of universities or public research institutes, or by graduates or former employees, such as post doctorates or Ph.D. students. Transfer of intellectual property rights was involved in many cases, but was not a prerequisite to be included in the sample. For analyzing the interactions with the parent organization we focused on the *parent unit*, which is the specific research laboratory from which the knowledge or technology on which the spin-off is based originated. For identifying the parent unit we followed Larédo and Mustar (2000) (p. 522), who request that a research laboratory must be recognized within its own institution as a budgetary unit; it must be visible as a whole for outsiders from the institution and have a clearly identified representative. Besides, the sampling strategy imposed a series of conditions the parent units and the spin-offs had to fulfill. Following our theoretical assumptions on possible conditions affecting interaction patterns, the sample was intended to be diverse in terms of technology sectors and institutional setting. Furthermore, the selection was constrained by a minimum threshold on the number of spin-offs that had originated from the parent unit. Those conditions were defined in common for all case studies organized within the PROKNOW project (Knie and Simon, 2009, pp. 24–25). As a consequence, the selected research laboratories belonged to organizations with a high spin-off activity, which in the case of France impacted the choice of the parent's institutional status. Following these guidelines, the French sample is composed of four parent organizations, two of which are dedicated research organizations. The third one is an engineering school and the last one is a mixed research unit between a national research center (*CNRS*) and a university. The Swiss sample comprises one technical university, a university of applied sciences (*Fachhochschule*), one public research institute and one semi-public research institute. (Universities of applied sciences provide a particularly practice-oriented form of higher education; they put a stronger emphasis on teaching and applied research than universities.) At these institutions, spin-off activity is fostered by a particular focus on project-oriented applied research as well as targeted technology transfer policies. At the national level, the institutional and cultural context of France and Switzerland differs to some extent: the French science system seems to be more prone to a linear model of science–industry interactions, while the Swiss science system is comparatively more supportive to an interactive model. Traditionally, French universities have had rather weak ties with industry, and employees of universities and research organizations have been allowed to participate actively in private companies only since the 1999 Innovation Act (Mustar et al., 2008). The Innovation Act from July 12, 1999, allows university members to create spin-off firms and work there for 6 years without losing their academic position and to patent the results of their research. It also created incubators (or innovation centers) supporting those firms in their early stage, research tax cuts (*Crédit Impôt Recherche*) and a simplified status for innovating firms. The French research system can be divided into two institutional groups, each of them having different missions and rules: higher education institutions, and dedicated research organizations, which are usually specialized (except for the CNRS, *Center national de la recherche scientifique*, which is the national research center). In practice, research is also carried out at universities through mixed research units with the CNRS, however, R&D is still dominated by dedicated research institutions (Thèves et al., 2007). Even within this latter group most patents are concentrated in a few fields and research organizations (IGF, 2007), namely the CEA (*Commissariat à l'Energie Atomique*) and the INRIA (*Institut national de recherche en informatique et en automatique*). National support measures for spin-offs in France are mostly targeted directly at the spin-off firms or at intermediary organizations, but not at the research organizations and emphasis is put on financial, not on knowledge issues (Mustar and Wright, 2010).

The Swiss science system and its governance structure are highly fragmented, which makes a national characterization difficult as such. At the policy and governance level a divide of bodies responsible for higher education and research on the one side and innovation support on the other follows a 'linear' model (Griessen and Braun, 2008). However, regarding the level of research organizations and the actual management of science–industry relationships a more 'interaction-friendly' picture emerges. Swiss universities and research institutes, in particular the large technical universities (ETH), are traditionally more open to science–industry interactions and to mixed careers. A recent study reported a high involvement of Swiss researchers in industry interactions in general and spin-off creation in particular (Arvanitis et al., 2008). Most research organizations have established technology transfer support entities. The institutional framework differs furthermore between types of research institutions, all the more in a federal country like Switzerland.

Thus, we stratified our sample in a way to cover the different types of research institutions prevailing in the two countries, encompassing different types of research institutes and universities. Hence, if the institutional and cultural context matters, our sample should not be biased unduly to the effects of a specific context. It should however be noted that our sample is not representative of the national science systems in a quantitative sense, due to our bias

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towards spin-off active organizations, impacting in particular the French sample (see above). Still, it covers well the variety of spin-off active research organizations in the two countries. Due to this bias, differences in the national context may not be fully translated into our sample. The cases were furthermore chosen from the domains of information technology, biotechnology and micro/nanotechnology. These domains account for the majority of academic spin-offs created (Shinn and Lamy, 2006). As suggested in Section 2, we may expect to see differences in the dynamic patterns across these domains given their differences in innovation models as well as IPR practices.

Our case studies on SPPs were based on interviews carried out between 2006 and 2009. The sample is composed of 25 spin-offs created out of eight research organizations, respectively nine parent units. The case study method is based on Eisenhardt and Graebner (2007) and Yin (1994), among others. For each SPP we conducted between two and four interviews with members from the parent unit and the spin-off. Each interview lasted between 1 and 2.5 h and was fully transcribed. For each pair we interviewed at least the head of the parent unit and a member of the founding team of the spin-off. Both were involved in the spin-off or parent unit respectively over the whole time period the spin-off existed. This is an important prerequisite for the reconstruction of the evolvement of interactions over time. Ideally, a longitudinal study should be based on data retrieved over the whole time span

Table 3.1
Overview on the 25 case studies according to their sectoral and country profiles.

	Swiss cases	French cases
Number of case studies	13	12
Average age of spin-off	6	7.5
Sectoral specialization (nb of cases)		
Biotech	3	3
IT/ICT	4	6
Micro and nanotechnologies	6	3

Table 3.2
Case studies description: profiling of the nine parent units and 25 spin-off firms. The acronyms are constructed in order to first indicate the country (CH or FR), then the parent organization (from UIT to BIO) and finally a number for the spin-off from this parent organization. Spin-offs from the same parent organization may have been spun off from the same or different research laboratory within the parent organization.

Parent ID	Type of institution (sector)	Spin-off creation policies	SPP interaction policies	Spin-off ID	Age (years)	Firm size (employees)
Swiss cases						
CH-UIT	University	Technology transfer	Access to university infrastructure	CH-UIT1	6	9
	(ICT)	Courses, business plan competitions		CH-UIT2	4	13
CH-UBio	University			CH-UBio1	4	4
	(Bio)	Incubator		CH-UBio2	8	30
				CH-UBio3	9	2
CH-MTRI	Semi-public research institute	Incubator	Consulting services	CH-MTRI1	6	40
		Financial support	Facilities,	CH-MTRI2	6	22
	(Micro/nano)	(capital injection)	administrative services	CH-MTRI3	6	5
			Search for investors	CH-MTRI4	7	45
CH-UApp	University of applied sciences	Technology transfer	Lecturers	CH-UApp1	5	11
	(ICT)	Financial support	participating in spin-offs can reduce their hours	CH-UApp2	4	3
		Incubator (spin-off park)				
CH-MRI	Public research institute	Technology transfer	Offices and infrastructure access for 3 years	CH-MRI1	6	7
	(Material science, partly nano)		Brand name	CH-MRI2	2	4
			Access to loans			
French cases						
FR-COMP	Public research institute[a]	Financial support	Website and seminars	FR-COMP1	7	35
		Label		FR-COMP2	6	13
	(IT)	Technology transfer		FR-COMP3	9	25
FR-TEL	Engineering school	Technology demonstrators		FR-TEL1	8	30
				FR-TEL2	4.5	3
	(IT)			FR-TEL3	8	80
FR-ELEC	Public research institute[b]	Financial support (capital injection)	Technical, equipment and know-how support	FR-ELEC1	4	10
				FR-ELEC2	15	700
	(Micro and Nano)	Technology transfer		FR-ELEC3	6	25
FR-BIO	University[c]	Incubator		FR-BIO1	5	40
	(Bio)	Financial support		FR-BIO2	8	50
				FR-BIO3	8	36

[a] FR-COMP is an EPST, Etablissement public à caractère scientifique et technologique.
[b] FR-ELEC is an EPIC, Etablissement public à caractère industriel et commercial.
[c] The Research laboratory is a mixed research unit between two research-based organizations of the EPST type and a Higher Education organization.

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considered. However, this seems at least difficult to realize for a time period of up to and beyond 10 years. To some extent, interviewing at least one person from each 'side' allowed to cross-validate the data, and counteract this limitation. If appropriate, additional employees were interviewed who were involved in interactions between the parent unit and the spin-off. Questions addressed the history of the spin-off or parent unit, the fields of research or business, the types and intensity of interactions with regard to research collaboration, personnel, equipment, finances as well as organizational conditions and institutional frameworks, potential changes in interactions and underlying reasons. Finally, the effect and importance of interactions for the spin-off or parent unit were addressed. Besides, basic information about the history of the research institution and the firm, the organizational rules and the activities carried out were gathered via desktop research. The material was then synthesized into SPP case descriptions on the basis of which the different structural and relational characteristics were derived (see below).

Table 3.1 presents an overview of the sample, which shows that the sectoral composition is quite balanced with six biotech firms, ten information technology firms and nine firms specialized in micro- or nanotechnologies.

Table 3.2 describes basic characteristics of the research organizations to which the parent units belong and of the spin-off firms. Five out of nine parent organizations belong to higher education organizations and the remaining are public (or semi-public) research institutes. In addition, we noted by which measures technology transfer and in particular spin-off creation is supported at these institutions (Table 3.2, column 3), and – what is even more relevant to our research question – which policies address interaction after the creation phase (column 4). Creation support policies are in place in all of the organizations in our sample. Furthermore, many organizations provided the possibility for spin-offs to benefit from their parent's facilities for several months after their creation. Measures targeted at more long-term interactions are not as common though. At FR-COMP a website and a club were created to maintain relations between the research unit and the local partners, including its spin-off firms, through seminars. MTRI continues to offer legal, human resources and financial services to its spin-offs after their creation, if desired,

Table 3.3
Interaction indicators and output.

Spin-off	Patent transfer	Students	Facilities	Contract research[a]	Double staff	Joint patent applications	Joint publications	Jointly acquired research[b]
CH-UIT1	No	MA	Initially office, no R&D equipment	No	Initially	Yes	No	No
CH-UIT2	No	MA, Ph.D.	Initially office, no R&D equipment	Postdoc	Yes	No	Yes	Yes (national)
CH-UBio1	No	No	Initially office	No	No	No	No	No
CH-UBio2	No	Ph.D.s	Yes	No	Initially	Yes	Yes	No
CH-UBio3	No	Ph.D.	Yes	No	Yes	Yes	Yes	Yes (European)
CH-MTRI1	Yes	No	Yes, infrastructure, equipment	Small services	No	No	No	No
CH-MTRI2	Yes	No	No	No	No	No	No	Canceled
CH-MTRI3	Yes	No	Yes, equipment	No	No	No	No	Yes (national)
CH-MTRI4	No	Ph.D.	Yes, equipment	Yes	No	No	No	Yes (national)
CH-UApp1	No	BA/MA	Equipment use in SO park	No	Yes	No	No	No
CH-UApp2	Yes	BA	Yes, office in SO park	R&D initially outsourced to UApp	Yes	Yes	Yes	Yes (European)
CH-MRI1	Yes	BA, Ph.D. planned	Yes first 3 years (offices)	No	No	No	No	Proposal (national)
CH-MRI2	No	No	Yes (offices)	No	No	No	Yes	No
FR-COMP1	No	Ph.D.	Yes, offices, 4 months	No	Yes	Yes	No	No
FR-COMP2	Yes	No	No	No	Yes		No	Yes, but fluctuating
FR-COMP3	No	Ph.D.	Yes, offices, 4 months	No	No	Yes	No	No
FR-TEL1	No	No	Yes, lab and offices, 1 year	No	No	No	No	No
FR-TEL2	No	No	Yes, lab use	No	No	No	Yes	No
FR-TEL3	No	No	Yes, lab and offices, 1 year	No	No	No	No	No
FR-ELEC1	Yes	No	Yes, offices and instruments	No	No	No	Yes	Yes (European)
FR-ELEC2	Yes	Ph.D.	Joint R&D facility since 2001	No	No	No	Yes	Yes (European)
FR-ELEC3	No	Ph.D.	Yes, offices and instruments	No	No	Yes	Yes	Yes (European)
FR-BIO1	Yes	No	Yes, offices, lab and equipment	No	Yes	No	Yes	No
FR-BIO2	No	No	Yes, offices, lab and equipment	No	No	No	Yes	Yes (cluster)
FR-BIO3	No	No	Yes, offices, lab and equipment	No	No	Yes	Yes	No

[a] Research commissioned to parent unit by spin-off or vice versa.
[b] Research projects jointly acquired by spin-off and parent unit from third party.

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especially in times of crisis, e.g. via common projects or the search for investors.

The parent unit can be a research department, a research group (within a department), or a team created around a project. The meaning and size of a department or a research group differs a lot between organizations. Hence, we did not stick to one type of organizational unit, but adapted it to local circumstances, following the criteria of Larédo and Mustar (2000) for identifying research laboratories. In any case, parent units comprised between 20 and 50 collaborators with the exception of one large department with 100 collaborators.

At the time of the interviews the firms were between 4 and 15 years old. The average age of the spin-offs in the sample lies around 6.5 years old (6 for the Swiss cases and 7.5 for the French), which usually allows the firms to get to an advanced stage of their development (at least to the product development phase). Besides, we find a variety of founders' types, from Ph.D. students to heads of research groups. We differentiate in particular between cases with at least one founder still involved in academia and with cases where all founders left academia (see Table 3.3). In the case of the former – double staff – arrangement interactions in the later stages might be more easily maintained than if a sole student or post-doc leaves the team to create a company (Johansson et al., 2005). We do not differentiate academic founders according to their skills or experience although these elements have been shown to play a role (D'Este et al., 2012), nor question their intentions here, as in (Prodan and Drnovsek, 2010).

For each spin-off–parent pair (SPP) we identified the *types and intensity of interactions* which have taken place and how these have changed over the lifetime of the spin-off, on the basis of our interview data. We took into account the information about formal as well as informal links.

Table 3.3 gives a stylized overview of the types of interactions involved in each case study. We included two groups of formal indicators: the ones indicating a joint use of resources (columns 2–5), and the second indicating a joint work and output (columns 6–9). As resources indicators, we considered for instance if intellectual property rights were transferred. We also looked if students were jointly involved, and if Ph.D.s and master theses were conducted at the firm. Some spin-offs could also benefit from the use of facilities and instruments at the parent institution. Some firms operate as a contractor to the research unit or vice-versa (contract research, column 5). In our analysis we furthermore considered recruitment of personnel (very common) and contributions to coursework by spin-off members (rather uncommon). Second, we have reported if the spin-off and the parent unit collaborated and created knowledge (joint patent applications or publications) or were involved in jointly acquired research. To be exact, contract research means that one of the SPP-partners is a contractor and the other the client. Jointly acquired research means both partners together acquire a project from a third party. Double staff appointments (column 6), for instance academic staff holding an operative position within the spin-off or a position as a board member, may also stimulate interactions between the spin-off and the parent unit. However, all the above mentioned formal elements do not guarantee that

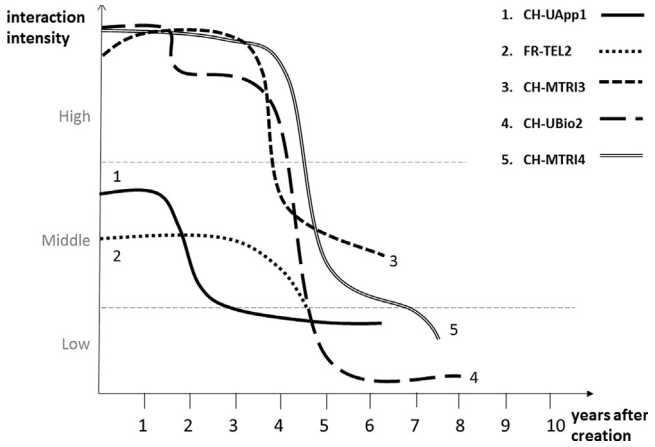

Fig. 2. Interaction dynamics for the Delayed Segregative cases.

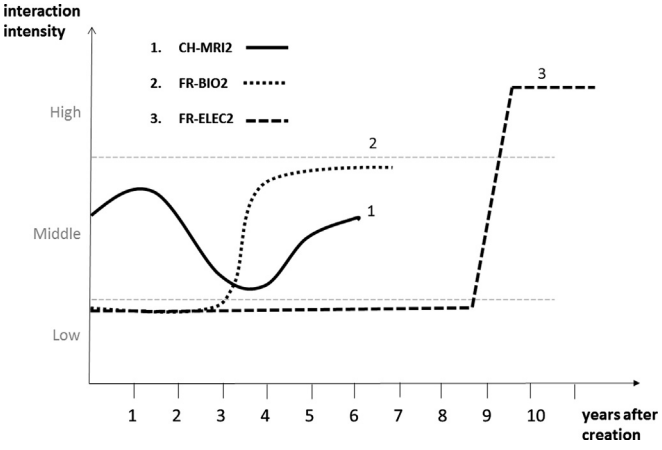

Fig. 3. Interaction dynamics for the Delayed Interactive cases.

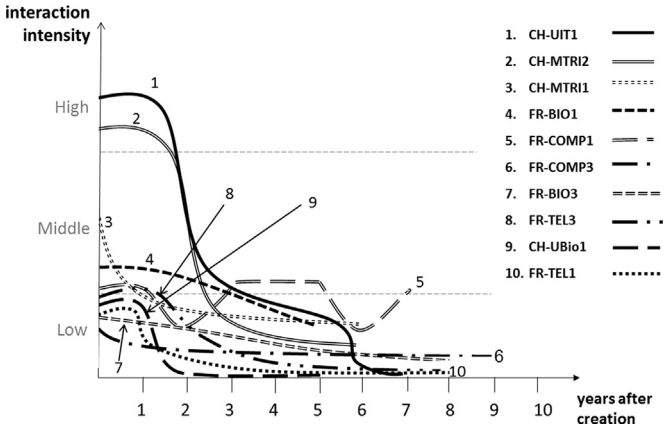

Fig. 1. Interaction dynamics for the Manifest Segregative cases.

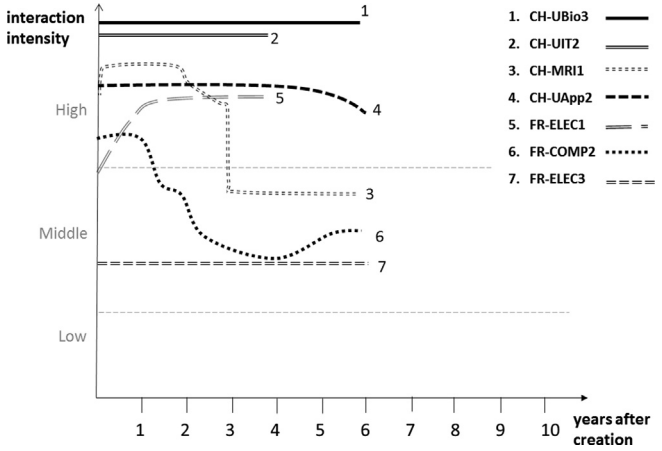

Fig. 4. Interaction dynamics for the Manifest Interactive cases.

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Table 3.4
Co-production of knowledge and main drivers explaining the interaction pattern.

	Co-production of knowledge?	Pattern
CH-UIT1	No: change of business model (now providing development services to third party), uneasy personal relations	MS
CH-UIT2	Yes: creation of dynamic capabilities, and knowledge (defining, solving problems), joint publications	MI
CH-UBio1	No: only equipment sharing, no potential for interaction	MS
CH-UBio2	Yes, but limited in time: cooperated while they shared the same location, joint Ph.D. supervision	DS
CH-UBio3	Yes: joint research, large involvement of university personnel in the spin-off	MI
CH-MTRI1	No: exchange of resources without cooperation due to the parent having stopped research in the field of the spin-off	MS
CH-MTRI2	No: competitive concerns due to CEO although shared research interests. After SO management change, renewed interest in cooperation	MS
CH-MTRI3	Yes, but limited in time: until the parent shifted its research agenda, jointly developed expertise and knowledge, transferable to other fields	DS
CH-MTRI4	Yes, but limited in time: cooperated until change of management and agenda at the parent, jointly developed knowledge, transferable to other fields	DS
CH-UApp1	No: some projects received from UApp, but downstream developments 'outsourced' by UApp	MS
CH-UApp2	Yes: joint work carried out at the University (R&D outsourcing), the firm only had a CEO, no employees	MI
CH-MRI1	Yes, but fluctuating: informal, regular discussions of problems, joint development of project proposal	MI
CH-MRI2	Yes, but delayed: particular knowledge of spin-off was necessary for applied project	DI
FR-COMP1	No: exchange of personnel without cooperation; competition without conflict	MS
FR-COMP2	Yes, but fluctuating: stronger when they are cooperating on a project	MI
FR-COMP3	No: only equipment sharing, no joint interest in cooperation due to change in parent's research agenda	MS
FR-TEL1	No: only equipment sharing, due to clear division of labor; however, informal relations are maintained	MS
FR-TEL2	Yes, but limited in time: cooperated while a Ph.D. student was at the firm, change of priority of the spin-off after	DS
FR-TEL3	No: Only equipment sharing through contractual arrangement, however informal relations are maintained	MS
FR-ELEC1	Yes: after first year, joint creation of knowledge based on parent technology	MI
FR- ELEC2	Yes, but delayed: after 10 years, joint research conducted on both sites, synergetic relation	DI
FR- ELEC3	Yes, but fluctuating: joint research as basis for collaboration—informal contacts in between	MI
FR-BIO1	No: only equipment sharing and scientific environment (support from the parent)	MS
FR-BIO2	Yes, but delayed: after 4 years of support from parent, a scientific collaboration and joint knowledge were developed when firm large enough	DI
FR-BIO3	Yes: creation of knowledge (joint patents), but did not imply any interaction	MS

Note: MS=manifest segregative; DS=delayed segregative; DI=delayed interactive; MI=manifest interactive.

interactions actually take place, or what their intensity is. Indeed, interactions are understood as actual contacts between members of the research institution laboratory and members of the spin-off firm, having to do with the work carried out in both organizations. This is important to differentiate for example whether a joint research project actually implies regular cooperation or not. The evaluation of the interaction intensity thus requires taking into consideration the *informal* elements extracted from the qualitative material.

We considered as *high* intensity of interaction all cases where interactions between members of the research unit and the spin-off took place on a regular, rather continuous basis, i.e. every other week or more often. This may occur in the course of joint research projects or in the form of regular informal meetings where people discuss on-going work, for instance, if the spin-off resides within the premises of the parent organization, or if close personal contacts continue after the spin-off creation. Regular interaction is also likely to happen, if academic staff participates in a spin-off, either in the actual operation of the spin-off or as a board member. *Medium* interaction intensity means that interaction occurs occasionally, not on a frequent regular basis. For instance, a master thesis is conducted in cooperation with the spin-off at a certain time, a research lab member is recruited a couple of months later, a joint project is conducted in a certain period of time, but at other times no cooperation takes place. If interactions take place even more rarely, but still take place once in a while, we speak of *low* intensity of interaction. No interaction implies that no interaction can be identified, which is of any relevance to the research groups academic work.

For identifying the relational dynamics, we constructed a diagram (see Figs. 1–4) representing the evolution of the interaction level over time for each SPP. The vertical axis of the graph represents the interaction intensity and the horizontal axis represents absolute time (years from the official creation of the start-up firm). In a second step, we examined for each SPP, whether co-production of knowledge has taken place and if so, over which time span. For this assessment, we used statements of the interviewees reporting on joint learning and information on tangible results and processes as joint publications or joint cooperative research projects. We also uncovered from the interviews the main drivers explaining the interaction patterns and knowledge production processes. The output from this last stage is reported in Table 3.4. This enabled us to relate the intensity of interactions to the potential output (co-production of knowledge) as well as observing how these two elements evolve over time. This inquiry gave us a good overview of the nature of the SPP relationships over the course of the entire spin-off process.

4. Typology of dynamic patterns

While the relational trajectories of the different SPPs show a lot of variety in their details, we could clearly identify four major patterns (see Figs. 1–4). In order to avoid linking particular modes of interaction *a priori* with particular modes of knowledge production, we chose to characterize the patterns by terms referring to the patterns of interaction only. Segregative patterns refer to patterns which showed a declining or initially low interaction intensity, and interactive patterns to those with a sustained high or increasing interaction intensity. If and how particular interaction patterns were related to particular modes of knowledge production was a second consideration, as just explained.

The first observation to make is that we identified both segregative and interactive patterns (respectively 15 and 10): What is more, very few pairs have a stable intensity of interaction over time. Many present a declining interaction intensity and some even an increasing intensity, with smooth or irregular variations. Within the segregative cases (i.e., a declining intensity of interactions), two groups can be identified: one in which interactions are always low or decreasing (11 pairs), and another group of four pairs that are characterized by a decrease in interaction intensity 4 or 5 years after the creation of the firm. We refer to the former group as "*Manifest Segregative*" and the latter as "*Delayed Segregative*". Similarly, within the interactive cases (i.e., the ones with sustained high or increasing interaction intensity) we also find two patterns. One in which the interaction intensity is always high (seven cases) and a second in which the

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interaction intensity becomes important only a few years after the creation of the firm (three cases). We refer to the former group as "*Manifest Interactive*" and the latter as "*Delayed Interactive*". Table 4.1 presents the distribution of cases in these four categories.

What is important, not all interactions lead to a co-production of knowledge: if interaction is restricted to the use of shared equipment, transfer of personnel, small contract research among the partners confined to the outsourcing of particular activities, or occasional master theses, they are not necessarily supporting the creation of new knowledge. However, interactions based on joint research are often associated to the creation of knowledge in the form of a patent, a publication, a product or in the form of joint learning, which may affect further activities beyond the concrete project. In order to understand better the diversity of interaction intensity dynamics, we cross-referenced our four groups with the indicator of co-production of knowledge. Thus, we were able to see if similar interaction *dynamics* can be explained by similar *types* of interactions and if they lead to specific knowledge creation processes.

4.1. Manifest segregative pattern

The first group of case studies exhibits a combination of a sharp decrease in the level of interactions between the parent organization and its spin-off (see Fig. 1) and the absence of a co-production of knowledge. This manifest segregative type corresponds to the theoretical expectations of a linear innovation model. While some cases show a middle or – rarely – high interaction intensity in the first 1 or 2 years which can still be considered as the creation phase, most start from a rather low initial level with interactions steadily decreasing.

Looking more deeply at the firms belonging to this group, we notice a clear-cut separation between the research organization and the firm right from the beginning, in terms of personnel as well as in terms of activity. There is no long-term participation of academics in the spin-off; the founders of the spin-offs are often former Ph.D.s or Postdoctoral researchers, who decided to commercialize the results of their research rather than trying to get a position as a professor (CH-UBio1, FR-COMP3 and FR-TEL1). They used the knowledge developed in academia to create the firm when their contract as a researcher ended. In the case of CH-UApp1, occasionally results of university projects were transformed into marketable products. In another case (FR-BIO3), the spin-off was created when the research phase was finished and the role of the firm was only to put the product on the market.

In the few cases (CH-UIT1, CH-MTRI1, CH-MTRI2 and FR-BIO1) where the initial level of interactions was middle to high, this was due to a more open support of the parent laboratory during the creation phase of the start-up: a researcher may help the spin-off during the first year, the laboratory may lend technical supplies to the firm, etc. Here, the intensity of interactions smoothly decreases over the life-cycle as the firm develops and concentrates on the commercialization of the product. As a consequence, most resource flows are directed towards the firm, while the parent organization gains only in terms of reputation.

Furthermore, in five cases (CH-UIT1, CHUBio1, CH-MTRI1, FR-COMP3 and FR-TEL1) there is no potential for interaction since the spin-off and the parent unit do not share similar research interests. It is either due to a change in the parent unit's research agenda (CH-MTRI1 and FR-COMP3) or to a lack of interest of the firm in research (FR-TEL1). In the very particular case of CH-MTRI1, the whole academic research group was deliberately transferred to the spin-off and the research institute stopped its activities in this research field. Therefore, the firm had no appropriate academic counterpart in the parent organization anymore, which largely prevented opportunities for joint research.

Thus, in all 11 case studies corresponding to this manifest segregative pattern, we find no evidence of co-production of knowledge. In most cases (eight out of 11), interactions are only due to the institutions' rules about basic support for spin-offs, allowing the newly created firms to take advantage of facilities and equipment of the parent organization during the first months of its activity. The exchanges are sometimes imposed by the administration rather than initiated by the parent unit. In three particular cases (CH-UIT1, CH-MTRI2 and FR-COMP1), the lack of interactions is due to a conflict between the parent unit and the spin-off firm: despite both partners being aware of the opportunities of collaborating, they decided not to follow this path because of competition or conflicts among personnel. For instance, uneasy personal relations were observed within the CH-UIT1 pair. In the case of CH-MTRI2, the CEO canceled joint projects initially approved and blocked further joint work. Thus the potential for collaboration was in both cases underplayed, which led to a detachment of the firm from its parent unit. Finally, in the case of FR-COMP1, the creation of the spin-off disorganized the parent's research team as three out of 12 researchers left the parent unit to go work at the firm.

4.2. Delayed segregative pattern

Within the delayed segregative pattern, we observe a sharp decrease in the interaction level after 4 or 5 years of sustained interactions (see Fig. 2). In the four cases belonging to this type, the overall dynamics are segregative over the long term, but showing a high initial level of interaction. At least initially, the conditions for cooperation were met. Compared to the manifest segregative type, the decline in interaction intensity happens later, mostly around the fourth or the fifth year after the creation of the firm. Two alternative explanations can account for such radical change: a longer process of detachment from the parent organization, or the occurrence of a negative event preventing cooperation from continuing.

A longer process of detachment from the parent organization is partly explained by the need for the firm to reach a critical size in order to become autonomous (as for CH-MTRI4), or by a particular event extending the period of interaction, although the decoupling could in principle have happened before (as for FR-TEL2). In the case of CH-MTRI4, an expected change in the benefits and resource flows deterred the spin-off from maintaining an intense relationship with its parent organization. After 4 years of collaboration the firm decided to focus on its internal growth and R&D while the parent unit transformed its agenda and personnel. The growth of the firm allowed it to have in-house research and be attractive enough to access alternative research partners. Members of the

Table 4.1
Distribution of cases within the four interaction patterns.

	Segregative pattern		**Interactive pattern**	
	Manifest Segregative (MS)	Delayed Segregative (DS)	Delayed Interactive (DI)	Manifest Interactive (MI)
Number of cases	11	4	3	7
	CH-UIT1	CH-UBio2	**CH-MRI2**	**CH-UIT2**
	CH-UBio1	**CH-MTRI3**	**FR-ELEC2**	CH-UBio3
	CH-MTRI1	**CH-MTRI4**	FR-BIO2	**CH-MRI1**
	CH-MTRI2	**FR-TEL2**		**CH-UApp2**
	CH-UApp1			**FR-COMP2**
Legend	**FR-COMP1**			**FR-ELEC1**
	FR-COMP3			**FR-ELEC3**
IT cases	**FR-TEL1**			
BIO cases	**FR-TEL3**			
Micro/Nano cases	FR-BIO1			
	FR-BIO3			

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spin-off expected that, from then on, knowledge transfer would become asymmetrical in that it would mainly flow in the direction of the parent. In turn, already after the first year of development of FR-TEL2, the research dimension, which was more essential and significant at the beginning, diminished when the market dimension increased, and exchanges became mainly informal. Still interactions remained at a medium level for another three years due to the presence of a Ph.D. student, even if at the time other research collaboration had ceased. For the other two cases, the sudden decline in interaction intensity is due to events preventing the initial collaboration from being maintained. The relationship's cut-off was initiated by a change in the parent organization structure or area of research, for both CH-UBio2 and CH-MTRI3. After the shift of research agenda, interactions revolved solely around the use of equipment on a contractual basis with spin-off employees, although the firm would have been interested in keeping up intense interactions.

While we observe heterogeneity in the reasons underlying such change in interaction intensity, in all cases the first years of intense interaction activated co-production of knowledge in the pair, until the interaction intensity dropped. The relationship then either was completely cut or remained limited to equipment sharing.

4.3. Delayed interactive pattern

In the three cases following a delayed interactive pattern we observe a low level of interactions for a couple of years or, as in one case (CH-MRI2), a sharp decrease of interaction intensity after the initial creation phase, which would correspond to a segregative pattern. However, after a number of years the interaction intensity increases clearly and co-production of knowledge, usually in the form of joint projects, is taking place. So, similar to the delayed segregative pattern we observe a major change in interaction intensity and modes of knowledge production at an advanced stage of the spin-off. However, the change goes in the opposite direction—contrary to conventional wisdom that interaction intensity of SPPs usually declines over time.

For the two firms FR-ELEC2 and FR-BIO2 joint research was put in place only when the firm reached a critical size (Fig. 3). Hence, these cases do not contradict the description of a firm life-cycle but give a different interpretation to it: while in the delayed segregative cases the implementation of in-house R&D was synonymous of detachment from the parent, in the case of FR-BIO2 it meant that the laboratory could finally interact with a viable partner. After a first phase of crucial support from the parent to the spin-off, the French Bio Institute also benefited from the relationship through a joint scientific project. In the third case interaction is more circumscribed: CH-MRI2 was founded in order to 'outsource' activities, which were considered to be not research intensive enough anymore to be carried out at the institute itself. CH-MRI2 and its parent unit had agreed on a clear division of labor although maintaining many informal contacts and sharing the same building. Still, the firm supported its parent unit on working on an a particular issue of an applied research project a few years after the creation. The collaboration was therefore based on the complementarities of the partners' skills and the continued informal interaction over the years; however it was limited in time.

What is striking is that in all three cases, when the conditions for co-production of knowledge were met (complementarity of skills and similar research agenda), the spin-offs decided to collaborate with their parent organization *rather than* another research organization. In the French cases we can even consider that the parent organization was *waiting* for its spin-off to grow in order to finally start collaborating. The founders of FR-ELEC2 invented a technology at the research organization and then licensed it exclusively to the spin-off. After 10 years and a thriving development of the firm, a large research project was conducted on both sites. The reason why the firm went back to its parent unit after so much time can be explained by the monopoly of knowledge in this very specialized area. Both partners developed a synergetic relationship ever since, partly through the research center they jointly created. Finally, in the French cases, the scientific collaboration was materialized in a joint contract (within a local cluster or a European program).

4.4. Manifest interactive pattern

This last group of seven case studies corresponds to a sustained high level of interactions (Fig. 4). The evolution of interactions can be steady or sometimes fluctuating. The presence of fluctuations in the interaction level over time reveals that the interaction intensity is highly dependent on joint projects, as in the cases of CH-MRI1, FR-COMP2 and FR-ELEC3, as well as exchanges of personnel or double staff appointment (as for CH-UIT2, CH-UBio3, CH-MRI1, CH-UApp2 and FR-COMP2). As suggested by Johansson et al. (2005), informal relations maintain the link between the partners in periods when no formal collaboration takes place (as for CH-UApp2 and CH-MRI1). When a new opportunity for joint work appears they are able to resume their collaboration. Instead, the interaction intensity is steadily high in the cases of CH-UIT2, CH-UBio3 and FR-ELEC1: both members of the pair co-evolved over time.

Frequent and intense relations are synonymous of joint projects in all cases studied here, in the form of European or national contracts based on joint research between a University and an industrial partner. Such collaboration therefore helps raising third party funding. Besides joint projects, patent transfer or sharing is important for explaining the sustained interaction in the cases of CH-UBio3, CH-MRI1, CH-UApp2, and FR-ELEC1, though we do not investigate the role of technology transfer professionals here (Kidwell, 2013). Still, joint knowledge production and long term opportunities can motivate long term relationships without any short term benefit (CH-UIT2 and CH-MRI1). Many parent units profited from the interaction with their spin-offs through learning effects and knowledge spillovers. For parent units focusing on basic research, these included for instance the identification of relevant research problems, for those focusing on applied research, knowledge from application domains and customers was important. For both, knowledge developed in the context of a common activity could sometimes be transferred to other fields.

Still, if such collaborations, exchanges and joint production of knowledge are considered essential for CH-UIT2 and FR-ELEC1, results fell short in the case of CH-UBio3: this research-oriented spin-off acted as an independent research group within the University. When the parent unit was closed, the academics involved in the spin-off were moved to other units and the research team fell apart. The founders chose their scientific career over their involvement in the firm. In this case, the close relationship meant that the disrupting event affecting the parent organization had a similar effect on the firm. It reveals the risks involved in the creation of a strong collaboration as well as the difficulties of long term double appointment. However, in the case of CH-COMP1, the relationship survived the entire replacement of the parent team.

5. Discussion

The empirical analysis proved our initial assumption of the co-existence of different modes of technology transfer related to distinct interaction patterns. In addition, our results show that

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interaction patterns and modes of technology transfer may change over time. Further, changes do not necessarily imply a decrease in interaction intensity, but might just as well imply an increase. Interestingly, we did not observe alternating trajectories with multiple changes between modes of technology transfer. An interpretation of this may be that - while patterns of interaction and modes of knowledge production are not fixed - they nevertheless exhibit a certain inertia, which makes frequent switches unlikely. We furthermore found that changes were not only due to the dynamic development of the spin-off, but also to developments on the side of the parent unit, for instance changes of its research agenda. Overall, while developments of interaction patterns mostly did not come as a sudden surprise to the partners, they were often the result of the interplay of various factors and not foreseeable over the longer term.

Before we reflect on the implications of these findings, we now turn to an analysis of the determinants that may affect how a pair interacts over time. Possible determinants may be external to the SPP, such as the institutional or national environment in which they are embedded, or internal to the SPP.

As for the *national context*, the distribution of case studies is quite regular between patterns and countries (see Table 4.1). We observe the whole range of dynamics in France as well as in Switzerland. Our sample is too small to be representative at the national level and we cannot claim that it adequately represents the distribution of patterns in each country. Still, this study reveals that the national context is not a firm obstacle to any of the patterns and we may speculate that other influences might be more crucial. Similarly, we also observe a broad variety of dynamic patterns for the specific *types of research organizations*, such as universities or public research institutes, which differed significantly with regard to mission, structure of staff, etc., or even for specific parent units. So, this indicates as well that characteristics of the SPP are probably more important for shaping the interaction patterns than external conditions. This is not to be mixed up with the question of whether or not the institutional setting affects spin-off creation as such.

With regard to the different *technology sectors*, our sample suggests that spin-offs in the field of information technology more often develop segregative patterns, whereas interactive patterns seem to be more common in micro- and nanotechnology. This confirms our assumptions made in Section 2. Biotechnology cases distribute evenly between those being manifest segregative and those entailing interactive patterns, at least over a couple of years. In a way, this is in accordance with the unclear positioning in literature (see Section 2). In line with what we expected, sharing of research equipment is an essential element in biotechnology and micro/nanotechnology, but much less so in information technology. Also, patents are less common in the information technology cases than in the biotechnology and micro-/nano cases. Overall, the assumption that technology sectors do matter for interactions between SPPs, is corroborated.

As expected, the similarity of *research interests* is a crucial condition for scientific collaboration. Whenever we observed a major change in the research agenda of one of the partners, it was accompanied by a major change in interaction intensity. If such events happened right at the creation of the spin-off, we observed a manifest segregative type of dynamics (FR-COMP3 or CH-MTRI1); when it happened later, we observed a delayed segregative dynamic pattern (CH-MTRI3 and CH-MTRI4). While seemingly occurring less often, a change in the *business model* of the spin-off can have the same effects, if the interest of collaborating changes fundamentally (CH-UIT1). The strategic value of the parent organization to the firm also depends on its internal capacity to develop research: once the spin-off reaches a critical *size* allowing it to build up its own R&D department (in terms of personnel and equipment), the need for cooperation may become weaker. In the case studies we observed, however, that the parent can then start interacting with its spin-off as well (as for the delayed interactive case FR-BIO2). In our case studies we have found that below a threshold size, biotech firms needed the technical support of the parent, because the cost of equipment is very high. For example, FR-BIO2 became valuable to its parent organization only when it acquired its own resources. In other words, when the potential benefits to the relation became symmetrical, the parent became interested in starting a scientific collaboration with its spin-off.

Adding to the elements described up to now, it is important to remember that we are considering not only how organizations are linked, but also how people create and develop *personal relationships* with one another. Literature on scientific collaborations takes this element into account by putting forward the importance of informal relations as a prerequisite for formal collaboration (Johansson et al., 2005). Our case studies reveal that both types, informal as well as formal relations, are at least complementary. Informal links play an important role in trust building as a basis for future formal relations or in maintaining the link when the partners are not directly working together. In that sense, informal meetings are crucial in long term relationships. What matters in the success or failure of a relationship is also the ability to manage conflicts and competition issues. Some segregative cases such as CH-MTRI2 and FR-COMP1 portray how much such conflicts can hinder the exploitation of a latent interaction potential. Instead, in the CH-MTRI4 case, the ability to repeatedly renegotiate the respective fields of activity of the partners has been considered as an important element in maintaining successful interactive relations, at least for a certain period.

6. Conclusion

Looking at the evolution of interactions between spin-offs and their parent unit after the creation of the firm, we have found that both the segregative and interactive models coexist and sometimes even follow one another. This confirms that a purely linear understanding of spin-offs as a unilateral transfer mechanism is too narrow, but it shows also that a co-production of knowledge view on spin-offs as hybrid intermediaries between academia and industry alone is too idealized as well. In our study, we could not investigate all details of the knowledge production process; still, our findings are in line with an understanding of new modes of knowledge production which sees a 'mode 2' type of knowledge production as an empirically important mode, but which does not completely substitute a more linear 'mode 1' type of knowledge production (Gibbons et al., 1994; Hessels and van Lente, 2008). Furthermore, our findings can be interpreted as supporting the assumption that the importance of the different modes of knowledge production varies between disciplines. However, given the small size of our sample and the limited set of disciplines considered we have to be cautious about such interpretations.

Our study also provides new elements to be considered by the theory, which call for further research. While management-oriented spin-off literature mostly focuses on issues related to the creation and early development of the firms (for an overview see Djokovic and Souitaris (2008)), our results clearly suggest that the longer-term development of relationships deserves attention as well. Furthermore, the contingent dynamics we observed over the longer-term development of spin-offs is congruent with a non-linear dynamic that cannot be captured by sequential stage models. However, contingency does not mean arbitrariness—changes of modes are less common than staying within one mode, and no alternating modes could be observed. This may be due to

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path dependencies. For instance, once research agendas of the partners de-align for some reason and interactions loosen, realignment may not be very likely, whereas continuous interaction may support alignment of research agendas. More detailed in-depth studies would be necessary for investigating this. Given the explorative nature of our study, there are a number of limitations to be mentioned. We could conceptually and empirically identify a number of determinants affecting interactions. For a more thorough analysis, however, quantitative analyses of a larger sample indicating their relative importance, as well as qualitative studies investigating dynamics of collaboration in more detail, would be needed to derive more specific policy implications. Furthermore, we collected the data by means of retrospective accounts, which implies potential drawbacks with regard to how much interviewees might recollect and how biased their perceptions may be. Instead, a longitudinal study of the development of SPPs over time would enable the investigation of the dynamics more thoroughly and in a more robust way. The time spans of major changes observed in our study suggest that a panel study over a period of at least 5 years would be required to capture the relevant developments.

Regarding policy and practice implications, our study shows that the model which is most adequate for a specific SPP – at a given point in time, and if this is actually realized – depends on a number of intermediating variables. For spin-offs and their parent organization these findings have important implications. As we have seen, in a minority of cases the partners stated to be dissatisfied with the factual pattern of interaction, for instance if potentials for a mutually beneficial co-production of knowledge could not be realized due to competitive concerns. These findings clearly show that the management of the long-term development of relations between spin-offs and their parent unit can be crucial, and is an all but trivial task. Proper management thus requires (1) determining what would be an adequate pattern for a given pair, (2) identifying what is necessary to realize it and how this can be achieved and, (3) since conditions may change, strategies may have to be reconsidered over time. This is all the more important because interactions matter for the development of the firm, just as for the parent unit. Within the limits of this article we could demonstrate the actual importance of interactions for the partners only in an indicative way by showing its tight link with the knowledge production of both partners. A more thorough analysis for the parent organization is provided elsewhere (Konrad et al. 2009; Zomer et al., 2010; Zomer, 2011), but a detailed analysis for the spin-off would be an important task for further research.

From the perspective of policy and technology transfer institutions, our findings imply that institutional frameworks and support measures should allow for different patterns to unfold without enforcing any of the modes. For instance, our results suggest that frameworks, which allow academic staff to participate in spin-offs, may be useful to facilitate interactive relationships over a longer time. As for support from technology transfer offices, it should be considered to which extent and how these services might also support the management of interactions, for instance the management of expectations of spin-off and academic staff about interactions, the support of joint projects or the management of related conflicts.

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