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Growth of New Technology-Based Firms: Which Factors Matter?

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ABSTRACT. This paper deals with the explanation of variations in the growth between New Technology-based Firms (NTBFs) and non-innovative firm foundations. Based on theoretical models explaining the growth of firms, hypotheses on potential determinants are derived. The regression results indicate strong correlations between the growth rate on the one hand and firm-specific, founder-specific as well as external factors on the other. These factors influence the growth rates of innovative and non-innovative young firms in different ways. Furthermore, based on the results of multivariate regressions, NTBFs achieve on average higher growth rates than non-innovative firm foundations. Moreover, the net employment effect of those NTBFs founded in 1989/90 is positive. This does not hold for non-innovative young firms, in which the number of jobs destroyed by closures and shrinking firms is larger than the number of new jobs in growing and expanding firms.

1. Introduction

During the past decade, small and medium-sized companies in general and New Technology-Based Firms (NTBFs) in particular have attracted growing interest from academics and politicians. One indicator of this interest is government expenditure on new technology-based firms. In Germany, federal funding for indirect promotion of NTBFs has risen from 45.9 million DM in 1991 to almost 82 million DM in 1993 (BMBF, 1996, p. 97). Similarly, the amount of venture capital provided by direct-investment and venture capital schemes of the Federal Ministry for Education, Science, Research and Technology (BMBF) has increased from about 10 million DM in 1989 to more than 458 million DM in 1997.

Final version accepted on April 22, 1999

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Public awareness of NTBFs arose in the early eighties, when several traditional industries faced severe problems and some fast growing new industries began to emerge. NTBFs have thereafter been regarded as an answer to ongoing structural changes; they are seen as an important source of new employment and important promoters of technological change and innovation in the German economy. The creation of such firms has been stimulated by public policies, such as the pilot scheme for the "Promotion of New Technology-based Firms" initiated by the Federal Ministry of Research and Technology (Kulicke et al., 1993; BMBF, 1996). Conclusions upon the appropriateness of the various policy initiatives are very limited. Most of the evaluations carried out have neglected control groups, therefore the derived results and implications are often less meaningful (Nerlinger, 1998).

While it is acknowledged that large numbers of jobs are created in small and medium-sized firms (SMEs), it should also be recognized that many jobs are lost by the closure of smaller firms (Davis et al., 1996; Gerlach and Wagner, 1997; Caves, 1998). The current debate focuses on the contribution NTBFs have made to employment, to technological innovation and to the diffusion of new technological knowledge. Some argue that new companies of this kind are rare, so their contribution to overall employment and national technological performance is marginal (Berndts and Harmsen, 1985; Sternberg, 1988), but others suggest that NTBFs are much more important, being the primary source of new employment and the engine of technological change and economic growth (Kulicke et al., 1993). However, the debate about the potential of NTBFs and other small firms for employment creation started long ago with the work of David Birch in the late 1970s (Birch, 1979), and since then it has become clear

Small Business Economics **13**: 141–154, 1999.

that the expectations of employment creation by NTBFs and other small firms as the solution for high unemployment has been exaggerated. Presently, the debate is more concentrated on the role of NTBFs and small firms in innovation than on employment.

Existing literature concerned with NTBFs only provides partial answers to the question of NTBFs' contributions to economic development, employment and technological performance (Storey and Tether, 1996). The major reason is that the empirical results derived vary considerably due to methodological differences as well as differences in the data base used and the study aims (Butchart, 1987; Breheny and McQuaid, 1988). This also holds for East and West Germany, where comparatively few empirical investigations have been conducted and which, at the same time, are limited to specific samples or regions (Nerlinger, 1998).

The purpose of this paper is to shed more light on the growth determinants of innovative firms founded between 1989 and 1996 in West Germany. Based on theoretical approaches, hypotheses on the influence of exogenous determinants are formulated. Due to the comprehensive unique database used in the analyses, firm-specific and founder-specific factors as well as external characteristics are available. Their influence is examined in multivariate analyses taking into account potential selection biases. In order to simplify the evaluation of the empirical results, comparisons with non-innovative firm foundation are carried out.

2. Theoretical models on the growth of NTBFs

A solid theoretical model for the explanation of growth of young firms as well as of NTBFs does not yet exist (Fritsch, 1990; Brueder et al., 1991). With respect to NTBFs, various existing theoretical concepts on the growth of firms have to be used and combined with further aspects which are particularly relevant for NTBFs (Nerlinger, 1998). This applies for growth theories (e.g. "theory of the firm", "minimum efficient size") as well as for organizational ecological approaches, in which the focus is mainly on the survival and failure of organizations rather than on the growth of firms.

The approach of the "theory of the firm" assumes a U-shaped form of the long-term average costs, i.e. costs increase with firm size up to an "optimal size" and then start to decrease (Williamson, 1981; Fritsch, 1990). A similar argument holds for the approach of the "minimum efficient size", assuming a minimum size which is required for a profitable production (Scherer and Ross, 1990; Audretsch, 1994). Therefore, the growth of firms can be regarded as an adjustment to the (minimum) efficient size which may vary between industries and with time.

Numerous industrial economic approaches analysing the determinants of growth are based on the learning theoretic model derived by Jovanovic (1982), assuming that on the one hand new firms only receive information about their effectiveness after their market entry and that on the other they are able to learn from previous periods and experiences. When firms become older they gain more and more information on their performance and their a priori unknown effectiveness, influencing decisions about future output levels including a possible closure (Frank, 1988; Jovanovic and McDonald, 1990; Ericson and Pakes, 1995). According to Jovanovic (1982) and Ericson and Pakes (1995), the effectiveness of firms is determined by various factors including, e.g. its ability to innovate, the human capital of founder(s) and employees as well as the location and structure of the industry.

Life-Cycle-Models applied by Markusen et al. (1986), Phillips et al. (1991) as well as Oakey (1993) are based on the idea that firms (and respectively their products) pass various development stages. The foundation of the firm takes place in the first stage, assuming that the decision to become self-employed has already been made. During this phase, also describe as innovation phase (Rees and Stafford, 1980; Markusen et al., 1986), the (innovative) product or process is developed up to its market launch suitability (Picot et al., 1989; Kulicke et al., 1993). After the (successful) market launch, first revenues are achieved and firms begin to expand their production and increase the number of employees (Rees and Stafford, 1986; Kazanjian, 1988). This growth phase lasts until demand is satisfied or a new or improved product/process replaces the "old" innovation.

Organizational ecology approaches analyse the survival and failure of firms and the relevant

exogenous determinants, such as size and age (Bruederl et al., 1996; Woywode, 1998). Although the majority of these approaches focus primarily on survival and failure, various factors can be derived which may contribute to the explanation of growth. This holds for the start-up characteristics of firms which are described in details in the "theory of founding characteristics" (Stinchcombe, 1965; Carroll, 1984; Bruederl et al., 1996). Dynamic effects and organizational change, however, are not considered, causing the long-run development in these models to be uniquely determined by start-up characteristics and conditions (Woywode, 1998).

The theoretic approaches discussed above can be used to derive hypotheses on the determinants of growth of young (innovative) firms. According to Storey (1994) the determinants can be separated into firm-specific, founder-specific and external characteristics. Due to the lack of appropriate data, the majority of empirical analyses do not include all three types of exogenous variables and are therefore limited in their implications.

(a) *Firm-specific characteristics:*
- The growth rate decreases c.p. with age (Jovanovic, 1982; Evans, 1987a,b; Hall, 1987).
- The start-up size is negatively correlated with growth, i.e. small firms grow c.p. faster than large firms (Evans, 1987a,b; Hall, 1987). This hypothesis contradicts "Gibrat's law", which assumes no systematic correlation between growth and firm size (Wagner, 1992; Audretsch, 1995a,b).
- Firms with limited liability realize c.p. higher growth rates than firms in which the founder(s) are liable with their private fortune due to differences in the incentives to pursue risky projects (Stiglitz and Weiss, 1981; Harhoff and Stahl, 1995).
- Tight links with external firms may provide additional know-how or capital as well as networks with customers/suppliers (Aldrich et al., 1990; Variyam and Kraybill, 1992; Nerlinger, 1998). Therefore positive effects on growth can be assumed from partnerships with external firms.
- Diversified firms realize c.p. higher growth rates than firms with a highly concentrated product/process spectrum (Nerlinger, 1998).

(b) *Founder-specific characteristics:*
- Due to the high complexity of innovation projects and the qualifications necessary for the application of new technologies, growth of NTBFs is positively correlated with the human capital of founders (Kulicke et al., 1996; Nerlinger, 1998). This holds especially for technical and engineering skills, reflecting the technical orientation of NTBFs (Kulicke, 1987; Storey and Tether, 1996). With respect to non-innovative young firms, a comparably lower influence of the human capital of the founder(s) can be assumed.
- Firms founded by a team grow c.p. faster than firms founded by a single person. This hypothesis is based on the assumption that potential individual know-how deficits may be compensated for by other members of the founding team (Eisenhardt and Schoonhoven, 1990; Reynolds, 1993; Storey, 1994).

(c) *External characteristics:*
- According to North and Smallbone (1993) and Storey (1994), there is a strong correlation between local characteristics and firm growth. A popular proxy for agglomeration effects is the population density, by which it can be assumed that advantages deriving from the density increase up to a critical threshold and then turn into disadvantages thus hampering growth.
- Average wage and salary rates, interpreted as a cost factor, prevent the hiring of new employees and therefore have a negative influence on growth (Rees and Stafford, 1986; Oakey, 1994). However, due to the high degree of capital-intensive production in NTBFs, it can be assumed that this factor has only minor influence on their growth.

3. Data and definitions

The multivariate analyses on the growth of NTBFs are based on data from the ZEW-Foundation Panel (West), which was started in early 1989. The firm-specific data are provided by the largest German credit rating agency CREDITREFORM. Typically, firms enter the CREDITREFORM data base for two reasons. First, a customer or supplier may inquire about the financial situation of the respec-

tive firm. Second, credit rating agencies exploit economies of scale by gathering information proactively, systematically recording publicly available information on new firms (Stahl, 1991; Harhoff and Steil, 1997).

The most important source of information is the commercial register. For all incorporated companies and large sole proprietorships, registration is compulsory. In the initial interview, CREDITREFORM records the name and address of the firm, industry affiliation, ownership structure, legal form, management, number of employees, annual sales, the date of incorporation and dates of incorporation of legal predecessors of the firm. If the information is updated, the respective interview date is recorded with the data. Every six months, newly recorded firm foundations and updated data on existing firms are delivered and integrated into the ZEW-Foundation Panel (West). This procedure, however, does not guarantee that each data delivery from CREDITREFORM contains updated information on all firms (Harhoff and Steil, 1997).[1] Cumulated up to 1998, the panel now consists of more than 580,000 firms in West Germany. One very important advantage of the Foundation Panel is that once a firm is registered it remains in the database regardless of whether it is still active or not. This is especially important with respect to potential biases in the analysis of the employment growth. Due to a time-lag in the data-collecting process, the multivariate growth analyses are restricted to firms founded between January 1989 and December 1996.

The definition of NTBFs goes back to a differentiation of "technology-intensive" goods derived by the OECD (Gehrke and Grupp, 1994). On the basis of this list, technology-intensive manufacturing industries are separated according to their average R&D-intensity into "High-Tech Industries" (R&D-intensity above 8.5%), "Medium-Tech Industries" (R&D-intensity between 3.5% and 8.5%) and "Other Manufacturing" (R&D-intensity below 3.5%). For a better understanding and evaluation of the results obtained in the multivariate growth analyses, other manufacturing industries have also been included.[2] In addition, the definition of firm foundation types (e.g. differentiation with respect to the degree of prior structural existence as well as the degree of independence) plays a crucial role with respect to the growth and survival patterns of firms (Mahmood, 1991; Bruederl et al., 1992; Geroski, 1995). Due to the aim of this paper, only newly founded independent firms, defined as firms without prior structural existence or major control influence from external firms (Nerlinger, 1998), have been considered. Consequently, the subsequent growth analyses focus on independent firms, founded between 1989 and 1996 in the three technology sectors "High-Tech Industries", "Medium-Tech Industries" and "Other Manufacturing" in West Germany.[3]

4. Derivation of the growth model

The analyses of the validity of the hypotheses are based on a growth model, which includes a control for potential selection biases.[4] A requirement for the calculation of a growth rate for firm i is the existence of employment numbers E at least at two different points in time, t_1 and t_2 ($t_1 < t_2$). Due to the varying frequency of inquiry, the firm-specific growth rate, G_i, is calculated on a yearly basis with a minimal time distance of six months ($t_2 - t_1 \geqq 0.5$ years) between the two employment figures.[5] The calculation of the growth rate follows Evans (1987a,b), assuming an exponential growth trend. Thus, for all N_1-firms fulfilling the requirements, the firm-specific growth rate can be computed as

$$G_i = \frac{\ln E_{t_{i2}} - \ln E_{t_{i1}}}{(t_{i2} - t_{i1})} \qquad \forall\ i = 1, \ldots, N_1.$$

At the same time, there are N_2-firms remaining ($N_1 + N_2 = N$) for which no growth rate can be computed due to missing employment numbers or a time difference smaller than six months.

The estimation of the growth equation is based on a specification in which the firm-specific growth rate G_i is a function $f(X_i'\beta)$ of X_i, comprising the exogenous variables, the parameter vector β and the normal distributed error term $u_i \sim N(0, \sigma_u^2)$

$$G_i = f(X_i'\beta) + u_i \qquad \forall\ i = 1, \ldots, N_1.$$

Similar to Hall (1987) and Evans (1987a,b) we assume the identity of $f(X_i'\beta) = X_i'\beta$. Thus the firm-specific growth rates for the N_1-firms can be estimated using the linear regression model

$$G_i = X_i'\beta + u_i \qquad \forall\ i = 1, \ldots, N_1.$$

Potential selection biases deriving from observations without growth rates are controlled for by using the sample selection approach developed by Gronau (1974) and Heckman (1974). In the first stage, the probability that a growth rate exists is modelled by all N-observations. The Bernoulli-distributed random variable Y_i used as the endogenous variable in the participation equation can take on the values

$$Y_i = \begin{cases} 1, & \text{if the growth rate can be computed} \\ 0, & \text{otherwise} \end{cases}$$

The growth estimations for the N_1-firms with growth rates follow in the second stage, using the results of the first stage.

The framework for the regression of the sample selection model is a bivariate Tobit-Model, simultaneously identifying the probability of an existing growth rate and the size to which it amounts. A further requirement is the bivariate normal distribution of the error terms of both the selection equation ε_i and the growth equation u_i

$$\begin{pmatrix} \varepsilon_i \\ \mu_i \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \sigma_{\varepsilon, u} \\ \sigma_{\varepsilon, u} & \sigma_u^2 \end{pmatrix}\right],$$

with the covariance $\sigma_{\varepsilon, u}$ between the error terms. The existence of selection biases is confirmed if the correlation coefficient ρ between the error terms of the selection and growth equation

$$\rho = \frac{\sigma_{\varepsilon, u}}{\sigma_u},$$

differs statistically significant from zero. If the correlation ρ proves to be statistically insignificant, either no selection processes exist or different effects interfere (Almus and Nerlinger, 1998).

We estimate the model using the maximum-likelihood method. The respective likelihood function takes on the form[6]

$$L = \prod_{i \in N_2} \Pr(Y_i = 0) \cdot \prod_{i \in N_1} \Pr(Y_i = 1) \cdot f(G_i | Y_i = 1)$$

$$= \prod_{i \in N_2} [1 - \Phi(Z_i' \gamma)] \cdot \prod_{i \in N_1} \Phi(Z_i' \gamma) \cdot \varphi(G_i | Y_i = 1),$$

with $\phi(\bullet)$ and $\varphi(\bullet)$ as the probability respectively cumulative density function of the standard normal distribution. Z_i represents the vector of exogenous variable which might influence the existence of the growth rate and γ is the parameter vector to be estimated. The first term on the right side of the equations above states the individual probability for the N_2-firms, that a growth rate does not exist. The remaining term represents the joint probability of the existence of an individual growth rate for the N_1-firms and its value.

5. Results of the growth regressions

In order to control for the validity of the derived growth hypotheses, separate regressions for the three technology sectors "High-Tech Industries", "Medium-Tech Industries" and "Other Manufacturing" are conduced. Moreover, in order to stress variations between these sectors and evaluate the average growth rates between them, a pooled model is estimated. The regression results all indicate insignificant coefficients of the correlation coefficient ρ, i.e. no selection biases or existing ones overlap mutually (cf. Table II).[7]

An important growth determinant is the size at start-up. This variable is approximated as the logarithm of the sum of employees and founders and its square is added in order to control for non-linear effects ("ln(size)", "ln(size)^2"). The estimation results confirm the theoretical considerations that firms are founded with a suboptimal size and therefore quickly grow to reach a (minimum) efficient size. Once this size is reached, no compelling reasons exist for further growth. In contrast, many founders prefer to stay small because, in their view, a large number of employees is often associated with increasing control and administration duties (Storey, 1994).

The estimated correlation between size and growth contradicts "Gibrat's law". This is confirmed by numerous empirical analyses, showing that the growth rate of small firms is c.p. higher than that of large firms (Evans, 1987a,b; Wagner, 1992; Sutton, 1997; Caves, 1998). An alternative way to assess the validity of "Gibrat's law" is to compute the elasticity of the employment E at time t_2 with respect to the employment in t_1 as

$$\xi_{E_{t_2}, E_{t_1}} = \frac{\partial \ln E_{t_2}}{\partial \ln E_{t_1}} = (t_2 - t_1)g + 1$$

$$= (\overline{t_2 - t_1})[\hat{\beta}_{\ln(\text{size})} + 2\hat{\beta}_{\ln(\text{size})^2} + \overline{\ln(\text{size})} + \hat{\beta}_{\ln(\text{size}) * \text{age}}\, \overline{\ln(\text{age})}] + 1$$

with $g = \partial G/\partial \ln E$ (Evans, 1987a). "Gibrat's law" is confirmed if the computed elasticity equals one, i.e. size influences the growth of firm proportionally.

In order to calculate the elasticity, the start-up size "ln(size)", the age "ln(age)", the average time difference between the two employment numbers ($t_2 - t_1$), as well as the estimated coefficients of the growth equations are used. The elasticities are individually calculated for the three sectors ("High-Tech Industries", "Medium-Tech Industries", "Other Manufacturing") and differentiated with respect to start-up size (All firms, 1–4 Employees, 5–19 Employees).[8] All values for the elasticity in Table I differ from one, indicating that "Gibrat's law" does not hold with respect to technology sectors, nor for the size classes. This is particularly true for firms with 1–4 employees, for which the elasticity takes comparably low values between 0.769 and 0.785. Moreover, the proportionally lower growth of small firms converges with increasing firm size to an elasticity of one, indicating proportional growth (Hall, 1987; Wagner, 1992; Caves, 1998).

A further important determinant for the explanation of growth is the age ("ln(age)"), and again, analogous to size, non-linear effects are controlled for by using its square ("ln(age)^2"). Both coefficients show a highly significant influence on the growth rates and fulfill the *a priori* hypothesis (cf. Table II). The concave shape matches the results of Evans (1987a,b), Harhoff and Stahl (1995) and Harhoff et al. (1998), indicating that young firms grow faster than mature

TABLE I
Employment elasticities differentiated according to technological sectors

	High	Medium	Low	Pooled
All firms	0.778 n = 1,853	0.769 n = 3,172	0.781 n = 15,577	0.785 n = 20,602
Micro firms (1–4 Employees)	0.769 n = 1,312	0.714 n = 2,115	0.720 n = 10,306	0.726 n = 13,733
Small firms (5–19 Employees)	0.842 n = 520	0.896 n = 982	0.877 n = 4,939	0.875 n = 6,441

High: High-tech industries.
Medium: Medium-tech industries
Low: Other Manufacturing.
Pooled: "High-tech industries", "Medium-tech industries" and "Other manufacturing" together.
Source: ZEW-Foundation Panel (West), own calculations.

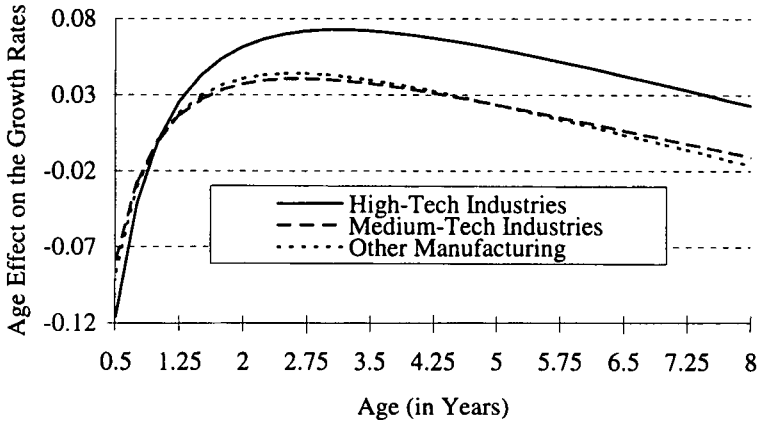

Figure 1. Partial effects of firm age on growth rates.

TABLE II
Results of the growth estimations (bivariate Tobit-Model)

Endogenous Variable: Average annual growth rate Coeff. (*t*-value)	High	Medium	Low	Pooled
Firm-specific characteristics				
ln(size)	–0.048	–0.138**	–0.104**	–0.105**
	(–1.663)	(–6.794)	(–12.980)	(–14.505)
$\ln(size)^2$	0.006	0.023**	0.015**	0.016**
	(0.926)	(4.913)	(8.034)	(9.309)
ln(age)	0.157*	0.102	0.092**	0.090**
	(2.290)	(0.973)	(4.702)	(5.050)
ln(size) * ln(age)	–0.022	0.007	0.000	0.000
	(–1.532)	(0.762)	(0.032)	(–0.074)
Limited liability	0.040**	0.031**	0.038**	0.038**
	(3.620)	(3.321)	(10.597)	(11.808)
Diversification	0.014	–0.003	0.002	0.002
	(1.494)	(–0.347)	(0.529)	(0.586)
Subsidiary/affiliated firm	0.012	0.051**	0.027**	0.030**
	(0.589)	(3.247)	(3.678)	(4.815)
Founder-specific characteristics				
Team-foundation	0.001	0.002	0.007*	0.005
	(0.147)	(0.276)	(2.009)	(1.759)
Skills_Tec	0.018*	0.021**	0.018**	0.019**
	(1.969)	(2.740)	(5.634)	(6.661)
Skills_MBA	0.011	0.034	0.032**	0.029**
	(0.505)	(1.756)	(3.563)	(3.776)
Skills_Tec & MBA	0.071	0.010	0.011	0.019
	(1.748)	(0.284)	(0.641)	(1.367)
Firm external characteristics[a]				
Inhabitants/km^2	–0.010	–0.039**	–0.011	–0.016**
	(–0.632)	(–2.601)	(–1.826)	(–3.033)
$(Inhabitants/km^2)^2$	0.001	0.010*	0.001	0.003
	(0.314)	(2.165)	(0.681)	(1.746)
Wage rate	–0.004	–0.003	–0.011**	–0.009**
	(–0.448)	(–0.409)	(–3.884)	(–3.562)
High-tech industries	–	–	–	0.020**
	–	–	–	(3.819)
Medium-tech industries	–	–	–	0.019**
	–	–	–	(4.518)
Constant	0.043	0.227**	0.170**	0.166**
	(0.577)	(3.958)	(7.521)	(8.160)
Correlation coefficient (ρ)	–0.068	0.014	–0.026	–0.022
	(–0.655)	(0.181)	(–0.741)	(–0.727)
No. of observations (N)	2,679	4,466	24,900	32,045
Log-likelihood	–733.61	–1,494.58	–7,204.19	–9,690.35
LR-Tests: χ^2 (df)				
Age and size (5)	147.07**	237.50**	1244.01**	1585.46**
Skills (3)	8.14*	10.37*	45.15**	62.29**
Population Density (2)	0.97	7.27*	11.30**	18.06**
Bundeslaender (9)	7.47	17.61*	30.30**	42.43**
Industries	11.52**	11.56**	45.04**	43.32**
(df)	(2)	(2)	(8)	(8)

High: High-tech industries; Medium: Medium-tech industries; Low: Other manufacturing; Pooled: "High-tech industries", "Medium-tech industries" and "Other manufacturing" together.
[a] Data on population density and wage rate refer to counties ("Kreise").
** Significant on the 1% level; * Significant on the 5% level.
Regressions contain dummy-variables for industries and laender ("Bundeslaender").
Source: ZEW-Foundation Panel (West), own calculations.

firms. With respect to the influence of size, this correlation once again confirms the suboptimal start-up size of firm foundations, which have to reach a (minimum) efficient size in order to become competitive (Fritsch, 1990; Scherer and Ross, 1990; Audretsch, 1994).

The shape of the partial effects of age on growth shows considerable variations for the three technology sectors analyzed. After a straight increase in growth rates at earlier stages, the squared term starts to dominate, leading to a declining partial effect of age on growth. This threshold is reached after 3.1 years in the "High-Tech Industries" and after 3.0 years in the "Medium-Tech Industries", whereas in "Other Manufacturing" the decline starts after only 2.6 years.

Apart from size and age, other firm-specific characteristics have an influence on the growth rate. This holds for the legal form, which is used as a dummy-variable (0/1), indicating the status of liability.[9] The estimated coefficients of the variable "Limited Liability" confirm the hypothesis that firms with limited liability achieve significantly higher growth rates than firms in which the founders are liable with their own personal fortune. The underlying assumption is a comparatively higher willingness to risk among founders who, in case of failure, are only liable with a limited amount of their own capital (Stiglitz and Weiss, 1981; Harhoff et al., 1998; Woywode, 1998).

Start-ups with tight links to external firms ("Subsidiary/Affiliated Firm") show significantly higher growth rates on average than firms which are entirely independent (Geroski, 1995). This holds for firms in "Medium-Tech Industries" as well as for non-innovative firms in "Other Manufacturing", indicating that additional support, e.g. know-how, capital or networks, is provided. In contrast, no significant effects come up with respect to the degree of product and process diversification ("Diversification").

In addition to firm-specific factors, founder-specific characteristics also contribute to the explanation of the growth of NTBFs and young non-innovative firms. The hypothesis that firms founded by a term ("Team-Foundation") achieve higher growth rates than firms established by a single person, is only confirmed in "Other Manufacturing". In contrast, no statistically reliable statement regarding the compensation of potential know-how deficits of the founders can be made (Eisenhardt and Schoonhoven, 1990; Reynolds, 1993). The importance of individual abilities and skills of the founders is clearly illustrated in the positive correlation between technical degrees ("Skills_Tec") and growth of NTBFs and of young non-innovative firms, whereby the influence has to be interpreted in relation to the basis category of other degrees (e.g. medical degrees, teachers, civil servants). Business skills ("Skills_MBA") only have significant positive effects on the growth of non-innovative firms. Surprisingly, complementary technical and business knowledge ("Skills_Tec & MBA") shows no significant influence on the growth of firms at all (Almus and Nerlinger, 1998; Nerlinger, 1998). The appearing differences between the technology sectors express the economic and technological emphasis of NTBFs and prove the importance of technological knowledge and human capital for their development.

The U-shaped relation between the population density of the 327 counties in West Germany ("Inhabitants/km^2", "(Inhabitants/km^2)^2") and the growth of firms seems to contradict the *a priori* hypothesis. It has been assumed that up to a critical threshold, advantages directly linked with the increasing density have a positive impact on growth. After this threshold, the advantages are expected to become exceeded by disadvantages deriving from a high population density. However, the regression results are only significant for the "High-Tech Industries", whereas the estimated parameters in the other two technology sectors are insignificant.

Apart from the structure of the counties, the average wage and salary rate of the counties is used to contribute to the explanation of growth. This cost factor only has a negative influence, on the growth of non-innovative start-ups, whereas no significant correlations show up with respect to NTBFs. Against this background, it can be suspected that this cost factor has only a minor influence on the growth of NTBFs, whereby variations in the level of the wage rate might also reflect variations with respect to the regional degree of existing human capital (Nerlinger, 1998).

6. Growth rates in comparison

Based on the theoretical growth models discussed, innovative and non-innovative firms can be assumed to start with a suboptimal size and have to grow in order to reach a minimum efficient size. In contrast to start-ups with traditional products and processes, innovative young firms offer new or improved products. According to Markusen et al. (1986), Roberts (1991), and Storey and Tether (1996, 1997), the products of innovative start-ups can be characterized by a high degree of specialization and technological complexity and therefore operate in market niches with a limited number of clients and in markets in early development stages. This might result in low growth rates of innovative firms because they have to convince potential clients from the benefits of the new products or processes. Moreover, the first products of various firms are still in early development stage, far away from being sold (Roberts, 1991; Storey and Tether, 1996). It can therefore be assumed that an increase of new jobs in innovative start-ups is comparably low in the first years of existence. Several well-known examples like SAP or MICROSOFT contradict this assumption, however, though they represent the famous needle in the haystack and can therefore not be regarded as representatives of young innovative firms (Licht and Nerlinger, 1997; Storey and Tether, 1997). The empirical results of Hunsdiek and May-Strobl (1986), Kulicke et al. (1993) and Nerlinger (1998) for innovative young firms in Germany, however, indicate higher growth rates compared to the ones of non-innovative firms. This is mainly explained by founder-specific characteristics. According to Licht and Nerlinger (1997) and Storey and Tether (1997), the majority of founders of innovative firms have an excellent educational and professional background, especially in technical, engineering and IT disciplines which enables them to weigh the risks and chances of becoming self-employed.[10] This argument is partly confirmed by the low failure rates of innovative young firms, indicating that these firms are susceptible to the market selection process (Storey and Tether, 1997; Almus and Nerlinger, 1998). Moreover, public and private promotion programmes towards innovative young firms offer financial help in order to overcome the cost-intensive development phase and speed up the time to market entry. However, a concluding hypothesis on whether innovative start-ups achieve higher growth rates than non-innovative ones or vice-versa can not be formulated (Nerlinger, 1998).

In order to evaluate differences in the average growth rates between innovative and non-innovative firm foundations, a pooled model is estimated in which separate effects of the three technology sectors are controlled for by the dummy-variables "High-Tech Industries" and "Medium-Tech Industries". The coefficients of these two variables have to be evaluated with respect to the reference category "Other Manufacturing". The results show that firms in both technology-intensive sectors achieve c.p. significantly higher growth rats than firms in "Other Manufacturing". Based on the results of the pooled model, separate expected average growth rates can be calculated for the firms in the technology sectors. The highest average annual growth rats are achieved by firms in "Medium-Tech Industries" (10.4%), followed by firms in "High-Tech Industries" (10.47%). Firms in "Other Manufacturing" achieve comparably low average growth rats (8.44%), indicating a lower growth potential than NTBFs. However, conclusions about the mid-term or even long-term employment effects cannot be derived because, on the one hand, differences in failure rates resulting in job losses have to be considered (Wagner, 1994; Gerlach and Wagner, 1997; Caves, 1998). On the other hand, indirect employment effects leading to a substitution of or an increase in the number of employees in already existing firms may also occur. Due to the lack of suitable data, the degree of complementary and substitution effects of young firms is hard to evaluate empirically. In order to get an impression of employment contribution of NTBFs, we refrain from indirect employment effects and compute the direct employment effect of a cohort of firms founded in 1989 and 1990, differentiated by technology sectors.

The results in Table III show clear variations between the three start-up cohorts with respect to their occurrence and average start-up size. These differences have an impact on the initial employment contribution in 1989/1990. Only 9.6% and 15.7% of all employees work in start-ups in "High-Tech Industries" and "Medium-Tech-

TABLE III
Empirical results on the employment development of firm foundations, differentiated according to technological sectors

	High	Medium	Low
Number of firm foundations (1989/1990)	979	1,449	7,220
Average size (1989/1990)	3.8	4.2	4.0
Employees in the cohort (1989/1990)	3,720	6,086	28,880
Number of surviving firms (1996)	519	787	3,560
Average annual growth rate (in %)[a]	10.47	10.49	8.44
Average size (1996)[a]	7.63	8.44	7.05
Number of employees in the cohort in 1996[a]	3,960	6,645	25,109
Employment change (1989/90 until 1996)	+240	+559	−3,771

High: High-tech industries; Medium: Medium-tech industries; Low: Other manufacturing.
[a] Based on the pooled bivariate Tobit-Model.
Source: ZEW-Foundation Panel (West), own calculations.

Industries" respectively, whereas the firm foundations in the "Other Manufacturing" account for 74.7% of the initial employment. In 1996, the share of employees in technology intensive industries increases due to higher survival rates. In addition, the above-average annual growth rates of NTBFs lead to a further positive impact, resulting in a positive overall effect of 240 employees in "High-Tech Industries" and 559 employees in "Medium-Tech Industries". In contrast, the comparably high mortality rates and low growth rates of non-innovative firms lead to a 13.1% decrease of initial employment to 25,109. This means that the job destruction due to firm closures as well as shrinking firms cannot be compensated for by the growth of the surviving firms.

The contrary is the case for the cohort of innovative start-ups. The high growth rates of innovative start-ups as well as their positive employment development are gaining in importance with respect to the economic development in the nineties. Both in technology-intensive sectors and in other manufacturing industries, high structural changes and adoption processes occurred (Gehrke et al., 1997). These changes had an unfavourable effect, especially on firms in industries like Aircraft and Spacecraft, Manufacture of Office Machines and Manufacture of Automobiles and Motors, which play a crucial role as clients for the products and processes of NTBFs. Taking these facts into consideration, it can be assumed that without the recessive phase, even higher differences between the growth and survival rates of innovative and non-innovative start-ups would occur.

The overall aggregate employment effects, however, are difficult to evaluate because it cannot be distinguished whether the new firms are complementary or substitutive to existing ones. Nerlinger (1998) assumes that the complementary and the substitutive effects are comparably weak with respect to NTBFs, which would lead to a higher aggregate employment effect. Moreover, the results show that NTBFs cannot be regarded as a short-term answer to unemployment. In the long run, their contribution may be of crucial importance, especially on a regional level.

7. Summary

The results of the growth regressions indicate strong correlations between growth rate, on the one hand, and firm-specific, founder-specific as well as external factors, on the other. It becomes obvious that large and mature firms have c.p. smaller growth rates than small and young innovative as well as non-innovative firms. Statistical tests lead to a rejection of "Gibrat's law", indicating a significant correlation between size and growth. Moreover, other firm-specific characteristics like legal form and formal links to other firms have an impact on the development of NTBFs. With respect to founder-specific characteristics, positive effects can be derived from the human capital of the founder(s). This holds especially true for technical disciplines whereas business knowledge plays a minor role. In addition to firm-specific and founder-specific characteristics, location-specific factors controlling for agglomeration effects and the industrial structure

in the West German counties have an impact on the growth of NTBFs. the results of the regressions indicate that NTBFs grow faster on average than non-innovative firms. Furthermore, NTBFs founded in 1989 or 1996 increase their initial employment until 1996, whereas firms founded in non-innovative industries suffer severe employment losses. Due to the small number of NTBFs, they cannot compensate for these employment losses, leading to a negative overall employment balance in the West German manufacturing sector for the cohort of firms founded in 1989 and 1990. Against this background, policy initiatives focussing on the stimulation of NTBFs as well as on their survival and growth chances can be regarded as appropriate.

Acknowledgements

Financial support form the German Science Council (DFG) within the main programm "Technological Change and Regional Development in Europe" (Technologischer Wandel und Regionalentwicklung in Europa) is gratefully acknowledged. We are indebted to Georg Licht, Richard Ferguson, Bruce Tether and an anonymous referee for detailed comments on an earlier version of this paper. All errors and omissions are, of course, our own.

Appendix

TABLE IV
Regression results of the selection equation (Probit-Model)

Endogenous variable: Existence of the average annual growth rate (0/1) Coeff. (*t*-value)	High	Medium	Low	Pooled
ln(size)	0.413**	0.218*	0.292**	0.273**
	(2.570)	(1.958)	(6.515)	(6.858)
$\ln(size)^2$	–0.065	0.045	–0.048**	–0.034**
	(–1.480)	(1.379)	(–3.614)	(–2.910)
ln(age)	2.343**	2.382**	2.323**	2.294**
	(8.439)	(12.149)	(32.656)	(35.699)
$\ln(age)^2$	–0.499**	–0.588*	–0.619**	–0.596**
	(–4.904)	(–7.840)	(–22.178)	(–23.806)
ln(size)*ln(age)	–0.013	0.002	0.103**	0.086**
	(–0.173)	(0.044)	(5.160)	(4.807)
Limited liability	0.466**	0.308**	0.377**	0.374**
	(6.840)	(5.721)	(16.125)	(18.630)
Subsidiary/affiliated Firm	0.008	–0.049	–0.101	–0.082
	(0.054)	(–0.460)	(–1.898)	(–1.817)
Team-foundation	–0.020	0.111*	0.048*	0.056**
	(–0.307)	(2.165)	(2.118)	(2.837)
Constant	–1.493**	–1.836**	–1.768**	–1.699**
	(–3.615)	(–5.106)	(–14.668)	(–15.533)
No. of Observations (N)	2,679	4,466	24,900	32,045
LR-Tests: χ^2 (df)				
Industries	4.86	8.48*	326.18**	321.80**
(df)	(2)	(2)	(8)	(8)
Vereine Creditreform	112.57	120.46	222.44**	260.34**
(df)	(99)	(106)	(104)	(107)

High: High-tech industries; Medium: Medium-tech industries; Low: Other manufacturing, Pooled: 'High-tech industries', 'Medium-tech industries' and 'Other manufacturing' together.
** Significant on the 1% level; * Significant on the 5% level.
Regressions contain dummy-variables for industries and local Vereine Creditreform (VC).
Source: ZEW-Foundation Panel (West), own calculations.

Notes

[1] The probability of getting actualized information depends on formal firm characteristics (e.g. legal form, size), on the demand for credit rating upon the firm as well as on the extent of economic relations to other firms (Harhoff and Steil, 1997; Nerlinger, 1998).

[2] Storey and Tether (1996) and Nerlinger (1998) also consider high-tech service sectors involving industries like software and technical consulting.

[3] Firm foundations in West Berlin are not taken under consideration due to the historic development and the a dearth of available data.

[4] Harhoff and Stahl (1995) and Nerlinger (1998) discuss various potential sources for selection biases in the ZEW-Foundation panel (West) in detail.

[5] A detailed description of the econometric model used is given in Almus and Nerlinger (1998).

[6] A detailed description of the derivation is given in Ronning (1991), Davidson and MacKinnon (1993) and Powell (1994).

[7] It has to be considered that the effects of the selection sources could interfere leading to an insignificant overall effect. This could, e.g., hold, if the effect of an overestimation of the growth rates caused by the classic 'survivor bias' is compensated for by a potential underestimation due to a higher inquiry probability of firms with only slight growth rates.

[8] Due to the small number of observations we did not compute elasticities for start-ups with 20–49 employees.

[9] The problem of endogeneity of the choice of the legal form is discussed in Harhoff and Stahl (1995) and Harhoff et al. (1996).

[10] However, experience in management issues like financing, controlling or marketing are rare (Gerybadze, 1991; Licht and Nerlinger, 19967; Storey and Tether, 1997).

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