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The effectiveness of university knowledge spillovers: Performance differences between university spinoffs and corporate spinoffs

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ABSTRACT

While much prior research has focused upon how the Technology Transfer Offices (TTOs) and other contextual characteristics shape the level of university spinoffs (USO), there is little research on entrepreneurial potential among individual academics, and to the best of our knowledge, no comparative studies with other types of spinoffs exist to date. In this paper we focus on an important but neglected aspect of knowledge transfer from academic research involving the indirect flow to entrepreneurship by individuals with a university education background who become involved in new venture creation by means of corporate spinoffs (CSO) after gaining industrial experience, rather than leaving university employment to found a new venture as an academic spinoff. We argue that the commercial knowledge gained by industry experience is potentially more valuable for entrepreneurial performance compared to the academic knowledge gained by additional research experience at a university. This leads us to posit that the average performance of CSOs will be higher than comparable USOs, but the gains from founder's prior experiences will be relatively higher among USOs whose founders lack the corporate context. We investigate these propositions in a comparative study tracking the complete population of USOs and CSOs among the Swedish knowledge-intensive sectors between 1994 and 2002.
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1. Introduction

The Bayh-Dole Act of 1980 was intended to facilitate that the knowledge created at universities would spill over to the benefit of the public (Mowery et al., 2004). Evidence seems to suggest that at least to some extent these intentions were fulfilled. Patenting activity of universities has increased as has revenues from the licensing of intellectual property (Merrill and Mazza, 2010). Technology Transfer Offices (TTOs) have been established to assure professional commercialization of the knowledge generated within the universities. With the US leading the way, similar efforts have been pursued around the world (see Guena and Rossi, this issue). These developments have received extensive scholarly attention (for reviews see Link and Siegel, 2005; Siegel et al., 2007; Rothaermel et al., 2007). Initially, scholars focused largely on the direct implications of licensing and patenting. To an increasing extent, however, it has been recognized that this may be an overly narrow view of university knowledge spillover (Shane, 2004; Lockett et al., 2005). Therefore, growing emphasis has been placed on university spinoffs created by scientists based on intellectual property generated in the university (see for example the special issue of Research Policy edited by Lockett et al., 2005). With examples of successful university spinoffs such as Google and Genentech each generating billions of dollars of revenue within a few years of establishment, this attention is easily understood. More generally, thanks to their learning from long periods of education and advanced work experience, academics possess substantial human capital and often have access to advanced technologies and innovations, which could provide them with unique qualities for starting and operating new ventures with the potential of creating substantial growth and economic value. Consequently, most governments are targeting the creation and growth of knowledge intensive firms and find academic entrepreneurship particularly promising in this regard (see Wright et al., 2008a, chapter 2. for a review).

While both policy and scholarly interest in university spinoffs are easily understood, it provides a relatively limited view of university knowledge spillover (Lester, 2005). Arguably, most

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university knowledge spillover is indirect (Breschi and Lissoni, 2001). For example, the education of students is the major task of most universities and the value of that knowledge is exploited during later employment. Comparing the magnitude of the total direct and indirect knowledge spillover of universities is indeed no easy task. It is, however, possible to assess and compare the impact of spinoffs that directly or indirectly utilize knowledge generated by universities. Given the policy interest in university spinoffs and the intention of the Bayh-Dole Act to facilitate direct university knowledge spillover to the benefit of society, we feel that this is a valuable exercise. In this paper, we suggest that there are two paths to knowledge-intensive entrepreneurship based on university knowledge. The first is the direct path where individuals first study, then work at universities and subsequently spin off their business directly from the university. We refer to spinoffs taking this direct path as university spinoffs (USOs). The second path is represented by university graduates who pursue careers in private industry and spin off their companies from that context (Parhankangas and Arenius, 2003). We refer to those as corporate spinoffs (CSOs).

As far as we are aware, little research has examined the relative effectiveness of these two paths to knowledge-intensive entrepreneurship (USOs and CSOs). The two exceptions are the studies by Zahra et al. (2007) and Clarysse et al. (forthcoming) that investigated performance differences between USOs and CSOs on small samples of relatively more established spinoffs. Further, a small number of other studies have compared USOs with non-USO start-ups (Ensley and Hmieleski, 2005; Colombo and Piva, 2008). Our study differs from Clarysse et al. (forthcoming) and the Zahra et al. studies that focused on relatively more established spinoffs. We take a broader perspective and look at a whole population of spinoffs from their very inception. Hence, we are able to draw inferences not just about how USOs and CSOs differ but also to gauge the relative impact of such firms. As such, our study carries a higher degree of generalizability to the overall economy.

The lack of broader perspectives on performance differences across types of spinoffs in the literature is surprising for three main reasons: First, a very large number of studies have attempted to evaluate the economic impact of university-based entrepreneurship (cf. Rothaermel et al., 2007; Siegel et al., 2007). In order for such undertakings to be relevant, a suitable baseline for comparison needs to be established. The comparison of entrepreneurial activities of knowledge-workers from the private sector, specifically in the context of corporate spinoffs (CSOs) represents such a baseline. Second, in many countries, millions if not billions of tax dollars are spent on efforts targeting university-based entrepreneurship (Wright et al., 2008a,b). Such policy efforts only make sense if this kind of entrepreneurship indeed represents an effective way of establishing knowledge-intensive firms with growth potential. Third, the spillover benefits through corporate spinoffs following industrial experience by knowledge workers may have implications for the design and assessment of labor market legislation such as non-compete covenants. Hence, comparative examination of the performance of USOs and CSOs has important policy implications. We undertake this comparison using a unique longitudinal dataset that tracks the complete population of USOs and CSOs among the Swedish high-tech sectors between 1990 and 2002. The Swedish context is a particularly interesting one in which to conduct this analysis given the provision of the Bayh-Dole Act and the debate over inventor ownership (Kenney and Patton, 2009; Merrill and Mazza, 2010) since in Sweden, ownership of university IP is vested with the inventor. Further, Sweden is a country that invests substantial amounts of money into supporting academic spinoffs, and does so primarily through the USO mechanism (Karlsson and Wigren, 2010). Finally, Sweden is known for its extensive and high quality data which facilitates the construction of the relevant databases. This dataset also has the important attribute that unlike many other studies of university spinoffs (Kenney and Patton, 2009), it does not rely on data provided by TTOs which may understate the extent of spinoff activity.

This paper makes several contributions to the literature on the nature and impact of university research commercialization. First, we add to the debate about the effectiveness of the commercialization of the knowledge and IP generated by universities by identifying and separating two different mechanisms for achieving this goal, i.e., USOs and CSOs. To date, research has mainly focused on USOs to the exclusion of CSOs. Given that we find that CSOs outnumber USOs 14 to 1, our paper represents a very significant shift of focus in an area where university education contributes but which has been neglected. Second, we provide robust empirical evidence of the effectiveness of the two mechanisms. This evidence has important implications for public policy related to the support of commercialization of university knowledge, in particular as we find that CSOs outperform USOs across a number of different performance measures. Third, we focus specifically on characteristics of the parent organization from which spinoffs are spawned and thus tap into a growing strand of research on how knowledge spills over from established organizations into *new* organizations (Acz et al., 2009; Agarwal et al., 2007). Specifically, we contribute to this spawning literature by investigating how characteristics of the parent organization foster not only spinoff formation (Sorensen, 2007) and survival (Agarwal et al., 2004; Klepper and Sleeper, 2005) but also the growth of spinoffs, both in terms of sales and employees. Thus, our research informs the specific debate about the consequences of the Bayh-Dole Act particularly in relation to the ownership of university generated knowledge and IP, the modes through which it is both transferred and used to create social and economic value.

The paper unfolds as follows. First, in the following section we outline our theoretical framework and develop testable hypotheses. Second, we outline our data source and the method of analysis. Third, we present our analysis. In a final section we discuss the implications of our findings for further research and for policy.

2. Theory and hypotheses

2.1. University-based entrepreneurship

The principal focus of research on the spillover of knowledge from universities into entrepreneurship has been on USOs because they are easily controlled by policy makers. Considerable debate has concerned the performance of USOs (Siegel et al., 2007; Colombo et al., 2010a). Central to this line of research is that academic entrepreneurship is strongly context-dependent.[2] A number of contextual factors have been identified as important if ventures emerging from a non-commercial environment are to grow (Vohora et al., 2004). For example, the extent to which scientists in a particular discipline engage in entrepreneurship (Stuart and Ding, 2006; Bercovitz and Feldman, 2008) and the nature of the resource endowments provided by the university environment (Mustar et al., 2006; Di Gregorio and Shane, 2003), including the capabilities and routines of the TTOs (Lockett and Wright, 2005) and technological resources available (Heirman and Clarysse, 2004), have been identified as important. This line of research has mainly focused upon the contextual effects of the university and the TTO.

The emphasis in this literature so far has generally been on enterprise creation and not subsequent performance. The few existing studies investigating the performance of USOs has identified specific resources and capabilities associated with university

[2] This has also been proposed in the broader area of entrepreneurship studies (Thornton, 1999).

spinoff's development such as intellectual human capital (Zucker et al., 1998; Siegel et al., 2007). For example, Colombo and Grilli (2005) find that individual academics' experience and team size facilitated the growth of technology-based new firms in Italy. However, this study did not distinguish USOs and non-USOs. A subsequent study by Colombo et al. (2010b) shows that the science quality of local universities has a positive effect but the commercial orientation of research has a negative effect on the growth of USOs. This study suggests that USOs with more scientific orientation in their entrepreneurial team have greater absorptive capacity to assimilate scientific knowledge. In an earlier study, Colombo and Piva (2008) also showed that USOs' founding teams exhibit greater scientific education and prior research experience than teams in non-USOs.

A US study by Ensley and Hmieleski (2005) find that USOs comprise more homogeneous top management teams (TMTs) with less developed dynamics, such as shared cognition and conflict, and had lower performance than independent new ventures. However, this study did not specifically identify the roles of team human capital in terms of prior commercial and educational experiences.

We know of only two studies directly comparing USOs and CSOs. Clarysse et al. (forthcoming) examine the relationship between technological knowledge of parent firms on the sales and employment growth of 48 CSOs and 73 USOs. This study measured growth only at one point in time and focused on relatively more established spinoffs. Zahra et al. (2007) surveyed a sample of 78 USOs and 91 CSOs in the US. They found that USOs and CSOs differed systematically in how they utilized a variety of self-reported "knowledge conversion capabilities" and that these capabilities benefited CSO to a higher extent in terms of productivity, revenue growth and return on assets. This study was conducted exclusively at the firm level of analysis and also focused on relatively more established spinoffs that had been in business for at least 3 years in 10 different industrial sectors.

To sum up, most studies to date have focused on the formation of USOs and not their subsequent performance, and there is a dearth of studies comparing USOs and CSOs. In the next sections we theorize how the contextual background of universities and corporations lead to differential access to scientific and market knowledge, potentially shaping the performance of both types of spinoffs.

2.2. Knowledge and new venture performance

The overarching logic of our argument suggests that the endowments of the new venture team in terms of knowledge, skills, and experience have important implications for the future performance of the venture. This appears to be a particularly well suited perspective for studying knowledge based entrepreneurship because interest in this area stems from the insight that individuals who holds certain knowledge are particularly well equipped to develop high-potential ventures. Since universities constitute a 'hub' of innovative activities, researchers have focused specific interest on the forces shaping the emergence of USOs (Vohora et al., 2004; Di Gregorio and Shane, 2003). Yet, very little research has discussed the relative benefits of corporate vs. university work experience for those individuals with a university education. We believe that experiences from private corporations provide a potentially more valuable background to successfully commercialize entrepreneurial opportunities than university experience alone.

The potential for discovering lucrative entrepreneurial opportunities stems from direct contact with the market and the knowledge of customer wants, needs, and processes (Cooper et al., 1995; Wiklund and Shepherd, 2003). Von Hippel (1986) also notes that an accurate understanding of the most pressing needs of the market is essential to successful innovative efforts. A higher level of market knowledge is better for the responsiveness to customer needs and the discovery of opportunities. The essence of discovering new opportunities is to be alert to changes in market demands (Kirzner, 1997). Similarly, increased levels of market knowledge allow a firm to have more up-to-date understanding of customer problems, an increased ability to determine the potential commercial value of market changes, and a superior ability to be able to match offerings to what the customer perceives as valuable (Narver and Slater, 1990). Being fully up to date and aware of customer needs will ultimately reduce uncertainty and allow firms to save time and effort in efficiently pursuing ways in satisfying customer wants. A firm's ability to discover shifts in customer needs and customers' willingness to pay for new things form the basis of opportunity and innovation (Kohli et al., 1993).

To a large extent, market knowledge is tacit in nature. It is difficult to formalize, articulate and transfer between organizational contexts (Nonaka and Takeuchi, 1995). In new ventures, this knowledge resides with its organizational members and their experiences prior to founding (Wennberg, 2009). Prior exposure to and experience of customer relationships is essential to the generation of this knowledge. Those who leave employment to start a business often benefit from their experiences with their prior employer, or the "parent" organization that spawned them (Agarwal et al., 2004; Klepper and Sleeper, 2005). Since resources and organizational routines transfer from old to new organizations through personnel migration (Nelson and Winter, 1982, pp. 115–121), individual founders' experiences may also provide strong influences on the new firm's performance.

Individuals who gain experience from working in a commercial context are more likely to be exposed to the encounters where market knowledge can be gleaned compared to those who spend their careers at a university prior to founding a business. Because individuals with a university education who spin off their ventures from commercial firms are likely to have greater exposure to commercial interaction and thus greater market knowledge, we posit that their firms are likely to perform better than those of individuals with academic experiences who spin off their businesses from a university. In support of our argument, one recent study found that spinoff firms benefitted relatively more from prior non-technical experience of the team members at their prior employer, such as marketing (Chatterji, 2009). This leads to our first hypothesis:

H1. Firms started by university-educated entrepreneurs as commercial spinoffs perform better than firms started by university-educated entrepreneurs as university spinoffs in terms of [a] growth in sales revenue, [b] growth in employment, and [c] survivability.

While market knowledge acquired through prior employment is important, it is by no means the only valuable source of knowledge for entrepreneurs with a university education. Prior research has established that years of schooling, industry experience and prior entrepreneurial experience all play important roles in the success of entrepreneurs (in respect of USO entrepreneurs, see Mosey and Wright, 2007; Ensley and Hmieleski, 2005).

Schooling increases the general human capital of the founder (Rauch and Frese, 2005) and can be important to the success of the new venture because it facilitates the integration and accumulation of new knowledge. Further, higher education provides founders with a larger opportunity set (Gimeno et al., 1997) and the societal positions facilitated by education increase the likelihood that advantageously placed individuals will discover entrepreneurial opportunities, sometimes by active search and sometimes simply by being in the right place at the right time with the right stock of knowledge (Baker et al., 2003). Since schooling leads to general human capital, it provides founders with knowledge, skills, and problem-solving abilities that are transferable across many different situations. Prior studies have identified the importance of the number of years of education both for new high tech ventures in general (Colombo and Grilli, 2005) and for USOs (Colombo et al., 2010b).

Several studies have provided evidence that spinoffs benefit from the specific learning provided by their founders' familiarity with the relevant industry in which their new venture operates. For example, Koster (2005) surveyed 289 Dutch firms and found that prior industry experience provided firm founders with more relevant knowledge, especially in regards to product related knowledge. Dahl and Reichstein (2007) followed 323 spinoffs in the Danish manufacturing sector from 1980 to 2000 and found that the vitality of the parent company combined with industry-specific experience of the spinoff founder positively affected the new firm's likelihood of survival. Italian studies by Colombo and Grilli (2005) and Colombo et al. (2010b) identify the importance of years of industry experience for both new high tech firms and USOs.

It is well established that entrepreneurs largely learn through their personal experiences. The skills and knowledge relevant to successfully managing and operating a business are mainly experiential in nature (Politis, 2005; Starr and Bygrave, 1992). Previous entrepreneurial experience provides specific learning that is typically considered important for success. Studies of habitual entrepreneurs have highlighted that the experience of operating a previous business assists in the management of subsequent ones (Ucbasaran et al., 2003). Case study evidence from USO entrepreneurs indicates that prior experience of owning a business enables them to learn to build relationships with experienced managers and potential equity investors (Mosey and Wright, 2007).

It would be possible to pose hypotheses for how schooling, industry experience and prior entrepreneurial experience influence entrepreneurial success. However, these relationships are well established in the literature and our main focus is on the differences between university spinoffs and corporate spinoffs. Therefore, we instead focus our attention on the differential effects of these variables between these two types of entrepreneurs. As we suggest above, university educated entrepreneurs who start their businesses as commercial spinoffs complement their university knowledge with a thorough understanding of the market. To a large extent, those who start university spinoffs lack this knowledge (Ensley and Hmieleski, 2005). Prior experience of the market through industry, schooling and entrepreneurial experience may then serve to compensate for the lack of market knowledge and provide alternative paths to gaining the knowledge needed to successfully start a new venture. This suggests the following hypothesis:

H2. Firms started by university-educated entrepreneurs as university spinoffs benefit more from the knowledge sources [a] years of education, [b] years of industry experience in the same sector, and [c] years of entrepreneurial experience, than firms started by university-educated entrepreneurs as commercial spinoffs.

2.3. Parent organizational context

In addition to the actual work that the individual entrepreneur performs, the wider context of the parent organization from which the new venture is spawned likely has substantial influence on the future destiny of the spinoff (Burton et al., 2002; Elfenbein et al., 2010), in relation to both technological knowledge (Malerba and Orsenigo, 1993) and other knowledge such as marketing know-how (Agarwal et al., 2004; Chatterji, 2009). For example, Fairchild is credited with generating a large number of spinoffs mainly in semiconductors during the early development of Silicon Valley, whereas Stanford University later rose in importance (Klepper, 2001), now spinning off substantially different kinds of firms. Therefore, a number of distinctive aspects of the university and corporate environments in which individuals gain their work experience prior to becoming entrepreneurs are important.

Spinoffs usually inherit both general technological, organizational, and market-related knowledge from their parents (Klepper and Sleeper, 2005), suggesting that the technological knowledge resulting from exploration activities in universities and corporations and which is exploited in the USOs and CSOs is likely to be distinct as the goals and missions of the two parent environments are quite different (Clarysse et al., forthcoming). The focus on highly scientific and engineering educated individuals in universities (Hsu et al., 2007) means that the technological knowledge in the university context is often novel and provide a broad based platform that is important in the market for technology, but it may be a long way from a product that can generate revenues streams in terms of sales. In contrast, technological knowledge resulting from corporate parents is likely to be narrower and closer to the market. An entrepreneur-to-be who works in a corporation dependent on more narrow and 'market ready' types of technology is likely to benefit from the exposure to a wide range of different technological knowledge bases (Chatterji, 2009). An entrepreneur-to-be in a university setting who is exposed to broadly based knowledge and technologies that are further from the market is likely to find it more difficult to make the connections between the different technologies. We therefore believe that the type of technological knowledge of the parent organization will be less important for entrepreneurs who start USOs than for entrepreneurs who start CSOs.

Further, the influence of the parent organization does not cease as the spinoff is formed. Many entrepreneurs remain in close contact with their former employers and their former colleagues make up an important part of their networks because of shared technological knowledge (Sapienza et al., 2004). Thus, the exposure to the different technologies of organization and production does not end as the entrepreneur leaves the parent organization but can have long lasting effects.

Organizations with a bureaucratic structure may be inimical to entrepreneurship as their checks-and-balances may stifle initiative (Sorensen, 2007). Entrepreneurial individuals are likely to be more frustrated by rigid bureaucracies that discourage entrepreneurial actions and thus leave to create new ventures (Chatterji, 2009). Large organizations are likely to be more bureaucratic and universities in particular are likely to be more bureaucratic, often involving decision-making by large committees that meet infrequently and that are not attuned to commercial demands (Wright et al., 2006), and a host culture that is generally less inclined towards commercial activities than corporations (Colyvas and Powell, 2007; Stuart and Ding, 2006). While prior research has revealed large inter-university variation in rates of spinoff formation (Lockett and Wright, 2005; Mustar et al., 2006; Di Gregorio and Shane, 2003), little research has investigated how the organizational characteristics of universities in general affect the performance of such spinoffs, conditional on their founding. While large universities may be more likely to have science and engineering departments generating world class knowledge, they are typically organized in a centralized and bureaucratic fashion (Thompson, 1965). It is therefore likely that university spinoffs in general will benefit less by the organizational characteristics of their parent university compared to corporate spinoffs Large corporations, on the other hand, especially those with many subsidiaries and divisions may have more spawnable activities that are peripheral and difficult to control and incentivize yet which may have good underlying performance prospects (Haynes et al., 2003). Being employed in such a large private corporation hence provides more fertile opportunities for employees to identify valuable market opportunities (Hellmann, 2007). We believe that once spun-off as independent entities with access to finance and more appropriately incentivized founders, a background from a large corporation with a more extensive set of production and organization technologies enables such spinoffs to be better positioned to realize strong growth. This leads to the following hypothesis:

H3. Firms started by university-educated entrepreneurs as commercial spinoffs benefit more from the spawning environments of the parent organization in terms of [a] the size of the organization, [b] the set of technologies, and [c] the breadth of technological knowledge in its employees, than firms started by university-educated entrepreneurs as university spinoffs.

3. Data and methods

3.1. Research design and sample

Examining and contrasting the performance of CSOs and USOs in a setting that allows for generalizable results poses a number of methodological challenges since there might be systematic differences between the individuals who start these two kinds of businesses as well as between the businesses themselves. First, it is necessary to obtain robust data on both types of spinoffs avoiding possible sample selection biases since the performance of spinoff firms are likely substantially different at founding compared to later phases of development (West and DeCastro, 2001; Vohora et al., 2004). Second, there is a risk of systematic differences between individuals who pursue the two different entrepreneurial options and such risks must be addressed and controlled for to the best extent possible. Third, many of the commonly used performance measures (e.g., patenting activity) vary by industry and the entry rates into different industries is likely to be different for USOs and CSOs. Therefore, it is important to rely on performance measures that are robust across industries and the two modes of entry (Delmar and Shane, 2006). Fourth, in order to avoid selection on the dependent variable (performance), we need a sample of firms that can be followed from inception and onwards because the lowest performing businesses are likely to exit very early.

In order to deal with these challenges, we constructed a unique longitudinal dataset, combining data from several different sources. First we selected all private incorporated companies started in Sweden during the 1994–2001 time period in knowledge-intensive sectors (i.e. high-tech manufacturing and knowledge-intensive services). The selection of knowledge-intensive sectors follows Eurostat and OECD's classification which is based on the R&D intensity being higher than the mean of the overall economy (Götzfried, 2004). These industries comprise about 35% of all firms started in Sweden (Folta et al., 2010) and include all 'rapidly growing' industries (chemicals/medicine, telecom, finance, business services, information technology, education and research). A full list of sectors included can be found in Appendix A. We excluded firms started in other sectors and other legal forms (sole proprietorships and partnerships). We did so in order to ensure that we focused on spinoffs where founders with a university education utilized their knowledge rather than part-time and life-style businesses (Folta et al., 2010) for which entry and exit may be "a trivial decision" (Gimeno et al., 1997). Detailed information about these firms was made available to us through Statistics Sweden's database RAMS, which contains annual data on all firms in Sweden.

We then added individual founder data taken from the database LISA, which is also maintained by Statistics Sweden and contains annual data about all Swedish inhabitants, including detailed information about education and employment. Given our focus, we limited our data to contain all individuals who had completed a university degree lasting at least 3 years in any field and who worked for a university or a private company at least some time during the 1993–2001 time period. Among these individuals, we identify those that leave their employer to start a new incorporated firm. We denote these firms as USOs or CSOs depending on whether they transferred into entrepreneurship directly from employment in a university or from a private corporation (Zahra et al., 2007).

The years included in the cohorts of individuals do not fully overlap with the years used for constructing the cohorts of firms. The decision to include the cohorts of firms and individuals that we did was based on three main concerns: (1) the importance of observing the pre-entry experience of entrepreneurs in order to theorize how this will shape the development of their firms (Helfat and Lieberman, 2002), (2) to sample more than one cohort to avoid time, cohort, and period effects, such as the influence of unique economic conditions at founding, and (3) the intent to follow the CSOs and USOs for several years so that performance differentials may be observed.

To ensure that the founders indeed were entrepreneurs, we also set the criteria that they must hold a majority ownership during the first year and work there full time.[3] In the case of team startups, to ensure that we focused on spinoffs, we further required that a majority of the team worked at the same university or corporation prior to the startup (Nicolaou and Birley, 2003; Shane, 2004; Lockett et al., 2005; Vohora et al., 2004). Through LISA we had access to the employment and education history of all individuals back to 1989, which allowed us to define and single out USOs and CSOs.

In total we have eight full cohorts fulfilling the sample criterion of individuals with a university education who engage in spinoff entrepreneurship by starting a firm originating from either a university or corporate setting during the 1994–2001 time period. With these definitions, we identified 528 USOs and 8663 CSOs started during the period 1994–2001. Thus, CSOs constitute approximately 94% of all spinoffs in Sweden. Concerning the individual entrepreneurs, we have access to their individual life histories dating back to 1989. In terms of the firms they start, we have full information from inception up until the year 2002 or its last year of existence if that occurs prior to 2002. For example, if an academic graduates from college in 1987, seeks employment in that year and goes on to start a business in 1995 that continues its operations in 2002, we would have access to annual education and employment data for that individual from 1989 until 2002, and access to annual performance information about the firm from 1995 until 2002. Given that we sample firms between 1994 and 2001 but have access to performance data until 2002, surviving firms provide performance data for 2–9 years, depending on the year of founding.

3.2. Dependent variable: performance

We investigate the relative performance of CSOs and USOs. To assess performance we rely on three different indicators measured at the level of the spinoff firm.

Firm growth: Growth is commonly considered as the most relevant indicator of performance among new ventures (Brush and VanderWerf, 1992). However, there is typically limited correspondence among different indicators of growth, with employment and sales being the most common indicators (Shepherd and Wiklund, 2009). We therefore estimated separate models for growth in terms of employment and growth in terms of sales. Consistent with prior research, we used the formula $\log(\text{size}_{t1}/\text{size}_{t0})$ to compute the respective growth rates (cf. Coad, 2010).

Firm survival: Disappearance from a data register was not considered a sufficient criterion for determining if a firm has failed

[3] Our interest is in entrepreneurial spinoffs and not corporate spinoffs. Therefore, building on Klepper's (2001) definition of these categories, we only include spinoffs where founding individuals maintain controlling rights and exclude spinoffs where firms or universities maintain controlling rights.

or continues to survive. In Sweden, by law, any legal change to an incorporated firm has to be reported to the authorities and this information is passed on to Statistics Sweden. Thus, we have information about all kinds of firm exits including discontinuance, merger, and acquisition. In particular, exit by merger or acquisition need not be a sign of organizational failure. On the contrary, divesting their equity can instead be seen as the peak of success for many firm founders. We therefore believed that discontinued and acquired/merged firms should not be pooled in our survival analysis. Two statistical tests based on a discrete choice model of the multinomial logit type were used to examine the validity of this belief: We used a log-likelihood ratio test to compare the vectors of coefficients of the discontinued and the sold firms (relative to surviving firms). The test revealed a statistically significant difference between the vectors of coefficients ($\chi^2 = 84.50$, d.f. = 28. $p < 0.01$), indicating that the two alternatives should not be pooled. A Hausman test of the Independence of Irrelevant Alternatives showed that the coefficients for surviving and non-surviving firms were not affected by excluding firms that were sold or merged from our analysis ($\chi^2 = 35.15$, d.f. = 28. $p < 0.34$). We therefore eliminated the 8 sold UFOs and 210 sold CFOs from our analysis of survival.

3.3. Independent variables

University/corporate spinoff: Our main independent variable pertains to the time-invariant dummy variable denoting type of spinoff (USO = 1, CSO = 0), created according to the definitions in Section 3.1.

Entrepreneurial experience: We used data from LISA to create the variable entrepreneurial experience, measured as the mean number of prior years of entrepreneurial experience in the entrepreneurial team from 1989 onwards. The variable was thus truncated, although it is possible that individuals were already involved in entrepreneurship prior to 1989. Truncation of independent variables can be problematic since there is a risk of underestimating the effect of the variance in the variable at the positive end of the distribution (i.e. we cannot distinguish between 10 years and 5 years of experience), increasing the likelihood of type-two errors. However, only 4 USOs (1.17%) and 38 CSOs (0.44%) of the sample had five or more years of experience, indicating low risk of systematic bias. [4]

Specific human capital – industry experience: Following earlier research we measure the mean years of prior work experience that the founding team has in the same industry as the current venture (SIC-2 digit level) from 1989 onwards (Delmar and Shane, 2006). Hence, this variable was also truncated at very high levels.

Education: We measured level of education as the mean number of years in education of the founding team. This is the most common measure of general human capital in the entrepreneurship literature and is consistent with previous studies (Colombo and Grilli, 2005). The variable was operationalized from education codes in LISA describing the length and type of an individual's highest education (e.g., 3 years of college, 4-year college, postgraduate or PhD).

Characteristics of the spawning parent organization: We use a number of indicator variables to investigate how characteristics of the parent organization influence spinoff survival and performance. Our first indicator is organizational size in terms of the *Number of Employees*. Larger organizations may be more bureaucratic but may utilize a larger set of technologies. We also included annual *Sales* as an alternative size measure. However, employee or sales size alone does not determine the spawning environments. Organizations with multiple plants or establishments are more likely to pursue multiple technologies. *Number of Establishments* was therefore also included. Finally, the type of knowledgeable employees of an organization says something about how many technologies it utilizes. We therefore relied on the *Number of Engineers* and *Number of PhDs* to tap into the overall breadth of technological knowledge of the spawning environments. All proxies except for establishments were measured in natural log format.

3.4. Control variables

Team size: With other founding factors held constant, we would expect spinoffs with larger founding teams to be better able to build a market position that allows them to survive (Klepper, 2001). We therefore include the variable *team size*, measuring the total number of firm founders. This variable ranges between 1 and 14.

Social capital: Social networks might help entrepreneurial firms overcome the first uncertain period and thus facilitate their long-run survival (Mosey and Wright, 2007). To control for the effects of social networks to the best extent possible, we include the variable *region tenure* which measures how long a firm founder had lived at one single location since 1989. Since tenure in a region has shown to be correlated with an extensive social network, this variable approximates, albeit in a coarse manner, for the possibility that a new venture's survival is positively enhanced by its firm founders' social capital (Dahl and Sorenson, 2009). Similar to our independent variables, the mean tenure of the team was computed to create a composite approximation of the founding teams' social network resources.

Industry affiliation: We control for industry measured at the SIC-3 equivalent level (see Appendix A for a list of industries).

3.5. Analytical strategy

To assess firm survival we use event history analysis. We estimated a Cox model without the need to make specific assumptions with regard to duration dependence of new ventures' survival. We used the Cox proportional hazards model since this does necessitate any assumptions with regard to duration dependence, and allows for flexible handling of curvilinear relations and time-dependent covariates. However, the Cox model assumes that there are no tied event times—that is, all events occur in distinct periods. This assumption is often violated in large-sample discrete-time data sets. We therefore used the exact partial likelihood option ("exactp") in STATA to adjust for ties in failure times. [5]

To assess firm growth in terms of relative change in employees or turnover we used panel data regression based on generalized least squares. Because most of our independent variables are time-invariant we used random effects estimation in all three models.[6] We control for serial correlation in growth rates by including a lagged measure of employee growth or sales growth. To test

[4] By way of robustness checks we fitted unreported models including a dummy variable for team with 5+ years of experience. This slightly decreased effect sizes but significance levels for the models in Tables 3 and 4 were still well below 5%., indicating that the results are robust to variable truncation (models available on request).

[5] Unreported models based on the piecewise and the log-logistic estimation procedures provided qualitatively similar results.

[6] To further account for unobserved heterogeneity we also estimated population-averaged models of the type generalized estimating equations (GEE), which employ quasi-likelihood estimation in a panel context by looking for time-varying deviations from the sample means (Liang and Zeger, 1986). This allows for robust variance estimation and controls for serially correlated data for comparison with the main random-effects models. The results of the population-averaged models (available upon request) were qualitatively very similar to the random-effects models, indicating that time-invariant unobserved heterogeneity between firms was not a major issue.

Hypotheses 2 and 3 regarding the relative benefits of experience for CSOs and USOs, moderator effects are constructed by interacting all predictor variables with a dummy for either CSO or USO.

4. Results

4.1. Descriptive statistics and univariate analyses

Descriptive statistics relating to the 528 USOs and 8663 CSOs are displayed in Table 1. As is apparent in the table, these firms differ significantly both in their parent organizational origin, the human capital structure of the team, and their subsequent performance. The first section of Table 1 entitled 'Parent Institution Variables' highlights that the different organizational structure origins between USOs and CSOs in terms of university/firm size in employees; size in sales (USD); size in number of establishments; university/firm mean salary; university/firm # engineers/scientists; and university/firm # PhDs. Specifically, we find that the parent institutions of CSOs are significantly larger than those of USOs in terms of employees, sales and number of establishments. In contrast, the universities from where USOs hail are – not surprisingly – characterized by a higher accumulation of technical employees than the corporations from which CSOs hail. The parent institutions of USOs have significantly more employees who are engineers/scientists and who have PhDs. These differences indicate that the knowledge structures of these parent organizations are quite distinct.The second section of Table 1 focuses upon 'Team human capital variables'. We find that the human capital within the founding team differs substantially between USOs and CSOs. The average USO (CSO) firm team has 15.3(13.8) years of education and 2.0(2.4) years of industry experience. USOs are significantly less likely to have entrepreneurial experience (5.6%) in their founding team compared to CSOs (19.3%). However, USOs are significantly more likely to have some prior managerial experiences in the founding team (8.86% vs. 4.62% for CSOs). This lends confidence to our view that the human capital resources of spinoff firms are systematically different between spinoff coming from a university background and spinoffs coming from a corporate background.Finally, the third section of Table 1 presents univariate comparisons of the significant performance differences in terms of survival, sales and employment between USOs and CSOs. Specifically, we find a significantly higher survival rate after both 2 and 5 years for CSOs (78.8% and 61.6%, respectively) than for USOs (72.6% and 53.5%). CSOs are also significantly larger after 2 years than USOs in terms of both sales and employees. The mean organic sales growth of CSOs (38.4%) is significantly greater than that of USOs (25.4%). Mean growth rates in employees are negative for both USOs and CSOs but the difference between them is not statistically significant.The means and standard deviations of all outcome and predictor variables, together with the correlation matrix, are displayed in Table 2. We manually examined the growth variables to see if either category (USO or CSO) contained substantial outliers that could potentially bias our estimations. A small number of extraordinary growth companies (gazelles) could potentially outweigh a large number of moderately growing firms (mice). We found no evidence of such outliers. Investigation of the variables and their correlations provided no indication of multicollinearity among the predictor variables except for the five predictor variables related to the organizational context from which spinoffs are spawned. We therefore fitted alternative models where outliers were removed from the data by using a Winsoring algorithm (STATA command WINSOR). Results (available upon request) were identical in directions and levels of significance, but effect sized differed somewhat depending upon specification. All variables were lagged 1 year to reduce problems of endogeneity.

4.2. Multivariate analysis

We now move on to test our hypotheses in a multivariate framework. Our dependent variable is performance and we use three separate indicators of performance – employment growth, sales growth and survival. Table 3 presents random effects GLS models on employee growth and sales growth. Table 4 presents exact Cox Regressions on spinoff Survival. In order to test Hypothesis 1, in all analyses we enter the time-invariant dummy variable for type of spinoff (USO = 1, CSO = 0) after the introduction of all control variables. In order to test Hypotheses 2 and 3, in all analyses we distinguish between the effects of our predictor variables on CSOs and USOs by interacting each variable with a dummy (USO = 1, CSO = 0). This allows us to conduct χ^2 tests of the difference of the effects of various variables on the two groups of firms. For brevity we display only the GLS models including all the interactions. Nested base

Table 1
Descriptives of USOs and ASOs.

	Academic spinoffs	Corporate spinoffs	Test of significance
N	528	8663	
Parent organization variables			
ln(university/firm employees)	2939	3717	T: 2.55, $p > 0.01$
ln(university/firm sales)	7,733,378 (USD)	78,666,666 (USD)	T: 4.97, $p > 0.001$
University/firm establishments	26.04	93.08	T: 8.55, $p > 0.001$
ln(engineers and scientists in university/firm)	965.27	277.62	T: −21.31, $p > 0.001$
ln(PhDs in university/firm)	757.77	40.195	T: −110.10, $p > 0.001$
Team human capital variables			
Mean years of education in team	15.32	13.82	T: −29.76, $p > 0.001$
Mean industry experience in team	0.200	0.240	T: 6.41, $p > 0.001$
Management experience (2/1/0)	8.86%	4.62%	T: −4.39, $p > 0.001$
Mean Entrepreneurial experience in team	5.58%	19.32%	T: 6.08, $p > 0.001$
Team size	2.45	3.03	T: 4.41, $p > 0.001$
Outcome variables			
DV1: Firm survival	72.56% (after 2 years)	78.79% (after 2 years)	χ^2 (Wilcoxon) 5.13, $p > 0.05$
Firm survival after 2 years	53.47% (after 5 years)	61.58% (after 5 years)	
DV2: ln(employee growth)	0.07	0.09	T: 0.70, $p > 0.240$
Mean employees after 2 years	3.66	4.59	T: 1.88, $p > 0.05$
DV3: ln(sales growth)	0.17	0.26	T: 4.08, $p > 0.001$
Mean sales after 2 years	357 621 (USD)	1 052 240 (USD)	T: 1.88, $p > 0.05$

Table 2
Correlation matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Firm death														
2	USO = 1	0.008													
3	ln(employee growth)	−0.077	0.016												
4	ln(sales growth)	−0.033	0.005	0.231											
5	ln(university/firm employees)	0.006	0.216	0.040	0.016										
6	ln(university/firm sales)	0.014	−0.163	0.045	0.040	0.303									
7	University/firm establishments	−0.011	0.124	0.008	−0.006	0.810	0.246								
8	ln(engineers scientists in university/firm)	−0.003	0.309	0.038	0.016	0.828	0.202	0.672							
9	ln(PhDs in university/firm)	0.000	0.528	0.025	0.012	0.701	0.073	0.601	0.845						
10	Team years education in (mean)	−0.006	0.151	0.014	0.002	0.079	0.000	0.067	0.203	0.217					
11	Team entrepreneurial exp. (mean)	−0.004	−0.015	0.027	0.015	−0.147	0.038	−0.084	−0.098	−0.062	0.039				
12	Team industry experience in (mean)	−0.013	−0.049	0.053	0.032	−0.059	−0.273	−0.026	−0.060	−0.062	0.036	−0.066			
13	Team management exp. (2/1/0)	−0.004	0.004	0.015	0.013	−0.014	−0.060	−0.003	0.003	0.005	0.055	0.062	0.068		
14	Team size	−0.027	−0.017	0.016	0.020	0.019	0.128	−0.049	−0.041	−0.041	−0.017	0.014	−0.219	−0.059	
15	Mean social capital in team	−0.023	−0.007	0.004	0.007	0.009	0.261	0.040	0.004	0.002	0.015	0.108	−0.215	−0.010	0.152

models without the USO/CSO dummy or the interaction effect for the models predicting employee growth and sales growth were significant ($p < 0.001$ and $p < 0.01$, respectively), explaining 15.5% and 9.5% of variance in employee growth and sales growth, respectively. Adding the dummy variable for USO/CSO to the base model for employment growth improved the R^2 to 16.9%, however the improvement in R^2 value was not significant ($p > 0.10$). Adding the variable to the base model for sales growth improved the R^2 for that model to 10.8%, representing a significant ($p < 0.05$) change in R^2 value.

The dummy variable for CSO/USO shows that CSOs grow more than USOs in terms of sales and that the survival probability is higher for CSOs than for USOs. However, there is no statistically significant difference in growth in employees between CSOs and USOs. This supports Hypothesis 1a and 1c but not 1b, all of which stated that CSOs would outperform USOs.

Next we add the interaction effects as displayed in Tables 3 and 4. The models with interaction variables for each predictor and USO/CSO explained 19.8% of the variance in employee growth and 13.3% of the variance in sales growth. Both were significant at ($p < 0.001$), as was the change in R^2 ($p < 0.01$). Hypothesis 2 relates to how different aspects of human capital influences performance differently in the two groups of firms. There is no statistically significant difference between the effect of years of education between CSOs and USOs for any of the three performance indicators (i.e., growth in employees, and sales, and survival. Thus we find no support for H2a. We speculate that the non-significance of education might be due to the fact that our sample only includes people with at least 3 years of university education and thus this variable is truncated.

There is a statistically significantly larger positive effect of industry experience among USOs than among CSOs for all three dependent variables. This supports Hypothesis 2b, stating that firms started by academic entrepreneurs as university spinoffs benefit more from the knowledge source years of industry experience in the same sector than firms started by CSO entrepreneurs as commercial spinoffs. However, contrary to our hypothesis we find a statistically significantly larger *positive* effect of entrepreneurial experience among CSOs than among USOs across all three dependent variables. This leads us to reject Hypothesis 2c in that firms started by academic entrepreneurs as USOs do not benefit more from the knowledge provided by prior entrepreneurial experience in the same sector than firms started by academic entrepreneur as CSOs.

Our Hypothesis 3 states that CSOs benefit more from the characteristics of the spawning organizations than do USOs. We relied on five separate proxies to characterize the spawning organization. For three of these indicators, we found a statistically significant larger positive effect among CSOs than among USOs across all three performance indicators (number of employees; revenues; number of establishments), providing support for hypotheses 3a and 3b. The number of engineers in the parent firm had a statistically significantly larger positive influence on the two growth variables but not on survival. Finally, we found no statistically significant differences pertaining to the influence of number of PhDs for any of the dependent variables. There is thus mixed support for Hypothesis 3c. In sum, we conduct 15 tests of Hypothesis 3 and find strong support for 11 and weak support for 2 of them, leading to the conclusion that overall, Hypothesis 3 is supported by our analyses.

Table 5 summarizes our hypotheses and results. Most hypotheses receive support across two or all three performance indicators. Only two hypotheses receive no support, i.e., the influence of years of education and entrepreneurial experience. All in all, 18 of our 28 theoretical predictions of performance differentials between USOs and CSOs received strong or moderate empirical support, speaking to the general validity of our findings.

Table 3
Panel Regressions on ln(sales growth) and ln(employee growth).

Variables	DV: ln(employee growth)			DV: ln(sales growth)		
	USOs	CSOs	Significant difference	USOs	CSOs	Significant difference
Growth at $t-1$	0.044	0.038***		0.006	0.164***	
	(0.040)	(0.006)		(0.056)	(0.010)	
ln(university/firm employees)	−0.015	0.008***	$p > 0.001$	−0.019	0.004^{+}	$p > 0.07$
H3:	(0.017)	(0.002)	Supported	(0.021)	(0.002)	Weakly supported
ln(university/firm sales)	−0.004	0.001**	$p > 0.05$	−0.006	0.001**	$p > 0.001$
H3:	(0.003)	(0.000)	Supported	(0.006)	(0.000)	Supported
University/firm establishment	−0.005	0.010***	$p > 0.001$	−0.038	0.010***	$p > 0.001$
H3:	(0.015)	(0.002)	Supported	(0.020)	(0.003)	Supported
ln(engineers/scientists in university/firm)	0.008	0.005*	$p > 0.05$	0.006	0.003*	$p > 0.05$
H3:	(0.015)	(0.002)	Supported	(0.016)	(0.001)	Supported
ln(PhDs in university/firm)	0.006	0.003	$p > 0.54$	0.002	0.005	$p > 0.71$
H3:	(0.008)	(0.003)	Not supported	(0.010)	(0.004)	Not supported
Mean years of education in team	0.004*	0.003**	$p > 0.43$	0.007*	0.003*	$p > 0.54$
H2a:	(0.002)	(0.001)	Not supported	(0.004)	(0.001)	Not supported
Mean industry experience in team	0.020**	0.014^{+}	$p < 0.01$	0.033**	0.012**	$p < 0.06$
H2a:	(0.001)	(0.001)	Supported	(0.002)	(0.003)	Weakly supported
Mean Entrepreneurial experience in team	0.005*	0.011***	$p > 0.10$	0.023	0.008*	$p > 0.10$
H2b:	(0.002)	(0.002)	Not supported	(0.015)	(0.003)	Not supported
Management experience (2/1/0)	0.036	0.008		0.002	0.014	
	(0.034)	(0.005)		(0.008)	(0.003)	
Team size	0.004*	0.003***		0.001	0.001	
	(0.002)	(0.000)		(0.005)	(0.001)	
Mean social capital in team	0.006*	0.002**		−0.001	0.003*	
	(0.003)	(0.001)		(0.005)	(0.001)	
USO dummy (in pooled model)	−0.004		−0.013***			
H1a:	(0.003)	H1b:	(0.001)			
R^2 (within)	0.096		0.065			
R^2 (between)	0.246		0.234			
R^2 (overall)	0.198		0.133			
Firm-year Obs.	2.670	38.034		2.670	38.034	
Unique firms:	528	8663		528	8663	
Wald χ^2 (42)	2696.42***		3097.88***			

Note: Both models estimated with random effects generalized least squares. Standard errors clustered by firms in parenthesis. Industry dummies included but not displayed.
* $p < 0.05$ (two-tailed).
** $p < 0.01$ (two-tailed).
*** $p < 0.001$ (two-tailed).
$^{+}$ $p < 0.10$ (two-tailed).

4.3. Robustness checks: sector analyses

Observed performance differences between USOs and CSOs may differ across industries. Accordingly, we extend our study by disaggregating the analysis on firm growth by industry sectors.[7] Appendix A shows that some sectors contain very few USOs. Accordingly, we first estimate models for sectors where both USOs and CSOs are prevalent, i.e., (1) computers and software, (2) finance/auditing, and (3) management consulting and other consulting, shown in Table B1 in Appendix B. Further, Table B2 in Appendix B shows models for the two sectors where CSOs were overrepresented (construction/engineering and real estate) and Table B3 in Appendix B shows models for the two sectors where USOs are overrepresented (education and research and development). The first sub-sector analyses in Table B1 show that overall, the findings in our overall models are robust to sub-sector differences. While the findings for the spawning environment of the parent organization had less impact on the performance of CSOs in terms of sales growth in the finance/auditing and computers/software sectors, our findings for employee growth were identical in all three sector analyses, as were the findings for the USO dummy and founding teams' human capital. Hence, our findings are apparent in all of the largest sectors. Table B2 in Appendix B shows that these findings are also similar in the sectors where CSOs were overrepresented (construction/engineering and real estate) but significance levels for USOs are weak as a result of the small sample size ($n = 25$). Finally, Table B3 in Appendix B shows that in the two sectors where USOs are overrepresented (education and research and development), our results are similar but significance levels are low for both groups, likely because of the small sample sizes (56 USOs and 96 CSOs). In sum, we find that our results are fairly robust across industrial sectors. While the effects of some of the proxies for the spawning environment are not statistically significant, other findings remain essentially unchanged. In the next section we discuss the implications of our research for theory and public policy.

5. Discussion and conclusions

This paper compared the effects of direct and indirect spillovers of university knowledge on the performance of spinoff ventures. Utilizing a unique longitudinal dataset including the whole population of spinoffs in Sweden, we compared and contrasted two distinct spinoff routes where the founders have had a university education; spinoff firms that emerge directly from universities (USOs) and firms that are spun out by university-educated founders from a commercial setting (CSOs).

A first interesting observation is that over close to a decade, we observed 528 spinoffs from universities and 8663 corporate

[7] We display robustness models for all sectors based on (log)growth in employees and (log)growth in sales rather than firm survival for (i) sake of brevity and (ii) firm growth is generally considered a more relevant performance measure for policy makers.

Table 4
Exact cox regressions on spinoff survival.

Variables	USOs	CSOs	Significant difference between predictors on USOs and CSOs (χ^2)
ln(employee growth)	0.547	0.405***	
	(0.209)	(0.032)	
ln(sales growth)	0.933	0.836***	
	(0.248)	(0.039)	
ln(university/firm employees)	1.000	0.991**	$p < 0.001$
H3	(0.000)	(0.000)	Supported
ln(university/firm sales)	1.000	0.993*	$p < 0.05$
H3	(0.000)	(0.000)	Supported
University/firm establishments	0.992	0.980**	$p < 0.05$
H3	(0.012)	(0.000)	Supported
ln(engineers/scientists in university/firm)	1.001	1.000	$p < 0.07$
H3	(0.000)	(0.000)	Weakly supported
ln(PhDs in university/firm)	1.002*	1.000	$p < 0.05$
H3	(0.001)	(0.000)	Supported
Mean years of education in team	1.026	0.992	$p > 0.69$
H2a	(0.015)	(0.010)	Not supported
Mean industry experience in team	0.587***	0.959*	$p < 0.001$
H2b	(0.081)	(0.016)	Supported
Mean Entrepreneurial experience in team	1.007	0.990**	$p > 0.10$
H2c	(0.163)	(0.000)	Not supported
Management experience (2/1/0)	0.353	0.988	
	(0.244)	(0.062)	
Mean Social Capital in team	0.983	0.960***	
	(0.033)	(0.006)	
Team size	0.921	0.969***	
	(0.046)	(0.005)	
USO = 1 (pooled model)	1.15***		
H1a:	(0.034)		
log-likelihood:	−32349.281		
Firm-year Obs.	2654	37,563	
Unique firms:	520	8453	
Failures:	352	3372	

Note: Coefficients in Hazard rate format, no constant estimated. Exact standard errors in parentheses. Industry dummies included but not displayed.
* $p < 0.05$ (two-tailed).
** $p < 0.01$ (two-tailed).
*** $p < 0.001$ (two-tailed).

spinoffs. In other words, the direct path to knowledge-intensive entrepreneurship via university spinoffs seems to represent only a small minority of cases. The indirect path via corporate spinoffs is much more common. We believe that this observation has some interesting implications. First, it seems that the traditional role of universities as producers of knowledgeable employees might be an appropriate one. Universities do educate individuals who eventually become entrepreneurs, but it is far more common that these individuals enter entrepreneurship from employment in the corporate setting rather than directly from their university employment. Second, given that our results indicate that CSOs perform better than USOs in terms of survival as well as growth, this seems to be an effective model for achieving knowledge-intensive entrepreneurship. Third, the vast outnumbering of CSOs compared to USOs in combination with the performance advantages of CSOs calls into question the dominance of public policy singling out and

Table 5
Summary of hypotheses and findings.

Hypothesis		Performance indicator		
		Survival	Employee growth	Sales growth
H1:	Dummy for USO/CSO	Supported ($p < 0.001$)	Not supported ($p > 0.51$)	Supported ($p < 0.001$)
H2:	Mean years of education in team	Not supported ($p > 0.69$)	Not supported ($p > 0.43$)	Not supported ($p > 0.54$)
	Mean industry experience in team	Supported ($p < 0.001$)	Supported ($p < 0.01$)	Weakly supported ($p < 0.06$)
	Mean Entrepreneurial experience in team	Reversed	Reversed	Reversed
H3:	ln(university/firm employees)	Supported ($p < 0.001$)	Supported ($p < 0.001$)	Weakly supported ($p < 0.07$)
	ln(university/firm sales)	Supported ($p < 0.05$)	Supported ($p < 0.05$)	Supported ($p < 0.001$)
	University/firm no. of establishments	Supported ($p < 0.05$)	Supported ($p < 0.05$)	Supported ($p < 0.001$)
	ln(engineers/scientists in university/firm)	Weakly supported ($p < 0.07$)	Supported ($p < 0.05$)	Supported ($p < 0.05$)
	ln(PhDs in university/firm)	Supported ($p < 0.05$)	Not supported ($p > 0.54$)	Not supported ($p > 0.71$)

supporting USOs. Moreover, Sweden is a country where IP arising from university research is vested with the inventor and can be transferred into the USOs that they start. This is different from CSOs, where the default is that IP remains the property of the employer. This should potentially lead to performance advantages of USOs. Our results, however, indicate the opposite. It seems that other advantages of working in a commercial firm rather than a university prior to startup outweigh this potential disadvantage of not owning the IP generated in the workplace. This is not to say that vesting IP arising from university research with the inventor is a failed policy. We do not know what the implications would have been if the IP were to have remained the property of the universities. USOs might have had even more of a performance disadvantage under such circumstances.

We developed a series of hypotheses addressing how knowledge endowments would differentially influence USOs and CSOs. To a large extent, these hypotheses were supported by our analyses. Generally, CSOs had more substantial endowments of important human capital such as entrepreneurial experience, but some human capital endowments such as industry experience mattered more for USOs than for CSOs. These findings suggest that it is important for USOs to include in their founding teams individuals who hold relevant experiences outside of the university, but that relatively few teams do so. It is possible that university employees lack the contacts to identify such individuals and recruit them to their teams (Rasmussen et al., forthcoming). Making connections with such experienced individuals could be an important task for public policy such as for TTOs, but these too may need to augment their own recruitment to be able to undertake this task (Siegel et al., 2007).

We also hypothesized and found that the nature of the parent organization mattered more for CSOs than for USOs. We found that our proxies for the size and knowledge endowments of parent organizations' significantly raises the performance of CSOs but had little effect on the performance of USOs. People spinning out their firms from the corporate environment benefitted from working at large firms with multiple establishments. This extends prior research on how parent organization's characteristics shape the evolution of spinoff firms which has tended to find that smaller parent organization foster spinoff formation (Elfenbein et al., 2010; Sorensen, 2007) by noting that such patterns are systematically different depending on the institutional environment of the parent organizations. While we know that some universities are more likely to generate spinoffs than others (Di Gregorio and Shane, 2003), our paper is – to the best of our knowledge – the first to highlight such systematic differences between universities and corporations. Our findings indicate that at least in Sweden, large firms provide a more lucrative seed bed for high-growth spinoffs than do small firms. From a supply-side perspective (Thornton, 1999), these findings signal that these entrepreneurs are exposed to a wider set of different knowledge bases during their employment and can draw on a more diverse set of contacts in their networks post start-up. A complementary interpretation from a demand-side perspective is that the opportunity costs for USO and CSO founders may differ. In the US, university scientists may have high opportunity costs since if they leave it may be difficult to get back into universities as there may be a gap in their publications record (Lacetera, 2009). In Sweden, this may be less of a problem since as it is easier to obtain leave of absence. Consequently, the opportunity cost of becoming a USO founder may be lower. As such, USO founders may engage in riskier ventures with high failure likelihood and lower growth prospects.

5.1. Implications for policy and research

Our research addresses knowledge spillover from universities and we examined entrepreneurship as a mechanism for direct

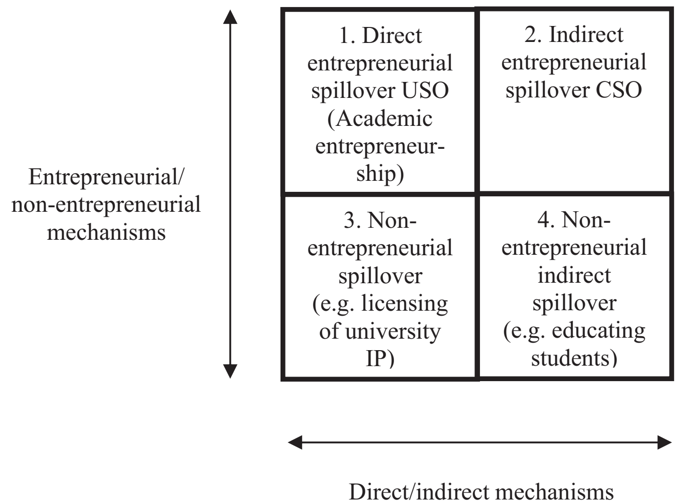

Fig. 1. A typology of university knowledge spillover.

knowledge spillover via university spinoffs compared to indirect spillovers via corporate spinoffs started by individuals with a university background. Of course, knowledge spills over from universities through other mechanisms as well, in addition to entrepreneurship. Fig. 1 contrasts direct and indirect spillover on the vertical axis and entrepreneurship vs. other mechanisms on the horizontal axis. This gives us a 2×2 matrix exhibiting four typified university knowledge spillover mechanisms. Currently, there is an interest in and focus on academic entrepreneurship through university spinoffs (quadrant 1) in scholarly work as well as in the policy debate. We believe that we contribute to this debate by offering a wider approach adding the indirect mechanism of corporate spinoffs (quadrant 2). This opens up for a wider policy debate on how knowledge spills over from universities. Our research does not at all touch upon quadrants 3 and 4 in the bottom half of Fig. 1. We want to take this opportunity, however, to note that research and policy on academic entrepreneurship also consider these non-entrepreneurial mechanisms for knowledge spillover. In order to appropriately assess the effectiveness of policies aimed at facilitating academic entrepreneurship, comparisons along the horizontal as well as vertical axes of Fig. 1 are needed. To date, it appears that academic entrepreneurship has been examined in relative isolation of these alternative ways of generating knowledge spillover. We strongly encourage future studies and policies to consider these alternative mechanisms.

Our study provides implications for intellectual property policy and university research commercialization, in that the findings indicate a need to take a broader view of the knowledge and intellectual property emerging from universities that is transferred into entrepreneurship. Specifically, our finding of the importance of commercial experience in addition to scientific knowledge in fuelling the growth and survival of spinoff ventures speaks to concerns that while there may have been an increase in the number of USOs, many of them fail. This suggests an important imperative to assist USOs in building viable teams that have the requisite commercial experience to succeed. Various studies have questioned the extent to which and indeed whether TTOs have the expertise to build these kinds of teams (Kenney and Patton, 2009; Siegel et al., 2007).

More generally, our analysis also goes beyond the more specific debate about the consequences of the Bayh-Dole Act to the policy debate on how knowledge spills over from established organizations into *new* organizations (Acz et al., 2009; Agarwal et al., 2007). Our findings suggest there may need to be attention to policy support to facilitate spinning out from established organizations, particularly where employees seek to exploit ideas, skills or customer relationships that parent organizations see as peripheral. An obvious potential policy variable to consider is non-compete covenants (Folta et al., 2010; Stuart and Sorenson, 2003). Such covenants are asymmetrically applicable to individuals with high human capital, which are the ones we find most likely to build prosperous CSOs. Further, policy makers may consider "softer policies" such as the promotion of role models that left existing organizations to start spinoffs (Cooper et al., 1995; Sorensen, 2007).

If knowledge-based entrepreneurship constitutes an important vehicle for realizing economic growth, then an exclusive policy focus on the direct start-up of ventures by academics employed in universities might be premature. Our results indicate that since realizing growth among knowledge-intensive firms involves general problems that apply to the whole population of spinoffs studied, it might be important to develop targeted policy favoring the establishment of growth-oriented entrepreneurship in general, so as not to exclude the important group of CSOs in favor of USOs.

5.2. Limitations and future research

As all papers, our study has a number of limitations that provide avenues for further research. First, the advantage of a "clean test" comparing the performance of USOs and CSOs in a small industrial nation with comprehensive publicly available data is also a limitation since we by research design exclude variation in institutionally oriented boundary conditions as these are primarily found to reside in cross-national variation in institutions such as taxation rates, intellectual property protection (Autio and Acs, 2010). Specifically, we note that at the time of the study, Sweden was experiencing a period when ownership of university IP was vested with the academic. Further research might usefully examine contexts where IP ownership is with the university or other stakeholders. Moreover, care must be taken in generalizing these results to other countries with different institutional and economic conditions. Second, while we could observe apparent performance differentials between USOs and CSOs both in terms of survival and in terms of growth during the period of observation, 8 years might not be long enough for an examination of the small but important subgroup of firms with long time to market, such as biotech firms (Stam and Wennberg, 2009). Third, while we make important headway in research studying the workplace and employment backgrounds of academic entrepreneurs (Sorensen, 2007) we do not directly control for the potential of negative selection into entrepreneurship (Parker, 2009). If the share of entrepreneurial individuals in the economy is relatively constant over time (Baumol, 1990), then there is the possibility that a relatively larger share of risk-averse individuals people will decide to work in incumbents firms rather than establishing independent new firms. In Sweden there is a strong tradition of large industrial companies producing most of the R&D and innovation (Granstrand and Alange, 1995). In other words, it may be that the Swedish industrial structure provides academics with employment in international firms with a strong internal labor market and the possibility to engage in corporate entrepreneurship, with the result that only entrepreneurs with human capital not adapted to these firms will choose to spin off and create CSOs. More research on the origin, structure, and relative merits of USOs and CSOs is dearly needed, especially since several policy measures to support entrepreneurship among academic entrepreneurs (Henrekson and Rosenberg, 2001) were initiated during the period of investigation.

Fourth, we defined USOs and CSOs to involve cases where the entrepreneurs work full time in the business, excluding part-time firms to better facilitate comparison between the two types of spinoffs. Academics starting businesses in particular may be likely to retain full-time employment at their university (Nicolaou and Birley, 2003) and inclusion of such part-time firms could raise the number of USOs. Further research might seek to undertake a more fine-grained analysis of the primary and secondary job positions of spinoff entrepreneurs. Fifth, our lack of findings in relation to education may be affected by the truncated distribution that arises from our definition of university educated entrepreneurs having to have at least 3 years education. Sixth, the academic entrepreneurship literature has noted the importance of the role of elite universities compared with so-called mid-range universities (Shane, 2004; Wright et al., 2008b). Our analysis did not control for elite universities since in the Swedish context there is little qualitative difference between universities.

Finally, given the focus of this special issue, our study has concentrated on the direct and indirect spillover of knowledge from universities through USOs and CSOs in order to obtain insights into the impact of the university on society. The entrepreneurial spawning literature (Agarwal et al., 2004; Chatterji, 2009) has examined the impact of the type of knowledge transferred to spinoffs from the parents and has compared the performance of these firms with new entrants that have not been spawned from a larger organization. Further research might usefully extend analysis in this area to compare the performance of CSOs founded by entrepreneurs with and without university education with USOs and non-spinoffs.

Acknowledgement

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Appendix A. Industry of spinoffs.

Industry of spinoffs	Academic spinoffs	Corporate spinoffs
Chemicals and fiber manufacturing	0.30%	0.19%
Electrical and optical equipment	2.37%	3.42%
Transport equipment	0.30%	0.12%
Networks, radio and TV	2.96%	2.27%
Finance	4.44%	4.65%
Real estate business	3.10%	12.07%
Computers/software	19.53%	16.25%
Research and development	11.54%	1.18%
Accounting/auditing	3.25%	6.16%
Construction/engineering	5.03%	11.09%
Advertising	3.25%	7.78%
Management consulting	19.53%	14.30%
Law firms	1.18%	5.03%
Other consulting services	3.25%	6.82%
Education	13.30%	0.02%
Institutions (elderly/children/care)	0.30%	1.64%
Private health care	4.14%	5.14%
News and entertainment	2.03%	1.86%

Note: These industries correspond to the OECD classification of knowledge-intensive industries, which is based on the R&D intensity being higher than the mean of the overall economy (Götzfried, 2004). At first glance, some industries may appear less knowledge intensive. In unreported regressions we therefore excluded certain industries (e.g., private health care) to test if results were sensitive to the inclusion or exclusion of certain industries. The results were virtually identical. Moreover we also conducted extensive robustness checks with industry specific analyses for the larger sectors, as reported in Appendix B. These analyses confirmed that our results were robust. Finally, we note that in-depth industry analyses have shown that the construction/engineering (Reichstein et al., 2005) and finance and advertising (Wennberg, 2009) industries have been shown to be knowledge intensive.

Table B1
Robustness analyses for (1) computers and software, (2) finance/auditing, (3) management consulting/other consulting.

Dependent variable:	ln(employee growth)		ln(sales Growth)		ln(employee growth)		ln(sales growth)		ln(employee growth)		ln(sales growth)	
Sector:	Computers/software		Computers/software		Finance/auditing		Finance/auditing		Consulting		Consulting	
Variables	USOs	CSOs	USOs	CSOs	USOs	CSOs	USOs	CSOs	USOs	CSOs	USOs	CSOs
Growth at $t{-}1$	0.140	0.101***	0.014	0.173**	0.025	0.025	0.103	0.209**	−0.159*	−0.043*	−0.187	0.021
	(0.112)	(0.020)	(0.003)	(0.037)	(0.076)	(0.014)	(0.173)	(0.020)	(0.069)	(0.017)	(0.377)	(0.034)
ln(university/firm employees)	−0.140	0.014**	0.036	0.009	0.071	0.005*	0.139	0.003	0.004	0.034	−0.210	0.002
	(0.112)	(0.005)	(0.163)	(0.009)	(0.056)	(0.001)	(0.100)	(0.007)	(0.025)	(0.005)	(0.434)	(0.009)
ln(university/firm sales)	0.000	0.117***	0.038	0.002	−0.010	0.003*	−0.011	0.002*	−0.006	0.001	0.071	0.001
	(0.001)	(0.035)	(0.044)	(0.001)	(0.005)	(0.001)	(0.009)	(0.001)	(0.005)	(0.001)	(0.276)	(0.001)
University/firm establishments	0.005	0.003*	−0.012	0.003*	−0.060	0.019**	−0.131	0.012*	−0.015	0.013*	0.539	0.012*
	(0.006)	(0.001)	(0.009)	(0.001)	(0.034)	(0.005)	(0.057)	(0.006)	(0.027)	(0.005)	(0.784)	(0.004)
ln(engineers/scientists in university/firm)	−0.019	−0.005	0.141	0.068*	−0.039	0.004	0.001	0.004*	−0.035	0.016*	−0.304	0.005
	(0.030)	(0.007)	(0.056)	(0.032)	(0.065)	(0.005)	(0.007)	(0.001)	(0.023)	(0.007)	(1.263)	(0.015)
ln(PhDs in university/firm)	0.051*	−0.016	0.060	0.006	−0.029	0.002	−0.119	0.004	0.027	0.011	−0.030	−0.020
	(0.023)	(0.010)	(0.028)	(0.016)	(0.057)	(0.007)	(0.099)	(0.008)	(0.014)	(0.007)	(0.031)	(0.022)
Mean years of education in team	0.036*	−0.004	0.010	0.008	0.008	0.001	0.005	−0.002	0.004	0.007*	0.040	0.001
	(0.013)	(0.003)	(0.027)	(0.005)	(0.009)	(0.003)	(0.016)	(0.004)	(0.004)	(0.003)	(0.054)	(0.004)
Mean industry experience in team	0.012*	0.006+	0.015*	0.008+	0.022**	0.022	0.914**	0.011*	0.018*	0.011	0.095*	0.007
	(0.004)	(0.003)	(0.004)	(0.004)	(0.005)	(0.280)	(0.363)	(0.005)	(0.009)	(0.004)	(0.038)	(0.007)
Mean Entrepreneurial exp. in team	(0.001)	0.010	0.022	0.018*	0.102	0.022*	0.273**	0.023*	0.047	0.015	0.028*	0.049*
	−0.000	(0.012)	(0.016)	(0.009)	(0.061)	(0.004)	(0.079)	(0.011)	(0.062)	(0.009)	(0.011)	(0.023)
USO dummy (in pooled model)	−0.010	−0.010**	−0.002	−0.008**	−0.005	−0.043**						
	(0.006)	(0.003)	(0.003)	(0.002)	(0.002)	(0.011)						
R^2 (within)	0.102	0.097	0.082	0.053	0.110	0.102						
R^2 (between)	0.164	0.136	0.153	0.267	0.197	0.246						
R^2 (overall)	0.132	0.155	0.123	0.123	0.143	0.198						
Firm-year Obs.	336	3396	336	3396	119	7810	119	7810	513	6028	513	6028
Unique firms:	127	866	127	866	37	1947	37	1947	164	1535	164	1535
Wald χ^2 (42)	186.69***	68.44***	605.31***	951.15***	1426.21***	696.42***						

Note: All models estimated with random effects generalized least squares. Standard errors clustered by firms in parentheses. Industry dummies and controls for management experience, team size and team social capital included but not displayed.

* $p < 0.05$ (two-tailed).
** $p < 0.01$ (two-tailed).
*** $p < 0.001$ (two-tailed).
\+ $p < 0.10$ (two-tailed).

Appendix B. Sub-sector analyses

See Tables B1–B3.

Table B2
Robustness analyses for (1) construction/engineering, (2) real estate.

Dependent variable:	ln(employee growth)		ln(sales growth)		ln(employee growth)		ln(sales growth)	
sector:	Construction/engineering		Construction/engineering		Real estate		Real estate	
Variables	USOs	CSOs	USOs	CSOs	USOs	CSOs	USOs	CSOs
Growth at $t-1$	0.013 (0.079)	0.015 (0.019)	0.051 (0.119)	0.214*** (0.033)	0.224* (0.085)	0.094*** (0.020)	0.059* (0.026)	0.091*** (0.020)
ln(university/firm employees)	−0.022 (0.047)	0.005 (0.005)	0.007 (0.007)	0.025*** (0.004)	−0.007 (0.011)	0.070*** (0.012)	0.118 (0.113)	0.013* (0.006)
ln(university/firm sales)	0.001 (0.001)	0.031** (0.011)	−0.047 (0.070)	0.002** (0.001)	0.000 (0.019)	0.001* (0.001)	0.002 (0.107)	0.003** (0.001)
University/firm establishments	−0.048 (0.039)	0.010* (0.004)	−0.006 (0.051)	0.010 (0.008)	0.005 (0.004)	0.010* (0.005)	−0.022 (0.061)	0.006 (0.007)
ln(engineers/scientists in university/firm)	0.013 (0.046)	0.006* (0.002)	0.046 (0.073)	−0.007 (0.009)	0.005 (0.003)	0.006 (0.006)	−0.040 (0.030)	0.001 (0.009)
ln(PhDs in university/firm)	0.006 (0.010)	−0.004 (0.008)	0.018 (0.019)	0.003 (0.012)	0.004 (0.003)	0.018 (0.011)	−0.002 (0.010)	0.010 (0.014)
Mean years of education in team	0.003 (0.002)	0.000 (0.003)	0.000 (0.006)	0.001 (0.005)	0.007 (0.004)	0.004 (0.003)	0.100 (0.056)	0.002 (0.004)
Mean industry experience in team	0.010* (0.003)	0.003 (0.006)	0.006* (0.002)	0.009 (0.006)	0.021+ (0.012)	0.007 (0.005)	0.020+ (0.010)	0.014 (0.008)
Mean Entrepreneurial exp. in team	0.103 (0.048)	0.003 (0.012)	0.028 (0.022)	0.034 (0.022)	0.006 (0.006)	0.009** (0.002)	0.004+ (0.002)	0.052* (0.020)
USO dummy (in pooled model)	−0.003 (0.002)	−0.054** (0.011)	−0.012 (0.005)	−0.021** (0.011)				
R^2 (within)	0.112	0.081	0.078	0.090				
R^2 (between)	0.123	0.367	0.226	0.219				
R^2 (overall)	0.163	0.218	0.140	0.162				
Firm-year Obs.	163	4120	163	4120	109	4311	109	4311
Unique firms:	41	946	41	946	25	918	25	918
Wald χ^2 (42)	98.83***	56.69***	523.12***	53.10***				

Note: All models estimated with random effects generalized least squares. Standard errors clustered by firms in parenthesis. Industry dummies and controls for management experience, team size and team social capital included but not displayed.
* $p < 0.05$ (two-tailed).
** $p < 0.01$ (two-tailed).
*** $p < 0.001$ (two-tailed).
\+ $p < 0.10$ (two-tailed).

Table B3
Robustness analyses for (1) education, (2) research and development (R&D).

Dependent variable:	ln(employee growth)		ln(sales Growth)		ln(employee growth)		ln(sales growth)	
sector:	Education		Education		R&D		R&D	
Variables	USOs	CSOs	USOs	CSOs	USOs	CSOs	USOs	CSOs
Growth at $t-1$	0.372 (0.245)	0.125*** (0.022)	0.109 (0.078)	0.131*** (0.024)	0.012 (0.044)	0.020 (0.106)	0.404** (0.092)	0.308* (0.148)
ln(university/firm employees)	−0.032 (0.282)	0.012* (0.006)	0.019 (0.035)	0.014* (0.006)	0.026 (0.023)	0.067* (0.015)	0.030 (0.032)	0.110* (0.029)
ln(university/firm sales)	0.020 (0.021)	−0.001 (0.001)	−0.003 (0.006)	0.007* (0.003)	−0.001 (0.003)	0.043 (0.065)	0.000 (0.004)	0.005+ (0.003)
University/firm establishments	0.071 (0.179)	0.018* (0.008)	0.012 (0.027)	0.003 (0.007)	−0.044 (0.026)	0.050* (0.020)	−0.047 (0.036)	0.020 (0.098)
ln(engineers/scientists in university/firm)	0.142 (0.509)	0.010* (0.004)	−0.035 (0.034)	0.005 (0.007)	−0.001 (0.033)	0.028+ (0.016)	0.001 (0.045)	0.039 (0.051)
ln(PhDs in university/firm)	−0.136 (0.820)	0.002 (0.015)	−0.004 (0.014)	0.008 (0.010)	0.001 (0.028)	0.031 (0.017)	−0.022 (0.038)	−0.014 (0.023)
Mean years of education in team	0.016 (0.020)	0.004 (0.002)	0.005 (0.005)	0.003 (0.003)	0.003 (0.008)	0.002 (0.050)	0.012 (0.011)	0.072 (0.341)

Table B3 (*Continued*)

Dependent variable:	ln(employee growth)		ln(sales Growth)		ln(employee growth)		ln(sales growth)	
sector:	Education		Education		R&D		R&D	
Variables	USOs	CSOs	USOs	CSOs	USOs	CSOs	USOs	CSOs
Mean industry experience in team	0.012* (0.005)	0.012* (0.023)	0.044** (0.015)	0.020+ (0.011)	0.038* (0.006)	0.345 (0.253)	0.324* (0.123)	0.002 (0.050)
Mean Entrepreneurial exp. in team	0.020 (0.025)	0.028 (0.022)	0.011 (0.013)	0.007 (0.082)	0.062 (0.116)	0.046 (0.034)	0.046 (0.160)	−0.345 (0.253)
USO dummy (in pooled model)	−0.010 (0.006)	−0.101*** (0.011)	0.006 (0.004)	−0.013*** (0.001)				
R^2 (within)	0.093	0.094	0.073	0.056				
R^2 (between)	0.146	0.195	0.242	0.195				
R^2 (overall)	0.109	0.156	0.154	0.098				
Firm-year Obs.	265	345	265	345	331	418	331	418
Unique firms:	74	83	74	83	56	96	56	96
Wald χ^2 (42)	93.34***	123.43***	54.43***	93.347***				

Note: All models estimated with random effects generalized least squares. Standard errors clustered by firms in parenthesis. Industry dummies and controls for management experience, team size and team social capital included but not displayed.

* $p < 0.05$ (two-tailed).
** $p < 0.01$ (two-tailed).
*** $p < 0.001$ (two-tailed).
\+ $p < 0.10$ (two-tailed).

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