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by

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Age, diversification and survival in the German machine tool industry, 1953-2002

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Abstract:
We focus on the relationship of age and diversification patterns of German machine tool manufacturers in the post war era. Based on trade journals we track the entire firm populations' product portfolio development throughout each firm's lifetime. We distinguish between 'minor diversification' and 'major diversification', where these two concepts refer to adding a new product variation within a familiar submarket, or expanding the product portfolio into new submarkets. Our analysis reveals four main insights. First, we observe that firms have lower diversification rates as they grow older, and that eventually diversification rates even turn negative for old firms on average. Second, we find that product portfolios of larger firms tend to be more diversified. Third, with respect to consecutive diversification activities, quantile autoregression plots show that firms experiencing diversification in one period are unlikely to repeat this behavior in the following year. Fourth, survival estimations reveal that diversification activities reduce the risk of exit controlling for various additional firm and industry specific fixed effects and business cycles. These results are interpreted using the Penrosean growth theory.

JEL codes: L20, L25

Keywords: Diversification, industry evolution, firm age, firm growth, machine tools

1. INTRODUCTION

A substantial body of literature in economics and business research focuses on the phenomenon of firm growth. Surprisingly little attention has been paid though to one of the core elements of the often referred to Penrosean growth theory (1959) in this field. Growth needs to be understood as a process of development in which "increases in size [are] accompanied by changes in the characteristics of the growing object" (Penrose 1995, p.1). Therefore, the widely-used perspective of Gibrat's Law, where firm size and growth can be easily quantified in terms of variables such as sales or employees, suppresses other crucial elements of business expansion.

In a recent review McKelvie and Wiklund (2010) likewise argue that this research stream is dominated by answers to the question of "how much?" instead of answers to the more fundamental question of "how?" firms grow. Especially the direction of growth, i.e. business expansion in terms of diversification patterns has been neglected to a large extent in this context, even though these dynamics are essential in the Penrosean growth framework. The base line argument works as follows: Growth and thus diversification is in the very nature of every firm and is meant to ensure their long term competitiveness and thus survival.

Three elements need to be highlighted in this context. First, when firms get engaged in new business activities, the choice of the expansion track is confined by the manager's perception and opportunity recognition given their experience and current resource base. Thus, the direction of expansion depends on the individual firm's history. Second, the expansion process is restricted in its extent at any given point in time, but not in the long-run, and represents a rather non-linear phenomenon over time. Current resources, i.e. financial and managerial capacity, restrict the investment into additional activities while keeping the established fields on a competitive level. Moreover, planning and executing the business expansion absorbs managerial capacity until the project's completion, and thus it takes time until these resources are released and new expansion plans can be initiated. Third, the rate of expansion varies throughout time for individual firms and typically declines as firms become established businesses in their older ages (Penrose 1995).

The underrepresentation of these more qualitative elements in the literature is related to the major obstacle facing research on firm growth through diversification in terms of the availability of data on the activities respectively the product portfolios of firms. While firms are required to report financial data to authorities for tax purposes, there is less interest in the product and submarket structure of firms at all and even less so over time. Another problem is that it is not always easy to clearly delineate product classes and hence submarkets. In particular, it is difficult to compare the diversification structure of firms operating in industries that differ greatly. The most commonly used differentiation of business activities along the Standard Industrial Classification (SIC) classification codes does not do justice to the immense heterogeneity of firm's product portfolios in terms of technology and customer related segmentations of the market, which all constitute individual submarkets following their own dynamics (Klepper and Thompson 2006).

In spite of these difficulties, however, some authors have focused on diversification patterns in the pharmaceutical industry, where submarkets can be defined in terms of the Anatomical Classification System (Matia et al 2004, Bottazzi and Secchi 2006). Others have delineated submarkets by using the well-known SIC codes (e.g. Teece, Rumelt, Dosi and Winter 1994, who investigate the technological relatedness of sectors). Klepper and Thompson (2006) present a theoretical model and empirical evidence from the US laser industry, where submarkets are broadly defined in terms of 9 types of lasers. Only in the last paper the interdependence with firm age has been dealt with, though in the broader context of industry evolution.

The aim of the paper is twofold: First, we intend to give a sophisticated description of the growth phenomenon in terms of business expansion via diversification and its interdependence with individual firm's age. Secondly, we attempt to link these diversification activities to their effects on firm's long term competitiveness in terms of firm survival. For this purpose, our approach is to focus on a specific industry over time, the German machine tool industry throughout the post war era. Based on the individual annual product portfolios, which we compiled from trade journals, we are able to track the entire firm population within the industry over roughly 50 years. Thereby, we are able to address the qualitative dimension of business expansion by distinguishing between two diversification modes. While 'minor diversification' represents an expansion of the product portfolio within the current fields of activity, i.e. a submarket, 'major diversification' takes place when a new submarket is entered. Our measure of these different diversification modes is defined in terms of machine tool submarkets as categorized by the trade journals classification scheme. By focusing on a specific industry, we do not attempt to generalize across all firms in all sectors, but we aim to obtain an accurate indicator of business expansion via diversification for the firms within this industry.

Our contribution to the literature is threefold. Firstly, research into firm growth has not been able to make much distinction between the different modes of growth and diversification that growth events entail. Nevertheless, efforts have been made to distinguish between organic and acquisitive growth (Davidsson and Delmar 2006, Cefis et al 2009, Lockett et al 2010). Our unique dataset allows us to address the relatively neglected dimension of firm growth/business expansion by distinguishing between minor and major diversification. Secondly, the population-based panel in our study offers the possibility to accurately describe the phenomenon of business expansion via diversification in a single industry of almost 2000 individual but comparable firms without any survivor bias as all firms active in this industry are included. Thirdly, our study contributes to the small set of empirical investigations regarding diversification with a special attention on product respectively submarket portfolio development and its interdependence with individual firms' age.

Our empirical analysis led to the following results: First, we observe that firms on average decrease their diversification rates as they age, even to the point where they eventually turn negative for old firms. Second, we find evidence that the submarkets of large firms are larger than the submarkets of small firms. Third, with respect to consecutive diversification activities, quantile autoregression plots show that firms experiencing diversification in one period are unlikely to repeat this behavior in the following year. Fourth, survival estimations reveal that diversification activities reduce the probability of exit controlling for various additional firm and industry specific fixed effects and business cycles.

The paper proceeds as follows. In Section 2 we give a short introduction to the industry setting and introduce the database before we run our analyses in Section 3. Section 4 concludes and shortly presents some discussion points and limitations of the presented study.

2. THE EMPIRICAL SETTING & THE DATABASE

2. 1. The machine tool industry

Within our analysis we stick to the broad definition of modern machines tools being defined as power-driven machines that are used to produce a given form of a work piece by cutting, forming or shaping metal (Wieandt 1994). Besides the core processing techniques such as milling, turning, pressing, and grinding, there exists an extensive variety of special purpose machinery, which are supplied especially to highly sophisticated industries such as automobiles, aircraft, military, and computers (Ashburn 1988). Given this diverse set of customers and their individual demand, the industry is marked by a high degree of product heterogeneity with respect to size, type, complexity and functionality (Sciberras and Payne 1985). Moreover, the industry consists foremost of traditional, often family-owned, small and medium sized enterprises.

These characteristics of the machine tool market offer an interesting opportunity to investigate the development of firms' product portfolios throughout their lifetime.

2. 2. The Database

The upcoming analyses are based on a dataset, which covers the entire firm population of machine tool manufacturers in West Germany between 1936 and 2002. The main data source for this data collection is the buyer's guide *Wer baut Maschinen*? (Who makes machinery?), which has been issued annually since the 1930s by the *Verein Deutscher Maschinen- und Anlagenbau (VDMA; Association of German machine tool producer).*[1] We start our analysis in the post war era from 1953 onwards. The data source does not only allow us to identify all approximately 2,000 firms that are active in the machine tool market between 1953 and 2002, it also delivers the annual product portfolio of each individual firm as well as entry and exit timing for each of these products. In particular in accordance with the trade registries the industry can be divided into 36 submarkets, e.g. drilling, turning, or milling machines, which in turn consist again of up to 70 individual product, respectively machine tool, variations, e.g. various types of drilling machines (Figure 1).

This classification scheme goes beyond a mere technological process categorization as the fine-grained product delineation in the buyer's guide includes detailed product features which allude to different customer segments.

[1] No catalogues were issued between 1944 and 1948 as heavy machine tool production was banned in Germany until 1949. Moreover, there is only one catalogue for the years 1949 and 1950, and the 1952 volume is not accessible anymore.

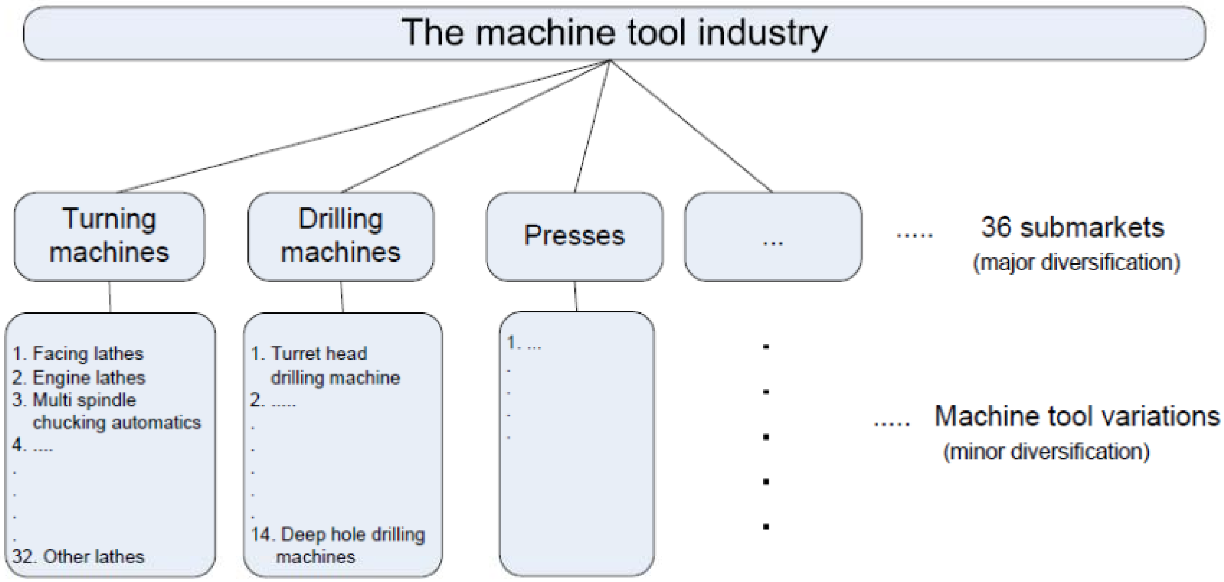

Figure 1: Classification scheme of the machine tool industry

This hierarchical structure builds the basis for our measures of the two modes of diversification. In the analyses we define *minor diversification* as the expansion of the product portfolio in terms of adding a new product variation within a submarket a firm has previously already been active in (that is, e.g. when a producer of milling machines offers a new variation of milling machines with a different lead screw positioning or a larger working range in addition to the existing set of milling machines). Minor diversification is therefore associated with what we call ‘machine tool variations’. In contrast to minor diversification we define *major diversification* as the expansion of the product portfolio beyond the previously supplied submarkets, e.g. when the milling machine specialist also starts supplying boring machines. In what follows, we associate major diversification with changes in the number of ‘submarkets’.

For the identification of firm’s product portfolio within this classification framework we follow Klepper and Sleeper (2005) among others in using the registries in annual trade journals. Given the fact that the data source is a buyer’s guide firms are highly interested in advertizing their products and draw attention to their existence and product offerings in this industry-wide catalogue as soon as possible. Therefore, we do not run the risk of leaving out very young and small firms, which makes us confident that we actually account for all products offered by each individual company. Moreover, we are able to identify the location of each company, a fact we will make use of in the survival analysis when controlling for agglomeration effects.

Diversification events are measured in terms of growth rates in the number of machine variations or submarkets, in the following way:

$$GR\_X(t) = (X(t) - X(t-1))/X(t-1); \quad (1)$$

where X corresponds to either the number of machine tool variations, or the number of submarkets.[2]

As argued above, in addition to interest in the diversification patterns within this population of manufacturers, we are also interested in its interdependence with firm age. The age of a firm is approximated by using the year of the first observation within our analysis timeframe as the founding date.[3]

A second data source (VDW 2005) was used to gather aggregated employment data. Individual annual data for sales, employees or any financial performance indicator are not available.

[2] We measure growth this way, instead of taking log-differences as is often done in the firm growth literature (e.g. Teruel-Carrizosa 2010, Coad and Tamvada 2012), because extreme diversification events are rare and measurement error is low in our present context. This measure of growth rate is more straightforward and commonly understood. In any case, there is not much difference between the two.

[3] We essentially measure age with reference to the first time a firm is observed in our dataset (which can be as early as the year 1936, although we drop observations prior to 1953 in our main analysis). This approach is also taken by Bellone et al (2008) and Kandilov (2009), among others.

2. 2.1 Descriptives

Before we start the analysis we will present a few summary statistics regarding the firm size distribution (Figure 2) as well as diversification events (Table 1).

Figure 2 presents the firm size distribution between 1953 and 2002 based on the number of products. We differentiate between highly specialized manufacturers offering only a single product, specialized producers (2-4 products), moderately diversified firms (5-16 products) and highly diversified suppliers offering more than 17 different machine tools. We find that the average number of different products offered by firms increases from 3.52 in 1953 to 4.13 in 1970, and decreases again after 1985 from 4.45 to 3.18 in 2002. Similar to Fleischer (1997) we find that the share of highly specialized manufacturers decreases from the mid 1950s to the late 1980s, while at the same time the percentage of moderately diversified firms increases from 18.06% to 30.89%. After 1985 these trends were reversed and the share of highly specialized firms increased again up to almost 50% while fewer firms (21.50%) were moderately diversified (5-16 products). Interestingly, the group of highly diversified firms continuously shrinks.

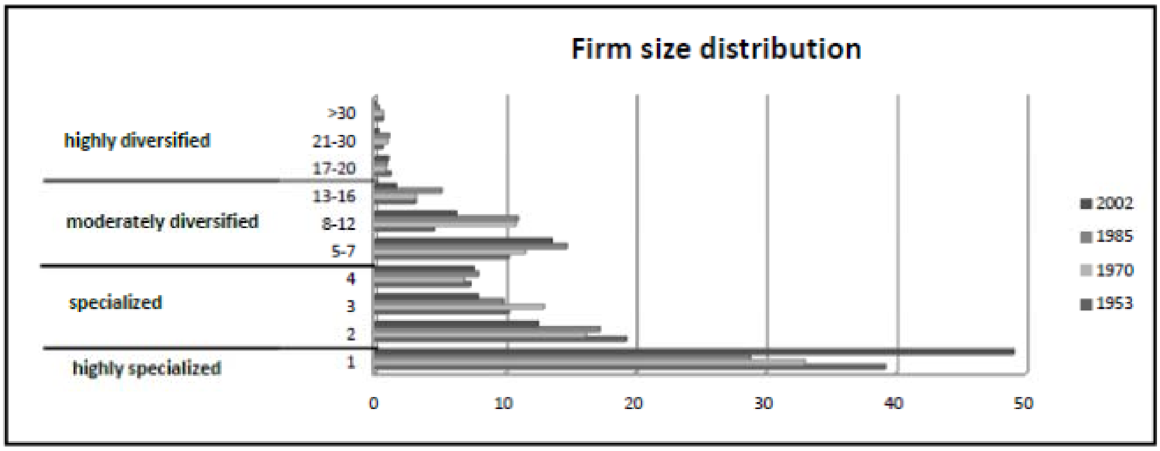

Figure 2: Firm size distribution based on the number of products, 1953-2002

While Figure 2 represents only four snapshots of the industry, we will now look deeper into the dynamics within the individual product portfolios and take diversification into consideration. Table 1 shows that in most years, firms do not diversify. In our data, positive diversification events are approximately equal in number to negative diversification events, but negative diversification occurs slightly more often. This observation clearly reveals that growth is not a linear process, or as Penrose puts it: “growth can take place in spurts, and periods of relative decline may well be followed by periods of accelerated growth” (Penrose 1995, p.213). Moreover, it is interesting to observe that in a few cases positive production of new machine variations is sometimes accompanied by a *decrease* in number of submarkets, and, conversely, that negative changes in machine variations is sometimes accompanied by an *increase* in number of submarkets. One explanation for the first pattern can be that firms decide to withdraw from one submarket in order to use their resources to increase their coverage in one of their other submarkets. Likewise, the second pattern might indicate that a firm reduces its coverage in one of its submarkets by discontinuing individual machine variations in order to increase its submarket scope by introducing a product in a new submarket. In the majority of cases, however, changes in the number of machine variations occur without diversification into new submarkets. This observation is in line with the Penrosean growth theory, as it argues that business expansion is more likely to take place in closely related activities. The further away a new activity is from the current resource and technology base, the more resources need to be involved in planning and executing the diversification step, and are therefore less frequent (Penrose 1995).

No change	23460		
No minor divn but major divn	307		
Minor diversification	6976		
of which:			
Positive minor divn		3389	
of which:			
no major divn			2122
increase in # submarkets			1219
decrease in #submarkets			48
Negative minor divn		3587	
of which:			
no major divn			2204
increase in # submarkets			90
decrease in #submarkets			1293
Total	30743		

Table 1: Summary statistics on diversification events, 1953-2002. 'Minor diversification' corresponds to changes in the number of machine variations, while 'major diversification' corresponds to changes in the number of submarkets.

Age	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	50+
Positive gr_mach	632	674	459	405	278	308	254	148	118	87	26
Negative gr_mach	478	606	471	421	351	316	273	263	202	159	47
No gr_mach	4479	3998	3379	2834	2392	1831	1515	1296	1059	722	262
Mean gr_mach	0.0814	0.0432	0.0393	0.0380	0.0320	0.0516	0.0357	-0.0001	0.0054	-0.0022	-0.0044
Positive gr_sub	354	311	172	153	124	108	93	88	40	34	6
Negative gr_sub	203	252	176	157	140	112	107	122	101	78	26
No gr_sub	5032	4715	3961	3350	2757	2235	1842	1497	1238	856	303
Mean gr_sub	0.0394	0.0235	0.0130	0.0124	0.0094	0.0110	0.0057	0.0027	-0.0094	-0.0133	-0.0258
No. Obs in each age category	5589	5278	4309	3660	3021	2455	2042	1707	1379	968	335

Table 2: Diversification events for firms of different ages, 1953-2002. All firm-year observations pooled together.

3. ANALYSIS

3.1 Age and diversification

In this section we consider the relationship between age and the two modes of diversification. Figure 3 shows how mean diversification rates vary with age, where diversification is measured in terms of entry into new machine variations (minor diversification), or into new submarkets (major diversification). Given that age is usually coded as a discrete variable, rarely exceeding values of about 50, we consider it appropriate to plot our results with age as a discrete horizontal axis.[4] We focus on means, not medians, because we are not especially concerned about extreme observations in our current context.

Both types of diversification decrease with age. It is interesting that the oldest firms have negative mean diversification rates. Although some authors seem to posit a direct positive relationship between age and size (e.g. Greiner 1972), our results caution that there is no clear relationship between age and number of submarkets. However, other work has shown that older firms do not have negative growth rates, on average (Coad, Segarra, Teruel 2010). How can these two results be reconciled? We suggest the following: older firms might put more emphasis on refocusing, and expanding within their existing product lines, rather than trying to enter new product lines and submarkets. This is consistent with conjectures that, along the life cycle, firms focus less on exploration and more on exploitation of existing capabilities. Older firms can be expected to be suffer from the liabilities of obsolescence and senescence, according to which they are relatively ossified and less able to adapt to new opportunities due to the burden of accumulated routines, rules and rigid structures (Barron et al, 1994).

[4] Our plots therefore bear some similarity to Figures 3 and 4 in Huergo and Jaumandreu (2004).

Figure 3: mean diversification rates for different ages, where diversification corresponds to entry into new machine variations (minor diversification) or into new submarkets (major diversification). 30743 observations over the period 1953-2002.

Knowing that diversification rates vary across age groups, we now want to investigate to what extent past growth activities affect future growth. This issue can be addressed by performing quantile autoregressions of firm growth. Figure 4 shows that, over most of the (conditional) distribution of diversification rates, diversification behaviour in the previous period has no effect on current diversification. This corresponds to those firms that did not diversify in the last period. At the upper and lower extremes of the distribution, however, the coefficient becomes negative. If a firm grew (declined) in the current period, it is unlikely that it is repeating a growth (decline) event from the previous period. This erratic, irregular pattern can again be explained within the Penrosean framework (1995). Business expansion needs to be planned and executed, which absorbs managerial capacity. This resource is only gradually released throughout the expansions completion, and only then new expansion plans can be initiated subsequently. Moreover, within the industry at hand product development cycles are rather long, i.e. between 3 to 5 years.

which is in line with the above argument of devoting managerial or R&D capacity to an expansion plan over a certain period of time.

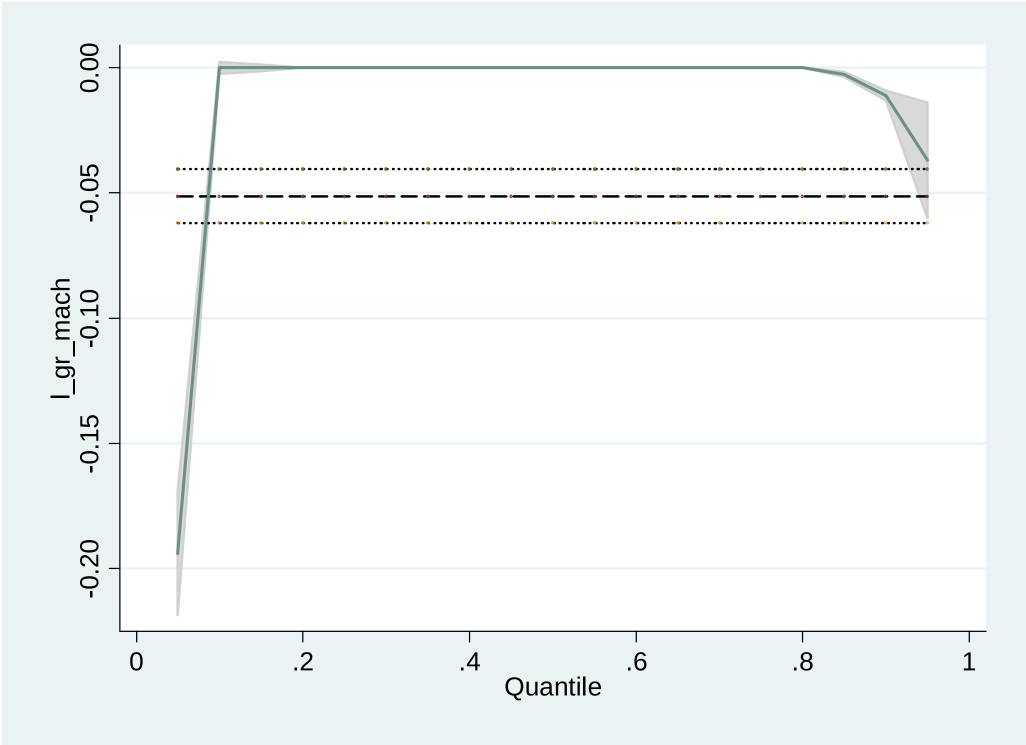

Figure 4: quantile autoregression of the dynamics of minor diversification, with confidence intervals obtained after 100 bootstrap replications. We regress minor diversification on lagged size (machine variations) and lagged minor diversification, with a constant term. Diversification in one period suggests that diversification was less likely to have occurred in the previous period. 28999 observations over the period 1953-2002. Horizontal lines depict the corresponding OLS estimate and OLS confidence intervals (for more information, see Azevedo 2004).

3.2 Diversification

Our previous results, relating to our interpretation of Figure 3 above, suggest that diversified firms may have submarkets of different sizes, i.e. the coverage of the individual submarkets varies. Based on Figure 3, we suggested that older firms may prefer to expand within existing submarkets (exploitation) rather than diversify into new submarkets (exploration). That is, a 'submarket' is not a unit of homogenous size, but may vary in size across firms.

An early investigation into the composition of submarkets or business units within firms was made by Hymer and Pashigian (1962). These authors sought to explain the negative relationship between growth rate variance and size, when firms are seen as collections of 'components' or 'departments.' If firms are all composed of equally sized departments, and that the growth of these departments is independent, then a strong negative relationship between growth rate variance and size should be observed. This is because the growth of component business units should largely cancel each other out as we aggregate up to the firm-level (see also the discussion in Lee et al 1998). However, the empirical relationship between growth variance and size is much weaker than would be expected from this model of independent business units. This has been explained by referring to firms as being composed of departments that are of unequal sizes (Matia et al 2004, Bottazzi and Secchi 2006).

Little is known about the structure of submarkets within firms, mainly because of data limitations. Previous work on the pharmaceutical industry has shown that total firm size and size in individual submarkets are correlated (Matia et al 2004, Bottazzi and Secchi 2006), such that growth in the number of submarkets occurs less than proportionally with respect to growth of sales.[5] However, to our knowledge, nothing is known about how business units vary with firm size outside the context of the pharmaceutical industry.

In our dataset, we can investigate how submarket size varies with firm size in the following way. We can compare total industry employment (dependent variable) with nonlinear functions of the total number of submarkets by all firms in the industry (explanatory variable) to get an idea of the evolution of the number of employees per submarket, and as a consequence to see how submarket size varies with firm size. Data

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[5] In these studies, submarkets are defined in terms of different micro-classes according to the Anatomical Classification System (Bottazzi and Secchi 2006, p828).

on total industry employment is taken from the second data source (VDW 2005), to complement our firm-level data on number of submarkets per firm[6].

Our baseline regression equation in this section is as follows:

$$IndustryEmpl_t = \beta_0 + \beta_1\ Submkts_t + \beta_2\ Firms_t + \beta_3\ (Submkt/Firm)_t + \beta_4\ ((Submkt^2)/Firm)_t + \varepsilon_t \quad (2)$$

40 observations - 1950-1989							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
# firms	48,1650						
	1,47						
# submarkets		**125,6898**	**107,3923**	35,5129			
		9,13	8,50	1,89			
# subm/firm			**47988,2400**				
			4,80				
(# subm^2)/firm				**37,1567**			
				5,40			
# MachineVariations					**48,8344**	**39,3171**	18,1166
					8,37	5,89	1,37
# MachVars/firm						**13982,3200**	
						2,30	
(#MachVars^2)/firm							**5,6945**
							2,35
Obs	40	40	40	40	40	40	40
R2	0,0311	0,6558	0,8108	0,8186	0,5859	0,6482	0,6547

Table 3: OLS regressions with total industry employees as the dependent variable. A constant term is always included in the regression but not reported here. Standard errors are robust for heteroskedasticity (Huber/White/sandwich estimator).

[6] Data on aggregate employment for West Germany are only available until 1989. After the reunification employment figures refer to West and East Germany. As we do not include East German firms in the analysis, our analysis ends in this case already in 1989.

In the results table above (Table 3) we investigate the determinants of total industry employment. To do so, we match industry level data (on employment) with aggregate data obtained by summing all observations per year in our firm-level dataset. These datasets do not correspond exactly, but they are closely related.

Column (1) shows that the relationship between total industry employment and number of firms is positive, but interestingly enough it is not statistically significant, and the associated R2 is very low. This is because firms vary greatly in size – simply counting the number of firms is not a good indicator of total industry employment. It is more informative to consider how industry employment varies with number of submarkets (column (2)) or number of machine variations (column (5)). These coefficient estimates are highly significant, and the R2 is considerably higher. These estimates can be improved upon, however, by taking into account the number of submarkets per firm: the R2 statistic increases substantially from Column (2) to (3), and from Column (5) to (6). When firms contain many submarkets, these submarkets are likely to be larger than submarkets operated by undiversified firms. Therefore, even after controlling for number of submarkets, we see that submarkets per firm, and also submarkets^2 per firm, are significantly positively related to total industry employment (see columns (3) and (4)). Similar results hold for machine variations (see columns (6) and (7)). In fact, the models with submarkets^2 per firm offer the best fits (when considering the R2 statistic), which suggests a nonlinear relationship between submarket size and number of submarkets per firm. In fact, in the regressions that include submarkets^2 per firm, we observe that the coefficients on number of submarkets (4) or number of machine variations (7) actually become insignificant, even though the overall model fit is the highest in these specifications.

Our results clearly indicate, therefore, that diversified firms are larger than undiversified firms for two reasons. First, of course, diversified firms are larger because they are active in more submarkets. Second, the individual business units of diversified firms are larger than the individual business units of undiversified firms.

These findings corroborate previous findings by Matia et al (2004) and Bottazzi and Secchi (2006) on diversification and submarkets in the pharmaceutical industry. Although data on submarkets is not easy to obtain, we use our unique dataset to show how average submarket size also increases with total firm size in the German machine tools industry.

3.3 Diversification and survival

Now as we have portrayed differences in diversification patterns among different age cohorts, we turn our attention to the interdependence of diversification and its effect on long-term competitiveness in terms of firm survival.

3.3.1 Descriptives

Several studies have shown that small firms have a higher risk to exit the market, the so-called liability of smallness (e.g. Aldrich and Auster 1986). Therefore, we will firstly investigate whether this pattern can also be observed for the case at hand. We follow Klepper and Thompson (2006) in determining the exit rates across different size classes in terms of the number of submarkets served by exiting firms in their final year of observation. Table 4 thus depicts the rate of firms in each size class that exit the market. Our findings clearly reveal that the more diversified firms exit less frequently than their smaller competitors, which corroborates the findings of previous studies.

Number of Submarkets	Exit rate
1	.071
2	.029
3	.027
4	.023
5	.013
6	.014
7	.008
>7	.003

Table 4: Exit rate across different size classes.

3.3.2 Estimation strategy

In the upcoming analysis we will thus investigate whether diversification is systematically accompanied by an increase in a firm's competitiveness, i.e. in its survival chances. The analysis will be conducted in two steps. First of all we will test whether size and age as such are related to the probability of exit, i.e. we will test for the frequently observed liabilities of smallness, newness and adolescence (Brüderl and Schüssler 1990). Secondly, we will investigate in how far age and diversification affect the likelihood of survival, and more specifically whether diversification at different ages has different effects on future survival.

To analyze these two sets of estimations we apply the following simple Cox proportional hazard model (Cox, 1972):

$$h_i(t) = h_0(t)\ exp(\alpha_e + \alpha_t + \alpha_p + \beta_1 x_{i1} + \beta_2 x_{ik} + \cdot\ \cdot\ \cdot + \beta_k x_{ik})$$

with $h_i(t)$ being the hazard rate, i.e. the probability of exit, at time t of firm i conditional on a set of k firm-specific (time-varying) covariates $x_{i1}, \ldots, x_{ik}$. $h_0(t)$ represents an unspecified baseline hazard function. All models include α_e , α_r and α_p , i.e. a set of dummies specifying the entry cohort, and the product portfolio of firm i further specified below.

α_e is a set of dummies differentiating all active producers in the machine tool industry between 1953 and 2002 according to their first year of observation, their entry timing. These dummies allow for entry-cohort specific variation within the baseline hazard. Accordingly, we define α_p and α_t as product-specific and year specific dummy variables in order to account for varying baseline hazards within individual products, and individual years. Thereby, we can capture all observed and unobserved effects that are due to industry-specific time trends such as product and industry lifecycle as well as business cycles respectively and are thus external to the firm.

Throughout the estimations we account for the fact that not all firms exit within the observation period, i.e. they do not experience exit and are thus right censored.[7]

For the upcoming analysis the following information was extracted from the data source introduced at the very beginning of the paper:

Dependent variable:
Survival: For each individual firm we track its overall survival time being defined as the time between the first and last year of observation within the machine tool industry. Given that the industry as well as firms existed already before the beginning of our observation period in 1953, we are aware of the fact that firms might have already been exposed to the probability of exit before we start the analysis. In order to account for this we redefine our age variable as follows.

Independent variables:
Age: Using the additional catalogues of the data source from 1936 until 1943, we are able to include this information and correctly account for the additional years of existence before the observation period of our analysis starts.

Age groups: To test for a non-linear relationship between age and survival we define 5 age groups: companies from 1 and 9 years (age group1; our reference group), 10-19 years (age group 2) 20 -29 years (age group 3) 30-39 years (age group 4) and older than 39 years (age group 5).

Size: is defined as the number of products in terms of machine tool variations a firm produces in the respective year. Accordingly:

Diversification: a firm experiences minor diversification if it increases (decreases) the

[7] Recent research (Headd 2003) has highlighted that business exit can correspond to either a failure (e.g. bankruptcy) or a success (e.g. merger or acquisition). We do not explicitly differentiate between exit by bankruptcy and M&A events in our analysis. Nevertheless, we can be sure that these events are rather similar in the case at hand and are both a sign of poor performance as opposed to exit dynamics observed e.g. in the biotech industry, where companies based on promising technologies are sold voluntarily (Buenstorf and Guenther 2011).

number of machine tool variations *within the same submarket* from one period to the next; thus, minor diversification is defined as in equation (1). the difference between the number of machine tool variations at time t and the number of machine tool variations at time t-1 divided by the number of machine tool variations at time t-1.[8]

Control variables:
In order to avoid an omitted variable bias in our survival estimations, we control for various effects, which are known to affect the survival chances of firms in general:

1. All models include regional controls at the level of regional planning districts. More precisely, we include the annual logged number of machine tool producers as well as the annual logged population density. Thereby, we can control for the otherwise unobserved heterogeneity of different locations due to knowledge spillover potential of similar producers (Marshall 1890) or the level of urbanization (Jacobs 1969) and their influence on the survival chances of the individual firm.
2. We include year fixed effects (of 5-year intervals) in order to take care of the unobserved heterogeneity due to business cycles as well as the industry life cycle as such.
3. We differentiate between five entry cohorts in the industry to account for the possibility of a first mover advantage phenomenon respectively for the heterogeneity of founding conditions of each cohort; the five entry cohorts (used as control variables) are defined as follows: (1) entry <1960; (2) 1960<=entry< 1970; (3) 1970<=entry< 1980; (4) 1980<=entry< 1990; (5) entry>= 1990.
4. We moreover control for the *type* of manufactured products per year as the survival might not only depend on the amount of products produced, respectively the size of the firm, but also on the actual type of product considering its individual product life cycle.

[8] To ensure that our results were not overly sensitive to extreme diversification events, we pursued a systematic outlier removal by cutting off the highest and lowest percentile of diversification observations.

3.3.3 Results

In our baseline Model 1 (see Table 5) we are interested in whether the size of a firm as well as its age in general influence the firm's probability of exit. As described above we control for regional and year specific effects as well as entry cohorts and the type of products for each firm and each year. The negative coefficients indicate that being larger and older results in a significantly higher future life expectancy, as the hazard risk is reduced by each additional product respectively year.

Model 2 extends the baseline model by including a diversification effect, i.e. we investigate whether on top of the level effect of size there are additional hazard reducing effects to be witnessed for firms that extend their product portfolio. As expected, diversification further reduces the probability of exit.

In Model 3 we allow for an inverted u-shaped relation between diversification and survival, i.e. we investigate the possibility that diversification may turn out to be life threatening in case it is realized too fast. Therefore, we add a quadratic diversification term to the analysis. The results indicate that expanding the product portfolio rather rapidly is indeed associated with a survival decreasing effect. This observation is again in line with the Penrosean growth theory: "if a firm deliberately or inadvertently expands its organization more rapidly than the individuals in the expanding organization can obtain the experience with each other and the firm that is necessary for the effective operation of the group, the efficiency of the firm will suffer" (Penrose 1995, p.47). Interestingly, the size of the diversification coefficient and its squared counterpart are very similar. Thus, about doubling the company size from one year to the next is the breakeven point where the diversification effect turns negative, as diversification is realized too fast. This is especially interesting as the first diversification move for small companies growing from one product to two represents exactly this case. Only subsequent diversification moves thus ensure substantial prolonged survival chances.

In Model 4 we likewise test for the possibility that the relation between age and survival is not linear, in the sense of the liability of senescence (Barron et al 1994). Therefore, we add the defined five age groups with companies up to 10 years serving as a reference category. The results reveal that up to the fourth age group (firms aged 30-39) growing older is accompanied by a stepwise reduction of the future hazard rate. For companies older than 39 years we still observe a significantly lower probability of exit as compared to the youngest group of firms, but the effect is smaller than for the second oldest age group. This suggests that while controlling for size and diversification there is indeed a liability of newness as all older firms have lower probabilities of exit than the youngest one, but there is also evidence for the liability of senescence, as the hazard risk of the oldest firms increases again as compared to the second oldest group.

In the last Model, we analyze if the hazard reducing effect of diversification affects all age groups in a similar way, i.e. we test if firms of all ages benefit equally from growing (on top of the level effect we see for size as such). Therefore, we include interaction terms for all age groups and diversification, age group 1 serves again as the reference group. All effects of the first four models are robust to this additional specification. Interestingly, we only see a significant effect of this interaction term for the fourth age group, indicating that companies that are able to introduce new products in their thirties significantly lower their risk of exiting the industry. This might be interpreted as follows: Those firms that are still innovative and introduce new products at these rather old ages, show that they do not run into the risk of becoming inflexible as claimed by the liability of senescence hypothesis (Barron et al, 1994).

All models were repeated with the second diversification mode, i.e. 'major diversification', when firms increase the number of submarkets they are active in instead of only increasing the number of products. All of the above results are corroborated by this alternative diversification measure except for the very last result; the interaction of the various age groups and 'major diversification' are no longer significantly different from each other.

	Model 1	Model 2	Model 3	Model 4	Model 5
Size	-.159***	-.154***	-.154***	-.152***	-.152***
	(-.029)	(.028)	(.029)	(.029)	(.029)
Age	-.021***	-.021***	-.022***		
	(.005)	(.005)	(.005)		
Growth_rate		-.454***	-.641***	-.642***	-.516**
		(.172)	(.138)	(.138)	(.209)
Growth^2			.633***	.630***	.584***
			(.161)	(.161)	(.165)
Agegroup2				-.395***	-.392***
				(.149)	(.149)
Agegroup3				-.650***	-.652***
				(.183)	(.182)
Agegroup4				-.853***	-.877***
				(.210)	(.211)
Agegroup5				-.820***	-.809***
				(.248)	(.248)
Agegroup2*growth					.094
					(.346)
Agegroup3*growth					-.433
					(.376)
Agegroup4*growth					-.951**
					(.455)
Agegroup5*growth					.032
					(.362)
Agglomeration externalities	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes
Entry cohort FE	yes	yes	yes	yes	yes
Product FE	yes	yes	yes	yes	yes
Subjects	1674	1674	1674	1674	1674
Failures	1278	1278	1278	1278	1278
Log pseudolikelihood	-8094.021	-8089.401	-8083.820	-8082.339	-8079.981
Pr>Chi2	0.000	0.000	0.000	0.000	0.000

Table 5: Survival regressions, applying a Cox proportional hazards model

4. CONCLUSION

Our paper aimed at bringing the attention back to a relatively neglected dimension within research on firm growth. It is meant to complement the substantial body of literature regarding firm growth in terms of employee and sales measures by focusing on growth direction and mode as well as its interdependence with firm age. For this purpose, we investigate age and diversification patterns of German machine tool manufacturers between 1953-2002 using data concerning product registration in trade journals. We observe that firms have lower diversification rates as they grow older, and even that old firms have negative diversification rates on average. Moreover, we find that firms have different submarket sizes, and larger firms appear to be composed of larger submarkets. Quantile autoregression plots show that firms experiencing diversification are unlikely to repeat this behavior in the following year. Lastly, survival estimations reveal that diversification activities lead to long-term competitiveness as they reduce the probability of exit controlling for various additional firm and industry specific fixed effects and business cycles in general. This effect turned out to vary with firm age. Of course our analysis has some limitations. We do not only consider just one single industry, and thereby cannot generalize from our conclusion, but we also only use a proxy for age (that is, time since a firm registers its products with the industry catalogue). Despite these obvious drawbacks of our study, we nonetheless think that it is worthwhile pursuing further investigations based on this setting. Future studies may explore the directions and patterns of diversification by firms in more detail. For example, do firms generally prefer to grow within existing product categories, such that they only diversify into new product categories once all the diversification possibilities within the existing family of products are exhausted (in analogy to an atom that fills up its innermost electron shells before moving further outwards)? Does this pattern differ for young and old firms? A second set of questions could be based on the technological relatedness of the submarkets firms decide to diversify in. Do firms choose technologically closely related submarkets when diversifying, or do they spread the risk even broader over relatively unrelated submarkets. Again the differentiation between the diversification strategies of young and old firms would be insightful as well as the combination with further survival analyses. Moreover, exploring the other side of the coin, i.e. patterns of divesting individual product lines or entire submarkets seems to be an equally promising research angle that has so far not gained equal attention as business expansion patterns.

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