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On the relationship between firm age and productivity growth

An empirical study into the relationship between productivity growth and firm age for established firms

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1 Introduction

1.1 Background

For young firms, a clear relationship exists between firm age and productivity. Various studies have shown that the productivity level of new firms is below the average level, while the productivity growth rate of (surviving) young firms is above average. During the first few years, the average level of productivity tends to increase while the average growth rate tends to decrease. For elder, established firms, the relationship between age and productivity becomes less clear. Established firms show on average a positive growth rate, but whether this growth rate is related to the specific age of these firms is not well established. It is nevertheless interesting to learn more about this relationship, since such a relationship would affect the interpretation of aggregate productivity indicators (and, hence, the choice for specific policy measures).

1.2 Objective and research questions

In this study we examine the relationship between the age of firms and their productivity growth, for establishes firms, where establishes firms are defined as firms of at least 10 years of age. Our research question is: to which extent are differences in productivity growth rates between individual firms related to firm age? To answer this research question, we will derive a number of hypotheses regarding this relationship. These will subsequently be tested by estimating regression equations to explain the productivity growth rate of individual firms. These regressions will be based on data from the Dutch manufacturing industry that cover all enterprises with at least 20 employees for the years 1994 - 1999.[1]

Both the choice of suitable indicators and the formulation of hypotheses require an understanding of previous research in this area. The next section therefore provides a brief overview of recent studies. Based on these findings, the research methodology will be developed in section 3. This includes a description of the available data set, the indicators that will be used, the regression equations that will be estimated and the hypotheses that will be tested. The next section presents the results, which are discussed in the final section.

[1] A previous and more elaborate account of the results of this study can be found in Brouwer et al. (2005)

2 Previous studies

2.1 Empirical findings

In general, economists are more interested in the development of productivity than in the level itself. This means that in many studies attention is directed towards productivity growth rates. When productivity levels are studied, they are usually compared to the average productivity level within an industry. When firms exhibit below average productivity levels, their productivity will have to grow, or they are likely to be forced to exit.

Bradford Jensen, McGuckin and Stiroh (2001) study productivity levels of different age cohorts. They find that new cohorts enter with productivity levels lower than that of incumbents, although new entrants exhibit higher productivity levels than earlier entrants did. At the same time surviving cohorts show increases in productivity levels over time. Taken together this leads to a convergence in productivity levels between different age cohorts. For entering cohorts they observe a convergence of productivity levels after five to ten years.

Similarly, Taymaz (2002) argues that new firms become aware of their actual productivity after observing their performance in the industry. If their performance is insufficient, they either grow or exit. New firms, which survive, experience higher productivity growth rates than existing firms. Taymaz (2002) also finds that productivity growth rates are negatively correlated with age and size of firms.

Huergo and Jaumandreu (2004) investigate the impact of firms' age and (process) innovations on productivity growth, using a semiparametric model. They find that firms, newly entering the market, show high productivity growth rates for a number of years. The productivity growth gradually declines over the first years of the firm's life to stabilise at a value which differs between activities (sector of industry). Substantial variation around the stable growth rate is observed, but shows no clear trend.

The results discussed so far suggest that productivity levels and productivity growth rates tend to converge. This implies that once firms are established, productivity is no longer related to firm age. However, some studies find support for a relationship between age and productivity for established firms as well.

For example, the study by Celikkol (2003) suggests that the oldest firms within a given industry show above average productivity growth rates. According to this study, which focused on the U.S. food and kindred products industry, older plants have higher productivity growth rates than younger plants. This positive relationship between age and productivity growth rates is usually attributed to the importance of selection effects, i.e. the best firms survive.

In contrast, Power (1998) finds a negative relationship between age and the growth rate of productivity, at a certain stage in the lifespan of organisations. She examines the relationship between productivity and plant age for plants in the U.S. manufacturing industry in the period form 1972 to 1988, and finds that productivity growth rates decrease with age (attributed to learning effects). In some cases, the growth rates even become negative. However, when looking at the level of productivity, she found productivity levels to increase monotonically with plant age.

Finally, Verhoeven, Kemp and Peeters (2002) find indications of a wave pattern in the level of productivity throughout the firm's lifespan. The most striking feature of the observed pattern is the decline in the level of labour productivity after 20 years and after 40 years.

2.2 Theoretical explanations

In the early stages of a firm's life, the relationship between age and productivity is for a large part driven by learning and selection effects. Once firms are older, the relationship may be more indirect, being the result of a correlation between firm age and changes in ownership/management, the size of the enterprise and product life cycles. These theoretical explanations are discussed in more detail below.

Learning

New firms generally enter their market with below-average productivity levels (Barnes and Haskel, 2000; Bradford Jensen, McGuckin and Stiroh, 2001). Within their first years of existence, they either learn how to adapt to the norms of their industry, or exit. A distinction can be made between active and passive learning (Farinas and Moreno, 2000). Passive learning refers to increases in the knowledge and know-how of an organisation that generally will be obtained without specific knowledge investments, due to learning by doing, learning by experience and learning by copying: "just staying in business increases the knowledge about their innate efficiency" (Farinas and Moreno, 2000, page 250). Active learning, on the other hand, refers to increases in the knowledge and know-how of individual organisations due to specific investments. This includes amongst others investments in research and development, leading to product or process innovations which improve productivity. Another example of active learning is investments in human capital: more attention for human resource management practices in general, and firm-provided training in particular, is often associated with increased organisational performance (Paauwe, 2004).

Although the learning effect is especially relevant during the first few years of existence (in order to catch up to the average productivity levels within the sector of industry), it continues to play an important role beyond these first years. The owner and/or the employees continue to gain experience, and firms can continue their investments in active learning activities. Majumdar (1997) notes that older firms are liable to experience some form of inertia. This may suggest that passive learning no longer automatically takes place when firms have reached a certain age.

Selection

Firms will not be fully aware of their productivity level until they actually start. Once started, the majority of new firms will find out that their productivity levels are not enough to generate profits. These firms will exit within a few years. Only the firms that are productive enough to generate (acceptable) profits will remain in business. While the productivity of individual firms remains constant in this simple selection model, the average productivity of a certain age cohort increases, because the firms with insufficient productivity levels cease to exist.

At aggregate levels, it is difficult to disentangle between learning and selection effects, since both result in relatively high growth rates for younger age cohorts. At organisational level, however, the differences are distinct: the learning effect suggests that individual firms will also show relatively high growth rates after their startup, while the selection effect suggests no such increase (but a relatively high exit rate for young firms instead).

Changes in ownership/management

During the life span of a firm, changes may occur in the ownership and/or management. These changes may be related to changes in the organisational structure, such as mergers, take-overs and divisions (or scissions). However, changes in ownership and / or management can also occur without changes in organisational structure. This occurs, for example, in the case of a management buy-out, the arrival of a new owner/manager in a small firm or the appointment of a new CEO of a large firm.

Changes such as these are likely to affect the way the firm operates, and therefore influence the productivity of the firm. In the short run the changes will often result in a temporarily slowdown (or even decrease) in productivity growth, due to organisational changes that occur when a new owner/manager is installed. The effects in the long run are largely dependent on how successful the changes are implemented (Boone et al., 1996; Dyck et al., 2002).

Huergo and Jaumandreu (2004) include dummy variables in their analyses to account for some sources in discrete changes in firms' efficiency levels (mergers, acquisitions, scissions). Mergers or acquisitions and scissions turn out to have a significant impact on productivity growth (with a one-year time lag). On average, the impact they report is positive for mergers or acquisitions and negative for scissions.

If the timing of changes in ownership/management is closely related to the age of firms, this could result in a (non-linear) relationship between age and productivity. However, the occurrence of changes in ownership/management is not likely to be strongly correlated with firm age. Only in the case of successions, it could be argued that this is more likely to happen in certain phases of the life of a firm: e.g. the first succession occurs when firms are 20-25 years of age, the second succession when they are 40-45 years of age, etc. Such a relationship between age and succession could explain the wave pattern in productivity levels that was reported by Verhoeven, Kemp and Peeters (2002). However, this reasoning implicitly assumes a strong relationship between the age of the firm and the age of its owner / manager. While the rate of nascent entrepreneurship (the share of people currently involved in starting a new business) indeed tends to be highest at the age group between 25 and 34 years of age, actual startups occur in all age groups (Wennekers, 2006, page 123). Similarly, the age at which the entrepreneur wants to hand over his/her firm may vary quite a lot. This implies that firm age at the moment of succession is likely to show a large variation, which makes it less likely that at meso or macro level a clear wave pattern can be identified.

Firm size

Productivity levels are likely to be correlated with the size of the firm, as measured by the number of employees. In general, smaller firms will organise the production process differently than larger firms. An increase in firm size is, initially, expected to have a positive effect on productivity levels, due to economies of scale (and scope). However, when a firm grows beyond a certain size diseconomies of scale may have a dominating effect, thereby negatively influencing productivity levels of the firm.

Especially for younger firms, age and size tend to be positively correlated. Thus, a relationship between productivity and firm age may be partly due to a correlation between firm age and size, and a causal effect of size on productivity.

Product life cycle

The productivity and performance of individual firms will be strongly related to the characteristics of the sector in which they are active. This effect can amongst others be explained by product life cycle theories. Young sectors bring new products to the market. Firms tend to focus on product innovations (Klepper, 1996) and low competition results in relatively high margins. Under these market conditions, firms are likely to experience high productivity growth rates. As sectors become more mature, competition becomes stronger and innovation activities are likely to shift towards process innovations (Klepper, 1996). Mature sectors may therefore show a slowdown or even negative productivity growth. Some sectors may innovate and reinvent their product, or come up with entirely new products. By increasing their attention for product innovations, these sector enter a new phase of the product life cycle and exhibit increases in productivity growth rates again. Sectors failing to enter this new phase will eventually vanish, or continue on a marginal level.

As different sectors of industry are in different phases of the product life cycle, at a given point in time, average productivity levels and productivity growth rates will vary between sectors. This sector effect is indeed found in various empirical studies. Huergo and Jaumandreu (2004), for instance, indicate that productivity growth stabilises at a value which differs between activities (sector of industry). Also, Power (1998) shows that the relationship between productivity and plant age varies across industries.

If average productivity differs between sectors, then average productivity may also vary with age (at the aggregate level). This would occur, if the age distribution of enterprises would differ between sectors. If young firms would typically be active in sectors with relatively high growth rates, the average productivity growth rate would be relatively high for young firms. This argument assumes that product life cycles that can be identified at sectoral level, also exist at the level of individual firms. It is not clear, however, how accurate this assumption is. For individual firms, the development of productivity over time is related to the specific life cycles of its own products. So, even if it is possible to identify a general product life cycle at sectoral level, there can still be a large variation in the product life cycles at the level of individual firms.

2.3 Conclusions

In the literature, there seems to be consensus about the relationship between age and productivity for young firms (i.e. up to the first 10 years of their existence). It is generally found that new firms enter with relatively low productivity levels. If they are to survive they need to catch up with the existing firms, resulting in high productivity growth rates for surviving young firms (due to both learning and selection effects). These high productivity growth rates tend to decline with age to converge to a certain average productivity growth rate, similar to that of incumbent firms. These average levels vary between sectors.

However, when looking at the relation between age and productivity for elder firms, the findings in the literature are divers. The default assumption is that for these firms, age and productivity (level as well as growth rate) are no longer related. In some cases, however, it is found that older firms exhibit above average productivity growth rates. This can be explained by assuming that only relatively successful firms can survive long enough to reach this age. In other cases, a negative relationship between age and productivity growth rates is found for older firms. The argument here is that older firms are less flexible in adopting new technologies, are less innovative, etc. Power (1998) called this the inertia effect. Regarding age and the level of productivity, Verhoeven, Kemp and Peeters (2002) observed a more elaborate wave pattern. Here, productivity levels generally increase with age, but show a distinct decline at certain age cohorts.

3 Research methodology

In this section we specify the equations and present the hypotheses to be tested, which is followed by a discussion of the available dataset, the measurement of the age of firms, and the estimation procedure. First, however, we discuss the indicators for productivity growth that we will use.

3.1 Indicators for productivity growth

The productivity level of firm i in year t can be defined as follows:

$$\text{Productivity}_{i,t} = \frac{\text{real output}_{i,t}}{\text{real input}_{i,t}} \qquad (1)$$

and the productivity growth rate is defined as

$$\text{Productivity growth}_{i,t} = \left(\frac{\text{productivity}_{i,t} - \text{productivity}_{i,t-1}}{\text{productivity}_{i,t-1}} \right) \cdot 100\% \qquad (2)$$

In order to operationalize this concept, both the input and output of the production process have to be defined. Two commonly used output indicators are gross production and value added. Regarding the input of the production process, we are not interested in the productivity of specific production factors; instead, we want to relate the output of the production process to all production factors involved (capital, labour and resources), i.e. total factor productivity. The resulting two productivity indicators that we use in this study are therefore total factor productivity of production and total factor productivity of value added. A description of the various input and output variables is included in table 1.

Productivity growth is usually analysed within a production function framework, where output is defined as the product of the outcomes of some production function (often Cobb-Douglas) and an efficiency parameter. This efficiency parameter may be linked to e.g. technological progress, experience, or learning by doing. Under the assumption of profit maximising behaviour by organisations, it is possible to decompose the growth of total factor productivity into technological progress (a shift of the production function) and returns to scale (a movement along the fixed production function) (Diewert and Nakamura, 2003).

Production functions can be assumed to be identical for all firms (see e.g. Barrios and Strobl, 2004), or to vary between firms (see e.g. Huergo and Jaumandreu, 2004). However, it is customary to assume they are constant over time for individual firms (apart from any technological progress). In other words, if firms grow older their general production function remains the same. The only thing that may change is the efficiency of the production process. Especially when firm age enters the equation, the validity of this assumption may be questioned. Small, young firms organise their production processes in different ways than larger, more mature firms. As firms grow older and / or become larger, their production process may be subject to fundamental changes, either because of new insights regarding the organisation of the production process or because of fundamental changes in the production technologies used.

table 1 Elements from productivity indicators

Variable	*Description*	*Deflator used*[1]
production	production value	price index turnover (1-digit SBI level)
value added	gross value added	price index turnover (1-digit SBI level)
Labour costs	Gross labour costs for employees, plus a fictive wage of € 45.400 for the entrepreneur (in the case of firms other than private or public limited enterprises).	price index labour costs (index of annual average labour costs/employee, defined at 3-digit SB(level)
Capital costs	Costs of depreciation	price index intermediate goods (1-digit SBI level)
Resource costs	Costs of energy, materials and services (e.g. housing)	price index intermediate goods (1-digit SBI level)

[1]: Price indices of turnover and intermediate goods are based on National Accounts; price index for labour costs is based on Production Surveys

In this study we treat productivity growth rates as statistical indicators of changes in the ratio between the inputs and the output of individual firms. We do not make any assumptions regarding the underlying production processes or production functions. Consequently, we cannot decompose productivity growth into technological progress and returns to scale.

3.2 Model and hypotheses

We estimate a regression equation where the productivity growth rate of firm i in year t ($GY_{i,t}$) is related to age, controlling for size, changes in the organisational structure and sector (equation 3).

$$\begin{aligned} GY_{i,t} = C &+ \varphi \cdot y\_rel_{i,t-1} + \beta_1 \cdot \log(age)_{i,t} + \beta_2 \cdot \log^2(age)_{i,t} + \beta_3 \cdot \log(wages)_{i,t} \\ &+ \gamma_1 \cdot int_{i,t-1} + \gamma_2 \cdot sep_{i,t-1} + \gamma_3 \cdot reorg_{i,t-1} \\ &+ \delta_1 \cdot text_{i,t} + \delta_2 \cdot publ_{i,t} + \delta_3 \cdot chem_{i,t} \\ &+ \delta_4 \cdot metal_{i,t} + \delta_5 \cdot mach_{i,t} + \delta_6 \cdot other_{i,t} + \varepsilon_{i,t} \end{aligned} \qquad (3)$$

Size is measured by the log of total wages[1], changes in the organisational structure are represented by three dummies indicating whether an integration (int), separation (sep) or reorganisation (reorg) occurred, and sectors are represented by including six sector dummies indicating different sectors within the manufacturing industry. The learning effect suggests that a relatively low *level* of productivity in the previous period may result in a higher productivity *growth rate* in the current period, hence we also include the (log of the) relative productivity

[1] We prefer to use wages rather than number of employees to indicate firm size, since the number of employees is only available for a specific point in time, while wages refer to the

level in the previous period (relative to the average level of productivity within each sector; $y\_rel_{i,t-1}$) as an explanatory variable.

We will test the null hypothesis that the estimated parameters do not differ significantly from zero. We expect the following results:

1 A relatively low *level* of productivity in the previous period will be associated with a higher productivity *growth rate* in the current period ($\phi < 0$).
2 For established firms, there is no relationship between age and growth rate of productivity ($\beta_i=0$ for i=1, 2). We neither expect an above average performance for older firms ($\beta_i \geq 0$), nor a below average performance for older firms ($\beta_i \leq 0$).
3 The average growth rate of productivity is not related with firm size ($\beta_3 = 0$).
4 Changes in ownership / management that are associated with structural changes have a negative effect on the growth rate of productivity ($\gamma_i = 0$ for i=1,2,3).
5 The average growth rate of productivity differs between sectors (not all parameters δ_i will be equal to zero).

Although we expect to find a negative relationship between productivity growth rate and the lagged productivity level, we cannot conclude from this that a learning effect is indeed present. A negative relationship may also be (partially) due to regression to the mean. This occurs if the productivity levels (from which the growth rates are determined) are observed with uncertainty (which will certainly be the case). In this case, low observed productivity levels in the previous year are partly due to measurement errors. For these firms, their average productivity levels in the current year are expected to be closer to the average for all firms than their average in the previous year was. This results in above average productivity growth rates. However, if we do not find a negative relationship between productivity growth rate and the lagged productivity level, we may conclude that there is no indication of a learning effect.

3.3 Available data

Data sources

Two different data sources from Statistics Netherlands have been used: the Production Surveys of the manufacturing industries (PS) and the General Business Register (GBR). The statistical unit in these data sources is the firm, considered to be the actual agent in the production process.

The key sources for the productivity indicators are the Production Surveys of the manufacturing industries. These surveys obtain annual data on turnover, costs, profit etc. for a large sample of firms whose main economic activity belongs to one of the following sectors (which together define the manufacturing industry):

- Food and tobacco industry
- Textile, clothing, wood industry
- Publishing, printing, reproduction industry
- Chemical, oil, artificial material industry
- Metal industry
- Machine, apparatus industry
- Other industries

We use data from the period 1994 – 1999. During this period, the Production Surveys targeted all firms with at least 20 employees and a sample of firms with less than 20 employees. Because of this sampling procedure, the Production Surveys contain relatively few firms with less than 20 employees for which observations for two consecutive years are available. Consequently, there is only limited information available about productivity growth rates for these small firms. We have therefore decided to leave firms with less than 20 employees out of this study.

After linking the Production Surveys with the General Business Register, valid observations on firm age are available for about 6.300 firms for each year (table 2). However, we need information on two consecutive years in order to determine productivity growth rates. The samples that can be used for these analyses are considerably smaller (table 2). This is mainly due to the fact that firms are not always present in two consecutive years of the PS. In addition, it is not always possible to obtain valid and reliable information about all productivity indicators. This further reduces the number of valid observations.

table 2 Valid observations from the Production Surveys for the Manufacturing Industries

Sample	*Year*				
	1995	*1996*	*1997*	*1998*	*1999*
Valid observations on firm age (for year t)	6.271	6.230	6.232	6.307	6.485
Valid observations for firm age and level and growth rate of productivity (for years t-1 and t)	4.398	4.329	4.305	4.431	4.586

Taken together, the resulting samples form an unbalanced panel. Entry and exit of firms from this panel may be due to entry and exit from the market, but also due to temporary unavailability of valid and reliable observations. The distribution of the sampled firms across sectors and size classes doesn’t change much over the measurement period. The average structure of the samples is presented in table 3.

Measurement of firm age

Available information about the age of firms reflects the age of the current legal entity. For our study we are interested in the economic age of firms (i.e. how long the production process is in operation). In some cases, the legal age may underestimate the economic age. This is for example the case if a firm is created by a merger between existing firms. Whereas the legal age may be one year, the economic age of the newly created firm is much older. The opposite effect can also occur: if an existing firm takes over a younger firm, the age of the existing firm will be adjusted downwards to incorporate the lower age of the newly added business unit.

We correct for this problem by taking into account available information about mutations in the legal status of firms. This information is available through the GBR from 1993 onwards. In case of integration (merger or take-over), the birth date of the new, integrated firm has been recalculated as the weighted average of the years of birth of all firms involved. The weights are determined by the relative number of employees of each of these firms.

table 3 Distribution of sampled firms over sectors and size classes (1994 - 1999 average)

Sector	*Share (%)*	*Size class (nr. of employees)*	*Share (%)*
Food and tobacco	13,4	20 to 50	49,2
Textile, clothing and wood	11,1	50 to 250	42,8
Publishing, printing and reproduction	9,6	250 and more	8,0
Chemical, oil and artificial material	11,5		
Metal	18,2		
Machine and apparatus	26,1		
Other	10,1		
Total	100		100

Source: different samples from the PS with valid observations for firm age and productivity (for years t-1 and t)

Integrations do not occur often. Each year, an average of 2,7% of the firms in our sample is involved in an integration (table 4). However, these integrations have a cumulative effect on the recalculation of firm age. For example, for firms in the 1995 PS, a two-year mutation history is available from the GBR. During these two years, 4,5% of the firms may have been involved in a merger or take-over, resulting in a recalculation of their age. For firms in the 1999 PS, the history of mutations has increased to six year, and firm age may be recalculated for 15,1% of the firms in the sample. The cumulative nature of the recalculations of firm age imply that the quality of (one of the main variables in) our dataset is higher for more recent years.

table 4 Firms in the Production Surveys involved in mergers or take-overs

	'94-'95	*'95-'96*	*'96-'97*	*'97-'98*	*'98-'99*
Sample size	4.398	4.329	4.305	4.431	4.586
Firms involved in integration					
absolute	81	172	107	109	125
relative	1,8%	4,0%	2,5%	2,5%	2,7%

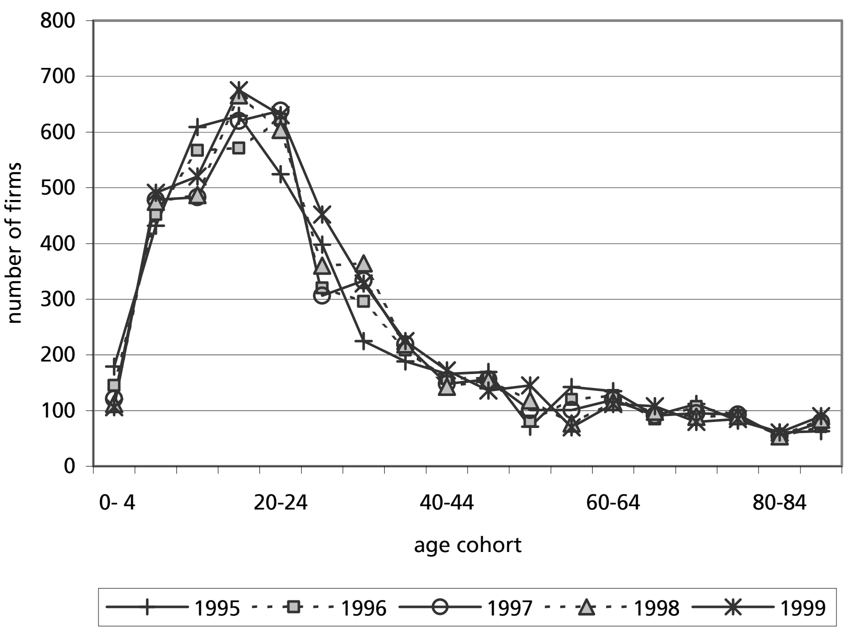
Source: own calculations, based on PS and GBR.

Based on firms for which valid observations are available for two consecutive years. The number of firms involved in integration only refers to the first year of each period.

Finally, for practical reasons, firm age has been truncated at the age of 85. The number of firms that are more than 85 years of age is relatively limited. Truncating their age at 85 will prevent these observations from exerting a too strong influence on the outcomes of the regression equations that we estimate.

The resulting distribution of firms over age cohorts is very similar for the different years of observation (figure 2). For each year, the age cohorts 10-14, 15-19 and 20-24 have the most observations (28% of all firms). Recall that our sample only includes firms with at least 20 employees. Most firms start with less than 20 employees and need a few years to reach this threshold (if they reach it at all). This probably explains the low share of the youngest age cohort and the rapid increase of the share of the following three to four cohorts in our data set. This is one of the reasons why we have excluded the youngest two age cohorts (0-4 and 5-9 years of age) from our analysis.

figure 1 Number of firms per age cohort, for different years



Source: Statistics Netherlands

For the following four age cohorts (25 – 45 years of age), the number of firms in our sample decreases sharply with each cohort. This decrease is likely to reflect decreasing shares in the actual firm population. This decrease might be the result of differences in the entry of firms over time (i.e. a sharp increase in the annual number of new firms during the period 1960 – 1980). However, it seems more likely that this decrease is caused by differences in the exit rate of firms between age cohorts. Exit may be caused by insufficient profitability, but also (especially in the case of firms with a single owner/manager) by succession problems.

3.4 Estimation procedure

With the available data we can estimate equation (3) for two different indicators of productivity growth rates and for different years. Arguments can be made to limit the estimations to the most recent observation year, but it can also be argued that the estimations should include all available years. To start with the latter arguments: estimating over a longer period of time renders the results less sensitive for fluctuations of the business cycle. In addition, using more observations results in more precise estimation results. On the other hand, the quality of the available information about the economic age of firms is highest for the most recent period. Since the objective of this paper is to examine the relationship between firm age and productivity, we consider it more important to strive for an optimal measurement of firm age than to try to limit any business cycle effects. As a compromise, we will estimate the regression equations for all individual years, but will pay most attention on the results for the most recent year.

We estimate equation (3) separately for five consecutive years (1995 – 1999), using ordinary least squares. We report the results for the most recent year (t=1999) and average parameter estimates for all years (t=1995 to 1999). These average parameter estimates $\overline{\beta}$ are calculated as the unweighted average of the parameter estimates β_t that result from estimating the equations separately for the available periods. Assuming that estimates for different periods are independent of each other, the standard deviations σ_{β} of the average parameter estimates are calculated as a function of the standard deviations σ_t of the individual parameter estimates, according to the following formula:

$$o_{\beta} = \sqrt{\frac{1}{n^2} \cdot \sum_t \sigma_t^2} ,$$

where n=5 refers to the number of periods for which separate estimation results are available.

4 Results

The results in tables 5 and 6 show that productivity growth rates differ between sectors, and that a relatively low level of productivity in the previous period is associated with a high growth rate. We cannot tell, however, to which extent this effect is due to a learning effect, and to which extent it is the manifestation of the regression to the mean fallacy.

More importantly, the results support our expectations that after the start-up phase of enterprises (the first 10 years of their existence) there is no relationship between firm age and productivity. This applies to all four equations presented here. These findings do not change if more elaborate analyses are performed. In Brouwer et al. (2005) we examine the same data set, using additional indicators for productivity growth[1], and including various age dummies (e.g. whether firms are at least 20 years of age or 40 years of age). Also here, we find no indication of a relationship between firm age and productivity for firms of at least 10 years of age.

Contrary to our expectations, we find no indication that changes in the organisational structure of firms have an observable effect on the growth rate of productivity. Changes in the organisational structure are no prerequisite for changes in ownership and / or management. Management buy-outs of private or public limited enterprises, the arrival of a new owner/manager in a small firm or the appointment of a new CEO of a large firm are examples which do not require structural changes. Since we have no information on the occurrence of these types of owner/management changes, we cannot test for their impact on productivity growth rates.

The results discussed so far do not depend on the estimation period: the conclusions are the same, whether we look at the parameter estimates for 1999 (table 5) or at the average parameter estimates for the years 1995 - 1999 (table 6). Regarding the effect of firm size, this doesn't apply. The estimation results for 1999 suggest a (significant) negative relationship between size and productivity growth rate, but the average parameter for the period 1995 - 1999 is smaller in size and no longer significantly different from zero (table 6). Since measurement of firm size is not more accurate for more recent years (as is the case with firm age), the results over the full period are likely to be more robust than the results for a single year. We therefore conclude, based on the results of table 6, that firm size is not related to productivity growth.

[1] Brower et al. (2005) also look at labour productivity.

table 5: OLS regression results for the growth rate of total factor productivity (1999)

Variable	*total factor productivity of value added*		*total factor productivity of production*	
	beta	*standard error*	*beta*	*standard error*
Intercept	14,55	11.20	13,88 **	3.77
$Y\_rel_{i,t-1}$	-6,33 **	0.87	-10,69 **	0.78
log(age)	1,31	6.72	0,34	2.23
log²(age)	-0,26	0.99	-0,04	0.33
log(wages)	-1,16 **	0.34	-0,41 **	0.11
Integration [1)]	0,04	2.16	0,26	0.72
Separation [1)]	-0,29	2.87	-1,14	0.95
Reorganisation [1)]	6,09	6.23	2,94	2.07
Textile [1)]	-8,99 **	1.41	-3,22 **	0.47
Publishing [1)]	-7,72 **	1.48	-2,74 **	0.49
Chemical [1)]	-7,29 **	1.39	-4,96 **	0.46
Metal [1)]	-4,82 **	1.25	0,49	0.42
Machine [1)]	-7,27 **	1.17	-2,41 **	0.39
Other [1)]	-5,61 **	1.43	-2,50 **	0.47
adj. R2	0.028		0.101	
Valid observations	3971		3971	

[1)] *dummy variable*

Note: the sample consists of firms of at least 10 years of age, with at least 20 employees

*: significant at 5% confidence level

**: significant at 1% confidence level

table 6: OLS regression results for the growth rate of total factor productivity (1995-1999)

Variable	*total factor productivity of value added*		*total factor productivity of production*	
	beta [2]	*standard error* [2]	*beta* [2]	*standard error* [2]
Intercept	11,04	11,51	12,08 **	3,78
$Y\_rel_{i,t-1}$	-10,04	0,90	-12,38 **	0,84
log(age)	2,73	6,52	1,12	2,23
log²(age)	-0,44	0,96	-0,14	0,33
log(wages)	-0,43	0,35	-0,16	0,12
Integration [1]	0,31	2,11	0,27	0,71
Separation [1]	1,50	2,95	0,39	1,08
Reorganisation [1]	-1,38	63,71	-0,58	7,37
Textile [1]	-3,43 *	1,42	-1,45 **	0,46
Publishing [1]	-2,77	1,52	-1,32 **	0,48
Chemical [1]	-1,42	1,44	-1,35 **	0,45
Metal [1]	-1,20	1,45	-0,30	0,41
Machine [1]	-1,87	1,22	-1,14 **	0,39
Other [1]	-2,56	1,47	-1,30 **	0,47
Average adj. R2 [2]	0,041		0,103	
Valid observations	19092		19092	

[1] *dummy variable*

[2] *average of the results for the five different periods*

Note: the sample consists of firms of at least 10 years of age, with at least 20 employees

*: significant at 5% confidence level

**: significant at 1% confidence level

5 Discussion and conclusions

The productivity of new firms that just entered a market tends to be lower than average. In the first few years after entering the market, these firms either catch up with the more mature firms or they exit. Both effects result in an above average growth rate of productivity. It is important to keep this relationship in mind when interpreting the developments of productivity at meso or macro level. After all, it matters whether the aggregate level of productivity decreases due to an increase in the share of start-ups, or because a majority of existing firms suffers from a productivity decrease.

Likewise, it is relevant to know whether age and productivity are still related to each other once firms have survived the first 10 years. Some studies have found that older firms tend to have above-average productivity growth rates, while others found an opposite relationship. Nevertheless, the general consensus is that for older firms, age and productivity are unrelated to each other. This is not to say that individual firms have a constant productivity growth rate over time. On the contrary: at the level of individual firms, the development of productivity over time is far from constant. Level and growth rate of productivity will vary with the phase of the life cycle of the products of the firm. Changes in the ownership and / or management of the firm also affect productivity. These changes are usually initiated to increase the productivity in the long run (even though they are likely to have negative short run effects). However, the timing of product life cycles and changes in ownership and/or management are likely to vary between firms. Consequently, there are no strong theoretical arguments to assume a relationship between productivity and firm age.

The results of our study are in line with the general consensus. We found no indications of a relationship between age and productivity for the Dutch manufacturing industry. Our results show that productivity growth rates differ between sectors, and we find a negative relationship between productivity growth and the relative level of productivity in the previous period. This may be explained by a learning effect, but may also be due to regression to the mean. These findings support the idea of a sector-specific equilibrium growth rate (which could be related to market structure, institutional settings, technological developments etc), with a considerable variation of individual firms around this equilibrium.

Limitations

The current study has not fully exploited the panel structure of the available dataset. Estimation techniques that explicitly take account of this structure, such as panel data or multilevel estimation techniques are more efficient. We doubt, however, whether the usage of these techniques would lead to different conclusions. The relative inefficiency of our procedure (estimating various cross-sectional samples) is countered by the large number of available observations.

A more important limitation of the current study is that we only included continuing firms. One of the consequences of this choice is that we are not able to examine the relevance of selection effects. The distribution of the number of firms by age cohorts shows a steep decline in the number of firms between 25 and 45 years of age, which suggests that the exit rate of firms may be related with firm age. It can be argued that, in the last few years prior to actually exiting the markets, these exiting firms show a below-average level and growth rate of productivity. This argument suggests a negative relationship between age and productivity. Since we have not found such a relationship, it is tempting to conclude that this prior-to-exit effect is not very substantial (if it exists at all). However, without explicitly modelling the exit process, this conclusion cannot be substantiated. Future research should therefore model the exit process.

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