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Losing my religion? Diversification into laser technology by German machine tool producers, 1975-2008

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Abstract

We investigate the strategic diversification into a new innovative industry by producers coming from an established industry. To this purpose, datasets on the long-term evolution of the firm populations in the German machine tool and laser industries are matched. Only a small number of diversifiers from machine tools into the laser industry are identified. These tended to be among the larger and more innovative machine tool producers. For early diversifiers, exit hazards from the industry of origin increase after diversification. We do not obtain robust evidence that diversification is pushed by agglomeration in the industry of origin or pulled by agglomeration in the target industry. Regional laser-related public

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Jelcodes:L25,D21

Losing my religion?

Diversification into laser technology by German machine tool producers, 1975-2008

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Abstract:

We investigate the strategic diversification into a new innovative industry by producers coming from an established industry. To this purpose, datasets on the long-term evolution of the firm populations in the German machine tool and laser industries are matched. Only a small number of diversifiers from machine tools into the laser industry are identified. These tended to be among the larger and more innovative machine tool producers. For early diversifiers, exit hazards from the industry of origin increase after diversification. We do not obtain robust evidence that diversification is pushed by agglomeration in the industry of origin or pulled by agglomeration in the target industry. Regional laser-related public research activities help predict the most challenging diversification moves.

Keywords: Diversification, capabilities, organizational identity, legitimacy, geography.

JEL codes: D22, L22, L25

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1 INTRODUCTION

A number of empirical studies in industrial evolution show that diversifying entrants with experience in related markets tend to outperform *de novo* competitors in the target market (cf., e.g., Dunne et al., 1988; Klepper and Simons, 2000; Klepper, 2002; Thompson, 2005). This finding is often interpreted as indicating that firm capabilities are "portable" across markets (Helfat and Lieberman, 2002). Such "recycling" of capabilities through strategic diversification may be particularly important –and possibly even indispensible for survival – for firms that are currently active in declining markets. At the regional and national level, the ability and willingness of existing firms to diversify into new markets is an important prerequisite to cope with structural change in the economy – think, for example, about the current pressure on the global automobile industry to develop viable strategies and products in the e-mobility market. Understanding determinants and success factors in the diversification of existing firms may therefore be of similar policy relevance as understanding entrepreneurial activities resulting in new firms.

Diversification is associated with profound challenges to the firm. Diversification typically requires substantial financial resources and managerial attention to be successful, which may result in resource bottlenecks in, and lack of attention devoted to, the firm's existing operations. Organizational ecologists moreover emphasize that the process of change itself may challenge the organization's identity and therefore entail substantial hazards to the organization (Hannan and Freeman, 1984; Barnett and Carroll, 1995). All this suggests that only a selective subset of all firms may possess the capabilities required for successful diversification (Helfat and Lieberman, 2002).

In empirical studies of industry evolution, researchers typically collect longitudinal data on a complete firm population in a particular industry and then study the performance of firms with different kinds of backgrounds that entered this industry at various points in time. The potential challenges that diversifying firms are confronted with are difficult to assess in this framework. While the respective studies can find whether diversifiers are successful in the target industry – which they typically are – these studies cannot compare diversifiers to their competitors in the industry of origin. Other interesting questions remain likewise unanswered, for example whether diversification is more likely and/or successful for firms with large existing product portfolios.

Besides firm-specific factors, diversification likelihood and success may also be related to geographic conditions. Do firms in agglomerated regions have a stronger tendency to diversify than more isolated ones? If so, is diversification primarily affected by concentration in the target industry, where spillovers from the target market may enable successful diversification, or by concentration in the industry of origin (creating competitive pressure and/or providing richer opportunities to develop capabilities allowing diversification moves)?

In the present paper, we begin to empirically address these issues by matching two unique datasets that encompass, respectively, the full populations of German machine tool producers and the full population of German producers of laser sources and systems from 1975 to 2008. In this way, we are able to identify machine tool producers that diversified into the broadly defined laser industry. Our data provide detailed information on the activities of the individual producers in both industries and how they developed over time.

This empirical context is particularly suitable to address the above issues. With machine tools and lasers, we study two markets that are markedly different in a number of dimensions, and which are less closely related than, e.g., radios and TV receivers studied by Klepper and Simons (2000) or even laser sources and laser systems (Buenstorf et al., 2010). Diversification into laser technology constituted a substantial technological challenge for machine tool producers. To be sure, machine tools are by no means a low-tech industry. Indeed, in standard statistical delineations, the German machine tool industry is characterized as having an intermediate level of R&D intensity between 2.5 and 7 per cent ("*hochwertige Technologie*"; cf. EFI, 2011). However, compared to traditional machine tools, laser technology is more directly based on recent scientific advances – in this sense, lasers constitute a "science-driven" market undergoing rapid change not only in technology, but also in the type and scope of applications (Grupp, 2000). It is therefore plausible to expect that, if diversification comes with relevant hazards to firms' identity and legitimacy (as can be inferred from the work in organizational ecology; e.g., Hannan and Freeman, 1984; Zucker, 1989), the ensuing problems should be observable among machine tool makers diversifying into the laser industry.

Our findings suggest that diversifiers into the broadly defined laser industry tended to be among the larger and more innovative incumbents in the machine tool industry. Among early diversifiers, exit hazards from the industry of origin increased after diversification. We do not obtain robust evidence that diversification is pushed by agglomeration in the industry of origin or pulled by agglomeration in the target industry. Regional laser-related public research activities help predict the most challenging diversification moves.

The remainder of this paper is structured as follows. In section 2 we present theoretical considerations and derive testable hypotheses. Section 3 describes the data and section 4 introduces the empirical methods. Results of the empirical analysis are reported in section 5 and discussed in section 6.

2 THEORY AND HYPOTHESES

According to Penrose's (1959/1995, pp. 52-3) theory of firm growth, active firms acquire new knowledge in the very process of repeated execution of tasks, and learning from experience enhances firm performance. Penrose suggests that as repeated tasks and processes require decreasing levels of individual attention, accumulating experience frees cognitive capacities of firm members. In this way, experience-based learning effectively expands the firm's cognitive resource base. In this perspective, diversification into related markets is a "natural" phenomenon – it enables firms to put the resources freed by learning to new, profitable uses. Obviously, diversification may also allow firms to benefit from more traditional economics of scope arising, e.g., from more efficient usage of indivisible inputs.

Empirical studies of industrial dynamics in various markets have shown that diversifiers tend to outperform *de novo* entrants. This finding may reflect the process highlighted by Penrose, indicating that diversifiers have been able to acquire organizational knowledge in their prior activities. It may also reflect the fact that diversifiers, having survived in the industry of origin long enough to be able to diversify, are a selected subset of all entrants into that industry, which are less prone to suffer from liability of newness (Stinchcombe, 1965; Thompson, 2005). Prior empirical evidence furthermore suggests that even among the surviving firms in the industry of origin, it tends to be the more successful ones that become diversifiers (Klepper and Simons, 2000; Buenstorf and Klepper, 2009). We therefore hypothesize:

H1: Success in the industry of origin increases the likelihood to diversify into the target industry.

A move into a new and technologically challenging market is a delicate step. Organizational experience and free resources alone may not be sufficient to overcome the barriers involved in the process. However, entering into new markets may itself be subject to experiential learning. As a consequence, past experience in the successful broadening of activities in the industry of origin, e. g. entering new submarkets or expanding their product portfolio, is indicative of firms' dynamic capabilities (Teece et al., 1997), which may facilitate further diversification moves. This leads us to a second conjecture:

H2: The likelihood of diversification into the target industry is increased by past successful expansion within the industry of origin.

Depending on the segment of the target industry that a firm diversifies into, past success and past experience in entering new product markets may differ in relevance. We would generally expect both factors to be more predictive for the likelihood of more challenging diversification moves, which leads to the following predictions:

H3a: The more challenging the diversification move, the more important is past success in the industry of origin.

H3b: The more challenging the diversification move, the more important is past experience with broadening activities within the industry of origin.

Prior work on diversification in the field of industrial dynamics has not normally investigated how diversification affects firm performance in the industry of origin. Although it may be the more successful firms that diversify (as posited above), it is still plausible that diversification has adverse effects on the firm's ongoing activities. As resources and cognitive attention are required for setting up the new activities, they may lack elsewhere in the firm. A complementary account for detrimental effects is provided by organizational ecology, which highlights the importance of an organization's identity. Organizational identity is related to the characteristics and behavior that various stakeholders expect from an organization of a certain type. Organizations not fulfilling these expectations risk being sanctioned by the respective stakeholders. In contrast, organizations benefit from being built on "coherent blueprints that foster reliability and accountability" (Hannan et al., 2006, p. 757).

According to organizational ecologists, firms' core characteristics – which help define their identities – become "imprinted" (Stinchcombe, 1965); attempts to alter them entail substantial costs and risks (Hannan et al., 2006). Among these core features, ecologists include the organization's mission, form of authority, core technology, and general marketing strategy (Hannan and Freeman, 1984). Even though the change may be appropriate as an adaptation to a dynamic environment, the very process of changing a core characteristic – and the ensuing challenge to the identity ascribed to the organization – may be harmful. Modifying organizational identity may moreover be more difficult for older organizations (Barnett and Carroll, 1995; Hannan, 2005).

Diversification from machine tools into the laser industry clearly qualifies as a move that challenges organizational identity. This is so, first, for purely technological reasons. Laser-based materials processing is based on physical principles, and requires technological capabilities, entirely different from those required in traditional metalworking. Dealing with these challenges forced German machine tool producers, which are typically small- and medium-sized companies belonging to the *Mittelstand*, to acquire new capabilities in laser physics and electrical engineering in addition to their core competences in mechanical engineering (Albrecht, 1997). This frequently necessitated the first-time hiring of scientists and electrical engineers and/or the close interaction with university researchers. At the same time, whatever the firm possessed in terms of traditional metal-working capabilities – possibly embodied in the founder or their family – became less central. Consider, for example, the case of Trumpf, which today is one of the world's leading makers of industrial laser sources and systems. The Stuttgart-based Trumpf firm, then a pioneer of nibbling technology (a specific method of cutting sheet metal) decided to enter the laser industry in the mid-1970s. This move successively involved (i) an – unsuccessful – attempt at sourcing lasers in the U.S., (ii) an – unsuccessful – research collaboration with a public research institute, and (iii) the – successful – development of in-house laser sources and systems. As a consequence of the encountered problems, Trumpf required about ten years to bring its own laser source to the market (cf. Fabian, 2011, for a detailed historical account).

Second, a pronounced change in capabilities and behavior is likely to affect how the existing internal and external stakeholders perceive the firm. The firm's perceived reliability and accountability may be at stake. For example, if a machine tool producer emphasizes their technological leadership in laser-based materials processing, this may cause employees in the "traditional" division of the firm, as well as suppliers, customers and other external stakeholders, to question the firm's legitimacy as an innovative firm *in machine tools*. Again, Trumpf is a case in point (cf. Fabian, 2011). Its move into laser technology initially faced internal resistance in the firm, as it put at risk the viability of the firm's current core competence (nibbling).

For both capability and identity reasons, based on the above considerations we expect to find that diversification has a significant impact on the performance in the industry of origin after the diversification move:

H4a: Diversification decreases future performance in the industry of origin.

We moreover expect that diversification moves are particularly difficult when the target market is still in its infancy. Organizational identity will suffer more from diversification moves into less established industries, as these moves will normally require more resources to be devoted to product development and also tend to be perceived as less legitimate by relevant stakeholders. In the empirical context of this paper, this conjecture is corroborated by anecdotal evidence about the early years of the laser industry. As industry observers have repeatedly suggested (cf., e.g., Albrecht, 1997), early euphoria about laser technology quickly gave way to the insight that economically viable applications of lasers were exceedingly hard to find. Early laser technology is conventionally referred to as a solution in search of suitable problems. This uncertainty about the commercial success of laser technology helps account for the slow start of the German laser industry in terms of entry rates and the absence of first mover advantages in firm survival (Buenstorf, 2007).

These considerations lead us to predict the following relationship:

H4b: The earlier the diversification move, the higher the likelihood of failure in the industry of origin.

Finally, we would expect resource bottlenecks and legitimacy problems to be the more problematic the less related the activities are in the industry of origin and in the target industries. Hence:

H4c: The greater the distance between activities in the industry of origin and the target industry, the higher the likelihood of failure in the industry of origin.

Urban and regional economists stress yet another dimension that may affect both the likelihood and success of diversification. They have for a long time argued that firms may reap substantial benefits from being located in the proximity of other firms active in the same or related markets, because proximity gives rise to positive external effects (Marshall, 1920; Porter, 1990; Henderson et al., 1995). These so-called localization economies may derive from a variety of processes and channels, most importantly knowledge spillovers, labor pooling and the emergence of specialized suppliers (Marshall, 1920). In addition to localization economies being operative within industries, benefits of being located in cities may derive from urbanization economies (Glaeser et al., 1992), and from the diversity of activities often found in metropolitan areas (Jacobs, 1969).

This traditional view of urban and regional economists has recently been challenged by evolutionary economists stressing the significance of pre-entry experience and firm capabilities for the geographic dimension of industry evolution. Entrants tend to locate close to their geographic roots (e.g., Figuereido et al., 2002; Klepper, 2007). And while new entry tends to be clustered in regions that already have sizeable numbers of incumbent firms in the respective industry, disaggregated studies suggest that geographically concentrated entry may just reflect regional differences in the numbers of potential entrants (Buenstorf and Klepper, 2010; Buenstorf and Geissler, 2011). The empirical significance of localization economies has also been questioned by studies that did not find that firms in regions where their industry is concentrated outperformed more isolated competitors, but rather the opposite pattern (Sorenson and Audia, 2000; Stuart and Sorenson, 2003; Buenstorf and Guenther, 2011). Even when regional performance differentials seem suggestive of localization economies, they may in fact stem from differences in entrants' pre-entry experience (Buenstorf and Klepper, 2009; Wenting, 2008).

The debate on the role of agglomeration economies in industrial dynamics is relevant in the present context because the alternative positions lead to contrasting predictions on whether and how geographical factors will affect diversification. If diversifiers are indeed "pulled" into new markets because a large number of local firms are already active in these markets and generate substantial localization economies, then the likelihood of diversification should increase with the regional concentration of firms active in the target industry, suggesting that:

H5a: The higher the regional concentration of firms in the target industry, the higher the likelihood of diversification.

In a science-based industry such as lasers (Grupp, 2000), the regional presence of universities and non-university public research organizations could exert another relevant “pull” factor, as it may help potential diversifiers develop the capabilities allowing them to actually diversify. This has in fact been found by Buenstorf and Geissler (2011) in an empirical investigation of all entrants into the Germany laser source industry. In line with their result, we predict:

H5b: The stronger the regional science base related to the target industry, the higher the likelihood of diversification.

It is also conceivable that diversifiers are “pushed” into diversification because of intensive competition in their original markets. In this case, the likelihood of diversification should increase with the concentration of firms in the industry of origin.

H5c: The higher the regional concentration of firms in the industry of origin, the higher the likelihood of diversification.

Finally, the presence of effective localization economies in the German machine tool market would be supported by finding that firms in regions with higher concentrations of machine tool firms on average had lower exit hazards than their more isolated competitors. This possibility informs our last hypothesis:

H6: Firms survive longer in the machine tool industry if they are located in regions with a larger number of active machine tool producers.

3 DATA

For our empirical analysis we matched two datasets describing the long-term evolution of firm populations in two specific German industries. The first dataset encompasses the complete population of machine tool producers in West Germany after World War 2. We take our information about active firms in the machine tool industry in the individual years, as well as their product portfolios in the respective years, from the buyer’s guide “Wer baut Maschinen” (“Who makes machinery”), which has been issued annually by the Verein Deutscher Maschinen- und Anlagenbau (VDMA) since 1932. In the post-war period, a total of 2,561 machine tool producers are listed. The classification scheme in the buyer’s guide allowed us to disaggregate the industry into four broad product categories: metal cutting, separating, forming and special purpose machine tools. We will refer to these four product categories as submarkets below (cf. also Buenstorf and Guenther, 2011, for a fuller description of the data).

The second dataset comprises information about the full population of Germany-based firms active in the broadly defined laser industry from 1975-2008, a total of 1,903 firms. It is based on the catalogue of the bi-annual LASER trade fair in Munich. Beginning in 1991, this data source is supplemented by entries from the “Europäischer Lasermarkt” (“European Laser Market”, b-quadrat publishing) buyers’ guide. The firms covered by the data can be classified into three broad (overlapping) groups according to the submarkets they are active in: laser sources (devices actually emitting coherent laser lights), laser systems (devices applying

OEM or in-house laser sources to useful uses), and “support devices” (a catch-up category including firms active in laser-relevant component and accessory markets).

Matching of these two datasets resulted in the identification of over 50 candidate firms that were active in both industries up to 2008. A common problem in establishing identity of the firms in both sources is the incomplete disclosure of company’ locations. We tried to mitigate this problem by a two step procedure: In step one, we listed potential diversifiers based on firm name. In step two, we conducted in-depth searches to establish identity even if location information was incomplete or inconclusive. If identity was still doubtful after these measures, firms have been excluded. Moreover, while most firms were first active in the machine tool industry and afterwards appearing in the laser industry, a few appeared to be active in the laser industry first. We concentrate on the former for the current analysis because we are interested in the diversification moves of machine tool producers. Thus, the resulting number of only 33 diversifiers should be considered a conservative lower bound. We also exclude all firms active in the machine tool industry that did not survive until 1975. Obviously we cannot observe diversification for them because our dataset for laser source and system producers only starts in 1975. This leaves us with a total of 1,550 machine tool producers active between 1975 and 2010. Out of these only 33 diversified into lasers sources or systems in the years between 1975 and 2008. Based on this information we constructed an unbalanced panel dataset of all machine tool producers with annual observations for each firms in all years the firm was active in the machine tool industry for the subsequent empirical analyses.

Starting from our primary datasets a number of specific variables have been constructed for the empirical investigations. Since reliable figures on employment or financial data cannot be obtained for the full population of firms over the full time period of our analysis, we measure firm size by the number of machine tool submarkets, or alternatively individual product markets in the machine tool industry, that a firm served in any given year. We also use a dummy variable denoting firms currently active in the market for flexible cells as a (crude) measure of machine tool producers’ innovative performance. This is based on the observation that flexible cells are a particularly innovative and technologically challenging product.

Past product portfolio change (a proxy for firms’ dynamic capabilities in the machine tool industry) is in each active year measured by the difference in the number of product markets (in the machine tool industry) currently served and the number of product markets served three years before. Firm age reflects the time since the firm first entered the machine tool industry.

The regional concentration of firms in the machine tool and laser industries is measured by the size of the regional firm population as a percentage of the total firm population in the respective year. The regional concentration of laser firms is likewise measured by the percentage of laser systems providers located in the respective region. By utilizing percentages rather than counts, we account for the fact that the absolute size of the respective populations changed over the time period under observation (cf. also Buenstorf and Klepper, 2010). Regions are defined as planning regions, or in German, *Raumordnungsregionen* (ROR). There are 97 ROR in Germany, which are defined by aggregating administrative districts (*Landkreise*) according to commuter flows. ROR thus balance the requirements for an economically meaningful regional delineation with the limitations stemming from data availability.

To obtain a measure of public research activities at the regional level, we count all laser-related doctoral dissertations submitted at universities in the region using the public catalog of the *Deutsche Nationalbibliothek* (DNB), which includes publication years and university affiliation. Laser-related dissertations were identified on the basis of titles and keywords. Dissertation counts are aggregated over a moving three-year window to minimize spurious effects caused by small number and short-run fluctuations. Population density measures were constructed from official data by the *Statistisches Bundesamt*, aggregating for ROR and interpolating for years without official numbers. Descriptive statistics for the variables and correlations are reported in Table 1.

4 EMPIRICAL METHODS

Our first set of econometric analyses deals with the probability of diversification. Various models are specified that estimate the likelihood to diversify into the target industry (lasers) for an individual machine tool firm in any given particular year. All observations after the year of diversification for a given firm were dropped to avoid an overestimation of successful diversification moves. (To avoid terminological confusion: in what follows, “diversification” refers to successfully moving into the target industry (lasers), whereas diversification within the industry of origin (machine tools) is dubbed “broadening of product portfolio” or “expansion of product base”.) Because of the low numbers of diversifiers in our data, simple logit models that were initially estimated suffered from a pervasively low model fit. To mitigate this problem and obtain more accurate coefficient estimates, we therefore adopted the methodology suggested by King and Zeng (2001) for analyzing rare events data with logit models. The major shortcoming of this methodology is that the available statistical software for STATA does not report measures of overall model fit.

Given that growth or profitability cannot be obtained retrospectively for the full firm populations of both industries, firm performance is proxied by longevity in the machine tool market. Using longevity as a measure of firm performance is a standard approach in industrial dynamics. It can be justified by opportunity cost considerations. In the presence of sunk costs, firms’ exit from a market is either involuntary (due to bankruptcy) or reflects the owner’s expectation to earn a higher return on investment by reallocating capital. We estimate models of exit hazards based on the assumption of proportional, Gompertz-distributed hazards, allowing for time-varying covariates with annual observations. In all models, longevity in the machine tool industry is estimated, and all active firms in this industry are taken into consideration. Our primary interest is in whether diversifiers into the laser industry differed significantly in their survival odds in the machine tool industry, compared to non-diversifying machine tool producers.

5 ANALYSIS

5.1 Likelihood of Diversification

The first noteworthy result of our analysis is that with only 33 actual diversifiers from a risk set of 1,550 machine tool producers, the overall share (about 2%) of firms diversifying from machine tools into the (broadly defined) laser industry is strikingly low. This is in spite of diversifiers being prominent among entrants into the laser industry (Buenstorf, 2007; Buenstorf et al., 2010). Earlier work on the (more narrowly defined) laser source industry indicates that diversifiers had rather varied backgrounds. Large firms diversifying into lasers came from many different segments of manufacturing (including electronics, optics, energy, chemistry and general machinery), while some smaller diversifiers had yet different backgrounds such as measurement technology or telecom equipment. As a consequence, by analyzing the population of machine tool producers we only capture a small proportion of all diversifiers into the laser industry. This is surprising both because of the size of the firm population in the German machine tool industry (which is part of the country's industrial core) and because machine tools are among the most important applications of laser technology in Germany. The small number of diversifiers from the machine tool industry may thus be a first indication that diversification from machine tools into lasers may have been accompanied by substantial challenges to organizational identity and legitimacy.

Turning to the econometric analysis, Models 1 and 2 (Table 2) address hypothesis H1 predicting a higher diversification likelihood of firms that are successful in their industry of origin. We first use the current number of active submarkets as a proxy of firm performance. A theoretical justification for this choice of proxy is given by the link between size and quality in industrial dynamics models such as Klepper (1996). Obviously, a higher number of submarkets may either reflect initially entering the machine tool industry on a broader basis and subsequently maintaining activities, or a successful broadening of submarkets in the past. The coefficient for the number of submarkets is significantly positive in both models, lending support to H1. In Model 2 we moreover find (weak) evidence in favor of H2, which predicted that past experience in adding new products within the machine tool industry to the firm's portfolio helps explain the diversification likelihood into the laser industry. A positive association of the respective variable to the likelihood of diversification is obtained, which however is only marginally significant.

To test Hypothesis 3, we split diversifiers into three categories according to their activities in the laser industry and estimate a multinomial logit model allowing for different influences on different types of diversification (Model 3). The first category contains machine tool firms that show up in the laser industry as providers of "supporting devices" as well as a few firms that could not be reliably classified. More detailed research in the original data sources suggested that these firms mostly offered products in the laser industry that did not differ too much from the ones offered in their industry of origin. This indicates that this first type of diversification requires comparatively little in terms of dynamic capabilities and should therefore be least challenging. The second category of diversifiers includes firms that offer laser systems. This at least requires the firm to successfully integrate a new and very different component into their existing products. Because of this, firms are likely to hire new staff with different skills and make investments into new assets, even though they do not necessarily develop their own laser sources. Finally the third category consists of firms that show up in the target industry as producers of laser sources, arguably the most daring of the diversification moves, because it may require completely different capabilities in both production and marketing.

The empirical results indicate that determinants of the alternative diversification patterns differ. The number of submarkets in the machine tool industry only helps predict diversification into laser sources, presumably the most challenging type of diversification. This finding is consistent with H3a. In contrast, past experience with enlarging the product portfolio of machine tools is positively related to the likelihood of less challenging moves into supporting devices. This (marginally significant) result runs counter to the prediction of H3b, which accordingly is rejected.

As a final step in analyzing factors that potentially affect the likelihood of diversifying into the laser industry, in Models 4 to 6 (Table 3) we add regional characteristics (lagged by one year). In Model 4 the measure of regional concentration in the laser industry is associated with higher diversification odds, indicating that localization economies may indeed operate as "pull" factors (as conjectured in Hypothesis 5a). Again, however, the obtained coefficient is only marginally significant. It is moreover not robust to entering public laser research activities as another regional characteristic in Model 5, which in that model is likewise insignificant. This result is inconsistent with Hypothesis 5b which therefore has to be rejected. However, when analyzing the different categories of diversifiers individually in Model 6, we find that the likelihood of machine tool firms to diversify into laser sources was increased by the level of regional laser research activities. Smaller (and for diversifiers into support systems even marginally significantly negative) coefficients are obtained for both other categories. This ranking is in line with expectations for the relative relevance of public research. Finally, no evidence in support of the conjecture that regional concentration in the machine tool industry served as a "push" factor into diversification is obtained. (Hypothesis 5c). The coefficient estimate obtained for the respective variable is (insignificantly) negative throughout Models 4 to 6.

5.2 Firm Longevity in the Machine Tool Industry

We now turn to the issue how diversification into the laser industry was related to the longevity of individual firms in the machine tool industry. In Models 7 and 8 (Table 4) we use a dummy variable to denote all firms that ever diversified into lasers ("MTL"). This time-invariant variable is used to capture inherent differences of diversifiers and non-diversifiers. Significantly negative coefficient estimates are obtained in both models, suggesting that it was indeed the more successful machine tool firms that diversified into the laser industry; lending further support in favor of Hypothesis 1. In addition, both the number of active submarkets and increasing product portfolios are systematically associated with lower exit hazards from the machine tool industry.

Regional characteristics (concentration of machine tool producers and population density) are included as further variables in Model 8. Prior results are robust to the inclusion of these variables. The coefficient for regional machine tool producers is significantly negative.

Consistent with Hypothesis 6, firms apparently benefitted from localization economies as their likelihood to fail was lower in regions with concentrated machine tool activity. It is moreover noteworthy that our proxy for urbanization economies is significant, but with an unexpected sign indicating that firms located in more densely settled regions performed relatively poorly.

In Models 9 and 10, the time-invariant dummy denoting firms that ever diversified into lasers, irrespective of whether this diversification had already taken place, is replaced by another dummy variable dubbed "diversify" which is 1 only in the year of diversification and all active firm years thereafter. No systematic relation between the diversification move and the subsequent exit hazard from the machine tool industry (as was predicted by Hypothesis 4a) is thus found in the data.

We further probe into these results by estimating additional hazard rate models that classify diversifiers according to the timing (Models 11 and 12) or laser submarket (Models 13 and 14) of diversification (Table 5). The disaggregation with respect to timing indicates strikingly different performance implications of early (1975-94) versus late (1995 to 2008) diversification moves, lending support to Hypothesis 4b. The coefficient estimates obtained for early diversifiers imply that these had more than twice the higher hazard of exit from the machine tool industry than non-diversifiers. In contrast, the (insignificant) point estimates obtained for the late diversifiers imply a more that 50 per cent *lower* exit hazard, with the difference between both groups significant in both models ($p < .05$ in Model 11 and $p < .06$ in Model 12). In contrast, no evidence is obtained in favor of Hypothesis 4c, as even the relative sizes of coefficient estimates are not compatible with the expected patterns.

6 DISCUSSION

In this paper, we investigated the incidence and determinants of diversification from the German machine tool industry into the broadly defined laser industry. We also studied whether and how diversification was related to firms' future performance in the machine tool industry.

Theoretical considerations motivated our expectation that diversification into new, science-based industries such as lasers is challenging for incumbent firms in existing industries. Accordingly, we predicted that diversifiers tended to be among the most successful firms in the machine tool industry, whereas diversification as such might be associated with lowered performance in the machine tool industry, particularly among those firms that diversified early.

Our empirical analysis corroborated but also helped refine the theoretical predictions. We already remarked upon the small number of firms diversifying from machine tools into the laser industry, which is unexpected because machine tools are among the core applications of laser sources produced in Germany. At the same time, diversifiers were selected from the more successful firms in the machine tool industry, as firms with broader and growing product portfolios were more likely to diversify. The scope of existing activities moreover helped predict the most challenging diversification moves, which were also favored by regional laser-related public research activities.

As for the success of firms after diversification, our findings did not provide general support to the prediction derived from organizational ecology that diversification challenges the identity and legitimacy of a firm. We did find, however, that early diversification into lasers was associated with higher hazards of exit in machine tools. This is consistent with diversification into an emerging industry being a relevant problem for a firm's identity and legitimacy.

Results regarding the relevance of the regional environment were mixed. On the one hand, we did not find robust evidence indicating that machine tool firms were pushed into diversification by the regional presence of other machine tool firms, or that they were pulled into new markets by the regional presence of firms already active in lasers. On the other hand, regional laser research helped predict the likelihood of diversification into laser sources, presumably the most challenging diversification move in our empirical setting. In addition, survival chances of machine tool firms were apparently enhanced by co-location with other machine tool producers. One possible interpretation of this pattern is that while firms benefitted from localization economies, co-location did not induce increased innovation activities in the field of laser technology.

Can we draw broader conclusions from this study, which is based on a single industry? We think that a cautiously affirmative answer can be given to this question. It is well-established that related diversification is a promising strategy of entry into innovative new markets. At the same time, we know that diversification is often necessary for firms that find themselves in declining markets. Yet our findings show that diversification into laser technology was a rare event for German machine tool makers. Apparently, the potential inherent in diversification cannot always be presumed to be unleashed easily. Qualitative evidence suggests that the human factor – finding Schumpeterian entrepreneurs at the helm of the firm – is an important trigger of innovative diversification. We would expect this to hold even stronger for other, more low-tech sectors than the one studied above. We also think that more research into the micro-processes of diversification is warranted.

Our findings point to potential avenues how policy makers may facilitate successful diversification moves by pre-existing firms in related markets. First, regional public research activities may be important in enabling challenging diversification moves, which corroborates our earlier findings on entry into the laser source (Buenstorf and Geissler, 2011) and laser systems (Buenstorf et al., 2010) industries. This suggests that the composition of the regional economy, including the number of potential diversifiers, may be a relevant factor to consider in strategic location decisions for public research institutes. Our results are also indicative of a substantial impact of localization economies on survival in the machine tool industry. These findings are noteworthy because recent work in industrial economics and economic geography (including some of our own) is highly skeptical about the importance of traditional agglomeration effects (cf. Frenken et al., 2011, for a survey).

At the present stage, we regard these policy implications as preliminary, as the above analysis is not without limitations. First, it would also be useful to complement the data by information about patenting activities. Unfortunately, this can be expected to result in new complications, as some of owners of smaller firms hold patents in their own rather than their firms' names, while for the larger firms a problem arises from the requirement to identify the relevant subset of laser-related patents. Second, we cannot rule out that our results on longevity in the machine tool industry in part reflect firms' deliberate "switching" from one industry to another. We do not think, however, that this would compromise the general relevance of our results, because it would still be indicative of relatively weak performance in the machine tool industry.

7 REFERENCES

Albrecht, H. (1997): *Laserforschung in Deutschland 1960–1970*, Habilitation Thesis, University of Stuttgart, Stuttgart.

Barnett, W. P. and G. R. Carroll (1995): "Modeling Internal Organizational Change", *Annual Review of Sociology*, 21: 217-236.

Buenstorf, G. (2007): "Evolution on the shoulders of giants: entrepreneurship and firm survival in the German laser industry", *Review of Industrial Organization*, 30: 179-202.

Buenstorf G., Klepper S. (2009): "Heritage and Agglomeration: The Akron Tyre Cluster Revisited", *The Economic Journal*, 119: 705-733

Buenstorf G., Klepper S. (2010): "Why does entry cluster geographically? Evidence from the US tire industry", *Journal of Urban Economics*, 68: 103-114.

Buenstorf, G., Geissler, M. (2011): "The origins of entrants and the geography of the German laser industry", *Papers in Regional Science*, 90(2): 251-270.

Buenstorf ,G., Guenther, C. (2011): "No place like home? Relocation, capabilities and firm survival in the German machine tool industry after World War II", *Industrial and Corporate Change*, 20(1): 1-28.

Buenstorf, G., Fritsch, M., Medrano, L.F. (2010): "Regional Knowledge and the Emergence of an Industry: Laser Systems Production in West Germany, 1975–2005", *Jena Economic Research Papers* # 2010-079.

Dunne, T., Roberts, M. J., Samuelson, L. (1988): "Patterns of Firm Entry and Exit in U.S. Manufacturing Industries", *RAND Journal of Economics*, 19: 495-515.

EFI (Expertenkommission Forschung und Innovation) (2011): *Gutachten zu Forschung, Innovation und Technologischer Leistungsfähigkeit Deutschlands*, Berlin.

Fabian, C. (2011): *Technologieentwicklung im Spannungsfeld von Industrie, Wissenschaft und Staat: Zu den Anfängen des Innovationssystems der Materialbearbeitungslaser in der Bundesrepublik Deutschland 1960 bis 1997*. Unpublished doctoral dissertation, Technical University Bergakademie Freiberg.

Figueiredo, O., Guimaraes, P., Woodward, D. (2002): "Home-field advantage: location decisions of Portuguese entrepreneurs", *Journal of Urban Economics*, 52: 341-361.

Frenken, K., Cefis, E., Stam, E. (2011): "Industrial Dynamics and Economic Geography: A Survey", Eindhoven Centre for Innovation Studies: *ECIS Working Paper* 11.07.

Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., Shleifer, A. (1992): "Growth in Cities", *Journal of Political Economy*, 100: 1126-1152.

Grupp, H. (2000): Learning in a Science-driven Market: The Case of Lasers, *Industrial and Corporate Change*, 9: 143-172.

Hannan, M. T. (2005): "Ecologies of organizations: Diversity and identity", *Journal of Economic Perspectives*, 19: 51-70.

Hannan, M. T., Freeman, J. (1984): "Structural Inertia and Organizational Change", *American Sociological Review*, 49: 149-164.

Hannan, M. T., Baron, J. N., Hsu, G., Kocak, Ö. (2006): "Organizational identities and the hazard of change", *Industrial and Corporate Change*, 15(5): 755-784.

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

Henderson, J. V., Kuncoro, A., Turner, M. (1995): “Industrial developments in cities”, *Journal of Political Economy*, 103: 1067-1090.

Jacobs, J. (1969): *The Economy of Cities*, Vintage Books, New York

King, G., Zeng, L. (2001): “Logistic Regression in Rare Events Data”, *Political Analysis*, 9, 137-163.

Klepper S. (1996): “Entry, exit and growth, and innovation over the product life cycle”, *American Economic Review*, 86, 562-583.

Klepper, S. (2002): “Firm survival and the evolution of oligopoly”, *RAND Journal of Economics*, 33: 37-61.

Klepper, S. (2007): “Disagreements, Spinoffs, and the Evolution of Detroit as the Capital of the U.S. Automobile Industry”, *Management Science*, 53: 616-631.

Klepper, S., Simons, K. L. (2000): “Dominance by Birthright: Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry”, *Strategic Management Journal*, 21: 997-1016.

Marshall, A. (1920): *Principles of Economics*, 8th ed. London: Macmillan.

Porter, M. (1990): *The Competitive Advantage of Nations*, New York: Free Press.

Sorenson, O., Audia, P. G. (2000): “The Social Structure of Entrepreneurial Activity: Geographic Concentration of Footwear Production in the United States, 1940-1989”, *American Journal of Sociology*, 106: 424-461.

Stinchcombe, A. L. (1965): “Social Structure and Organizations”, in: J. G. March (ed.): *Handbook of Organizations*, Chicago: Rand McNally, pp. 142-193.

Stuart, T., Sorenson, O. (2003): “The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms”, *Research Policy*, 32: 229-253.

Teece, D.J., G. Pisano, A. Shuen (1997) “Dynamic capabilities and strategic management”, *Strategic Management Journal*, 18: 509-533.

Thompson, P. (2005) “Selection and Firm Survival: Evidence from the Shipbuilding Industry, 1825-1914”, *Review of Economics and Statistics*, 87: 26-36.

Wenting, R. (2008): “Spinoff dynamics and the spatial formation of the fashion design industry, 1858-2005”, *Journal of Economic Geography*, 8: 593-614.

Zucker, L. G. (1989): “Combining Institutional Theory and Population Ecology: No Legitimacy, No History”, *American Sociological Review*, 54: 542-545.

8 TABLES

Table 1: Descriptive Statistics and Correlations

	Mean	Std. Dev.	Min.	Max.	Correlation				
					(2)	(3)	(4)	(5)	(6)
Submarkets (1)	2.01	1.51	0	11					
Firm Age (2)	25.70	16.06	1	59	0.19				
Product portfolio change (3)	-0.11	2.09	-30	34	-0.09				
Regional Mach Tool Producers (4)	4.62	4.58	0	15.18	0.13	-0.01			
Regional Laser System Producers (5)	2.48	4.57	0	41.18	0.01	-0.00	0.11		
Regional Laser Research (6)	2.24	2.77	0	18.64	-0.01	-0.01	0.22	0.45	
Log Population Density (7)	6.06	.86	4.31	8.40	0.05	-0.02	0.60	0.19	0.48

Table 2: Likelihood of diversification

	Model 1 (rare event logit)	Model 2 (rare event logit)	Model 3 (multinomial logit)		
			Divtype 1	Divtype 2	Divtype 3
No. of Submarkets	.261*** (.081)	.242*** (.088)	.189 (.141)	.145 (.160)	.404** (.160)
No. of products					
Age	-.009 (.012)	-.007 (.012)	-.018 (.023)	-.003 (.018)	.006 (.023)
Product Portfolio Change		.086* (.047)	.114* (.063)	.070 (.057)	-.024 (.100)
Constant	-6.669*** (.455)	-6.666*** (.460)	-7.42*** (.821)	-7.319*** (.615)	-9.284*** (1.255)
Observations (subjects)	17785 (1550)	17785 (1550)	17785 (1550)		
Log-pseudo likelihood			-261.249		
Pseudo R^2			0.023		

***, **, * indicating significance at 1%, 5% and 10% level respectively, clustered standard errors in parentheses.

Table 3: Likelihood of diversification

	Model 4 (rare event logit)	Model 5 (rare event logit)	Model 6 (multinomial logit)		
			Divtype 1	Divtype 2	Divtype 3
Submarkets	.243*** (.094)	.242** (.094)	.213 (.148)	.140 (.176)	.367** (.152)
Age	-.005 (.012)	-.005 (.013)	-.018 (.023)	-.000 (.019)	.014 (.025)
Product Portfolio Change	.052 (.046)	.051 (.047)	.129 (.079)	.046 (.055)	-.034 (.062)
Log population density	.027 (.251)	.001 (.226)	.623 (.405)	-.574** (.275)	.310 (.506)
Regional Mach-Tool Producers	-.060 (.057)	-.059 (.056)	-.089 (.098)	-.034 (.095)	-.032 (.074)
Regional Laser System Providers	.045* (.022)	.039 (.030)	.071 (.051)	.035 (.037)	.041 (.047)
Regional Laser Research		.026 (.075)	-.347* (.188)	.048 (.082)	.161** (.080)
Constant	-6.738*** (1.476)	-6.610*** (1.344)	-10.487*** (2.509)	-4.101*** (1.528)	-11.972*** (3.702)
Observations (subjects)	17785 (1550)	17785 (1550)	17785 (1550)		
Log-pseudo likelihood			-253.440		
Pseudo R^2			0.052		

***, **, * indicating significance at 1%, 5% and 10% level respectively, clustered standard errors in parentheses.

Table 4: Survival of diversifying firms (ex-post, Gompertz specification of baseline hazard, coefficient estimates)

	Model 7	Model 8	Model 9	Model 10
MTL	-1.032*** (.288)	-1.043*** (.277)		
Diversify			-.017 (.322)	-.017 (.313)
Submarkets	-.346*** (.036)	.338*** (.036)	-.352*** (.036)	-.343*** (.035)
Product Portfolio Change	-.079*** (.018)	-.078*** (.018)	-.076*** (.018)	-.076*** (.018)
Regional Mach-Tool Producers		-.038*** (.008)		-.037** (.008)
Log population density		.199*** (.041)		.202*** (.040)
Constant	-3.058*** (.082)	-4.133*** (.256)	-3.067*** (.082)	-4.160*** (.254)
Gamma	.002 (.003)	.003 (.003)	.002 (.003)	.003 (.003)
Observations (Subjects)	18089 (1550)	18089 (1550)	18089 (1550)	18089 (1550)
Log-pseudo likelihood	-1747.589 (.0000)	-1734.897 (.0000)	-1754.369 (.0000)	-1741.837 (.0000)

***, **, * indicating significance at 1%, 5% and 10% level respectively, clustered standard errors in parentheses.

Table 5: Survival after diversification at different times / into different laser markets (Gompertz specification of baseline hazard, coefficient estimates)

	Model 11	Model 12	Model 13	Model 14
Early Div.	.829** (.355)	.749** (.341)		
Late Div.	-.774 (.600)	-.737 (.599)		
Divtype 1			.039 (.589)	.048 (.589)
Divtype 2			-.363 (.514)	-.361 (.505)
Divtype 3			.364 (.468)	.339 (.403)
Submarkets	-.352*** (.036)	-.343*** (.035)	-.352*** (.036)	-.343*** (.035)
Product Portfolio Change	-.078*** (.018)	-.078*** (.018)	-.074*** (.018)	-.075*** (.017)
Regional Mach-Tool Producers		-.037*** (.008)		-.037*** (.008)
Log population density		.199*** (.040)		.201*** (.040)
Constant	-3.069*** (.082)	-4.147*** (.254)	-3.067*** (.082)	-4.157*** (.254)
Gamma	.002 (.003)	.003 (.003)	.002 (.003)	.003 (.002)
Observations (Subjects)	18089 (1550)	18089 (1550)	18089 (1550)	18089 (1550)
Log-pseudo likelihood	-1751.606 (.0000)	-1739.458 (.0000)	-1753.937 (.0000)	-1741.424 (.0000)

***, **, * indicating significance at 1%, 5% and 10% level respectively, clustered standard errors in parentheses.