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Why are some university researchers more likely to create spin-offs than others? Evidence from Canadian universities

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Abstract

This paper addresses the following question: why are some university researchers more likely to create spin-off companies than others? In order to explain why university researchers create spin-offs, we draw on the resource-based theory of the firm. The study database consists of 1554 university researchers funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). The logistic regression results suggest that the traditional and entrepreneurial visions of university research complement each other when one looks at the resources mobilized by researchers to launch spin-offs.

Keywords: University spin-offs; Resources; Determinants of university spin-off creation; Natural sciences and engineering

1. Introduction

Changes in the economic, social and knowledge environment provide opportunities to develop new or improved products. University research knowledge is increasingly considered as providing a significant number of opportunities to develop new or improved products. There are ever-growing number of publications on the opportunities of knowledge transfer undertaken by universities and university researchers. This literature approaches knowledge transfer from many perspectives which vary significantly, primarily with respect to the mechanisms of knowledge transfer considered and the units of analysis used to explain knowledge transfer.

The three major forms of mechanisms through which universities and university researchers transfer knowledge are the diffusion of research knowledge through conferences and scientific publications, the training of a skilled labor force, and the commercialization of knowledge. The commercialization of knowledge can itself be considered under many alternative mechanisms, notably through consulting activities, research contracts with industry, patenting and spin-off formation. Spin-off companies from universities and university researchers are the most visible form of commercialization of university research. The interest in academic spin-offs reflects the increasing importance of research knowledge as a strategic resource that creates competitive advantages. The formation of spin-off companies can

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also be considered as the flagship of the commercialization of university research as well as a tangible implementation of the entrepreneurial vision of university research (Fontes, 2003; Clarysse and Moray, 2004; Chiesa and Piccaluga, 2000; Jones-Evans and Magnus, 1998; Roberts, 1991; Carayannis et al., 1998; Smilor et al., 1990; Shane, 2004; O'Shea et al., 2005). Prior studies have contributed to advancing significantly our understanding of university spin-offs. However, while a vast majority of these studies focus on universities as their unit of analysis, very few studies pay attention to resources controlled by individual researchers. Moreover, studies using the individual researchers as their unit of analysis are frequently limited to faculty members in life sciences or in medical schools. To our knowledge, no studies have focused on faculty members from a large variety of research fields and universities of different status. The aim of this paper is to address these shortcomings by investigating the following question: why are some university researchers more likely to create spin-off companies than others? This paper contributes to advancing our knowledge on the determinants of university spin-offs by focusing on the resources accessible to individual researchers of many different research fields operating in various types of universities.

The rest of the paper is structured as follows. In the next section, we present the studies and the empirical findings on the determinants of university spin-offs. Then we examine empirically the determinants that may influence the decision of Canadian researchers to launch spin-offs. Finally, the implications of the empirical findings are discussed in the last section of the paper.

2. Literature review

2.1. Prior theoretical and empirical studies of university spin-offs

2.1.1. Units of analysis

Empirical studies on the determinants of university spin-off creation tend to use either macro units of analysis such as the university, or micro units of analysis, such as the individual researchers (Di Gregorio and Shane, 2003). Studies based on the university as the unit of analysis tend to focus on the impact of university policies on spin-off formation (Roberts and Malone, 1996; Degroof and Roberts, 2004; Di Gregorio and Shane, 2003; O'Shea et al., 2005; Lockett et al., 2003; Lockett and Wright, 2004; Nerkar and Shane, 2003).

Empirical studies based on the individual researcher as the unit of analysis examine the propensity of individual faculty members to create spin-offs using characteristics of resources of the researchers (Levin and Stephan, 1991; Shane and Khurana, 2003; Roberts, 1991; Zucker et al., 1998) and characteristics of their research projects and research findings (Shane, 2001) as predictors of spin-off formation. This paper aims to contribute to the advancement of knowledge by using the individual researcher as the unit of analysis in order to focus attention on resources and other factors that are closer to the individual researcher than the macro-level factors of explanation. Such a unit of analysis is especially appropriate to take into account the impact of the knowledge and skills of the founders of the spin-offs. Furthermore, using the individual researcher as the unit of analysis is also appropriate to better understand the co-existence of the traditional and entrepreneurial visions of university research.

2.1.2. A process view of spin-off formation

Prior studies on the formation of spin-offs view these as involving discrete decisions. Ndonzuau et al. (2002) claim that the formation of spin-offs needs to be understood as part of multi-stage processes. Based on their data analysis, they suggest modeling the spin-off process as a four-stage process defined as follows: Stage 1: "to generate business ideas from research"; Stage 2: "to finalize new venture projects out of projects"; Stage 3: "to launch spin-off firms from projects"; Stage 4: "to strengthen the creation of economic value by spin-off firms". This study focuses its attention on Stage 3 regarding the launching of spin-off firms. To collect the data on this stage, we asked individual researchers to indicate whether or not they had ever attempted personally, or their university on their behalf had attempted, to create a spin-off firm from the results of their research. This question aimed at collecting data regarding the individual initiatives over and beyond the university TTO official records. Such a research strategy provides a more complete picture of spin-off formation than a strategy limited to the number of spin-off firms created through the university TTOs. Using such a strategy enables us to overcome the fact that many university researchers do not report their commercial activities to their TTOs.

2.1.3. Samples

A large number of studies on spin-off formation are based on the AUTM surveys, consequently focusing on the university TTOs as their unit of analysis. Many other studies are based on samples of the elite research universities (see Siegel and Phan, 2004, for a review). Some of these studies use the university TTO as their unit of analysis and a smaller number use the individual researcher as their unit of analysis. Most of the studies using the individual researcher as their unit of analysis concern faculty members in life sciences (e.g. Louis et al., 1989) or in medical schools (e.g. Bercovitz and Feldman, 2004). The results based on data from such samples might not be generalizable to the rest of the universities that have lower resource endowments. The data of this study are based on a random sample representative of all the Canadian universities and it includes individual researchers in natural sciences and engineering who have succeeded in obtaining research grants from the Natural Sciences and Engineering Research Council of Canada (NSERC). Therefore, the sample of the present study includes faculty members from a large variety of research fields and universities of different status, including non-elite research universities. The attributes of such a sample are appropriate to capture the impact of these differences on the likelihood of forming spin-offs.

2.1.4. Conceptual framework and hypotheses

In order to explain why university researchers create spin-offs, we draw on the resource-based theory of the firm (Barney, 1991; Kogut and Zander, 1992; Conner and Prahalad, 1996; Grant, 1996) to assume that, like entrepreneurs in private firms, researchers are entrepreneurs who use a great number of idiosyncratic resources and capabilities, which are deployed and coordinated in the process of spin-off creation. Hence, researchers have access to bundles of tangible and intangible resources that differ from one individual to another, thus generating heterogeneity between researchers. Such a perspective suggests that the likelihood of spin-off creation by researchers will increase when either the resources or their coordination will be appropriate or sufficient. Such a conceptual framework is especially appropriate because, as hypothesized by Cooper and Bruno (1977, p.21), “for a new, high-technology firm, the primary assets are the knowledge and skills of the founders. Any competitive advantage the new firm achieves is likely to be based upon what the founders can do better than others.” In the literature on the commercialization of university research, resources that enable spin-off creation include knowledge assets, financial assets, organizational assets, social capital assets, and intellectual property assets. The relationship between these factors and spin-off creation is

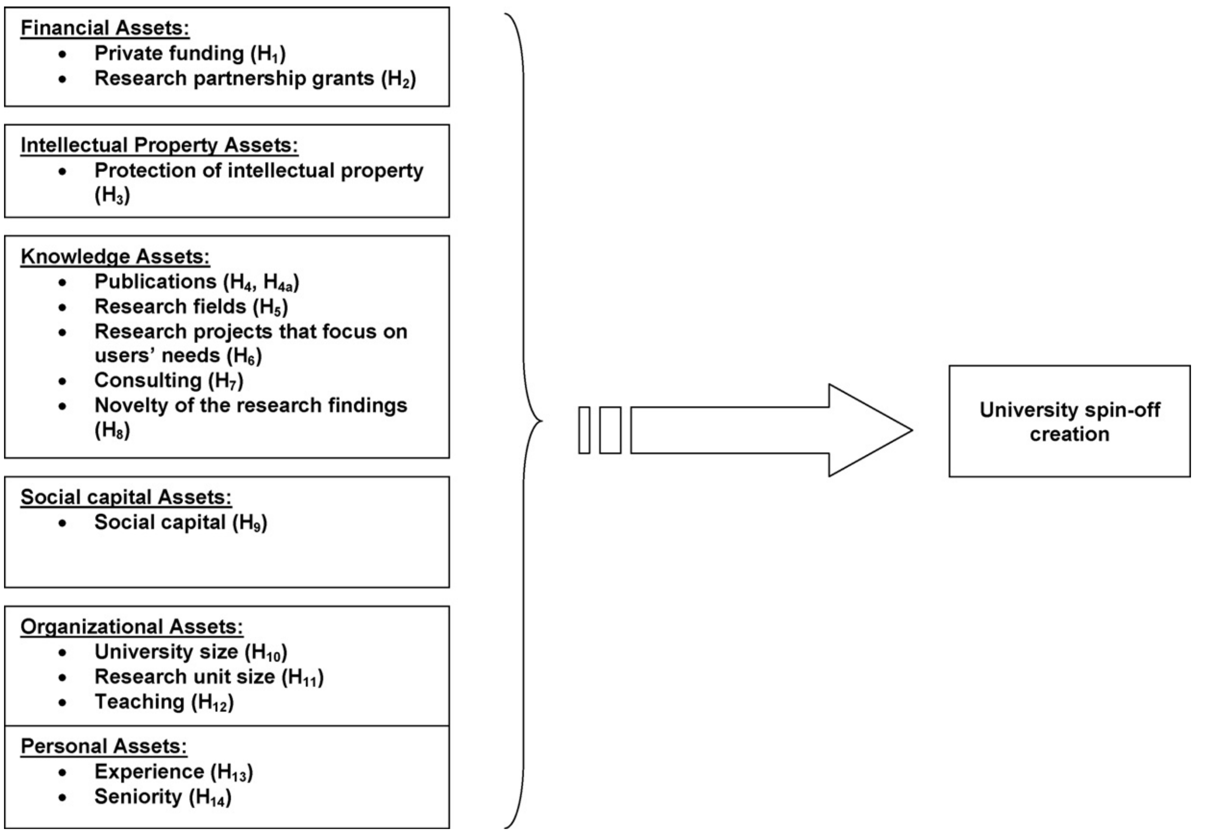

Fig. 1. A conceptual framework and hypotheses.

depicted in Fig. 1. We will review the literature on each of these factors in turn, beginning with the dependent variable spin-offs.

2.2. *The dependent variable*

In spite of the specificity of university spin-offs as a knowledge transfer mechanism, there is no consensus on this phenomenon (Clarysse and Moray, 2004; Pirnay et al., 2003). The concept is used in a large variety of ways (Chiesa and Piccaluga, 2000; Mustar, 1997; Fontes, 2003). In this paper, a university spin-off refers to the creation of a new company established in order to commercially exploit research knowledge created by university researchers.

2.3. *Explanatory variables*

2.3.1. *Financial assets*

Previous studies point to the importance of financial resources as a necessary condition for the creation of university spin-offs (e.g. Carayannis et al., 1998). The literature on spin-offs usually investigates the impact of two categories of actors with respect to the funding and support of the creation of research spin-offs (De Coster and Butler, 2005): (i) business angels who focus more on an assessment of the entrepreneurs than on an assessment of market risk; (ii) venture capitalists acting with seed capital (Zucker et al., 1998). These studies rarely consider the impact of the financial assets under the control of the university researchers at the time of launching spin-offs.

To shed new light on spin-off creation, this study lays stress on the impact of the sources of research funding accessible to researchers, especially the funding from industry and funding through industry–university research partnership grants provided by research granting councils on spin-off creation. Industry-funded research and university–industry partnership research grants act as incubators of spin-off creation because these sources of funding are more focused than traditional university funding sources on the creation of commercially oriented discoveries (Di Gregorio and Shane, 2003; O'Shea et al., 2005). Based on this rationale, we hypothesize that

H1. The greater the importance of industry financial support to the success of research projects, the higher the likelihood of spin-off creation by researchers.

H2. The greater the importance of financial support obtained through university–industry research partnership grants provided by research granting councils to the success of research projects, the higher the likelihood of spin-off creation by researchers.

In this paper, industry financial support (PRIFUND) obtained by the researcher is measured by a binary variable coded 1 if the researcher considered that funding from private firms or private foundations was *important*, *very important* or *extremely important* to the success of her/his research projects over the past 5 years, and 0 otherwise. Similarly, research grants (RGRGP) is a binary variable coded 1 if, over the past 5 years, the researcher has obtained grants from the NSERC Operating Research Grant Program (RGP) and NSERC University–Industry Research Partnership Program (RPP), and 0 if the researcher has obtained RGP grants only.

2.3.2. *Intellectual property assets*

Patents are the indicator that is the most frequently used to reflect the entrepreneurial activities of university researchers. Furthermore, patents represent alternative sources of revenue for universities and university researchers (Sapsalis and Van Pottelsberghe de la Potterie, in press). Researchers are therefore induced to invest in activities aiming at the protection of research knowledge that has some commercial potential. In turn, protected intellectual property generates original and distinctive assets that cannot be legally imitated for a certain period of time. Therefore, protected intellectual property represents an asset that can be used as a resource to create spin-offs. Based on this rationale, we hypothesize that

H3. The greater the effort made by researchers in activities aiming to protect their intellectual property, the higher the likelihood of spin-off creation by researchers.

In this paper, efforts made by researchers in activities aiming to protect their intellectual property (PIP) is measured as a binary variable coded 1 if, over the past 5 years, the researcher or her/his university on her/his behalf was engaged at least in one of the following seven forms of intellectual property protection, and 0 if the researcher or her/his university on her/his behalf was never engaged in such forms of intellectual property protection: (1) filling out patent applications; (2) registration of copyright for computer software or databases; (3) registration of copyright for educational material; (4) registration of integrated circuit topographies; (5) registration of industrial designs; (6) filling out protection of trademarks; (7) filling out applications for plant breeders' rights.

2.3.3. Knowledge assets

2.3.3.1. Publication assets. Only for a small proportion of the research knowledge produced by university researchers is it worth investing in its legal protection. Indeed, most of the research knowledge produced by university researchers contributes to the pool of open science. Therefore, a question that deserves attention is whether or not publications induce researchers to use their research knowledge to create spin-offs (Grandi and Grimaldi, 2003). On the other hand, the entrepreneurial and traditional visions of university research each have their own incentives and rules inducing their members to invest more or less of their time in research activities. The assumption underlying the traditional vision of university research is that faculty members who have high publication records exhibit a strong commitment in time and orientation to advancing research knowledge at the expense of knowledge transfer outside the scholarly community. It should be pointed out that publication assets may have opposite impacts on spin-off creation. These predicted opposite impacts reflect the tensions under which researchers operate: the traditional vision of the university, which induces the researchers to publish, competes with the entrepreneurial vision of the university, which induces the researchers to consider their publications as knowledge assets that can be transferred and commercialized outside the scholarly community. Therefore, one can hypothesize that

H4. The greater the publication assets of researchers, the higher the likelihood that researchers will launch spin-offs.

H4a. The greater the number of publications by faculty members, the lower the likelihood of spin-off creation by researchers.

The researcher's publication assets (SRPUB) are measured as the total number of articles, chapters of books and books published during the last 5 years (with the books being weighted by a factor of 5). This variable was matched with the normal distribution using a square root transformation.

2.3.3.2. Other attributes of knowledge assets. The number of publications provides an indication of the size of the pool of knowledge created by researchers. The literature on the diffusion of innovation has looked at the impact of attributes of knowledge on its transferability. Rogers (1995) has identified five knowledge attributes that influence the transferability of knowledge: relative advantage in relation to the knowledge it supersedes; compatibility with the existing values, past experiences and needs of potential users; complexity to understand the new knowledge for potential users; potential of experimentation of the new knowledge on a small scale; observability of the benefits for potential users. Although highly suggestive, these knowledge attributes have not yet been used in cross-sectional surveys on researchers' involvement in knowledge transfer. In the literature on technology and knowledge transfer, the market needs and demand have been measured by using indicators relating to various factors regarding the context in which firms and research organizations operate (Szulanski, 1996, 2000; Landry et al., in press). Factors such as research fields, attention paid to needs of users, experience in consulting, and distance between research knowledge and applications (degree of 'radicalness' of the research knowledge) are therefore likely to influence the transferability of knowledge into spin-offs.

2.3.3.3. Research fields. Empirical studies on knowledge transfer show that research fields matter in that the researchers involved in certain fields are more active in knowledge transfer than those in other fields. Hence, researchers in engineering are significantly more involved in knowledge transfer than their colleagues in other research fields (Landry et al., in press). The literature on spin-offs also suggests that research fields are a determinant of university spin-off creation (Fontes, 2003; Lowe, 1993; Orsenigo, 1989; Zucker et al., 1998). Based on this rationale and prior empirical studies, one can hypothesize that

H5. The researchers operating in engineering will exhibit a higher likelihood of becoming involved in spin-off creation than researchers in other fields.

In this paper, research fields were measured with a series of binary variables defined as follows: CHEMI is a binary variable coded 1 if the respondent was a researcher in chemistry, and 0 otherwise; PHMST is a binary variable coded 1 if the respondent was a researcher in physics, space sciences, mathematics and statistics, and 0 otherwise; COMPU is a binary variable coded 1 if the respondent was a researcher in computer sciences, and 0 otherwise; EARTH is a binary variable coded 1 if the respondent was a researcher in earth sciences, and 0 otherwise; LIFE is a binary variable coded 1 if the respondent was a researcher in life sciences, and 0 otherwise; finally, ENGIN is a binary variable coded 1 if the respondent was a researcher in engineering, and 0 otherwise. This last category of researchers was used as the reference category in the regression model.

2.3.3.4. Focus on users' needs. The promotion of the entrepreneurial vision of university research might induce researchers to pay more attention to commercially oriented research knowledge and to the existence of commercial opportunities for their particular expertise. This vision of academic research corresponds to the new philosophy of knowledge production in academic institutions across the OECD countries (Etzkowitz et al., 1998), which encourages the production of scientific knowledge oriented on problem solving. Based on this rationale, we hypothesize that

H6. The greater the extent to which the researchers' research projects focus on users' needs, the higher the likelihood of spin-off creation.

The researcher's assessment regarding the extent to which her/his research projects focused on users' needs (USERF) is measured by a binary variable coded 1 if the researcher asserted on a 5-point Likert scale that her/his research projects *often* or *very often* focused on users' needs, and 0 otherwise.

2.3.3.5. Consulting. Moreover, the involvement of researchers in consulting activities indicates their greater capacity and experience to commercialize their research knowledge and a greater capacity to use their research knowledge as an asset usable to create spin-offs (Louis et al., 1989). Therefore, we hypothesize that

H7. The greater the extent to which researchers are involved into consulting, the higher their likelihood of spin-off creation.

The researcher's involvement in consulting (CONSU) refers to services provided to private firms, government agencies or organizations associated with her/his research field. Consulting is measured by a binary variable coded 1 if the researcher asserted on a 5-point Likert scale that she/he *often* or *very often* provided such services over the past 5 years, and 0 otherwise.

2.3.3.6. Novelty of research. The spin-off literature does not provide any direct evidence on the relationship between the creation of university spin-offs and the novelty of research results. On the other hand, studies on innovation and knowledge transfer have found a positive effect of novelty of research on innovation (Amara et al., 2004) and a negative impact of the novel character of research on knowledge transfer (Landry et al., in press). Based on this rationale and this indirect evidence, we hypothesize that research novelty could have an impact on the creation of university spin-offs.

H8. The higher the degree of novelty of the research results of the researchers' projects, the lower the likelihood of spin-off creation.

The degree of novelty of research results (NOVELTY) was measured by using a four-item index regarding: (1) the use of new materials; (2) use of radical new technology; (3) use of new production techniques; (4) significant financial investments. For each statement, the respondents were asked to assess what would be required for their research results to be used in the development of new or improved products, processes or services, using a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Hence, the varying degree of novelty of research results is measured by the sum of the scores of the items corresponding to the responses to these four assertions. The scores of the respondents, which initially ranged from 4 to 20, were weighted in order to take into account "does not apply" answers. Thus, for each respondent, the sum of the score was divided by the number of applicable items. Even though the initial index has integer values from 1 to 5, once weighted, it can take on non-integer values. The value of Cronbach's α for this index is 0.73, indicating that the index's four items are reliable.

2.3.4. Social capital assets

The creation of academic spin-offs also depends on bridges linking research and market factors. As pointed out by Rogers (2002): "the fundamental difficulty in the technology transfer process traces to the dissimilarity . . . of the participants in the process." Research findings are commodities characterized by asymmetries and excludability. Asymmetry of information between university researchers and market actors arises when the business actors cannot precisely evaluate the applicability of the research transferred until one actually attempts to translate it into new or improved products or services. In a context of asymmetry, the transfer of knowledge is unlikely if researchers and market do not have frequent interactions. As for excludability, it arises either from the complexity of the research knowledge or from the tacit nature of the knowledge that is necessary to efficiently translate research findings into commercial applications (Szulanski, 1996, 2000). The creation of academic spin-offs depends on the opportunities created by the linkages joining the researchers to market actors. Therefore, one of the most important determinants of spin-off creation refers to the linkages joining the researchers to users of research in the market place (Starr and MacMillan, 1990; Allen, 1977; Tidd et al., 1997; Mustar, 1997; Grandi and Grimaldi, 2003). Therefore, one can hypothesize that

H9. The greater the social capital assets of researchers, the higher the likelihood of spin-off creation.

In this paper, the level of social capital (LINK) was measured by using an index assessing the intensity of the linkages that the researcher had with managers and/or professionals from three types of organizations: (1) private firms; (2) government departments; (3) university communication department (media relations, public affairs). For each type of organization, the respondents were asked to assess how frequently they had person-to-person contact with managers and/or professionals, using a 5-point scale ranging from 1 (never) to 5 (very often). The social capital index is thus the sum of the scores of the items corresponding to the researcher's responses. The respondents' scores, which initially ranged from 3 to 15, were weighted in order to take into account "does not apply" answers. Thus, for each respondent, the sum of the score was divided by the number of applicable items. Even though the initial index ranges from 1 to 5, once weighted, it can take on non-integer values. The value of Cronbach's α for this index is 0.71, indicating that the index's three items are reliable.

2.3.5. Organizational assets

2.3.5.1. University research size. According to Pérez and Sanchez (2003), the literature exhibits conflicting views with respect to the impact of an organization's size on spin-off creation. However, Ndonzuau et al. (2002) suggest that the asset basis of the parent organization (university) may be mobilized to facilitate the launching of spin-off companies. Indeed, the larger the size of universities, the larger the reservoir of resources and expertise linked to laboratories, technology transfer offices (Feldman et al., 2002; Di Gregorio and Shane, 2003; Bercovitz and Feldman, 2004) and star scientists' expertise (Zucker et al., 2002) that can be mobilized to foster the entrepreneurial vision of university research. Significant positive externalities among researchers could be generated within leading universities and laboratories: "critical knowledge spillovers, reputation, sharing of equipment instrumentation and facilities, complementarities between different types of researchers, or between different research agendas" (Carayol and Matt, 2004). This rationale suggests that large university research infrastructures provide more resources that facilitate the undertaking of knowledge transfer activities (O'Shea et al., 2005). Therefore, one can hypothesize that

H10. The larger the total research funding obtained by universities, the higher the likelihood of spin-off creation by researchers.

University research size was measured with a binary variable coded 1 if the researcher is affiliated with a large-sized research university and 0 otherwise. Large-sized is taken as a reference category in the regression model. This categorization of universities in large, medium and small sizes was developed by the staff of the Natural Sciences and Engineering Research Council of Canada (NSERC) based on the levels of the total funding received by the various universities from national and provincial research councils.

2.3.5.2. Laboratory size. However, in spite of the larger size of the assets provided by large research universities, researchers could find themselves in situations where the idiosyncratic assets required to succeed in launching a spin-off company in their specialized research field do not primarily depend upon university assets, but on idiosyncratic assets based at the level of their research unit or laboratory. In these situations, the resources that matter are not linked to the size of the university assets, but rather to the size of the resources available in the immediate laboratory environment of the researcher. Therefore, one can hypothesize that

H11. The larger the laboratories of researchers, the higher the likelihood of spin-off creation by researchers.

In this paper, laboratory size was measured by the number of equivalent full-time research personnel (excluding administrative support) supported by the researcher's research grants and contracts. This variable was matched with the normal distribution using a square root transformation.

2.3.5.3. Teaching. University and laboratory size can influence the likelihood of spin-off creation in another more direct way through incentives and rules inducing their members to invest more or less of their time in teaching. The assumption here is that faculty members who spend a larger number of hours in classrooms exhibit a higher commitment of time and orientation to the training of qualified personnel at the expense of the entrepreneurial activities of universities. Therefore, one can hypothesize that

H12. The greater the number of teaching hours of faculty members, the lower their likelihood of getting involved in the creation of spin-offs.

Involvement in teaching was measured as the percentage of time spent by the researcher on teaching activities. This variable was matched with the normal distribution using a square roots transformation.

2.3.6. Personal assets

Louis et al. (1989) suggest that more experienced researchers may have more to "sell", and may be less motivated by traditional academic incentives (tenure, disciplinary awards), than by greater financial incentives expected from the commercialization of their research results (Zuckerman and Merton, 1972; Etzkowitz, 1983). These studies suggest that the number of years of experience and seniority are an indication of opportunities of prior learning by doing in knowledge transfer and commercialization of research. Therefore, we hypothesize that

H13. The greater the experience of researchers, the higher their likelihood of spin-off creation.

H14. The higher the academic rank of researchers, the higher their likelihood of spin-off creation.

The experience of researchers (SREXP) was measures as the number of years between 2002 and the year of completion of PhD. To match a normal distribution with this variable, the square roots transformation was used. The level of seniority in the academic ranks was measured as follows: grantee researcher (GRANTEE) is a binary variable coded 1 if the researcher is not tenured and if his salary is supported by research grants and coded 0 otherwise; assistant professor (ASSIST) is a binary variable coded 1 if the researcher is an assistant professor and coded 0 otherwise; associate professor (ASSOC) is a binary variable coded 1 if the researcher is an associate professor and coded 0 otherwise; finally, full professor (FULL) is a binary variable coded 1 if the researcher is a full professor and coded 0 otherwise.

The control variable gender was added and measured as a binary variable coded 1 if the researcher is a man and coded 0 if the researcher is a woman.

3. Data and descriptive statistics

3.1. Sample

The population of the present study consists of 8191 university researchers funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). A random sample of 4000 university researchers was prepared by NSERC for this study in order to represent 25 research field categories (Appendix A). All researchers included in the sample were funded by NSERC during the 1997–2002 period.

The survey was conducted by telephone between 18 February and 27 March 2002. Of the 4000 people included in the sample, 2075 were excluded from the sample for the following reasons: no response after 25 calls ($n = 1637$), inability to respond ($n = 2$), residential phone number ($n = 66$), discontinued phone number ($n = 194$), ineligible respondent ($n = 8$), and other reasons such as being retired, wrong number, etc. ($n = 168$). The sample thus comprised 1925 people. Of these 1925 people, 19 did not complete the questionnaire, 274 refused to participate (after a recall) and 78 asked to be interviewed later, but were never reached. Finally, the survey generated 1554 usable questionnaires for a net response rate of 81% (1554/1925). The possibility of non-response bias was verified by comparing the number of respondents to that of the original population sample for 25 categories of research fields. Every research field category is statistically well represented in the completed questionnaires except for the pure and applied mathematics category, which is under-represented. With the help of NSERC staff, we merged the 25 research fields into the following six categories: 1—chemistry, 2—physics, space sciences, mathematics and statistics, 3—computer sciences, 4—earth sciences, 5—life sciences, and finally, 6—engineering. This procedure allowed us to have enough observations to conduct comparative analyses.

3.2. Instruments and measures

For the two independent variables based on multiple-item scales and included in the econometric model, namely the index referring to the radical character of the research, and the index measuring the intensity of social capital, we conducted a principal components factor analysis (PCFA) on the construct scales to assess their unidimensionality (Ahire and Devaray, 2001). The results of the PCFA indicate that, in both cases, one factor explains, respectively, 55.88% and 49.57% of the original variance of these two constructs with an initial Eigenvalue of 2.23 and 1.49, respectively.

Once the unidimensionality of the additive scales measuring the two independent variables based on multiple-item scales was established, an assessment of the statistical reliability was necessary. In order to make such an assessment, an item analysis of the components of these additive scales was performed by computing Chronbach's alpha. This coefficient provides a reliability coefficient for multiple-item scales, such as those included in the scales of radicalness of research and social capital. Chronbach's alpha is 0.73 for the four items of radicalness of research index, and 0.71 for the three items of social capital. Hence, the values of the α coefficients for multiple-item scales employed in this study are reliable.

Furthermore, we used the probability plots to determine whether the distribution of each of the six continuous variables included in the model matches a normal distribution. More specifically, we used the *Q–Q* plots procedure, which plots the quintiles of a variable's distribution against the quintiles of a normal distribution. In doing so, we found that only the variables linkages and radicalness of research seem to match a normal distribution. In fact, the observations of these variables are clustered around a straight line, corresponding to normal distributions. The skewness value of these two variables is lower than 1, which generally indicates that their distributions do not differ significantly from a normal distribution. For the four other continuous variables included in the model, namely research unit size, time spent on teaching activities, experience of researchers, and publication assets of researchers, we found that the observations are not clustered around a straight line corresponding to normal distributions. For these four variables we used a square roots transformation; the probability plots for the transformed values as well as the skewness statistics indicated that the transformed variables did not differ significantly from a normal distribution.

Finally, the correlation matrix between the independent variables used in the regression model (Appendix A) indicates that the highest correlation coefficient between the independent variables is that existing between the binary variable assistant professor (ASSIST) and the variable referring to the experience of researchers (SREXP). This correlation coefficient is equal to −0.536, which ensures that no serious multi-collinearity problems can arise in the regression model.

3.3. Descriptive statistics

The descriptive statistics of the variables used in this study are reported in Table 1. Moreover, we used the Chi-square test to compare the proportion of researchers who have created spin-offs over the past 5 years accord-

Table 1
Descriptive statistics

Variables	Type of variables	Minimum	Maximum	Mean	S.D.	Cronbach's α
Continuous variables						
Research unit size	Continuous: number	0	60	4.14	4.32	–
Publications assets	Continuous: number	0	223	19.92	18.41	–
Experience of the researcher	Continuous: number	2	51	21.22	11.01	–
Percentage of time spent on teaching activities	Continuous: number	1	100	31.43	14.76	–
Social capital	Index: 3 items	1	5	2.54	0.92	0.71
Novelty of research	Index: 4 items	1	5	2.94	0.77	0.73
Categorical variables						
Researcher has created a spin-off	16% (YES)					
Private funding	24.3% (private funding was *important*, *very important* or *extremely important* to the success of the research projects)					
University–industry Research partnership grant	79.7% (research grant and partnership grant)					
Consulting activities	23.1% (researchers who provided, *often* or *very often*, consulting services)					
Focus on users' needs	40.3% (research projects, *often* or *very often*, focused on users' needs,)					
Protection of intellectual property	32.6% (researchers who had undertaken at least one form of PIP)					
Gender	86.4% (men)					
Size of University of affiliation	Small = 8.8%, medium = 21.5%, large = 69.7%					
Research fields						
Engineering	30.8%					
Chemistry	8.3%					
Physics, space sciences, mathematics and statistics	15.8%					
Computer sciences	8.1%					
Earth sciences	8.1%					
Life sciences	28.9%					
Seniority						
Grantee researcher	8.0%					
Assistant professor	18.91%					
Associate professor	20.52%					
Full professor	52.57%					

Table 2
Distribution of the university spin-off creation by researchers according to the size of the university

University size	Researcher has created a spin-off		Researcher has not created a spin-off		Pearson[a] χ^2
	N	%	*N*	%	
Small university	13	9.6	122	90.4	11.07***
Medium university	41	12.5	288	87.5	
Large university	195	18.3	871	81.7	

*** Indicates that we can reject the null hypothesis (independency between the two variables) at 1% level.
[a] The χ^2 tests the independency between the variable referring to the size of the university where the researcher is involved and the variable indicating if the researcher has created a spin-off or not.

ing to the research size of university of affiliation, and according to the research fields. The results (in Table 2) show that the proportion of researchers who have created spin-offs in large research universities (18.3%) is greater than the proportion of researchers who have created spin-offs in medium and small research universities, respectively, 12.5% and 9.6%. For its part, Table 3 reports the results of the test of independency between the field of research of the researcher and the fact that he/she has ever created a spin-off. The results show that the proportion of researchers who have created spin-offs is particularly larger in computer sciences (25.4%) and engineering (22.8%) than in the other four fields, especially more than for the researchers in physics, space sciences, mathematics and statistics (7.5%).

4. Regression results

The decision to create spin-offs by researchers was measured by a binary variable. It takes a value of 1 when the respondent attempted to create a spin-off company from the results of her/his research, and 0 otherwise. To identify the determinants explaining the likelihood of creation of spin-offs by researchers, the basic model that has been estimated is

$$\log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1\mathrm{PRIFUND} + \beta_2\mathrm{RGRGP} + \beta_3\mathrm{PIP} + \beta_4\mathrm{SRPUB} + \beta_5\mathrm{CHEMIS} + \beta_6\mathrm{PHMST} + \beta_7\mathrm{COMPU} + \beta_8\mathrm{EARTH} + \beta_9\mathrm{LIFE} + \beta_{10}\mathrm{USERF} + \beta_{11}\mathrm{CONSU} + \beta_{12}\mathrm{NOVELTY} + \beta_{13}\mathrm{LINK} + \beta_{14}\mathrm{SRTEACH} + \beta_{15}\mathrm{LARGE} + \beta_{16}\mathrm{SRUNIT} + \beta_{17}\mathrm{EXPER} + \beta_{18}\mathrm{GENDER} + \beta_{19}\mathrm{GRANTEE} + \beta_{20}\mathrm{ASSIST} + \beta_{21}\mathrm{ASSOC}$$

where β_i ($i = 0, \ldots, 21$) are the coefficients; the independent variables used in the model have been defined in the section discussing the conceptual model and its derived hypotheses. $\log(P_i/1-P_i)$ is the logarithm of the ratio of the probability that a researcher i has created a spin-off relative to the probability that the same researcher has not created a spin-off.

The results of the regression about whether or not researchers have created spin-offs are summarized in

Table 3
Distribution of the university spin-off creation by researchers according to the research field

Research fields	Researcher has created a spin-off		Researcher has not created a spin-off		Pearson[a] χ^2
	N	%	*N*	%	
Engineering	107	22.8	362	77.2	42.29***
Chemistry	20	15.9	106	84.1	
Physics, space sciences, mathematics and statistics	18	7.5	223	92.5	
Computer sciences	32	25.4	94	74.6	
Earth sciences	19	15.2	106	84.8	
Life sciences	53	12.0	390	88.0	

*** Indicates that we can reject the null hypothesis (independency between the two variables) at 1% level.
[a] The χ^2 tests the independency between the variable referring to the research field of the researcher and the variable indicating if the researcher has created a spin-off or not.

Table 4
Estimated Logit model of factors affecting the creation of spin-offs by academic researchers

Independent variables	Dependent variables: spin-off/no spin-off	
	Coefficients (β)	*P* value[a]
Intercept	−6.611	0.000
Financial assets		
Private funding [PRIFUND]	−0.228	0.127*
NSERC university–industry research partnership grant [RGRPG]	0.279	0.172*
Intellectual property assets		
Protection of intellectual property [PIP]	1.098	0.000***
Attributes of knowledge assets		
Publication assets [SRRPUB][b]	0.026	0.602
Chemistry [CHEM][c]	−0.436	0.179*
Physics, space sciences, mathematics and statistics [PHMST][c]	−0.566	0.075**
Computer sciences [COMPU][c]	0.875	0.001***
Earth sciences [EARTH][c]	−0.019	0.951
Life sciences [LIFE][c]	−0.448	0.042**
Focus on users' needs [USERF]	0.185	0.312
Consultation activities [CONSU]	0.398	0.029**
Novelty of research [NOVELTY]	0.298	0.030**
Social capital assets		
Social capital [LINK]	0.343	0.004***
Organizational assets		
Teaching activities [SQRTEACH][b]	0.03	0.977
Large-sized university [LARGE]	0.359	0.057**
Research unit size [SRUNIT][b]	0.235	0.012***
Personal assets		
Experience [SREXP][b]	0.223	0.002***
Gender (man = 1) [GENDER]	0.859	0.014***
Grantee [GRANTEE][d]	−0.298	0.333
Assistant [ASSIST][d]	0.311	0.277
Associate [ASSOC][d]	0.216	0.391
Number of cases	1286	
Chi-square (d.f.)	181.86 (21)	
Nagelkerke R^2 (pseudo R^2)	0.216	
Percentage of correct predictions	82.8%	

[a] *,** and *** indicate that the variable is significant at 10%, 5% and 1%, respectively.
[b] SQR indicates the square roots transformation of the variable whose name it precedes.
[c] The reference category is engineering.
[d] The reference category is full professor.

Table 4. The equation has good predictive power, with 82.8% of correct predictions. Therefore, the model correctly classified 83.1% of the researchers between those who created a spin-off and those who did not create a spin-off. The value of the Nagelkerke R^2 (pseudo R^2) is 0.216, which is quite reasonable for qualitative-dependent variable models. Furthermore, the computed value of the likelihood ratio (i.e., 181.86) is much larger than the critical value of the chi-squared statistic with 21 degrees of freedom at the 1% level. This suggests that the null hypothesis, that all the parameter coefficients (except the intercept) are all zeros, is strongly rejected. Consequently, the model is significant at the 1% level.

The likelihood that researchers create spin-offs increases as the laboratory size increases, as their social capital assets increase, as the degree of novelty of research results increases, and as their number of years of experience in research increases. As for the dichotomous variables, the results indicate that researchers who consider that funding from private firms or private foundations was *important* or *extremely important* to the success of their research projects are less likely to create spin-offs than researchers who consider these sources of funding less important. Similarly, being a researcher active in consulting activities with private firms, government agencies or organizations associated with her/his research field increases the probability that such researchers engage in spin-off creation. In the same way, researchers who have carried out over the past 5 years activities linked to the protection of intellectual property are more likely to create spin-offs than those who did not carry out such activities. As for gender, being a man increases the likelihood of creating spin-offs. The dichotomous variables capturing the researchers' university research size and their fields of research are also significant to predict the likelihood of spin-off creation. More specifically, the researchers affiliated to large-sized research universities are more likely to create spin-offs than those affiliated to small and medium-sized research universities. As for research fields, the researchers in physics, space sciences, mathematics and statistics, those in chemistry, and those in life sciences are less likely to create spin-offs than researchers in engineering. However, researchers in computer sciences are more likely to create spin-offs than those in engineering. Moreover, there is no statistical significant difference in this matter between researchers in engineering and earth sciences. Finally, the seniority of researchers as measured by their academic rank seems not to have a significant impact on their likelihood to create spin-offs.

The results shown in Table 4 are based on the signs and significance of the coefficients of the explanatory variables. They do not take into account the scope of these coefficients because, in the logistic functional form upon which Logit regressions are based, the estimated values of coefficients, such as those presented in Table 4, cannot be interpreted as elasticity coefficients or as coefficients reflecting the marginal impacts of the explanatory variables. In order to assess the scope of the impact of the explanatory variables on the likelihood of creation of spin-offs by researchers, we have ascertained the partial elasticities of the variables, which significantly explain the likelihood of spin-off creation. The partial elasticities for the variables that have been found to significantly explain the likelihood of spin-off creation by researchers were calculated with NLOGIT Statistical Package Version 3.0. These partial elasticities reflect the average of the elasticity coefficients evaluated for each of the 1286 researchers. As can be seen in Table 5, the elasticity coefficients of the variables experience in research and social capital are the highest. These coefficients take respectively the values of 0.766 and 0.609, thus indicating that a positive relative change of 10% in the number of years of experience of the researcher, and in the index of social capital assets, increases the likelihood of creation of spin-offs by 7.66% and 6.09%, respectively. Likewise, a positive relative change of 10% in the degree of novelty of research results, and in the size of the research unit, increases the likelihood of creation of spin-offs by 5.97% and 3.73%, respectively.

Table 5
Impacts of the statistically significant variables on the creation of spin-offs

(A) Continuous variables	Partial elasticity[a]
Novelty of research [NOVELTY]	5.97
Social capital [LINK]	6.09
Experience [SREXP]	7.66
Research unit size [SRUNIT]	3.73
(B) Binary variables	**Impacts[b]**
Protection of intellectual property [PIP]	1.44
Consultation activities [CONSU]	0.50
University–industry research partnership grant [RGRPG]	0.31
Private funding [PRIFUND]	−0.26

[a] Elasticities are reported for a 10% increase in the different continuous variables.
[b] The impacts of the binary variables were not calculated for binary control variables (gender, fields and university size).

As for the dichotomous variables, the lower section of Table 5 presents the percentage of change in the likelihood that researchers create spin-offs in relation to changes in the state of the significant explanatory variables that are binary. These results are also calculated by using NLOGIT Statistical Package Version 3.0. The coefficients show that the likelihood of spin-off creation by researchers would be increased by 1.44% if the researchers who are not engaged in any form of protection of intellectual property decided to do so. Similarly, the likelihood of spin-off creation by researchers would be increased by 0.50% if the researchers who do not provide consulting services to private firms, government agencies or organizations associated with their research fields, decided to provide such services. Furthermore, the results of Table 5 also indicate that the likelihood of spin-off creation by researchers would decrease by −0.26% if all the researchers who did not obtain funding from private firms and private foundations did obtain funding from these sources. Finally, the likelihood of spin-off creation by researchers would increase by 0.50% if all the researchers who did not obtain simultaneously research grants and university–industry partnership grants from NSERC succeeded in obtaining simultaneously funding from these two NSERC programs.

5. Conclusion and discussion

This paper deals with the following question: what are the determinants of the creation of university spin-offs by

Canadian researchers in natural sciences and engineering? Based on the answers of a representative sample of 1554 Canadian researchers in natural sciences and engineering who hold research grants from NSERC, the findings of this study show that, on the whole, 16.8% of the respondents exhibited entrepreneurial behaviour through their attempts to create spin-offs. Furthermore, 32% of the respondents have also used diverse types of mechanisms to protect their intellectual property. These simple descriptive findings suggest that the reality of research commercialization is more extensive in Canadian universities than commonly assumed. How can one explain spin-off creation? This question was considered with a regression model.

The regression model shows that a complementary set of resources needs to be mobilized by researchers in order to launch university spin-offs. Hence, as expected in the hypotheses developed in the conceptual framework, the likelihood of launching university spin-offs increases as the researchers have access to more financial resources from the NSERC operating grants and university–industry partnership grants programs, have more intellectual property assets, have knowledge assets in the fields of computer sciences and engineering rather than in the other natural sciences, have knowledge expertise in consulting, have higher social capital assets, have access to the resources of large research universities, have access to the resources of large laboratories, and have many years of experience in research.

However, contrary to expectations, some hypotheses were not supported by the data analysis. First, increases in financial resources from firms have been found to have a negative impact on the creation of university spin-offs, while combined funding from the Natural Sciences and Engineering Research Council operating grants and university–industry partnership grants programs has a positive impact on the creation of university spin-offs. On the one hand, these results suggest that getting financial support from firms might induce researchers to transfer directly their knowledge to the firms that support them rather than to induce them to get involved independently in the launching of spin-offs. Indeed, contractual arrangements with firms might include obligations to transfer the intellectual property to the firms who paid for the knowledge creation, thus preventing researchers from launching spin-offs. Furthermore, researchers involved in collaborative research projects with firms might assume that they cannot launch spin-offs that would become rivals of the firms supporting their research activities. On the other hand, the results of this study also suggest that incentives to launch spin-offs are increased when researchers are supported by complementary financial resources provided by the operating grants program, a program supporting investigator-driven research, and the university–industry partnership grants program, a program where researchers become eligible to funding when they partner with private firms. These results suggest that university–industry partnership grants in combination with traditional funding of university research provide a better incubator for spin-off creation, but that financial support from the private sector might be a good mechanism for fostering knowledge transfer directly to private firms. The incubation capacity of university research on spin-off creation is also likely influenced by differences in the business models of start-ups. Some types of spin-offs require patents and high start-up capital whereas other types involve the commercialization of expertise that does not require patents and high start-up capital.

Moreover, contrary to expectations, publication assets (number of publications) were found to have no impact on spin-off creation by researchers. A positive impact of publication assets would have suggested that they could be considered as a tool supporting the entrepreneurial vision of university research. On the other hand, a negative impact of publication assets would have suggested that they are a tool supporting the traditional non-entrepreneurial vision of university research. This unexpected result suggests that publications might constitute resources supporting both the entrepreneurial and the non-entrepreneurial visions of university research. This study used the number of publications as an indicator of scientific output. Future investigations should perhaps use other indicators, given that scientific output is a type of resource used to build other things (Sapsalis and Van Pottelsberghe de la Potterie, in press; such as spin-offs).

The number of teaching hours per week was also found to have no relation with the likelihood of spin-off creation. The confirmation of a negative impact of teaching on spin-off creation would have suggested a conflict between the entrepreneurial and the more traditional and non-entrepreneurial visions of universities and university research. The absence of a statistically significant relation between teaching activities and spin-offs suggests that the traditional and entrepreneurial visions of universities and university research can successfully co-exist in the same milieu without harming each other.

Contrary to expectations, the results of the regression show that the degree of novelty of research knowledge increases the likelihood of spin-off creation. These results imply that the greater the degree of novelty of the research, the greater the distance between the research results and their applications in products or services.

These unexpected results might be due to the fact that, until recently, access to venture capital to establish university spin-off companies was relatively easy in Canada. The current context where access to venture capital is increasingly difficult might induce researchers to use proof-of-principle programs to fill the gap between their research knowledge and marketable products. Again, further research is needed on this issue in order to better document the attributes of research knowledge that are the most likely to lead to the creation of research spin-offs.

One of the most interesting results of this study relates to the impact of laboratory size on spin-off creation. This result suggests that researchers not only depend on the overall university assets, but also on the specific resources located in their immediate research environment. It suggests that positive externalities among researchers are generated not only at the university level but also at the laboratory level. This result might be explained by the fact that launching research spin-offs benefits from spillovers and access to highly dedicated assets that are available only at the laboratory level. In such a context, university assets that may be mobilized to launch spin-offs can be considered as resources that are not specific but easy to redeploy from one laboratory to another, whereas laboratory assets represent highly specific technical assets that are required to launch research spin-offs.

Overall, these results suggest that the traditional and entrepreneurial visions of university research complement each other when looking at the resources mobilized by researchers to launch spin-offs. More specifically, the results of this study suggest that Etzkowitz's entrepreneurial university could not exist without the resources and capabilities of the traditional university. In short, the results of this study suggest that university administrators and policy makers should promote the co-existence of the traditional and entrepreneurial visions of universities in order to foster both the creation of new research knowledge and its transfer into commercial and non-commercial applications.

The results of this study carry more specific implications pertinent for managers of research granting councils and managers of university TTOs who aim to increase the likelihood of spin-off creation. When attempting to increase the launching of spin-offs, they should consider paying attention to a complementary set of resources in a context where they would encourage researchers: (1) to seek grants simultaneously from investigator-driven operating grants and university–industry partnership grants programs; (2) to undertake actions to better protect their intellectual property; (3) to invest their time in research that carries high degrees of novelty; (4) to become involved in large laboratories; (5) to operate in large research universities; (6) to encourage the recruitment (and retention) of experienced researchers. The computation of the partial elasticity coefficients suggests that out of all the investments that could be made, those related to the support of experienced researchers, the consolidation of social capital (networks) and a high degree of novelty of research knowledge would have the largest marginal impact on the likelihood of university spin-off creation.

Although it sheds new light on the complementary resources that are required to foster the creation of spin-offs by university researchers, this study has some limitations that can only be overcome with further research. A first limitation is that, in adopting 'creation of spin-offs' as its unit of analysis and its dependent variable, it does not take into account what happens beyond creation. Thus, the results of this paper do not explain other significant aspects of spin-offs, such as their type, their survival and their capacity to create economic value over time. As suggested above, there might be differences in the types of business models of spin-offs regarding intellectual property and initial start-up costs. Secondly, this study focuses on the initiatives of individual researchers without taking account of university TTO initiatives and policies. Such a focus carries the advantages of stressing the fact that the competitive advantages of research spin-offs are likely to be based on what the individual founders can do better than others. Such a focus is also appropriate to capture the impact of the resources accessible to individual researchers on the launching of spin-offs. However, in focusing on factors and resources that are close to individuals, this paper might have underestimated the impact of systemic factors related to public policies and university policies. Thirdly, although this study is based on a representative sample of researchers from a large variety of disciplines and diverse types of research universities, it includes only researchers who have succeeded in obtaining research grants. These researchers are likely to be better researchers than those who either did not apply for research grants or did not succeed in obtaining research grants. Therefore, studies that compare these two groups of researchers would provide additional insights on both the likelihood and determinants of spin-off creation. Finally, this study did not address the issue of the optimal balance required to ensure a productive co-existence of the traditional and entrepreneurial visions of universities. Empirical studies are needed to look at the balance between the co-existence of these two visions.

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Appendix A

Correlations between explanatory variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PRIFUND	1																				
SRUNIT	0.275	1																			
RGRGP	−0.206	−0.340	1																		
LINK	0.320	0.334	−0.248	1																	
CONSU	0.209	0.226	−0.090	0.342	1																
USERF	0.347	0.280	−0.276	0.436	0.268	1															
NOVELTY	0.055	0.173	−0.077	0.198	0.014	0.100	1														
PIP	0.186	0.266	−0.201	0.264	0.169	0.233	0.225	1													
SRPUB	0.080	0.335	−0.178	0.188	0.147	0.048	0.094	0.103	1												
SREXP	−0.061	−0.077	0.046	−0.011	0.043	−0.039	−0.112	−0.03	00.258	1											
GENDER	0.038	0.028	−0.018	0.074	0.066	0.065	0.000	0.072	0.130	0.203	1										
LARGE	0.040	0.116	−0.084	0.020	0.062	0.028	−0.025	0.074	0.138	0.123	0.006	1									
SRTEACH	−0.123	−0.160	0.072	−0.100	−0.135	−0.092	−0.018	−0.045	−0.187	−0.26	−0.073	−0.136	1								
CHEMIS	−0.010	0.086	−0.015	−0.039	−0.064	−0.056	0.090	0.022	0.116	0.081	0.028	−0.032	−0.089	1							
PHMST	−0.180	−0.233	0.133	−0.214	−0.091	−0.209	−0.029	−0.18	−0.026	0.119	0.071	0.002	0.062	−0.130	1						
COMPU	−0.015	−0.034	0.032	−0.033	−0.040	0.001	−0.070	0.018	−0.146	−0.137	−0.032	−0.015	0.088	−0.089	−0.129	1					
EARTH	−0.004	−0.010	−0.093	0.100	0.022	0.030	−0.062	−0.07	0.030	0.093	0.066	0.001	−0.035	−0.089	−0.128	−0.088	1				
LIFE	−0.040	0.036	0.084	−0.132	−0.077	−0.145	−0.033	−0.01	0.082	−0.006	−0.182	−0.010	−0.085	−0.191	−0.276	−0.189	−0.189	1			
GRANTEE	0.043	0.054	−0.056	0.025	0.033	0.032	0.003	0.029	0.030	0.048	0.018	0.020	−0.046	0.021	−0.018	−0.041	−0.032	−0.032	1		
ASSIST	0.043	0.003	0.050	0.007	−0.082	0.008	0.087	−0.007	−0.222	−0.536	−0.133	−0.014	0.071	−0.007	−0.057	0.067	−0.078	0.001	−0.139	1	
ASSOC	−0.049	−0.061	0.044	−0.077	−0.045	−0.044	−0.002	−0.033	−0.150	−0.265	−0.138	−0.074	0.145	−0.013	−0.015	0.053	−0.011	0.043	−0.146	−0.247	1

References

Ahire, S.L., Devaray, S., 2001. An empirical comparison of statistical construct validation approaches. IEEE Transactions on Engineering Management 48 (3), 319–329.

Allen, T. (Ed.), 1977. Managing the Flow of Technology. MIT Press, Cambridge, MA.

Amara, N., Landry, R., Becheikh, N., Ouimet, M., 2004. Radical innovations in traditional manufacturing industries. In: The DRUID Summer Conference on Industrial Dynamics, Innovation and Development, Elsinore (Helsingor), Denmark, June 14–16.

Barney, J., 1991. Firm resources and sustained competitive advantage. Journal of Management 17 (1), 99–120.

Bercovitz, J., Feldman, M., 2004. Academic entrepreneurs: social learning and participation in university technology transfer. University of Toronto, Mimeo.

Carayannis, E.G., Rogers, E.M., Kurihara, K., Allbritton, M., 1998. High-technology spin-offs from government R&D laboratories and research universities. Technovation 18 (1), 1–11.

Carayol, N., Matt, M., 2004. The exploitation of complementarities in scientific production process at the laboratory level. Technovation 24 (6), 455–465.

Chiesa, V., Piccaluga, A., 2000. Exploitation and diffusion of public research: the case of academic spin-off companies in Italy. R&D Management 30 (4), 329–340.

Clarysse, B., Moray, N., 2004. A process study of entrepreneurial team formation: the case of a research-based spin-off. Journal of Business Venturing 19, 55–79.

Conner, K.R., Prahalad, C.K., 1996. A resource-based theory of the firm: knowledge versus opportunism. Organization Science 7 (5), 477–501.

Cooper, A.C., Bruno, A.V., 1977. Success among high-technology firms. Business Horizons 20, 16–22.

De Coster, R., Butler, C., 2005. Assessment of proposals for new technology ventures in the UK: characteristics of university spin-off companies. Technovation 25 (5), 535–543.

Degroof, J.J., Roberts, E.B., 2004. Overcoming weak entrepreneurial infrastructure for academic spin-off ventures. Journal of Technology Transfer 29 (3/4), 327–357.

Di Gregorio, D., Shane, S., 2003. Why do some universities generate more start-ups than others? Research Policy 32, 209–227.

Etzkowitz, H., 1983. Entrepreneurial scientists and entrepreneurial universities in American academic science. Minerva 21, 198–233.

Etzkowitz, H., Webster, A., Healey, P. (Eds.), 1998. Capitalizing Knowledge: New Intersections of Industry and Academia. State University of New York Press, Albany, NY.

Feldman, M., Feller, I., Bercovitz, J., Burton, R., 2002. Equity and the technology transfer strategies of American research universities. Management Science 48 (1), 105–121.

Fontes, M., 2003. The process of transformation of scientific and technological knowledge into economic value conducted by biotechnology spin-offs. Technovation 25 (4), 339–347.

Grandi, A., Grimaldi, R., 2003. Exploring the networking characteristics of new venture founding teams. Small Business Economics 21, 329–341.

Grant, R.M., 1996. Toward a knowledge-based theory of the firm. Strategic Management Journal 17 (Special Issue), 109–122.

Jones-Evans, D., Magnus, K., 1998. The role of the university in the technology transfer process: a European view. Science and Public Policy 25 (6), 373–380.

Kogut, B., Zander, U., 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. Organization Science 3 (3), 383–397.

Landry, R., Amara, N., Ouimet, M., in press. Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineering. Journal of Technology Transfer.

Levin, S., Stephan, P., 1991. Research productivity over the life cycle: evidence for academic scientists. American Economic Review 81 (4), 114–132.

Lockett, A., Wright, W., 2004. Resources, capabilities, risk capital and the creation of university spin-out companies, technology transfer and universities' spin-out strategies. In: Paper Presented at the Proceedings of the Technology Transfer Society Meetings, Albany, NY, September 30, 2004.

Lockett, A., Wright, M., Franklin, S., 2003. Technology transfer and universities' spin-out strategies. Small Business Economics 20, 185–200.

Louis, K., Blumenthal, D., Gluck, M., Stoto, M., 1989. Entrepreneurs in academe: an exploration of behaviours among life scientists. Administrative Science Quarterly 34 (1), 110–131.

Lowe, J., 1993. Commercialization of university research: a policy perspective. Technology Analysis and Strategic Management 5 (1), 27–37.

Mustar, P., 1997. Spin-off enterprises—how French academics create hi-tech companies: the conditions for success or failure. Science and Public Policy 24 (1), 37–43.

Ndonzuau, F.N., Pirnay, F., Surlemont, B., 2002. A stage model of academic spin-off creation. Technovation 22, 281–289.

Nerkar, A., Shane, S., 2003. When do start-ups that exploit academic knowledge survive? International Journal of Industrial Organization 21 (9), 1391–1410.

Orsenigo, L., 1989. The Emergence of Biotechnology. Institutions and Markets in Industrial Innovation. Pinter Publishers, London.

O'Shea, R.P., Allen, T.J., Chevalier, A., Roche, F., 2005. Entrepreneurial orientation, technology transfer, and spinoff performance of US Universities. Research Policy 34 (7), 994–1009.

Pérez, M.P., Sanchez, A.M., 2003. The development of university spin-offs: early dynamics of technology transfer and networking. Technovation 23, 823–831.

Pirnay, F., Surlemont, B., Nlemvo, F., 2003. Toward a typology of university spin-offs. Small Business Economics 21, 355–369.

Roberts, E., 1991. The technological base of the new enterprise. Research Policy 20, 283–298.

Roberts, E.B., Malone, D.E., 1996. Policies and structures for spinning off new companies from research and development organizations. R&D Management 26 (1), 17–48.

Rogers, E.M., 1995. Diffusion of Innovations, 4th ed. The Free Press, New York.

Rogers, E., 2002. The nature of technology transfer. Science Communication 23, 323–341.

Sapsalis, E., Van Pottelsberghe de la Potterie, B., in press. The institutional sources of knowledge and the value of academic patents. Economics of Innovation and New Technology.

Shane, S., 2001. Technology regimes and new firm formation. Management Science 47 (9), 1173–1190.

Shane, S., 2004. Academic Entrepreneurship. University Spin-offs and Wealth Creation. Edward Elgar, Northampton, USA.

Shane, S., Khurana, R., 2003. Bringing individuals back in: the effects of career experience on new firm founding. Industrial and Corporate Change 12 (3), 519–543.

Siegel, D.S. Phan, P.H., 2004. Analyzing the effectiveness of university technology transfer: implications for entrepreneurship education. In: Proceedings of the Colloquium on Entrepreneurship Education and Technology Transfer. URL: http://www.rpi.edu/dept/economics/www/workingpapers/rpi0426.pdf.

Smilor, R.W., Gibson, D.V., Dietrich, G.B., 1990. University spin-out companies: technology start-ups from UT-Austin. Journal of Business Venturing 5, 63–76.

Starr, J.E., MacMillan, I.C., 1990. Resource cooptation via social contracting: Resource acquisition strategies for new ventures. Strategic Management Journal 11 (1), 79–92.

Szulanski, G., 1996. Exploring internal stickiness: impediments to the transfer of best practice within the firm. Strategic Management Journal 17, 27–43.

Szulanski, G., 2000. The process of knowledge transfer: a diachronic analysis of stickiness. Organizational Behavior and Human Decision Processes 82 (1), 9–27.

Tidd, J., Bessant, J., Pavitt, K., 1997. Managing Innovation: Integrating Technological, Organizational and Market Change. John Wiley and Sons, Chichester.

Zucker, L., Darby, M., Brewer, M., 1998. Intellectual human capital and the birth of US biotechnology enterprises. American Economic Review 88 (1), 290–306.

Zucker, L.G., Darby, M.R., et al., 2002. Knowledge capture, and firm performance in biotechnology. Management Science 48, 138–153.

Zuckerman, H., Merton, R.K., 1972. Age, aging and age structure in science. In: Riley, M.W., Johnson, M., Foner, A. (Eds.), Aging and Society: Sociology of Age Stratification. Russel Sage Foundation, New York, pp. 292–356.