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Smart people come, smart people go: What spin-off entrepreneurs already know and what they take from their previous employers.

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Abstract

In this paper, we begin to disentangle the role of academic competences of entrepreneurs and early employees from other mechanisms underlying spin-off performance. To this purpose we exploit an original dataset encompassing all PhD graduates of German universities as well as their thesis-related publication activities. The data are matched with information about the whole laser firm population in Germany between 1964 and 2005. For all covered years, diversifying de alio entrants can be distinguished from de novo entrants, and the latter can be distinguished according to their pre-entry experience. We study the role that the academic accomplishment of spin-off founders plays in the longevity of their ventures, and we trace the employment choices of PhD-holding laser inventors. Our results suggest that founders' academic competences help explain the odds of survival of spin-offs, and also those of academic startups in the German laser industry. We moreover find that spin-offs are attractive employers for PhD-holding inventors with intermediate levels of publications, but not for those who have the largest publication output. Both regional proximity and a shared academic background of founders and employees help predict employment choices.

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1. Introduction

To what extent do incumbents train or rather attract future spin-off entrepreneurs? Klepper's "heritage theory" predicts higher performance, in terms of growth and firm survival, of firms founded by entrepreneurs with previous work experience at incumbents (Klepper, 2002; Klepper, 2007; Buenstorf and Klepper, 2009). In this view, knowledge and skills that founders transfer to the new venture are seen as crucial for entrepreneurial activity and performance, which turns incumbents into "involuntary training grounds for future entrepreneurs" (Agarwal et al., 2015a). A contrasting view on spin-offs attributes their performance primarily to selection effects. More capable individuals may be hired by better firms, and have more to lose if they give up their current job. As a consequence, spin-off founders, particularly those coming from leading firms in the industry, are a highly selected group of entrepreneurs. It is straightforward that they perform better than other *de novo* entrants. Knowledge about whom to hire is another potential driver of spin-off performance (Carias and Klepper, 2010). Convincing suitable co-workers to leave their previous employer as well seems to be an ability that spin-off entrepreneurs benefit from. It has even been suggested that recruitment, especially of prior co-workers, may be more important as a driver of spin-off performance than knowledge about products and processes acquired at previous workplaces (Dahl and Sorenson, 2014). However, just employing former colleagues does not systematically reduce the hazard rates of spin-offs, whereas the previous work experience of those employees does. In addition, the ability to hire new workers is related to founder abilities (Dahl and Klepper, 2015).

Whatever it is that makes entrepreneurs with industry work experience outperform their less experienced peers - in any case there seems to be something "magic" that spin-offs inherit from their parent firms. This "magic" might consist of knowledge and capabilities that workers with high abilities bring to their own venture, or vice versa incumbents' "magic" might lie in the ability to select top-performing employees in the first place. One aspect of (self-) selection relates to the academic competences of spin-off founders and their early employees. Interacting with the scientific community seems not only linked to a higher innovative output, but may also help attract employees with a pronounced "motive for intellectual challenge" (Sauermann and Cohen, 2010).

In this paper, we begin to disentangle the role of academic competences of entrepreneurs and early employees from other mechanisms underlying spin-off performance. To this purpose we exploit an original dataset encompassing all PhD graduates of German universities since 1970 as well as their thesis-related publication activities. The data are matched with information about the whole laser firm population in Germany between 1964 and 2005. For all covered years, diversifying *de alio* entrants can be distinguished from *de novo* entrants, and the latter can be distinguished according to their pre-entry experience, including diversifiers, spin-offs and the small group of (other) start-ups (Buenstorf, 2007). The identity of firm founders and their background in laser research have also been established. For the PhD-holding entrepreneurs, academic competences are proxied by the number of publications related to their PhD research. The data also allow us to reconstruct founders' academic "roots".

We study the role that the academic accomplishment of spin-off founders plays in the longevity of their ventures, and we trace the employment choices of PhD-holding laser inventors. Our results suggest that founders' academic competences help explain the odds of survival of spin-offs, and also those of academic startups in the German laser industry. However, after controlling for founders PhDs and firms' pre-entry patent portfolio, a substantial performance difference between spin-offs and academic startups remains unexplained. We moreover find that spin-offs are attractive employers for PhD-holding inventors with intermediate levels of publications, but not for those who have the largest publication output. Both regional proximity and a shared academic background of founders and employees help predict employment choices.

The remainder of the paper is structured as follows. The theoretical background of our analysis is discussed in Section 2. Testable hypotheses are derived in Section 3. In Section 4 we outline the data used in the empirical analysis. Results of this analysis are presented in Section 5, and Section 6 concludes.

2. Theoretical background

It is stylized fact of the empirical literature on pre-entry experience and industry evolution that spin-offs, defined as firms started by former employees of other firms active in the same industry[1], frequently outperform other *de novo* entrants, while they tend to be similarly successful as *de alio* entrants diversifying from other industries (cf., e.g., Klepper, 2009; Peltoniemi, 2011 for reviews of the relevant empirical work). In a wide variety of empirical contexts, spin-off performance has moreover been found to be related to the performance of the spin-offs' "parent" firms, indicating that success tends to breed success. Accounting for the performance premium of spin-offs has turned out to be elusive, however. An apparently straightforward way to think about spin-off performance is to attribute it to capabilities derived from the spin-off founder's experience at the parent firm. In other words, industry incumbents are conceptualized as involuntary breeding grounds for capable entrepreneurs (Klepper and Sleeper, 2005). The more capable an incumbent firm is, the more there is to learn for budding entrepreneurs. As a consequence, more and more capable spin-offs are expected to emerge from higher-performing firms – a predicting that is largely borne out by the empirical literature (e.g., Klepper and Sleeper, 2005; Buenstorf, 2007).

While consistent with the patterns of spin-off emergence and performance, to date there has been no conclusive evidence in favor of this employee learning or "heritage" (Buenstorf and Klepper, 2009) account of spin-off entrepreneurship. An alternative view, which underlies e.g., the "strategic disagreement" theory of spin-off entrepreneurship (Klepper and Thompson, 2010, Thompson and Chen, 2011), holds that spin-off founders are superior to other entrepreneurs in the first place. Because of their competence, they tend to be hired by the better firms. And since they leave their

[1] We follow the terminology used, among others, by Klepper (2001, 2009) or Helfat and Lieberman (2002). Other authors eschew the spin-off term (which is used differently in the financial management literature) and refer to intra-industry employee startups as spin-outs (e.g., Agarwal et al., 2004).

current employer only if they expect a higher payoff from starting up themselves, their firms will be based on a highly selective set of business ideas. Their ability to outcompete other de novo entrants primarily derive from this selection effect.

Spin-off capabilities do not only derive from what their founders know. Founder competences are complemented by those of the employees that the spin-off hires. As a consequence, spin-off performance may also be conditioned by the competences that these employees bring to the firm (Agarwal et al., 2015b). These are obviously not independent from those possessed by the founders. To the contrary, some of the useful knowledge that spin-off founders acquired during their work for incumbent firms may be knowledge about whom (not) to hire. Using matched employer-employee data for Portugal, Carias and Klepper (2010) found that a substantial share of spin-offs' hires are from the founders' prior employers. Hiring former co-workers is associated with longer employment spells and lower exit hazards of the spin-off, both of which suggests that former co-workers, about whom the spin-off founders presumably know more than about other hires, are better matches for the spin-off firm. Besides this finding on matching quality, little is known about how the competences of spin-off employees and how they contribute to spin-off performance. We will explore this in the subsequent empirical analysis.

3. Hypotheses

The competing accounts of spin-off entrepreneurship outlined above are difficult to disentangle empirically. In particular, individual management skills are unobservable for the academic observer and defy quantitative measurement. To nonetheless make headway, our subsequent empirical analysis will utilize data on the academic qualifications of spin-off founders and employees in the German laser source industry. We chose this empirical context because spin-off incidence and performance have been studied, and spin-off founders have been identified, in prior work on this industry (Buenstorf, 2007). In addition, we were able to obtain data on all laser-related doctoral dissertations in Germany, and also on the scientific publications of the dissertation authors. We use this information as a measure of spin-off entrepreneurs' pre-start up competences. The same information is also utilized for spin-off employees, where employees are identified through the inventor names on patents assigned to the spin-off firm. Accordingly, the focus of the empirical analysis is on technical rather than market competence (cf. Agarwal et al., 2004). It is performed in an industry setting, allowing us to juxtapose spin-off entrepreneurs and their employees to those of other types of entrants. As will emerge below, it is particularly informative to compare spin-offs (again: defined as intra-industry employee startups) to academic startups organized by scientists and engineering leaving jobs at universities and non-university public research organizations (PROs).

If spin-off performance is primarily due to what future spin-off entrepreneurs have learned in their employment spells with incumbent firms, then we would expect spin-off performance to vary little with the academic background of their founders. In contrast, the competing view outlined above, which holds that spin-off founders may be a self-selected group of entrepreneurs and therefore able

to outcompete other *de novo* entrants, even a partial control of individual competence is expected to explain a major share of the variation in performance.

Both competing views inform our first pair of hypotheses:

H1a (learning): Spin-off entrepreneurs' academic competences are not systematically related to spin-off performance.

H1b (selection): Spin-off entrepreneurs' academic competences are systematically related to spin-off performance.

We likewise study the role of spin-off employees' academic competence. Here, we begin by studying the employment choices of individuals with laser-related academic training. We expect that spin-off founders want to hire high-class scientists to complement their own knowledge. By definition, spin-off founders come from private-sector jobs. Compared to academic entrepreneurs, their own scientific knowledge will more often be outdated, requiring them to hire researchers possessing the knowledge that they lack themselves. At the same time, superior academic competences of spin-offs' R&D staff would be consistent with the superior performance of spin-offs. This rationale suggests the following hypothesis:

H2 (employees' academic competences): R&D employees hired by spin-offs have stronger academic competences than R&D employees hired by other types of firms.

Extending the prior work by Carias and Klepper (2010), we moreover expect that

H3 (employees' geographic background): Spin-offs preferentially hire R&D employees having the same geographic background as the spin-off founder(s).

H4 (employees' academic background): Spin-offs preferentially hire R&D employees having the same academic background as the spin-off founder(s).

4. Data and empirical methods

Our empirical analysis is based on a two-step matching of individual-level data. In particular, we matched the names of all laser-related PhD graduates of German universities (1970-2010) with the names of all inventors listed on the patents of laser source producing firms, as well as with all author names on laser-related scientific publications.

We started our data collection effort by extracting all priority patent applications filed by German applicants in IPC H01S from PATSTAT (2014b), a total of 2,922 patents for the time period 1970 to 2010. Laser source producers among the applicants were identified using the list of firms analyzed in (Buenstorf 2007), which includes 143 German laser source manufacturers. These firms can be categorized according to their (founders') backgrounds prior to entering the laser industry. Specifically, we distinguish diversifiers from other industries (*de alio* entrants, which include well-established firms such as Siemens and Carl Zeiss, as well as smaller firms that often integrated from laser sales or component manufacturing into the production of laser sources) from newly established ventures (*de novo entrants*, which predominantly consist of academic startups and employee spin-offs).

Names of applicants and firms were standardized[2]. Standardized applicant and firm names (and where available previous or alternative firm names) were matched using a fuzzy string matching algorithm[3]. Positive matches were manually checked to detect false positives. Forty-eight of the firms included in the list were identified as having at least one patent. The patenting firms account for 1,337 patent applications (about 45%).

Entrepreneurs may apply for patents before the firm is founded. In these cases the firm name is not listed among the applicants. To cover the whole patent portfolio of a firm the above procedure was repeated for the firm founders as well. For 123 firms information of altogether 186 firm founders is available. Applying the above matching procedure resulted in 31 additional patent applications filed by 12 firm founders. We identified PhD-holding entrepreneurs using a variety of sources including current and archived firm websites, trade publications, incorporation files, and professional online networks.

In the next step we identified PhDs among the inventors in the patent dataset. 3,264 distinct inventor names were listed on the patent applications in the sample. The inventor names were cleaned according to the procedure described above. In addition we retrieved the academic title from the inventor names. Since in Germany the "Dr." is an official part of the name, a high coverage of academic titles can be assumed. Our data on PhD graduates is based on the catalog of the German National Library (DNB). Since 1969 the DNB has had a legal mandate to collect all German publications and all publications by Germans. This provision includes PhD theses. We use a subsample of PhD theses listed in the DNB catalog that were categorized as theses in physics, electrical or mechanical engineering. Dissertations classified as medical theses were excluded. The dataset used contains 152,679 PhD theses and their authors.

The set of H01S inventor names was disambiguated using information on common co-inventors, applicants, addresses and titles. This procedure identified 1,268 distinct inventors. These were next matched to the list of PhD authors, which resulted in 2,022 positive PhD inventor pairs. Several filters were applied to distinguish true from false positive matches. PhD theses were classified as "laser dissertation" if the title includes words closely related to laser research[4]. For all matched PhDs homonyms were searched in the full PhD sample. If no homonym (PhD with exactly the same surname first name combination) could be found, the PhD was classified as having a unique name. In the respective cases the PhD is the only person with this specific name combination who graduated in Germany in the relevant disciplines. The unique name in combination with a "Dr." in the inventor name data provides a strong predictor of being a true positive match. In addition, the lag between the year of graduation and the year of the first patent filing was calculated. All positive matched inventor PhD pairs were manually processed to detect false name matchings and

[2] The standardization procedure includes removal of punctuations and whitespaces, correcting German umlauts, removing annexes of firm names like "GmbH" and "AG".

[3] For all string matchings a 2-gram Jaccard similarity as proposed by (Schoen, Heinisch, and Buenstorf 2014) for German patent data. While the author use a minimum required similarity smaller than 0.9 we use a threshold of 0.8. The smaller sample size allows using a more relax threshold, which is preferable since false negative matches are reduced by keeping the manual data checking effort manageable.

[4] The following words were classified as indicating a laser-science related dissertation: laser, light, spectroscopy, spectral, pulse, optical, induced and the German translation of these words.

inconsistencies (e.g., patent antecedes graduation but inventor has a "Dr." in their name). In cases where no clear decision was possible additional information was used (using the title of the PhD thesis, field classifications of the DNB, keywords, and depatis.net information – the "Dr." is often listed in depatis.net even if it is not available in PATSTAT). After eliminating false positive matched PhD-inventor-pairs, we obtained a full sample of 443 PhDs active in patenting for German laser source producers. By applying the same procedure to the 186 laser firm founders, 57 entrepreneurs were identified to hold a PhD degree.

For all PhDs information about their thesis-related publication activities was collected from the Web of Science (WoS). The algorithm developed to match PhD theses with publications in the WoS (originally developed for all science and engineering theses contained in the DNB catalog) uses a two-step procedure. In the first step publications in the WoS were clustered in distinct author groups. The basic steps of the procedure follow those recommended by (Wang et al. 2012). All authors were grouped by their name and affiliation. Other similarities between the authors were searched within the name-affiliation groups (common co-authors, self-citations, time lags of publication dates, second names if available and identical keywords). To test whether the matching procedure worked accurately the average number of papers assigned to the 100 most common (German) surnames were tested against all other names. No significant difference was found. This suggests that no bias is introduced by assigning more papers to more frequent names that were poorly disambiguated, indicating that the matching procedure worked with a satisfactory degree of accuracy. After the WoS disambiguation procedure WoS authors were matched with the PhD data by using author names and affiliations (affiliation of the author group and the affiliation the PhD graduated from). The matched pairs were filtered for false positive using (lack of) similarity in titles[5] as well as the time lag between the first paper published and the submission of the PhD thesis. Of the 443 PhD inventors 228 PhDs were found to have published during their PhD time.

The procedure described above provides us with the universe of PhD-holding laser inventors in the German laser industry. Besides characteristics of the firm and their firm founders, characteristics of the PhDs like their alma mater, the year of their graduation and publications related to their thesis are available. More than half of the PhD holding inventors have published at least one paper while conducting their PhD (mean: about 6.28 publications; median: 1). Their patenting activity ranges from 1 to 36 patents per person, with a mean of 3.37 patents. Numbers of publications and patents are not correlated (excluding Professors from the dataset correlation increases slightly to 0.08, significant on 10% level).

5. Results

Of the 143 laser source producers only 48 patented in IPC H01S (laser sources). However all types of entrants are represented among the patenting firms. 14 of the 45 diversifiers are active in patenting (31%), 20 of the 59 spin-offs (33%; including integrating distributers as per Buenstorf (2007)), and 12 of the 29 academic startups (41%). About 35% of the inventors' active for

[5] Using a LCS function with minimum string length of 5 characters.

diversifiers hold a PhD, while they account for only 28% at spinoffs. Inventors with PhD make almost half (48%) of the inventors patenting for academic star-ups. Academic start-ups have highest average publications per PhD with 11.23. Differences in the time lag between graduation and the first patent filing are more similar between the distinguished firm types. PhDs patenting for diversifiers do this on average 6.23 years after graduation on average. PhDs at spin-offs and academic start-ups are slightly faster with 5.17 and 4.51 years.

Table 1: descriptive statistics

	diversivier	spinoff	academic start-up	others
number of firms	45	59	29	10
firms patenting	25	25	15	2
average number of patents filed	41.76 (137.39)	8.40 (10.32)	11.40 (24.99)	2.50 (0.71)
average lag: first patent to market entry	5.64 (9.75)	1.72 (7.03)	0.40 (4.60)	-1.00 (1.41)
average years firm is in the market	8.64 (7.61)	6.15 (5.12)	4.38 (4.07)	5.90 (6.10)
PhD is founder	2	17	17	0
number of inventors	1,015	169	122	2
number of PhDs among inventors	360	48	58	1
average number of publications per PhD	5.82 (18.96)	4.27 (6.86)	11.23 (21.11)	--- ---
average time lag: PhD thesis submission to first patent filed at firm	6.23 (9.94)	5.17 (7.74)	4.51 (8.77)	--- ---

(standard errors in brackets)

Competing Hypotheses 1a and 1b deal with the academic competences of spin-off entrepreneurs and how they relate to spin-off performance. To probe into this relationship, we estimate a set of parametric hazard rate models assuming Gompertz-distributed baseline hazards. Model specifications build on those utilized by Buenstorf (2007), and we also use an extended version of his dataset for the estimation. As noted above, three types of entrants are distinguished: diversifiers, spin-offs, and academic startups. The dataset also contains a small number of other *de novo* entrants; i.e. startups whose founders neither worked for industry incumbents nor organized the firm out of employment in public research.

Model 1 in Table 2 has our baseline regression. Consistent with Buenstorf (2007), we find a substantially and systematically reduced hazard rate of diversifiers and spin-offs, as compared to the control group (primarily) consisting of academic startups. It is also noteworthy that, counter to what is found in most studies of industry evolution, the coefficient estimate of the "age" term measuring how the exit hazard changes with the duration of stay in the laser industry is positive and not significantly different from zero. Accordingly, entrants into the German laser industry did not suffer from a "liabilty of newness" relative to firms that already had a longer tenure in this industry.

Table 2: firm survival

proportional hazard rate model (Gompertz specification)

	model 1			model 2			model 3			model 4			model 5			model 6		
diversivier	-0.7689	*(0.3386)*	**	-0.7880	*(0.376)*	**	-0.4788	*(0.3514)*										
spinoff	-1.0332	*(0.3606)*	***	-1.1014	*(0.3644)*	***												
academic start-up										0.9026	*(0.3223)*	***	1.2860	*(0.3512)*	***			
spinoff (non PhD)							-0.7069	*(0.37)*	*									
spinoff (PhD)							-2.3624	*(1.0265)*	**									
acad. start-up (non PhD)																1.4141	*(0.3884)*	***
acad. start-up (PhD)																0.2767	*(0.4802)*	
founder is PhD				-0.9001	*(0.4289)*	**							-1.1877	*(0.4379)*	***			
patents filed before entry				-0.7544	*(0.3805)*	**	-0.8363	*(0.3705)*	**				-0.7849	*(0.3526)*	**	-0.7444	*(0.3521)*	**
age	0.8686	*(0.966)*		0.9710	*(0.8596)*		0.5831	*(0.8295)*		-0.0554	*(0.8047)*		-0.1174	*(0.7087)*		-0.3425	*(0.6695)*	
n	143			143			143			143			143			143		
events	51			51			51			51			51			51		
logLik	-201.7794			-196.2526			-196.8163			-202.7821			-195.2443			-197.5430		

*: p < 0.1 regression coefficient
**: p < 0.05 (standard errors in brackets)
***: p < 0.01

Model 2 adds a dummy variable indicating firms whose founders hold a doctoral degree to the specification. We also add a dummy variable measuring whether a firm had laser-related patents prior to entering the laser industry as a general measure of technological capabilities. The coefficients estimated for both variables are negative and significant. But they do little to change the results obtained in Model 1, suggesting that founders' academic competences and technological capabilities at entry alone are not enough to account for firm performance in the German laser industry. In Model 3, the spin-off dummy is split up to denote two groups of spin-offs: those whose founder has a doctoral degree and those where this is not the case. In line with the above results, coefficient sizes are suggestive of a performance difference (they are not different at conventional levels of significance, $p < .12$), However, spin-offs without PhD-holding founders still outcompete the firms in the reference group. (The coefficient is different from zero at the .10 level.) Due to collinearity, the founder PhD variable is excluded from this specification.

Models 4-6 correspond to Models 1-3 but take a reverse perspective. We now focus on academic startups, while all other entrants are part of the reference group. As would be expected given the above findings as well as the prior literature, results in Models 4 and 5 show that academic startups were the poorest-performing group of entrants in the German laser industry. In Model 6, the group of academic startups is further distinguished into those whose founders hold PhDs and those with less accomplished founders, e.g. laser firms started by lab technicians.[6] This provides new insight into the performance of this type of entrant, as it is primarily the first group (firms without PhD-holding founders) that performed poorly. (Coefficient estimates are significantly different at the .05 level.)

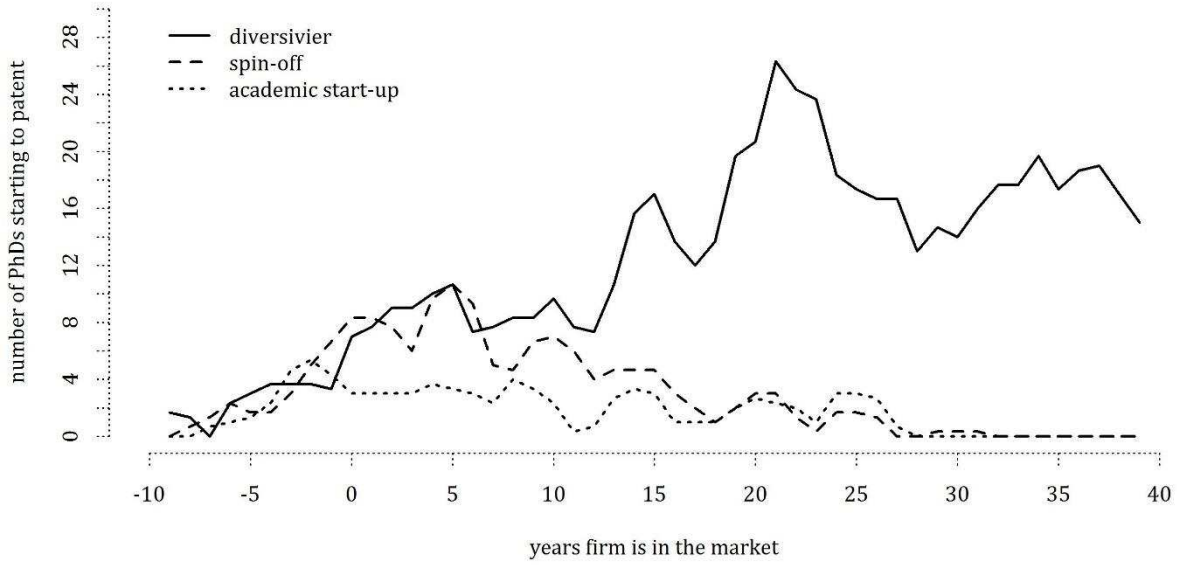
Summing up, our results from the analysis of exit hazards provide a nuanced picture of the role of founders' academic competence. With regard to spin-offs, they provide support to Hypothesis 1b in that spin-offs with PhD-holding founders have a substantially lower hazard. A similar pattern is obtained for academic startups. At the same, even after controlling for founder PhDs and pre-entry patenting, there remains a systematic performance differential favoring spin-offs. This suggests that spin-off performance may reflect both learning and selection effects.

We now turn to the role of R&D employees hired by the various types of firms. To probe into Hypotheses 2 and 3 we employ a conditional logit framework. Specifically, for all PhD-holding inventors we reconstruct the set of potential applicants active that the time that they finished their PhD. We then analyze the factors that help predict the actual corporate applicant of their first patent, which we assume to be their employer. As can be seen in Figure 1, a substantial fraction of the PhDs' first patents is applied for before the applicant is listed as a laser producer. To some extent, this reflects some entries in our dataset are slightly delayed compared to information on the firms' own websites. However, we interpret this pattern as also indicating that freshly minted PhD-inventors play an important role in technology development underlying the entry of laser firms. It is also noteworthy that in these early years the role of patenting new PhDs is very similar across types of entrants. Subsequently, the importance of patenting new PhDs decays, first for academic startups

[6] The group of academic startups with founders without a PhD also includes some early entrants, for which information is sparse. We cannot exclude that some of these firms may be misclassified, in which case our results on performance may be biased in favor of PhD-holding founders.

and subsequently also for spin-offs. In contrast, patenting new PhDs remain important for diversifiers, suggesting that these firms replenish their R&D competences by hiring young inventors for a longer time than the *de novo* entrants do.

Figure 1: number of new PhDs patenting by firm type and markte experience (0 = entry)



Since recruitment is in the focus of our analysis, patenting PhDs who are identified as founders of the applicant firm are excluded from the sample for the analysis of R&D employees. This reduces the dataset by 20 inventors to 423. In addition, professors are identified among the inventors using Kürschners Gelehrtenkalender, which includes all German Professors. Professors often collaborate with several firms and are not directly employed at the patenting firms. They are removed from the sample reducing the dataset to 386 inventors. For the remaining PhD holding inventors a risk set of all potential applicants is constructed. The risk set includes all firms which are active in laser source production after the submission year of the thesis. Firms that newly entered laser source production after graduation are also placed as potential employers in the risk set. In total this leads to 36,330 matched PhD firm pairs with 386 truly realized pairs taking the value 1. This implies that an individual PhD could in principle have become an inventor for any of about 100 laser source producers. Which firm characteristics either attract or select PhDs is estimated by using a conditional logit model.

Table 3: selection on firms and PhD-inventors

conditional logit regression: PhD patenting for laser source producer

	model 7		model 8		model 9		model 10	
firm age at submission	0.1313	*(0.0065)* ***	0.1352	*(0.0068)* ***	0.1359	*(0.0066)* ***	0.1389	*(0.0069)* ***
years till entry	-0.0510	*(0.015)* ***	-0.0528	*(0.0153)* ***	-0.0548	*(0.0149)* ***	-0.0569	*(0.0152)* ***
# firm patents at submission	2.3484	*(0.1717)* ***	2.2227	*(0.1759)* ***	2.3914	*(0.1704)* ***	2.2934	*(0.1736)* ***
academic startup					-0.8938	*(0.4329)* **	-1.2652	*(0.4476)* ***
spin-off					-0.6246	*(0.2658)* **	-0.5907	*(0.2688)* **
diversifier	0.9001	*(0.2442)* ***	0.9955	*(0.2496)* ***				
acad.*pub					1.1692	*(0.5503)* **	1.3735	*(0.5686)* **
acad.*pub5					1.3701	*(0.5393)* **	0.9603	*(0.5893)*
spin-off*pub					0.7837	*(0.3498)* **	0.8482	*(0.3535)* **
spin-off*pub5					0.2226	*(0.4129)*	0.3332	*(0.4133)*
div.*pub	-0.8941	*(0.3098)* ***	-1.0276	*(0.3173)* ***				
div.*pub5	-0.6649	*(0.3371)* **	-0.5684	*(0.3533)*				
same region (firm)			1.8695	*(0.1997)* ***			1.8951	*(0.2009)* ***
same origin (founder)			2.3867	*(0.4235)* ***			2.4227	*(0.4596)* ***
n	36330		36330		36330		36330	
events	386		386		386		386	
logLik	-939.2752		-872.5463		-939.4044		-874.2760	

*: p < 0.1 regression coefficient
**: p < 0.05 (standard errors in brackets)
***: p < 0.01

Results of the conditional logits are reported in Table 3. Model 7 focuses on the diversifiers. It finds that the first patents of PhD-holding inventors are primarily applied for by diversifiers. However, interacting the diversifier variable with dummies denoting inventors with 1-5 or 6+ thesis-related publications indicates that diversifiers predominantly hire inventors who have no publications, while apparently they are less attractive as employers for the more prolific researchers. To control for some of the heterogeneity across firms, this and all following models contain further variables measuring firm age at the time the PhD thesis was submitted, as well as the time to entry in the case of pre-entry patenting (see above). The coefficients estimated for both variables suggest that a firm's likelihood to attract PhD-holding inventors increases over time, both prior to and after entry into the laser industry.

Model 9 shifts the focus to the de novo firms. We find that the baseline coefficients are very similar and significantly negative for both academic startups and spin-offs. Academic startups are more likely to hire inventors with medium to high levels of publications. Spin-offs fare best among the group of inventors with 1 to 4 publications, but not among the top-level publishers. Accordingly, the evidence in favor of Hypothesis 3 is mixed. It does not suggest that spin-offs hire more academically competent R&D staff members than academic startups do. However, they are more likely than diversifiers to attract freshly minted inventing PhDs with intermediate numbers of publications, whereas they are less likely to attract inventing PhDs without publications.

In Models 8 and 10 we add two further variables to see whether, in line with the predictions of Hypotheses 3 and 4, inventing PhDs are preferentially hired by firms located in the same region as

the PhD-granting university and/or firms whose founders graduated from the same school. The variable "same region (firm)" is a dummy taking the value one if PhD-granting university and patent applicant are located in the same NUTS-3 region. The variable "same origin (founder)" which takes the value one if the PhD graduated from the same university at approximately same time (+/- 5 years) as the firm's founder. We obtain sizeable and strongly significant coefficient estimates for both variables, providing support to Hypotheses 3 and 4. The other results are hardly affected by including these extra variables.

6. Conclusions

What explains spin-off performance – founders' on-the-job learning in their prior employment, self-selection of better entrepreneurs into spin-off entrepreneurship, and/or the early hiring decisions made by spin-offs? While this paper could not provide conclusive answers to this long-standing issue in the literature on spin-off entrepreneurship, it did provide new results on the role of founders' and employees' academic accomplishments. In particular, we studied the association between founders' academic accomplishments and the longevity of spin-off ventures. While we found that PhD-holding entrepreneurs tend to start more successful firms, a substantial unexplained performance premium of spin-offs remained. We also traced the employment choices of PhD-holding laser inventors. Here our results suggest that PhDs with intermediate publication output tend to be associated with spin-offs, and those with high publication output to be associated with academic startups. In addition, having the same geographic and academic origins as the entrepreneur is a strong predictor for patenting activities at the same firm. The link back to the academic origins seems to be an important source for labor recruitment, providing PhD-holding entrepreneurs with an advantage in recruiting R&D personnel.

In this study we could build upon a rich prior literature, and also on substantial prior work on the empirical example of the laser industry. However, we hasten to admit the limitations of what our data allow us to do. Most importantly, our results are based on data for a single industry, and with academic accomplishment they focus on only one dimension of founder and employee competences. We therefore consider this paper as another step in the long journey towards an encompassing explanation of spin-off entrepreneurship. Much more work remains to be done.

Agarwal, R., R. Echambadi, A. M. Franco, and M. B. Sarkar (2004): "Knowledge transfer through inheritance: Spin-out generation, development, and survival." *Academy of Management Journal* 47(4): 501-522.

Agarwal, R., G. Buenstorf, W. M. Cohen, and F. Malerba (2015): "The Legacy of Steven Klepper: Industry Evolution, Entrepreneurship, and Geography." *Industrial and Corporate Change* 24 (4): 739–53.

Agarwal, R., B. Campbell, A. Franco, and M. Ganco (2015): "What Do I Take with Me?: The Mediating Effect of Spin-Out Team Size and Tenure on the Founder-Firm Performance Relationship." *Academy of Management Journal*, June, amj.2012.0853.

Buenstorf, G. (2007): "Evolution on the Shoulders of Giants: Entrepreneurship and Firm Survival in the German Laser Industry." *Review of Industrial Organization* 30 (3): 179–202.

Buenstorf, G., and S. Klepper (2009): "Heritage and Agglomeration: The Akron Tyre Cluster Revisited." *The Economic Journal* 119 (537): 705–33.

Carias, C., and S. Klepper (2010): "Entrepreneurship, the initial labor force, and the location of new firms." Mimeo, Carnegie Mellon University.

Dahl, M. S., and S. Klepper (2015): "Whom Do New Firms Hire?" *Industrial and Corporate Change* 24 (4): 819–36.

Dahl, M. S., and O. Sorenson (2014): "The Who, Why, and How of Spinoffs." *Industrial and Corporate Change* 23 (3): 661–88.

Helfat, C. E., and M. B. Lieberman (2002): "The birth of capabilities: market entry and the importance of pre-history." *Industrial and Corporate Change* 11(4): 725-760.

Klepper, S. (2001): "Employee startups in high-tech industries." *Industrial and Corporate Change* 10(3): 639-674.

———. (2002): "The Capabilities of New Firms and the Evolution of the US Automobile Industry." *Industrial and Corporate Change* 11 (4): 645–66.

———. (2007): "Disagreements, Spinoffs, and the Evolution of Detroit as the Capital of the U.S. Automobile Industry." *Management Science* 53 (4): 616–31.

———. (2009): "Spinoffs: A review and synthesis." *European Management Review* 6(3): 159-171.

Klepper, S., and S. Sleeper (2005): "Entry by spinoffs." *Management Science* 51(8): 1291-1306.

Klepper, S., and P. Thompson (2010): "Disagreements and intra-industry spinoffs." *International Journal of Industrial Organization* 28(5): 526-538.

Peltoniemi, M. (2011): "Reviewing Industry Life-cycle Theory: Avenues for Future Research." *International Journal of Management Reviews* 13(4): 349-375.

Sauermann, H., and W. M. Cohen (2010): "What Makes Them Tick? Employee Motives and Firm Innovation." *Management Science* 56 (12): 2134–53.

Schoen, A., D. Heinisch, and G. Buenstorf (2014): "Playing the 'Name Game' to Identify Academic Patents in Germany." *Scientometrics* 101 (1): 527–45.

Thompson, P., and J. Chen (2011): "Disagreements, employee spinoffs and the choice of technology." *Review of Economic Dynamics* 14(3): 455-474.

Wang, J., K. Berzins, D. Hicks, J. Melkers, F. Xiao, and D. Pinheiro (2012): "A Boosted-Trees Method for Name Disambiguation." *Scientometrics* 93 (2): 391–411.