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

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Abstract

Two seemingly contradictory interpretations of academic spin-offs' potential benefits are presented in the literature: according to one view they are seen as an outreach activity of academic research, leading to regional economic growth. The other view sees spin-offs as the harbingers of a new model of societal knowledge production, creating a synergistic synthesis of academic science and industrial research and development. In this paper, we examine the dynamic patterns of interactions between academic spin-offs and their parent organizations over a mid- to long-term period (4-10 years) and compare the observed patterns to ideal-type patterns that would be in accordance with either of the two interpretations. Empirically, the paper draws on a series of 25 intensive case studies of spin-off/parent organization pairs from France and Switzerland. We show that a broad range of relational trajectories can be identified. Both models found in the literature are empirically relevant. In addition, the intensity of exchanges and forms of knowledge production within a pair can be subject to change depending on dynamics internal or external to the pair. We conclude that management of spin-off processes and support policies for academic spin-offs should embrace this high dynamic diversity.

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1. Introduction

Due to their emblematic quality, academic spin-offs have received increasing attention in various literatures such as 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 the assumed widening gap between scientific research and economic exploitation and by this increasing the contribution of science to innovation, and ultimately economic and societal welfare. The hopes attached to spin-offs can be related to two largely diverging perspectives on the structure and deficits of the current science-industry interface. Following a 'linear' innovation model, spin-offs are a very effective means for 'transferring' knowledge from the lab into the economy (Rothwell, 1994)[2]. In this view, one may basically expect a unilateral transfer of a more or less confined set of 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. Following an early incubation phase, there would be no need for further substantial interaction. The second view maintains that knowledge production is undergoing a fundamental paradigmatic change in science and industry (Gibbons et al., 1994). The emerging 'mode 2 knowledge production' being characterized by much more hybrid competence profiles both from academia and industry and has therefore been called the co-production of knowledge model. In this latter view, spin-offs may be seen as palpable candidates for exemplifying this new mode of knowledge production. We would then expect rather a continuous exchange of knowledge or a joint production of knowledge, with strong and long lasting interactions between spin-offs and their parent organizations.

These diverging interpretations suggest different policy and management advice on how to support academic spin-off processes. Whereas the linear knowledge transfer model recommends to focus on the creation phase and to set up incentives for quick separation, the co-production of knowledge model would propose to improve conditions for sustained and mutually beneficial collaborations.

The existing empirical literature on spin-off processes gives somewhat contradictory evidence, 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 phase (Johansson et al., 2005). These interactions may imply the transfer of personnel, the exchange or joint use of resources or they may be related to collaborative projects. Thus, we assume that the two views represent two ideal type models which may co-exist and ask what explains the prevalence of one of the two relationships. This is supported by

[2] For a detailed description of the construction of the concept, see Godin (2006)

former studies showing that interactions with the academic sphere may vary for different types of spin-offs (Stankiewicz, 1994; Rappert et al., 1999).

What is more, as the literature amply shows, spin-offs are no static entities, but evolve and transform over their lifecycle (Klepper, 1996; Spender, 1996; Perez and Sanchez, 2003; Clarysse and Moray, 2004; Druilhe and Garnsey, 2004; Vohora et al., 2004; Johansson et al., 2005). This is likely to influence the interactions with the parent organization. In addition, as pointed out by Rasmussen and Borch (2010), although the academic context is often considered as fixed, the development and learning of the research unit the spin-off originated from may introduce a further dynamic. Due to the interplay of both, the actual evolvement of interactions over time may be hard to predict in advance. In order to be able to capture this complexity, in this paper we take a dynamic and longitudinal perspective on interactions between spin-offs and their parent organizations.

More specifically, we examine how the interactions evolve over the mid- to long-term (4-10 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. Do we observe specific patterns which correspond to the abovementioned models of science-industry interaction? We analyze these questions with a sample of 25 qualitative case studies of French and Swiss spin-off-parent organization (SO-PO) pairs chosen from the domains of information technology, biotechnology and micro/nanotechnology.[3] For the parent organization we focus on the department or research group from which the spin-offs originated, because interactions are largely taking place at this level.

In so doing, we expect to develop a more differentiated understanding of conditions that shape the relationship between spin-offs and their parent organizations. Our study thus contributes 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 elaborate the literature on science-industry interactions, from which we derive two explanatory frameworks for expected spin-off dynamics. In the third section, we will introduce the methodological approach, our empirical sample and specify the operationalization of the core variables that characterize our case studies. Section four analyzes the observed interactions and proposes four ideal type dynamic patterns for spin-off/parent organization dynamics. Section five discusses a set of explanatory variables that could differentiate between the dynamic patterns. Section six concludes by reflecting on the academic, management and policy implications.

2. Conceptual framework

[3] These case studies have been conducted within the EU-funded project *Production of Knowledge Revisited: The Impact of Academic Spin-Offs on Public Research Performance in Europe* (PROKNOW).

The linear knowledge transfer model is based on an understanding of the science-industry interface as a contact zone between largely incompatible societal sub-systems. The idea of a strong separation between the public science system and the private economic sphere has in particular been put forward by Mertonian sociology of science (Joly and Mangematin, 1996; Shinn, 2003). Merton's framework induces a double dichotomy between science and technology on the one side and public and private research on the other. Rothwell (1994) indicates that since the 1950s, the industrial innovation process was perceived as a linear progression from scientific discovery to the marketplace, calling for a clear-cut division of labor between academics and firms. Moreover this dichotomy was due to a cultural hostility between science and the commercial sphere (Stankiewicz, 1994).

This model has been challenged by showing that innovation processes often progress in a non-linear way (Kline, 1985) and the observation of a general tendency towards a blurring of boundaries between the academic and industrial knowledge production processes (Gibbons et al., 1994; Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2002). In non-linear models of innovation as depicted by Rothwell (1994) or by what Kline and Rosenberg (1986) call the "chain link model", innovation is seen as a dynamic process of joint creation, with backward flows of information and no clear-cut division of labor between academic laboratories and firms (Joly and Mangematin, 1996). As a consequence, public and private research are linked by a complex system of interactions and knowledge flows, and university-industry spheres increasingly start to overlap.

Depending on the specific account of the relationship between academic and industrial knowledge production and its recent evolvement, academic spin-off processes may be interpreted as radically different phenomena: in the linear knowledge transfer model the academic and industry spheres have different interests, skills, products and performance criteria and therefore are not called to work too closely together (Autio, 1997). A blurring of spheres might distract both partners from focusing on their core tasks, e.g. might lead academics to neglect basic research or even become biased (Krimsky, 1999; Krimsky, 2006) and spin-off founders might not fully adapt to the challenges of developing a growth-oriented business. As a consequence the basic challenge of spin-off processes is to manage the passage from one societal system into another as quickly and seamlessly as possible. The opposite view rather presents the science-industry frontier as a place for co-production of knowledge, where differences are largely evaluated as potential complementarities. The interface between the academic and the industrial realm are therefore fraught with shared interests and potential synergies. Academic spin-offs, represent a phenomenon with a particularly high fit for a co-production of knowledge constellation, due to the overlap of core research interests, shared epistemic preferences and complementary access to diverse knowledge stocks. Therefore, spin-offs may constitute a sort of ideal-type intermediaries for bridging academia and industry (Etzkowitz and Leydesdorff, 2000).

Seen from a dynamic point of view, within the linear model a quick separation from the parent organization or a fading process is expected, and seems most beneficial for both partners. This assumption 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. Authors like Clarysse and Moray (2004), Perez and Sanchez (2003) or Ndonzuau et al. (2002) have conceptualized a spin-off life cycle, as composed of several successive stages of development, from the creation to the commercialization of the first product. As a rule, the spin-off's business priorities as well as its co-operations change a lot over the first years after creation and provide a natural development process from technology focused R&D towards a more product and customer-oriented innovation mode. Interactions with the academia might then be relevant mainly in the early stage. Interestingly, these models conceptualize the spin-off as a dynamic entity, whereas potential dynamics of the parent organization are not considered.

Already the use of the expression "parent organization" pinpoints to a specific relational pattern: parent organizations are expected to provide their "offsprings" with research equipment, advice and space, transferring intellectual property rights, skills and competences, or even access to potential partners from their own network (Mustar et al., 2006). In the longer run – as resources are expected to flow mainly from the parent to the spin-off – it is likely that the parent cannot afford the costs of supporting the spin-off for a very long time and therefore have all interest of dissociating with their spin-off as quickly as possible. Several studies have furthermore shown that the gains for the parent are mostly of a non-pecuniary kind. They rather provide reputation and legitimization of their activities which are provided by the mere fact that a spin-off has been created at some point in time (Konrad et al., 2009; Zomer et al., 2010).

According to the co-production of knowledge view, collaborations between spin-offs and parent organizations are potentially beneficial for both partners by providing access to complementary knowledge sources and by opening access to new funding sources. The academic institution would choose its spin-off as a preferential industry partner, since it is particularly likely to have an adequate knowledge base for joint learning. Indeed, it exhibits at the same time a high overlap resulting in a high absorptive capacity and the necessary diversity to allow new learning (Cohen and Levinthal, 1990). A high absorptive capacity is likely to result from a shared cultural and educational background and similar research interests. Proximity and established personal links, trust relations and joint tacit knowledge are likely to be additional complementarities (Polanyi, 1962; Leonard and Sensiper, 2000; Johansson et al., 2005). At the same time, over its lifecycle the spin-off is likely to develop a diverse

knowledge base of its own. All these elements position the spin-off as a preferential partner for the parent organization and might lead to tight collaboration long after the foundation process has been completed. This relationship may then be backed by formal collaborative agreements, double appointments, or other informal exchanges. This model has found empirical support by some studies showing sustained linkages over longer time frames. Some give a detailed analysis of a small number of such cases (Johansson et al., 2005; Shinn and Lamy, 2006); further studies have observed this at least for part of the spin-offs in their respective samples (Mustar, 1997; Rappert, 1997).

On the other hand side, long term relationships can lead to growing interdependence, as source of synergies and knowledge creation, but also, as creation of asset specificity and knowledge monopoly. The risk for the firm is to become totally dependent on the idiosyncratic knowledge of the parent, would it be anterior or posterior to the creation of the spin-off. In that case, switching costs (the cost to change partners) become so huge that they prevent the firm from making its own decisions anymore (Riordan and Williamson, 1985; Parhankangas and Arenius, 2003; Johansson et al., 2005).

The two perspectives on the role of spin-offs in science-industry knowledge development processes provide two opposing predictive frameworks for how spin-off processes should unfold over time. The linear knowledge transfer model essentially predicts a continuous decoupling of the spin-off from its parent organization as the spin-off develops, becomes more autonomous, and diversifies its activities. This could be measured by a downward trend of the interaction intensity, leading to few or no interactions after the creation phase, although the process can be more or less rapid and more or less monotonous. Instead of a smooth distancing we can also expect a series of downward jumps corresponding to a sequence of development phases and therefore of interaction patterns. Moreover, the resource flows are expected to be predominantly oriented from the parent to the spin-off. We refer to this dynamic pattern as "*segregative*".

In the co-production of knowledge model, on the contrary, we expect rich and sustained exchange and collaboration activities between the spin-off and its parent organization. Rich because they will not be limited to financial resource flows, but will contribute to the creation of new knowledge and other capacities. Furthermore, we would expect the collaborations being maintained under or even giving rise to changing research and development priorities on the side of the parent organization and/or the spin-off. Therefore, we may expect a high level of interactions at the beginning and a longer phase of stable or even increasing interaction intensity over the longer term. We refer to this second dynamic pattern as *"interactive"*.

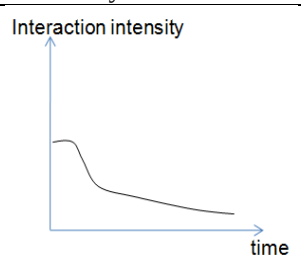
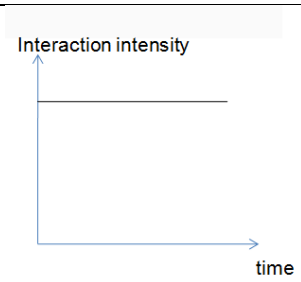
Knowledge production model	Predicted SO-PO interaction dynamics	
Linear knowledge transfer - Limited shared research/ commercialization interests. - One way flow of resources - Decoupled development	**Segregative**: - interactions decrease over time - starting generally at a low level	
Co-production of knowledge - Synergies in research/ commercialization - Two way flow of resources - Mutual determination of research/ development priorities	**Interactive**: - interactions remain relatively high over extended periods of time - may de- or increase over time and change in quality	

Table 1: Predicted dynamic patterns of spin-off (SO) and parent organization (PO) according to the linear knowledge transfer and the co-production of knowledge model.

At first glance, these models seem quite deterministic in terms of dynamics: either we should observe a steady decrease in interactions over time or a sustained high level. From this we would expect that everything is determined at the creation of the spin-off. The relationship would fall in one or the other category (segregative or interactive) given the fundamental characteristics of the partners and the environment. However, when we look at some of the elements advocating for a looser or a closer connection between the spin-off and its parent mentioned above, such as potential complementarities and shared research interests, availability of research equipment, proximity and personal links, we may expect that these are dynamic variables changing over time. Hence, the conditions and relative benefits and costs of the relationship for both partners can evolve and trigger a change in its nature and intensity. Moreover, we assume that not only the spin-off should be expected to evolve, but just as well the parent organization, in particular the department or research group the spin-off originated from, which is likely to be the primary partner in interactions. 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 spin-off parent pairs.[4]

[4] The study of Johansson *et al.* (2005)comes closest to our approach, but relies on a set of 4 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 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.

The paradigms of the innovation process may also depend on other structural characteristics of the SO-PO pair. For instance they may depend on the type of technology in which the firms are specialized and as a consequence we might expect that these differences affect the types and intensity of linkages. For example, in Biotechnology, the complexity and extreme specialization of the knowledge needed to compete on the innovation frontier calls for a close relationship with the academic field and the time-to-market is typically quite long. Micro- and nanotechnology research is mostly dependent on expensive equipment, which small firms might have to access via the parent organization. As a comparison, research intensity and the need for expensive equipment are typically less salient in information technology.

Furthermore, development of the SO-PO interaction might be influenced by specific characteristics of the national research systems and systems of innovation more general (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 systems differences at the level of types of organizations may even aggregate at the national level.

3. Sampling and operationalization

The dynamics of interactions between research organizations and their spin-offs will be analyzed in the following by drawing on a sample of case studies. We will first specify the empirical sample and the methodological framework before we introduce the core variables.

3.1 Research context and data sample

The analysis relies on case studies carried out in the context of an international research project (PROKNOW) running from 2006-2009 which investigated the impact of the creation and interactions with academic spin-offs on their parent organizations in seven countries. The current analysis is based

on pairs of spin-off companies and their corresponding parent institute from two national surveys conducted by the authors in France and Switzerland.

As noted above, the development of the SO-PO interaction might be influenced by specific characteristics of the national research systems and systems of innovation. Countries' institutional setting and regulation might provide support or hinder co-production of knowledge between the academic and the industrial sphere. France and Switzerland are rather heterogeneous in their science systems, their approach to supporting spin-offs and in their way to manage science industry relationships.

Traditionally, French universities have had rather weak ties with industry, even if this seems to be changing by now, and employees of universities and research organizations were prohibited to participate actively in a private company until 1999 (Mustar et al., 2008). 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).In some specific sectors strong networks involving research insitutes and the industry have been created (in biotechnology, nuclear energy as well as aeronautics) but the French Government was always the essential driver of such collaborations. Hence, it is probably fair to say, that the institutional and cultural context in France pends rather towards a linear model of science-industry interactions. For Switzerland the situation is less clear. 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. While the national environment may affect science-industry interactions, the institutional framework differs furthermore between types of research institutions, all the more in a federal country as 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. The main criteria for case selection were, however, the intensity of spin-off activity of a research institution in general and in particular the specific institute or department where the firms originated from. In the following we will refer to this organizational entity as parent unit. Therefore our sample is not representative of the national science

systems in a quantitative sense, but it covers well the variety of spin-off active research organizations in the two countries. 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 the theoretical section, we may expect to see differences in the dynamic patterns across these domains given their differences in innovation models as well as IPR practices.

Case studies on SO-PO pairs were based on interviews carried out between 2006 and 2008. The sample is composed of 25 spin-offs created out of 9 research organizations. For each SO-PO pair we conducted between 2 and 4 interviews with members from the parent unit and the spin-off. Each interview lasted between 1 and 2,5 hours 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 considered. However, this seems at least difficult to realize for a time period of in some cases 10 years and more. 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 and the effect and importance of interactions for the spin-off or parent unit. Besides, basic information about the history of the research institution or the firm, the organizational rules and the activities carried out were gathered via desktop research. The material was then synthesized into SO-PO case descriptions on the basis of which the different structural and relational characteristics were derived (see below).

The sectoral composition of the sample is quite balanced with six biotech firms, ten information technology firms and nine firms specialized in micro or nano technologies.

	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 2: Overview on the 25 case studies according to their sectoral and country profile

At the time of the interviews the firms were between four and fifteen years old; we discarded spin-offs that were too young to allow us to analyze the dynamics of their interactions with the parent organization. As presented in table 2, 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).

	Institutional status	Field of research	Spin-off ID	Age
Swiss cases				
Univ IT	University	Information Technology	CH-UIT1	6.5
			CH-UIT2	4
Univ Bio	University	Biotechnology	CH-UBio1	5
			CH-UBio2	8
			CH-UBio3	6
Microtechnology Research Institute (MTRI)	Semi-public research insititution	Micro, nanotechnologies	CH-MTRI1	6
			CH-MTRI2	6
			CH-MTRI3	6
			CH-MTRI4	7.5
Univ of applied science	University	Information Technology	CH-UApp1	6
			CH-UApp2	5
Material Research Institute	Public Research Institute	Micro and nanotechnologies	CH-MRI1	6
			CH-MRI2	5
French cases				
Computer Science Institute	Public Research Institute	Information Technology	FR-COMP1	7
			FR-COMP2	6
			FR-COMP3	9
Telecom Institute	Engineering school	Information Technology	FR-TEL1	8
			FR-TEL2	4.5
			FR-TEL3	8
Electronics Institute	Public Research Institute	Micro and nano technologies	FR-ELEC1	4
			FR- ELEC 2	15
			FR- ELEC 3	6
Bio Institute	Public Research Institute	Biotechnology	FR-BIO1	5
			FR-BIO2	8
			FR-BIO3	8

Table 3: Profiling of the 25 case studies: 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. Parent organizations are here identified as research organizations like universities or research institutes). Spin-offs from the same parent organization may have been spun off from the same or different research groups (parent units) within the parent organization.

3.2 Operationalization of key variables

In order to relate the different biographies to the patterns inferred from the literature, we have constructed a measure of the intensity of interactions within a SO-PO pair so as to determine the relational dynamics by changes in the interaction intensity between SO and PO. We also constructed

an indicator of co-production of knowledge using the statements from the interviewees reporting on joint learning or on more formal results and processes as joint publications or joint research projects. This enables 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 gives us a good overview of the nature of the SO-PO relationships over the course of the entire spin-off process.
In order to understand better such dynamics we cross-referenced these results with other information about core characteristics of the firm as well as the research interests of both organizations, the knowledge and skills of their respective members, the type of founder, the location of the firm, or even the business model of the firm.

For identifying the relational dynamics, we constructed a measure for the interaction intensity over time. This enabled the construction of a diagram (see Figures 1-5) representing the evolution of the interaction level over time. The interaction level (the vertical axis of the graph) was constructed taking into account the information about formal as well as informal links. 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 (research or not) carried out in both organizations. The more frequent these contacts, the higher the intensity of interaction. The measure for interaction intensity was derived assessing the following indicators: (i) interaction in terms of people (academic staff holding an operative or board position, students doing theses work in the spin-off, recruitment of personnel), (ii) in terms of resources (funds acquired from leasing equipment or personnel, contract research projects, patents and licenses or from jointly acquired third party funding) and (iii) in terms of knowledge exchange (number of joint publications, number of joint participations in conferences, number of joint patent applications, number of occasions where test data, facilities, instruments and prototypes were obtained from spin-offs). This information was specified during the interviews in order to understand for example whether a joint project meant actual collaborative work on a day-to day basis.

Building on this procedure, we defined three levels of interaction intensity, referred to as “high” ”medium” or “low:

- *High interaction intensity:* 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.
- *Medium: interaction occurs* occasionally, not on a continuous basis.
- *Low*: interaction occurs rarely.

The horizontal axis of the diagrams (Figure 1-5) represents absolute time (years from the official creation of the start-up firm).[5]

Second, for each SO-PO pair we inquired whether there has been some element of knowledge exchange, mutual benefits or even co-production of knowledge during the period under study, in the form of joint research, joint projects, joint publications or joint patents. Contrary to the intensity of interaction indicator that relies to the actual process of exchanges, we now consider the output of such processes only.[6] This is a variable which may change over time, as co-production of knowledge may happen in certain periods and others not.

Building on this database, we will analyze the relationship between the knowledge production process and the prevailing interaction dynamics of SO-PO pairs.

4. An empirically derived typology of spin-off dynamics

The first observation to make is that we identified both segregative and interactive patterns (respectively 15 and 10): segregative cases being those which showed a declining or initially low interaction intensity and interactive patterns those with a sustained high (or even increasing) interaction intensity. 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 pattern, 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 four or five 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 (7 cases) and a second in which the interaction intensity becomes important only a few years after the creation of the firm (3 cases). We refer to the former group as "*Manifest Interactive"* and the latter as "*Delayed Interactive"*.

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 or occasional master theses, they are not necessarily supporting the creation of new knowledge. However, interactions

[5] An alternative could have been to process phases as a measure of evolution of the spin-off. Our choice therefore doesn't take into account the duration of the innovation process, which might be different depending on the activity undertaken (for example it is usually shorter in IT than in the biotechnology sector). However it is more precise given that the interviewees were able to determine the dates at which particular events happened, while it is sometimes more difficult to determine how far in each phase the firm was at the time.

[6] An overview of the 25 cases can be found in the Appendix.

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-reference our four groups with the indicator of co-production of knowledge. Thus, we are able to see if similar interaction *dynamics* can be explained by similar *types* of interactions and if they lead to specific knowledge creation processes. As shown in the detailed descriptions in the Appendix, interaction and co-production of knowledge patterns are intrinsically related.

	Segregative		**Interactive**	
	Manifest segregative	Delayed segregative	Delayed interactive	Manifest interactive
Nb of cases	11	4	3	7
IT cases BIO cases ***Micro/Nano cases***	**CH-UIT1** CH-UBio1 ***CH-MTRI1*** ***CH-MTRI2*** **CH-UApp1** **FR-COMP1** **FR-COMP3** **FR-TEL1** **FR-TEL3** FR-BIO1 FR-BIO3	CH-UBio2 ***CH-MTRI3*** ***CH-MTRI4*** **FR-TEL2**	***CH-MRI2*** ***FR-ELEC2*** FR-BIO2	**CH-UIT2** CH-UBio3 ***CH-MRI1*** **FR-COMP2** ***FR-ELEC1*** ***FR-ELEC3*** **CH-UApp2**

Table 4: Interaction patterns

4.1 The manifest segregative pattern

The first subgroup of case studies exhibits a combination of a sharp decrease in the level of interactions between the parent organization and its spin-off (see Figure 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 one or two 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 first subgroup, 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 PhDs 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 the academia to create the firm when their contract as a researcher ended. In the case of CH-UApp1, two university projects were continued in order to

transform the applied research into marketable products. After this, the professor leading the project moved to the spin-off and the firm cut almost all links with the University. 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 start-up 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 are in terms of reputation.
In the very particular case of CH-MTRI1, the whole academic research group was 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 segregative pattern, we find no evidence of co-production of knowledge. In most cases (8 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 being imposed by the administration rather than initiated by the parent laboratory thus no knowledge exchange takes place. In two particular cases (CH-MTRI2 and FR-COMP1), the lack of interactions is due to a conflict between the parent organization and the spinoff 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. In the case of CH-MTRI2, the CEO cancelled 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.

4.2 The delayed segregative pattern

In the delayed segregative pattern, we observe a sharp decrease in the interaction level after four or five years of sustained interactions (see Figure 2). In the five 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. 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 four 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 inhouse research and be attractive enough to access alternative research partners. Members of the spin-off expected that, from then on, knowledge transfers would become asymmetrical in that they would mainly flow in the direction of the parent.
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, leading interactions to become mainly informal. Still interactions remained at a medium level for another three years due to the presence of a PhD student. His work called for cooperation between the firm and the lab for an artificially long period.

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, as in the case of CH-Ubio2 and CH-MTRI3. After the shift of research agenda interactions revolve 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 The delayed interactive pattern

In the cases following a delayed interactive pattern we observe for a couple of years a low level of interactions or, as in one case (CH-MRI2), a sharp decrease of interaction intensity after the initial creation phase, which corresponds 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 then observed.

For the French firms FR-ELEC2 and FR-BIO2, joint research was put in place only when the firm reached a critical size (Figure 3). Hence, these cases don't 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.

The Swiss case is more accidental: CH-MRI2 and its parent institute had agreed on a clear division of labor although maintaining many informal contacts and sharing the same building. The firm developed empirical know-how through its applied research and accepted to help its parent unit on an applied issue a few years later. The collaboration was therefore due to 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 ten 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 The manifest interactive pattern

This last subgroup of seven case studies corresponds to a sustained high level of interactions (Figure 4). The evolution of interactions can be steady or sometimes fluctuating. The presence of fluctuations in interaction levels over time reveals that the interaction intensity is highly dependent on joint projects, as in the cases of CH-MRI1, Fr-COMP1 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 of no formal collaboration (as for CH-UApp2 and CH-MRI1). When a new joint opportunity appears they are able to resume their collaboration.

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. If the financial aspect is therefore present, joint knowledge production and long term opportunities can motivate long term relationships without any short term benefit (CH-UIT2, CH-MRI1). Many parent units profited from the interaction with their spin-offs through learning effects and knowledge spillover. 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 and exchanges and joint production of knowledge are considered as 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 institute 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 the co-existence of segregative as well as interactive patterns. This confirms our assumption presented in the introduction that both the linear and the co-production of knowledge models might rather be interpreted as two idealtype interaction patterns. Their occurrence may depend on various circumstances internal and external to the partners involved, and they are strongly related to modes of knowledge production. In addition, our results showed that these interaction patterns change over time, and that this evolvement is in many cases more complex than the decoupling processes observed in a number of former studies (see section 2). Before we reflect on the implications of these findings, we now turn to an analysis of the type of factors that may determine how a pair interacts over time. Possible determinants may be *external* to the relationship (such as the sector, institutional or national environment in which they are embedded) or *internal* to the relationship.

Having a look at Table 4, a few general comments can be put forward regarding the *external* factors i.e. the influence of the national, institutional and sectoral characteristics of the pairs on the type of dynamics observed. As for the national context, the distribution of case studies is quite regular between patterns and countries. 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 an 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 patterns of interactions for the specific types of research organizations (universities, research institutes) or even within the same organization. As for the different types of technology, our sample suggests that spin-offs in the field of information technology rather tend to develop segregative patterns of interaction, whereas interactive patterns seem to be more common in micro- and nanotechnology. This confirms our tentative assumptions made in section 2, even though we have to be cautious with that kind of conclusions given the small size of our sample. The assumption that a high research intensity in biotech ventures favors interactive patterns is, however, not confirmed.

While we have to be cautious in interpreting the results regarding the determinants external to the relationship, our study clearly reveals the importance of determinants internal to the relationship. These internal determinants either relate to the evolvement of the relationship *per se*, or to the evolution of one of the members of the pair, be it the spin-off or the parent unit. The former refer to personal relations, direction of resource flows or the management of conflicts and competition, the latter to fields of (research) activity, business models, size and success of the partners and their location. Both types of internal determinants are intrinsically dynamic and, what is more, are largely difficult to predict in how they will develop over time, therefore making the changes in interaction intensity similarly unpredictable.

As found in the case studies, the interaction patterns can be modulated due to changes in the couple, affecting the quality or the strategic value of the partnership. We confirm that similar location, similar research interests, easy personal relations and success of the collaboration are all positively linked with a sustained level of interactions (see description of the manifest interactive pattern in section 4.4). On the contrary, different location or research interests, conflicting relations and unsuccessful collaboration are observed in our segregative cases (see sections 4.1 and 4.2).
According to the co-production of knowledge view, firms and academic organizations look for partners with strategic value to their activities and development. Indeed, potential partners with a similar research agenda and/ or complementary skills or resources are valuable because they can be involved in a process of joint knowledge creation. This strategic value is a combination of the interests and research agenda, and the quality and complementarity of skills and resources, and is negatively

related to the availability of other academic partners[7]. It is important to point out that none of these elements is static, but are driven by internal processes of their own. Therefore, as the environment or these variables evolves, the strategic value of the couple can be increased or decreased, and, as a consequence, the partners can choose to intensify or loosen their relationship.

The similarity of research interests is a crucial condition for scientific collaboration. Whenever we observed a radical change in the research agenda of one of the partners, it was accompanied by a radical change in interaction intensity. If such events happen right at the creation of the spin-off, we observed a segregative type of dynamics (FR-COMP3 or CH-MTRI1); when it happens later, we observed a delayed segregative dynamic pattern (CH-MTRI3, CH-MTRI4).

What is more, if one or several conditions change in time, the pattern of interactions may be affected in terms of levels, length or dynamics. This is in particular observed in the delayed patterns (sections 4.2 and 4.3). This proves that the course of events and the environment affecting the relationship matter at least as much as the elements on which the relation is initially based on. Changes in interaction level, as drastic as in the delayed segregative case, can therefore be explained by a change in location, in the quality of relations (or simply in personnel), in the success of the private venture, or more specifically in the strategic value of the relationship from the point of view of one or both agents. A change in the business model of the spin-off can have the same effects, if the interest of collaborating changes fundamentally. If the event happens at the creation, we observe a segregative pattern of relationship (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, 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 as well that the parent can then start interacting with its spinoff (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.

In a way, the success or failure of the spin-off, its ability to grow and reach other partners can greatly affect the relative power of both entities, as well as their interest in working together, reevaluated at each phase of development of the spin-off.

[7] The quality of the parent and the availability of other academic partners in the same area of research to the firm define the competitive environment faced by the parent, and its capacity to convince the spin-off to work together.

Besides the strategic value, a successful relation often relies on mutual interests, but also mutual benefits. If the benefits are highly asymmetrical, the relation may be halted by the partner who doesn't get as much as it gives. That's why the direction and content of the resource flows between the spin-off and its partner are a key element in explaining the dynamics of their interaction. As it is sometimes difficult to evaluate and anticipate the strategic value of a relationship, the actors are more aware of the potential benefits they might obtain from it. Comparing the costs and benefits they may then decide to go on with their partnership or not. This explains the unwillingness of certain parents to bond with their spinoffs, as found in the segregative cases such as CH-UIT1 or CH-UBio1. On the contrary, the interaction may stop due to the growth of the spin-off, for which the benefits of the relationship become too weak (as for CH-MTRI4).

Adding to the elements described up to now, it's important to remember that we are considering not only how organizations are linked, but also how people create, develop or stop personal relationships with one another. The 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, whereas 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 (MTRI4), at least for a certain period.

6. Conclusion

Looking at the evolution of interactions between spin-offs and their parent organization 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 located in an overlapping sphere between academia and industry alone is too idealized as well. In our study, we couldn't investigate all details of the knowledge production processes; still, our findings are in line with an understanding of new modes of knowledge production which sees 'mode 2' type of knowledge production as an empirically important mode, but

which doesn't completely substitute a more linear 'mode 1' type of knowledge production (Gibbons et al., 1994; Hessels and van Lente, 2008; Hessels and van Lente, 2008)[8] .

For spin-offs and their parent organization these findings have important implications. It depends on a number of intermediating variables which model is most adequate for a specific SO-PO pair – at a given point in time - and if this is actually realized. 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[9]. These findings clearly show that the management of the long-term development of relations between spin-offs and their parent organization can be a crucial and all but trivial task, which implies firstly determining what would be an adequate pattern for a given pair, secondly, what is necessary to realize it and how this can be achieved and, thirdly, 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. As an implication, while the management-oriented spin-off literature usually focuses on issues related to the creation and early development of the firms, our results suggest that the longer-term development of relationships deserves attention as well.

From the perspective of policy and technology transfer institutions, this implies that institutional frameworks and support measures should allow for different patterns to unfold without enforcing any of the models. For instance, our results suggest that frameworks, which allow academic staff to participate in spin-offs, may be an important requisite to maintain 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.

[8] 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 our sample and the limited set of disciplines considered we have to be cautious. While our study supports a 'ço-existence' model of modes of knowledge production, our research design does not allow any conclusions regarding a potential increase of mode2 over time (for an overview on mode 2 claims and its criticisms see Hessels and van Lente(2008)).

[9] The effects of the different patterns for the partners, in particular the parent organization, are discussed in more detail elsewhere (Konrad et al., 2009) .

Appendix

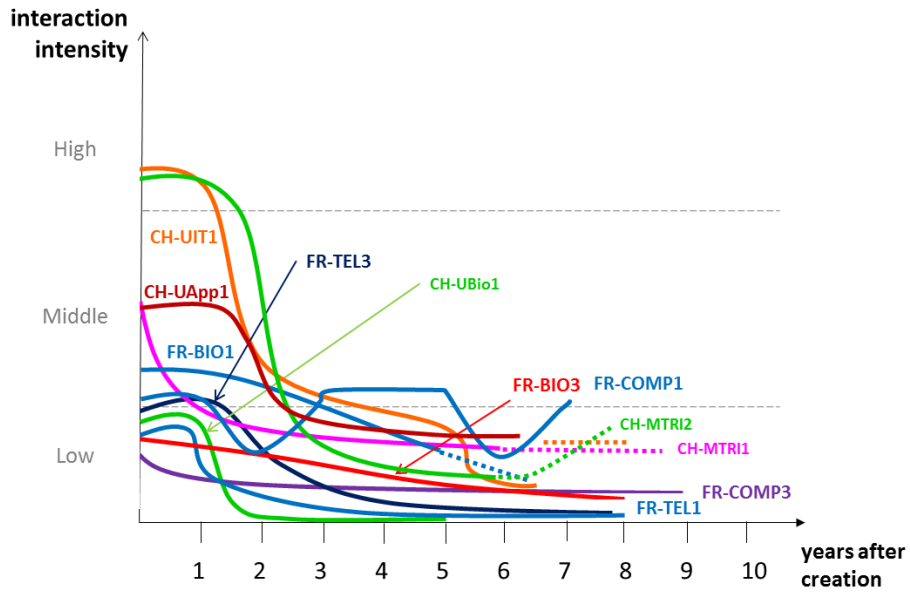


Figure 1: Manifest segregative cases

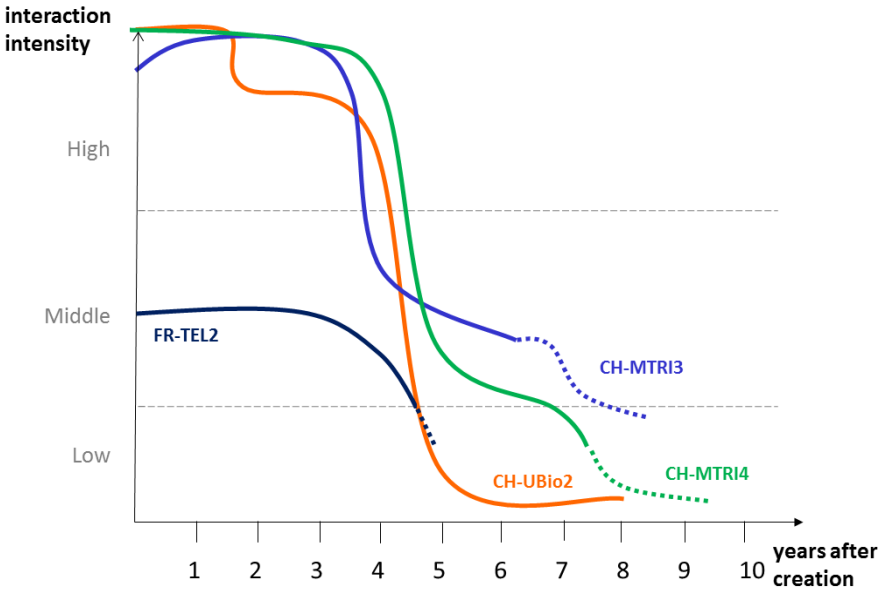


Figure 2: Delayed segregative cases

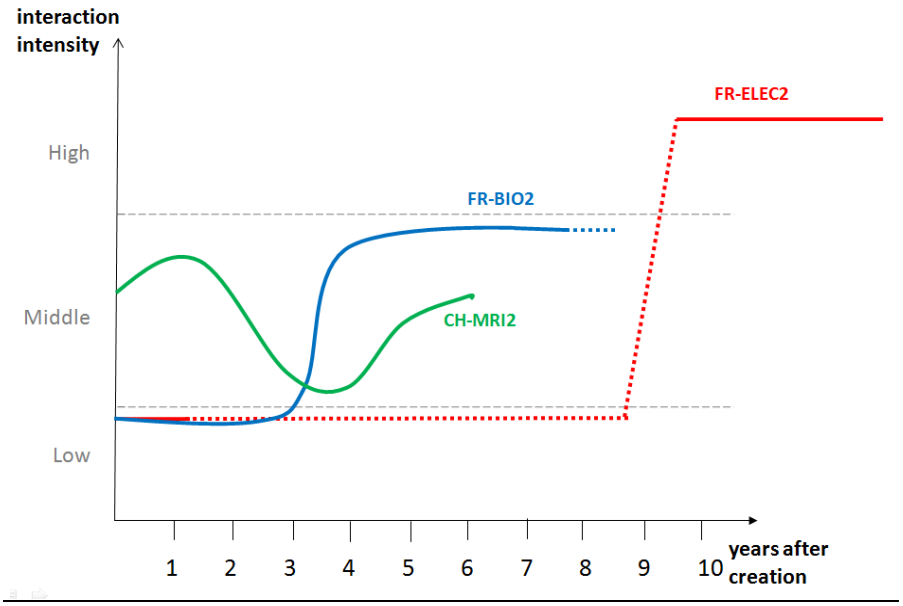


Figure 3: Delayed interactive cases

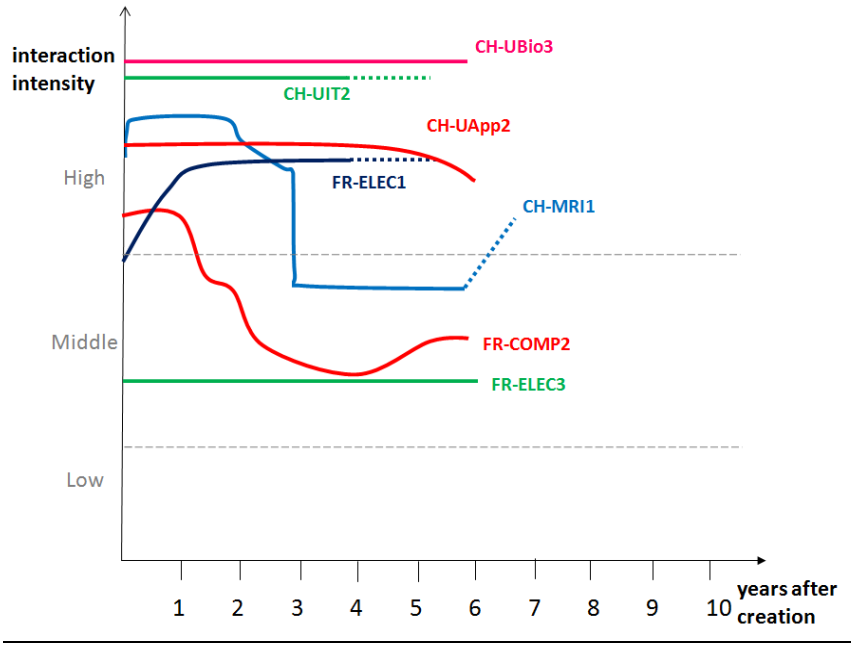


Figure 4: Manifest interactive cases

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