

THE DYNAMICS OF TECHNOLOGY TRANSFER AND NETWORKING IN THE DEVELOPMENT OF UNIVERSITY SPIN-OFFS

3. 1. Knowledge creation and transfer in inter-organizational networks

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Abstract. Measuring the contributions of ‘hi-tech’ small firms by looking only at their product sales, innovation outputs and employment generation may understate their effectiveness. Another important contribution of ‘hi-tech’ firms is their catalyzing role to knowledge creation and transfer in innovation networks. However there are very few empirical studies which have analyzed the role of entrepreneurship and innovation networks on the dynamics of technology transfer during the early years of ‘hi-tech’ star-ups, and none of these studies has analyzed university spin-offs. This paper addresses two research questions: How active in network development and technology transfer are university spin-offs during their early years to overcome initial disadvantages? Is there any relationship between early networks development and knowledge creation and technology transfer in university spin-offs? Using data from companies spun off from an Spanish university in the period 1990-1999, the results suggest that technology transfer and networking at university spin-offs decreased after their early years but at the same time the relationships with customers increased.

Key words: Technology transfer. University spin-offs. Regional innovation networks.

1. Introduction

A knowledge-based view of the firm is a contemporary approach to strategic management that guides attention toward the understanding of the organizational learning process and the management of a firm's knowledge base (Conner and Prahalad, 1996; Grant, 1996; Spender, 1996; Teece et al, 1997). The management of knowledge plays an outstanding role in any interdisciplinary theory of entrepreneurship (Ripsas, 1998), and in the development of technology-based companies. 'Hi-tech' small firms are a key element in the creation and transfer of knowledge. Measuring the effectiveness and contributions of 'hi-tech' small firms by looking only at their product sales, innovation outputs, and employment generation may understate their contribution. Although the traditional body of research on new 'hi-tech' firms and their regional impact overwhelmingly focuses on the growth of these firms, many empirical studies suggest that rapid organic growth is both rare and often even unwanted among new 'hi-tech' firms. For example, Kamshad and Hay (1996) found that profitability, not growth, constituted the key managerial goal of small and medium-sized firms in the UK. Other studies show that new 'hi-tech' firms do not perceive rapid or even moderately rapid organic growth as a feasible way to develop their activities (Oakey, 1994).

Another important contribution of 'hi-tech' firms is their catalyzing role to technology and knowledge accumulation processes in innovation networks. Through the process of becoming embedded to local institutional and organizational design, 'hi-tech' firms start contributing to knowledge spillovers and technology accumulation processes. Then an important part of their economic contribution should be delivered through mechanisms other than direct organic growth. However, there are very few empirical studies which have analyzed the role of

entrepreneurship and innovation networks on the dynamics of technology transfer during the early years of ‘hi-tech’ start-ups and none of those studies has analyzed university spin-offs.

The purpose of this paper is to study the evolution of the technology transfer practices used by university spin-offs during their early years and the influence of innovation networks on the dynamics of technology transfer. The paper is structured as follows: the next section reviews the literature on university spin-offs; the third section studies the technology transfer practices used by the surveyed spin-offs and the development of their innovation network; finally some concluding remarks are presented.

2. Academic spin-offs: features and propositions

2.1. Technology-related spin-offs - state of the art

An entrepreneurial spin-off arises when an entrepreneur leaves an organization to start a firm of her/his own. To be a spin-off, this must also include the transfer of some rights, e.g. knowledge, from the existing organization to the new firm. Spin-offs can be categorized depending on what organization they are spun off from, and on where the entrepreneur has gained her/his background experience. According to Oakey (1995), the two major sources of new technology-based firms are higher-education institutions (university spin-offs) and well-established industrial firms (corporate spin-offs). Although the two kinds of entrepreneurial spin-offs have a lot in common, there are considerable differences. For example, while a private company often tries to keep research and technology within the firm, a university often encourages the transfer of the results to be used outside the university.

From the existing literature, very few empirical studies of technology-related spin-offs have been made. Most studies deal with the background characteristics of spin-offs, including the spin-off entrepreneurial motivations (Chell et al, 1991; Autio and Kauranan, 1994; Martínez and Urbina, 1998). University spin-offs are founded primarily on the basis of some technological advance rather than on the presumption of competitive advantage in regard to marketing, sales or distribution. The founders are for the most part engineers and scientists, with some marketing/sales and business experience present in the multifounder teams. Not all university entrepreneurs have unique ideas and high need for achievement; some of them are initially merely pursuing more independence or are somewhat dissatisfied (Roberts, 1991). A comparison of founders' personal motives between spin-off and non-spin-off companies, found that the motive of having the freedom to explore new ideas was more common than to test one's entrepreneurial ability (Dahlstrand, 1997).

Roberts and Malone (1996) identified four principal entities involved in the spin-off process: (1) the technology originator, the person or organization that brings the technology from basic research through the stages of the innovation-development process to the point at which the transfer of technology can begin, (2) the parent organization in which the R&D is conducted by the technology originator, (3) the entrepreneur(s) who take(s) the technology created by the originator (an entrepreneur her/himself) and attempts to create a new business venture centered on the technology, and (4) the venture investor that provides funding for the new company in return for partial equity ownership or benefit-sales sharing in the new company.

On the other hand, Olofsson et al (1987) and Roberts (1990) studied how spin-off companies changed business priorities over the first several years after founding toward more product-oriented businesses and away from consulting and R&D contracting. Their founders were

initially primarily oriented toward engineering and technology, not sales and marketing, with evolution toward marketing occurring over time, if the firm survives. They also found that a multifounder firm showed a greater tendency toward both product and sales/marketing orientation initially, and also evolves more rapidly in both areas, than the single founder company.

Some other scholars have studied the relationship of entrepreneurial spin-off with the parent organization from which it originates. The importance of the parent organization in technology transfer has already been demonstrated by Roberts (1991) because that is where most of the 'hi-tech' entrepreneurs acquire the knowledge transferred to their own companies. Besides, there is a higher degree of technological transfer from the earlier employer to the spin-off than to the non-spin-offs, and the degree of technology transfer from the parent organization can be assumed to contribute indirectly to the development and higher growth of the spin-off (Roberts, 1991; Harmon et al, 1997).

Regarding the parent organization size, the literature reveals conflicting views of what size of organization creates the higher share of spin-offs. In some studies, the large organizations are argued to be more favourable to the formation of spin-offs (Granstrand and Alänge, 1995); in others the small organizations are found more likely to spin-off new firms (Dorfman, 1983; Cooper, 1984). Regarding the type of parent organization the literature offers more conclusive results: corporate spin-offs are far more frequent than university spin-offs (Cooper, 1984; Dahlstrand, 1997). But considering the vast difference in number of employees between industry and universities in most parts of the world, this result is not very surprising. If instead a relative measure of spin-offs per employee were used, the results might be rather different.

Nevertheless, Smilor (1987) found indications that business parent organizations could assist better than universities in providing benefits to a spin-off company. Besides the transfer and support of more different kinds of knowledge, a business parent organization can support the spin-off firm with physical assets. For example, production machinery is more likely to be found in a private corporation than in a university. Similarly, developed products, marketing channels, customer and supplier contacts and so forth, are more common within a business organisation than in academia. A university spin-off may initially face more difficulties than a corporate spin-off.

2.2. Technology transfer, networking and spin-offs - research questions

Technology transfer is the application of information into use, and involves a source of technology that possesses specialized technical skills, and the transmission to receptors who do not possess them and who cannot or do not want to create the technology themselves. Spin-offs are one, although not necessarily the most important, means of technology transfer. Nevertheless, spin-offs represent one potential mechanism for technology transfer from universities, as they increasingly seek to contribute to their region's economic development (Mian, 1997). 'Hi-tech' firms can catalyse economic growth without growing themselves, by contributing to the dynamism of regional innovation systems through an innovative combination of their technological resources with those provided by the other constituents of the regional innovation network (Table 1). For example, new technology-based firms have strengths such as internal flexibility or technological expertise in highly specialized fields that cannot be easily replicated by a large firm. The innovation advantages of large firms, in turn, are usually associated with their relatively greater financial and technological resources. Then

a skilful combination of these advantages can offer benefits for both parties and contribute to a high innovation efficiency (Rothwell and Dodgson, 1993; Forrest and Martin, 1994).

Table 1. Regional impacts of university spin-offs

<ul style="list-style-type: none">• Create jobs and taxable wealth in the local community. Generally, spin-offs locate near the parent organization, and the economic benefits of a spin-off accrue locally. In contrast, technology transfer from a university to a large corporation usually means that the benefits thus created pass to distant regions.• Provide role-models for entrepreneurs, a key factor in peripheral regions which have a technology-base, but lacks the entrepreneurial and marketing capacities needed to establish a critical mass of spin-offs.• Offer an effective means of transferring the technology developed jointly by the university and other technology centers.• Contribute to the university by providing jobs for its graduates plus, in some cases, a share of revenues in the new company.

Source: Steffensen et al, 2000

University spin-offs transfer technology from their parent organization but later they transfer that technology to their customers. University spin-offs should be more active in technology transfer than corporate spin-offs in order to overcome the early disadvantages of university entrepreneurs for company development. Therefore we propose as our first exploratory hypothesis:

H1: University spin-offs are more dynamic in technology transfer during their early years.

On the other hand, the entrepreneur plays a central role in the formation of regional innovation network (Donckels and Lambrecht, 1995). The literature describes and explains networks in various ways. However, it agrees upon the fact that networks encompass a firm's set of relationships, both horizontal and vertical with other organizations including relationships across industries and countries. These relations constitute the network structure that may in turn take a lot of different forms. Through the development of a network, entrepreneurs are

more likely to communicate and to receive information accurately, resulting in a improvement of business (Donckels and Lambrecht, 1995). Information gathered from the network contributes to the growth of the company by strengthening understanding and intuition. However, setting up an efficient network requires considerable resources (effort, time and money).

The establishment of close links with various agents is a key element of success for the survival and development of an spin-off. Firms set up by researchers which remain isolated are just as likely to perish as any other small company. The links must be established very early on, that is to say, as soon as the project has been defined or immediately after the firm has been created. It is still possible to form a network of different players later on, but much more difficult. Particularly, science-based entrepreneurship is presumed to demand especially dynamic and flexible networking, because it is concerned with commercial application of new knowledge partly and because an entrepreneurial career in that sector is usually organized as a set of ventures/projects. These often reflect elaborate linkages to individual customers. Network dynamics are accentuated in young science-based firms like university spin-offs where an originally academically-oriented personal network has to be partly replaced with a considerably more market-oriented network. As a consequence, we propose as our second exploratory hypothesis:

H2: University spin-offs are more dynamic in network formation during their early years.

In order to study both hypotheses, an exploratory survey was carried out among university spin-offs. The purpose of the study was to develop ideas from induction of data more than propose general conclusions.

3. University spin-offs: technology transfer and company evolution

3.1. Sample and data collection

The data analyzed here come from interviews held in March 2000 with founders of companies spun off from the University of Aragón¹ during the period 1990-1999. The list of spin-offs was obtained from the R&D university transfer Office and from the regional network of Business Innovation Centers. Table 2 shows some basic data from these companies: activity, founding year, and number of employees. Structured interviews with a detailed questionnaire lasting typically one hour, were used to gather data from each founding entrepreneur about her/his company's technology transfer practices and its relationship with network development. Due to the small number of companies, no claim of generality to other population of spin-offs can be made from the primary data and their analysis.

Table 2. University spin-offs in Aragón

Company	Activity	Founding year	No. of employees
Bioingeniería Aragonesa	Domotics. Telemedicine	1990	9
Meditel	Medical instruments	1995	5
ZEU Inmunotec	Biotechnology	1995	6
Umbelco	New materials	1996	7
ATRI	New materials	1998	5
IDE	Machinery	1998	5
Inst.Ciencias Médicas	Medical instruments	1998	5
Com.Solar	Solar energy	1999	2
Gotatot	Medical instruments	1999	1
Tecnoluz	Measurement services	1999	3

Source: Own elaboration

Employee data indicates that even companies with five years or more in business were still very small which it is very common among university spin-offs. For example, a 35-year longitudinal survey of the spin-off firms of the Chalmers University in Sweden revealed that

the majority of these firms employed fewer than 15 employees (Wallmark and Sjösten, 1994). Some of the Aragonese spin-offs are still located near the university in the Innovation Business Centers. Firms located close to major universities exhibit higher innovation rates than their counterparts that reside elsewhere (Acs et al, 1994; MacPherson, 1998), mainly because new technical knowledge from the university sector can be more readily accessed by firms that forge face-to-face linkages with academics. Despite the diffusion of modern telecommunications systems, the balance of empirical evidence suggests that the intensity of university-industry interaction varies inversely with the distance that separates academics from firms (Anselin et al, 1996).

Next sections show the results from the survey. A review of the literature indicated that the main questions to explore regarding the dynamics of technology transfer and network development on university spin-offs were the change on: mechanisms used; barriers to technology transfer; product strategy and knowledge needs; network development agents; and formally network support. The approach employed has been a case study of the university spin-offs surveyed. Next paragraphs brief the main features of the cases studied and the exploratory results related to the paper's hypotheses.

3.2. Technology transfer mechanisms

Table 3 shows the technology transfer pattern of the university spin-offs surveyed. The most important mechanisms used to transfer technology from the parent organisation are training and transfer of people. On the other hand, the mechanisms most used to transfer technology to the customer are cooperation in product development and consulting. Table 3 also indicates that the importance of some mechanisms of technology transfer from the parent organisation

was greater in the early years than nowadays which it would support the paper's first hypothesis. For example, consulting and cooperation in research and product development was much greater with the university at the beginning but thereafter the technology flow from the university decreased. However the technology flow to the customer increased through those mechanisms since the company start-up.

Table 3. Technology flow generated by different technology transfer mechanisms between the spin-offs and the university and customers

	University (parent organisation)		Customer	
	Founding year	1999	Founding year	1999
Consulting	4.1	2.3	2.6	3.6
Cooperation in product development	4.8	2.3	1.8	3.8
Cooperation in research	4.6	2.9	1.3	3.2
Patenting and licensing	1.8	1.2	1.9	1.9
Subcontract product development	3.5	1.8	1.5	1.7
Sale or purchase of products and services	1.0	1.0	1.6	2.3
Training	3.6	3.8	1.2	2.7
Transfer of people	3.9	3.0	2.3	3.4

Notes: The intensities of technology flows were evaluated using a five-step Likert scale from 1 (non-existent) to 5 (very intensive)

Source: Own elaboration

The majority of these enterprises invested a very high proportion of their turnover in R&D: more than 10% in most of the cases were invested in R&D projects and to implement new technologies. Besides in-house R&D activities, some of them had very close research links with academia and business, which materialised in technology transfer through scientific papers and/or joint R&D projects. University spin-offs are not a significant source of employment (see Table 1) but their technology transfer role is more important because they act as mediators between basic and applied research, from which they originated and a network of customers. They enable the results of academic research to be converted into innovation which it will enhance the ability of their customers to compete.

Table 4 indicates the degree of difficulty -evaluated using a five-step Likert scale from 1 (nothing) to 5 (very intensive)- of some obstacles to technology transfer at the surveyed spin-offs. The small size of market and the lack of financial resources were the main obstacles to technology transfer during the first year of activity. Afterwards the difficulties seem to have diminished. The interviews emphasized the crucial role of public funding during a firm's start-up and initial network development phase. The dynamic of this type of firm is to a large extent determined by its links with public institutions. Local capital and public funding are the key to its launch. When neither the markets nor the technology exist, support from public authorities is needed to help companies and their clients co-create the technologies in question as well as the corresponding markets.

Table 4. Obstacles to technology transfer of university spin-offs

	Founding year	1999
Lack of financial resources	4.4	3.5
Small size of market	3.9	3.2
Too risky	3.1	3.3
Lack of information on market characteristics	2.8	1.6
Lack of time	2.1	2.8
Lack of information on potential business partners	1.9	1.4
Lack of information on know-how	1.7	1.2
Lack of trust among partners	1.3	1.1

Note: The obstacles were evaluated using a five-step Likert scale from 1 (nothing) to 5 (very intensive)

Source: Own elaboration

3.3. Technology transfer and product strategy

A common feature of these companies is that their turnover comes from marketing both research services and products. In some cases, it is difficult to separate these two activities. Some of the entrepreneurial founders were unclear when they started their companies as to

who would become the initial customers for their products or services. They tried to be rather flexible doing some consulting or contract R&D while developing new products or applications. For example, the company 'ZEU Immunotec' devoted its two first years to R&D activities and it was not until the third year that its first product was marketed. The product was a follow-up and evolution of its start-up activities, including the product development efforts that were initially underway but not yet completed. Since then the company has kept researching in new products development, marketing new tests and expanding their activities to foreign markets.

Other companies do exclusively services. It is the case for example of 'Tecnoluz' dedicated to measurement services of optical parameters, and calibration of optical measurement equipment and control. There are companies which had a product from the beginning; for example, the company 'Umbelco' has been manufacturing the same patented civil construction material for solar protection. However, other companies started manufacturing products and offered R&D services later. For example, the company 'Bioingeniería Aragonesa' is specialized in domotics and telemedicine, but can solve any problem that needs specialized electronics and software. The company also participates in European R&D programmes and works for some of the large European telecommunication companies. For this firm, products resulted as an indirect consequence of contract R&D and consulting effort carried out for governmental and industrial customers.

In other instances the development of a product was the result of a conscious decision to change the character of the firm. The company 'Meditel' had initially been engaged primarily in contractual development work. Although this work often provided a stable source of

entrepreneurial income, the founders realized that far greater profit margins and better opportunities for corporate growth existed in the sale of products.

What many of these spin-offs have in common is that a few main customers account for virtually all the spin-offs turnover. On average, more than half of their turnover comes from their four largest customers, who serve as lead users and helped to determine how the enterprise and their products will develop. This concentration was greater in those companies that they were not based on horizontal technologies. For example, the company 'IDE' has patented a machine that remove automatically bones out of cured hams which has no other applications. Another company with a high degree of concentration of their customers is 'ATRI' which has developed and manufactures new materials and fibers for construction and transportation companies. Von Hippel's (1988) studies on the importance of customers as a source of innovation suggest that the customer can be an important early source of technological know-how for new 'hi-tech' firms. In order to start-up, enterprises must have a few privileged customers, but their development will depend on their ability to distance themselves from these initial customers and to move to specific products or customised production to standard products.

3.4. Technology transfer and network development

These results suggest that university spin-offs, like most 'hi-tech' companies, were polarized during their early years more towards the technology than to the market. Six out of ten spin-off companies analyzed were technology-oriented and were still doing R&D projects to develop new products and improve their technology. The reason to the more frequent polarization towards technology is that these spin-offs had greater technology flexibility to

accommodate product changes in order to generate new applications and market niches. For example, Olofsson *et al* (1987) found that the Swedish 'hi-tech' university spin-offs were little market-oriented because only 20% of the companies had their own products from the beginning, while 30% made consultancy services and 50% did R&D works for another companies. Nevertheless, technology-oriented spin-offs are in risk of developing sophisticated technological products which are little market-oriented and so with great chances of market failure.

These spin-offs were then in need of developing and changing capabilities to complete its initial know-how base. The companies polarized to the technology had to complete their market capabilities and, conversely, those which had a market orientation got technical capabilities. Raffa *et al* (1996) in a study of software spin-off companies found that there was an important difference between the two groups of companies during their early years because technology-oriented companies explored a larger number of new development strategies than market-oriented companies and had a more complex evolution. Therefore we would expect - as our second exploratory hypothesis states- that university spin-offs should be more dynamic in network development during their early years.

Table 5 shows the degree of importance of some network development agents for the surveyed spin-offs. The importance was measured with a five-step Likert scale according to each network objective. Networking with universities and R&D centers was more important during the early years than later on. The opposite holds for customers and suppliers. This network evolution pattern is similar to the technology transfer pattern (Table 2). University spin-offs are more interested in technology transfer and networking activities with their parent organization during their early years which it comes in support of our second exploratory

hypothesis. Later on these firms become less receptive to cooperate with university departments or technology centers. This is a difference from corporate spin-offs which develop formal and informal relations with their parent organization after the spin-off (Roberts, 1991).

Table 5. Degree of importance of network development agents

Network objective	University, R&D center		Seminars, Conferences		Trade fairs		Customers and suppliers		Relatives	
	F	1999	F	1999	F	1999	F	1999	F	1999
Enrichment of own knowledge	4.3	3.6	3.8	3.5	2.5	3.6	2.8	4.4	1.1	1.2
Gathering of information	3.8	2.9	2.3	3.7	3.5	3.4	2.5	4.2	1.2	1.2
Looking after customers and suppliers	1.5	1.5	1.4	1.7	2.5	3.7	2.2	4.5	1.4	1.1
Motivation	1.8	1.4	1.3	1.3	1.5	2.7	2.6	3.4	2.7	2.5
Response from external environment	1.8	1.3	2.4	2.8	2.8	3.9	1.9	3.7	1.3	1.1

Notes: F - Founding year. The importance and use of each network mechanisms was evaluated using a five-step Likert scale from 1 (not used) to 5 (very intensive).

Source: Own elaboration

Enrichment of own knowledge was the most important objective for the establishment of a network. Knowledge of ‘who knows what’ is an important competence for ‘hi-tech’ companies. Continually updating this ‘knowledge of knowledge’ through constant interaction within the established networks. Spin-off managers depended a great deal on strategic knowledge regarding the technological and commercial opportunities and limitations of their spin-off. Managers reported several kinds of network connections, of varying degrees of permanence, that provided knowledge and expertise to support the spin-off. Full-time staff who bring with them know-how and experience relevant to the venture are commonly found and recruited through specialist networks.

University spin-off networking with customers increased after their early years at the same time that technology transfer did. It is more difficult to establish a mutual-trust relationship to transfer technology with an unknown company because technology transfer deals mostly with

intangible assets. When companies try to establish another relationship like exports, they may look or use product samples. However technology is difficult to ‘see’ and ‘touch’ in catalogues or Fairs, and networking seems to become a prior condition to technology transfer to customers.

Table 6. Main nodes of the regional innovation and technology transfer network

<ul style="list-style-type: none"> • Research results transfer office (OTRI). This is an interface cell located within the University. Its aim is to link university R&D and its socioeconomic environment. It provides management services to researchers (contract negotiation, administration of funds, patent filing, etc.) and markets and disseminates the university research results. There are other technology transfer points but less important because they are out of the University structure which reduces the possibility of being involved in the university R&D policy. • Innovation business centers (CEEIA). There are three centers located across Aragón. They were created in the early 1990s and host technology oriented emerging companies in new fields such as microelectronics, software, and scientific and medical instruments. The new firms receive not only facilities but also managerial assistance in their relationships with universities and other research centres. • Innovation Relay Center (IRC CENEO). Its main target is to transfer and explode the R&D results of the european technologies, giving support to the technology suppliers and the managers and companies demanding such technologies. CENEO establishes deep links with another IRCs in order to present the most suitable technologies.
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Source: Own elaboration

Besides networking with customers, suppliers and their late parent organization, university spin-offs make use of the formally institutionalized innovation and technology transfer network developed by the regional government to promote technological innovation and entrepreneurship (Table 6). Firstly and most important, they use technical resources from this network: some companies needed basic testing equipment, measurement, calculation and problem-solving support but these were usually too expensive to have in-house. Secondly they received expert technological advice on the use of sophisticated technologies such as new telecommunication networks. Thirdly, they were supported on information services about patents and exploitable technologies. Finally, some companies made use of the network's gateway services that enabled them to be brought into partnership with leading edge firms and

research institutes and to form groups and alliances in order to afford services together. There were entrepreneurs which had even contributed to the development of the regional network. For example, the CEO of the company 'Bioingeniería Aragonesa' was an evaluator of the European Union CRAFT Programme and consults regional companies.

Concluding remarks

This has been an exploratory study on the relationship between technology transfer and network development during the university spin-offs' early years; we wanted to develop ideas from induction of data more than propose general conclusions. Our modest set of descriptive data suggest that technology transfer and networking at university spin-offs decreased with the university after their early years but at the same time the relationships with customers increased. The companies were very active in consulting, product development and training with the university in the founding year. Later on the technology transfer flow diminished. On the contrary that corporate spin-offs, university spin-offs reduced their relationships with the parent organization.

End notes

1. Aragón is a region located in the northeast of Spain, which accounts for a 3.5% of Spain's economic activities. The University of Aragon provides high education to over 40,000 students. Regarding to the corporate spin-offs, data from a survey carried out among Aragonese manufacturing companies indicated that 23% of surveyed companies had spun off 970 firms during the period 1985-1995. Sixty per cent of these spin-offs had initially the same product that their parent organization, which means that they were actually their competitors.

Twenty eight per cent of spin-offs were supported in the early stages by their parent organization (no ownership link), in order to create a distributor or supplier on their own and because they had very good relationships with their former employees.

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