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Can firm age account for productivity differences?

A study into the relationship between productivity and firm age for mature firms

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1 Introduction

Background

The productivity of enterprises is an important indicator, for individual enterprises as well as for policy makers. For individual firms, their productivity is a main determinant of their performance, while the aggregate productivity is one of the main determinants of economic growth.

Changes in aggregate productivity are not only caused by changes in the productivity of existing firms, but also by entry and exit of firms (Balk and Hoogenboom- Spijker, 2003). 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. Thus, an increase in the levels of entry will have a negative effect on the aggregate level of productivity, and a positive effect on the aggregate growth rate of productivity. The total combined effect of entry and exit on aggregate productivity is, however, less easy to determine. This is due to the loss of productivity from the exiting firms, and the effect of entry and exit on the productivity of other firms (Kemp, Nieuwenhuijsen and Bruins, 2002). Nevertheless, there are indications of a positive effect (Bosma and Nieuwenhuijsen, 2002).

For young firms, a clear relationship exists between firm age and productivity. Elder firms show on average a positive growth rate, but whether this growth rate (or the level of productivity) is related to the specific age of these elder 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). For example, a recent study by Verhoeven, Kemp and Peeters (2002) suggests that productivity levels are below average for firms of 20 – 25 years of age and 40 – 45 years of age. A possible explanation for this pattern could be that firms in these age cohorts are relatively often confronted with succession problems, which could have a negative effect on their productivity. In such a case, a reduction in the growth rate of productivity within each age cohort would have a similar effect on the aggregate growth rate as an increase of the share of firms of 20-25 years of age, but policy implications would be very different.

Objective and research questions

In this study we examine the relationship between the age of firms and the level and growth rate of productivity, focusing on firms of at least 10 years of age. For these firms, we will examine the following two research questions:

How does the distribution of firm productivity (as characterised by mean and standard deviation) change over age cohorts?
To which extent are differences in productivity between individual firms related to firm age?

To answer the first research question, we will present figures that show how different indicators for level and growth rate of productivity differ between age cohorts. These figures will be based on data from the Dutch manufacturing industry that cover all enterprises with at least 20 employees for the years 1994 - 1999.

To answer the second research question, we will derive a number of hypotheses regarding this relationship. These will subsequently be tested by estimating regression equations to explain level and growth of productivity of individual firms.

Both the choice of suitable indicators and the formulation of hypotheses require an understanding of previous research in this area. The next chapter therefore provides a brief overview of recent studies. Based on these findings, the research methodology will be developed in chapter 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. Chapter 4 discusses the results, after which the final chapter presents the main conclusions.

2 Previous research

2.1 Introduction

This chapter provides a brief overview of previous empirical findings on the relationship between firm age and productivity. This overview is followed by relevant insights about the causes of this relationship. First, however, we have to be more precise about the definition of productivity.

Generally speaking, productivity is concerned with the ratio of inputs and outputs in the production process: how much output is generated with the available production factors. In order to operationalize this concept, both the input and output of the production process have to be defined. Regarding the production factors, productivity can be defined regarding a specific production factor (e.g. labour) or regarding all production factors (total factor productivity). Regarding the output of the production factors, two commonly used output indicators are gross production and value added (see e.g. Balk and Hoogenboom – Spijker (2003) for a detailed discussion on measurement of productivity).

In this study we look at labour productivity as well as total factor productivity, while production is measured by gross production as well as value added. This implies that both regarding level and growth rate of productivity, we will use four different indicators. The reason for this is that we want to determine if our hypotheses are sensitive for the way in which productivity is measured.

2.2 Empirical findings

Productivity is not constant throughout the lifetime of a firm. Several empirical findings indicate a relationship between age and productivity. When looking at empirical results it is important to make a distinction between *productivity levels* and *productivity growth rates*. 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[1] 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 for firms that survived the first ten years, productivity is no longer related to firm age. However, some studies find support for a relationship between age and productivity for these surviving firms.

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.

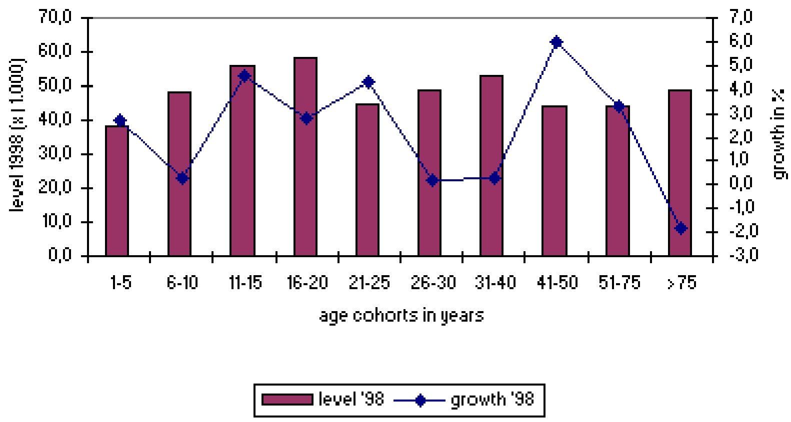
In contrast, Power (1998) finds a negative relationship between age and the growth rate of productivity, at a certain stage in the lifespan of organisations. She examines the relationship between productivity and plant age for plants in the U.S. manufacturing industry in the period form 1972 to 1988, 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[2].

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 (see figure 2). This is an interesting feature that could well be relevant for policy makers. However, policy measures aimed at specific age cohorts are only useful when the observed patterns are consistently found in various studies. If different studies indicate turning points at different ages, no meaningful policy recommendations can be drawn from empirical results.

[1] The period that new firms exhibit above average growth rates, tends to be 8 years for the various Spanish industries studied by Huergo and Jaumandreu.

[2] After controlling for plant-level fixed effects; ignoring these fixed effects would result in a negative relationship for older firms.

figure 1 Level and growth rate of labour productivity 1998



Source: Verhoeven, Kemp and Peeters, 2002..

2.3 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 typically need time to accommodate to the situation within which they operate. They also have to assess how their performance relates to the performance of their competitors and in which ways performance needs to be improve. As Taymaz (2002) puts it: "new firms become aware of their actual productivity after observing their performance in the industry". This is consistent with the finding that new firms generally enter with productivity levels lower than that of incumbents (Bradford Jensen, McGuckin and Stiroh, 2001).

When the performance of new firms is below that of the existing firms in the market, the new firms need to catch up in order to be competitive. Because of this, it is to be expected that new firms will show higher productivity growth rates than existing firms. Hence, productivity growth rates are negatively correlated with firm age[1].

The learning effect continues beyond the first few years of a firm's existence. The owner and/or the employees continue to gain experience (learning by doing). However, Majumdar (1997) also notes that older firms are liable to experiencing some form of inertia, which may hinder the prolonging of the learning effect.

[1] Since for young firms, age and size are positively correlated, this also suggests a negative correlation between productivity growth rates and firm size.

Selection

As mentioned above, new firms learn in order to attain a level of productivity which is sufficient for their competitive position within the market. Firms that do not learn fast enough and are not able to catch up (or keep up) with the productivity growth rate in the market will be forced to exit (Taymaz, 2002).

This process is usually called the selection effect: firms with good performance survive, while firms that do not perform well exit. Barnes and Haskel (2000), for instance, observe that entry and exit mainly take place in the lower quintiles of productivity levels within an industry. While the selection effect does not influence productivity of surviving firms, it strengthens productivity growth for the industry as a whole.

Changes in ownership/management

During the life 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 or succession of a family 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 (Van Witteloostuijn, 2003). The effects in the long run are largely dependent on how successful the changes are implemented.

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 and stronger for scissions.

If the timing of changes in ownership/management is closely related to the age of firms, it may help explain a possible relationship between age and productivity. However, the occurrence of most of these changes 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 with the age of the owner of the firm. Data on starting entrepreneurs shows considerable variation in the age of the owner at the time they start their company[1]. 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.

[1] See e.g. EIM's BLISS database "starters and young companies panel".

Firm size

Productivity is likely 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 differ between age cohorts. This would occur, for instance, if the composition of age cohorts over sectors would differ between age cohorts. If firms in younger age cohorts would typically be active in sectors with relatively high growth rates, the average productivity growth rate would be relatively high for these age cohort. In contrast, the average productivity growth rate could be relatively low for elder age cohorts, if elder firms are more likely to be active in sectors with relatively low growth rates.

The above 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.

2.4 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 older 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. Powers (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 generally increases with age, but shows a distinct decline at certain age cohorts.

3 Research methodology

3.1 Introduction

Previous studies present a rather ambiguous picture of the relationship between age and productivity for older firms. The aim of this study is to increase our understanding of this relationship, by answering the two research questions as presented in the introduction for the Dutch manufacturing industry.

The first research question is how the distribution of firm productivity changes over age cohorts. We will answer this question by examining the mean and standard deviation of various productivity indicators over a range of age cohorts. Which indicators we will use, will be discussed in section 3.2.

The answer to this research question may indicate the existence of a relationship between productivity and firm age, at the level of age cohorts. Such a relationship may be the result of a relationship at the level of individual firms, but it may also be caused by differences in the composition of age cohorts regarding (e.g.) sector and size class. To disentangle these two effects from each other, the second research question focuses on the productivity of individual firms: to which extent are differences in productivity between individual firms related to firm age (controlling for sector and size class)?

To answer this second research question, we will estimate regression equations to explain the level and growth rate of productivity of individual firms. Section 3.3 presents the hypotheses we intend to test and the equations we will estimate. Following the existing literature on this subject, these hypotheses will focus on investigating which of the following three types of relationship can be supported by our sample:

1 above average performance for older firms;
2 below average performance for older firms;
3 a wave pattern in performance, related to age, with marked decreases in performance at 20 and 40 years of age,

where performance relates to both level and growth rate of productivity.

The data that is used for this study is taken from two data sources (Production Surveys and General Business Register) from Statistics Netherlands, concerning the period 1994 – 1999. The main characteristics of these data sets will be presented in this chapter[1].

3.2 Productivity by age cohorts

In this section we discuss how age has been defined, how productivity has been measured, and discuss the validity and reliability of the productivity indicators. First, however, we present some basic characteristics of the available dataset.

[1] Details can be found in annex I.

Data

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[1].

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 1)[2]. However, most analyses also require valid observations about productivity levels and growth rates. The samples that can be used for these analyses are considerably smaller (table 1). This is mainly due to the fact that firms are not always present in two consecutive years of the PS (which is required to determine productivity growth rates). In addition, it is not always possible to obtain valid and reliable information about all productivity indicators[3]. This further reduces the number of valid observations.

[1] A firm is characterised by its autonomy with respect to the production process and by the sale of its goods or services to the market. A firm can consist of one or more juridical units or can be part of a larger juridical unit.

[2] How firm age is determined will be discussed later on in this section.

[3] How productivity indicators are determined will be discussed later on in this section.

table 1 Valid observations from the Production Surveys for the Manufacturing Industries

	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 2.

table 2 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)

Age of firms

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[1].

Integrations do not occur often. Each year, an average of 2,7% of the firms in our sample is involved in an integration (table 3). 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%[2] 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 3 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. First of all, the number of firms in this age cohort is relatively limited. Also, this will prevent these observations from exerting a too strong influence on the outcomes of the regression equations that we estimate[3].

The resulting distribution of firms over age cohorts is very similar for the different years of observation[4] (figure 2). For each year, the age cohorts 10-14, 15-19 and 20-24 have the most observations (28% of all firms). For the following four cohorts (25 – 45 years of age), the number of firms decreases sharply with each cohort. 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

[1] A more detailed description of this procedure can be found in annex I.

[2] The annual share of firms involved in an integration can be interpreted as the probability than an individual firm from the PS sample is involved in an integration in a certain year. The probability of being involved in an integration since 1993 can then be calculated as 1 – Prob(never involved in an integration) = 1 – Prob(not integrated in 1993)*..*Prob(not integrated in t-1). The share of integrations in 1993 is estimated by the overall share of integrations for the period 1994 – 1999.

[3] The data contains a few firms that are well over 100 years old. In a regression equation where productivity is related to age, these few observations will have a relatively strong effect on the estimation outcomes.

[4] The correlations between the five years range from 0.95 to 0.99.

cohorts. Exit may be caused by insufficient profitability, but also (especially in the case of firms with a single owner/manager) by succession problems.

figure 2 Number of firms per age cohort, for different years

Source: Statistics Netherlands

Productivity indicators

Generally speaking, the productivity level of firm i in year t can be defined as follows:

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

Different choices regarding the measurement of the input and output of the production process result in different indicators for the level of productivity. For this study we will use two different output measures, and for each output measure two different input measures. This results in four different indicators (table 4). This allows us to determine if the choice for a specific indicator influences the answers to our research questions.

table 4 indicators for the level of productivity

Indicator	*Input*	*Output*
labour productivity of value added	labour	value added
labour productivity of production	labour	production
total factor productivity of value added	capital + labour	value added
total factor productivity of production	resources + capital + labour	production

Definitions of the input and output measurements, as well as deflators that have been used, are reported in the annex

For each indicator of the level of productivity, the accompanying growth rate is defined as follows:

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

Validity of the productivity indicators

It is not always clear whether the available statistical information represents the actual usage of production factors and the resulting output. This could be interpreted as a problem regarding the content validity[1] of the indicators. To take account of this problem, we use different measurements for production factors and output, resulting in different indicators. This doesn't improve the validity of the individual indicators, but it does allow us to determine to which extent our results are determined by the choice for a specific indicator.

If, according to a certain indicator, a substantial number of firms would have a negative level of productivity, it would be difficult to interpret the associated growth rate[2]. The validity of the productivity growth rate indicator would then be insufficient. In theory, negative productivity levels are possible for indicators that represent output by value added, so we have examined if this occurs often. As it turns out, less than 1% of the firms in a specific year has a negative value added. These firms are left out of the analysis, but the number of firms is so low that this doesn't affect the overall validity of the associated indicators.

Reliability of the productivity indicators

Having discussed the validity of the indicators, we now turn towards their reliability. In other words, is the available statistical information measured correctly? How accurate is the available information about gross production and value added? Just as with the validity of the indicators, this is difficult to determine. We assume that the indicators follow a normal distribution, which a.o. implies that only a very small fraction of the observations (0,26%) should differ more than 3 standard deviations from the average. Furthermore, we assume that if an observation lies outside this interval, that it is more likely to represent an unreliable measurement than a reliable measurement of an exceptional firm. These firms are therefore also excluded from our analysis[3].

Most analyses will be performed on the same subset of firms, namely those firms for which valid and reliable observations for all relevant variables are available for two consecutive years. This may result in a loss of observations for individual analyses, but

[1] Content validity is about the question whether the content of a specific measure is representative of the content of the property being measured – in this case, the productivity.

[2] For example, suppose that in year t-1 the productivity for a firm equals –1, after which it increases to +6 in year t. This suggests a growth rate of 700%. At the same time, the productivity of another firms increases from–7 in year t-1 to +7 in year t. The growth rate for the second firm is calculated as 200%. This is considerably lower than the 700%-increase for the first firm, while it seems clear that the improvement in performance is larger for the second firm.

[3] This outlier removal procedure has been carried out within each combination of sector (1-digit SBI groups) and size class (<100 employees vs >= 100 employees).

ensures the comparability of the different results. Moreover, we eliminate firms with an incomplete financial year (on which we have information through the GBR) and with incomplete financial records.

3.3 Productivity at firm level

3.3.1 *The level of productivity*

To determine whether the level of productivity of individual firms is related to their age, we estimate an equation where the level of productivity of firm i in year t ($Y_{i,t}$) is related to age, controlling for sector and size. Size is measured by the log of total wages[1] (logwage), and sectors are represented by including six sectordummies.

For young firms (less than 10 years), both the learning effect and the selection effect suggest a positive relationship between age and productivity. For elder firms, Verhoeven, Kemp and Peeters (2002) suggest a wave pattern with break points at 20 and 40 years. This could be explained by a combination of changes in ownership and/or management (in particular in the case of succession) and product life cycle effects. To test for the presence of each of these effects, we include age dummies that indicate whether firms are younger than 10 years (age<10) or at least 20 years (age>=20) or 40 years (age>=40), and cross-terms of age with each of these dummies[2]. An overview of the variables included in this equation can be found in table 5.

In addition, we include several indicators of changes in ownership and/or management. In particular, they indicate changes in the organisational structure due to a merger or take-over (int), separation (sep) or reorganisation (reorg) in the previous year. This results in the following equation:

$$\begin{aligned} Y_{i,t} = {} & C + \beta_1 \cdot age_{i,t} + \beta_2 \cdot (age < 10)_{i,t} + \beta_3 \cdot (age < 10)_{i,t} \cdot (age_{i,t} - 10) \\ & + \beta_4 \cdot (age \geq 20)_{i,t} + \beta_5 \cdot (age \geq 20)_{i,t} \cdot (age_{i,t} - 20) \\ & + \beta_6 \cdot (age \geq 40)_{i,t} + \beta_7 \cdot (age \geq 40)_{i,t} \cdot (age_{i,t} - 40) \\ & + \gamma_1 \cdot int_{i,t-1} + \gamma_2 \cdot sep_{i,t-1} + \gamma_3 \cdot reorg_{i,t-1} \\ & + \delta_1 \cdot text_{i,t} + \delta_2 \cdot publ_{i,t} + \delta_3 \cdot chem_{i,t} \\ & + \delta_4 \cdot metal_{i,t} + \delta_5 \cdot mach_{i,t} + \delta_6 \cdot other_{i,t} + \delta_7 \cdot logwage_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

For each of the parameters in equation (3), we will test the null hypothesis that it does not differ significantly from zero. We expect that some of these hypotheses will be accepted, while others will be rejected. In particular, we expect the following:

1 The average level of productivity differs between sectors (not all parameters δ_i will be equal to zero).
2 The average level of productivity increases with firm size ($\delta_7 > 0$).
3 Changes in ownership / management that are associated with structural changes have no effect on the level of productivity ($\gamma_i = 0$ for i=1,2,3).
4 For young firms, productivity levels are below average ($\beta_2 < 0$ and /or $\beta_3 > 0$).

[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

[2] We have experimented with various other functional forms, such as including the log of firm age and a 5th-degree polynomial function. This did not result in significant firm age effects.

5 For elder firms, there is no relationship between age and level of productivity (β_i=0 for i=1 and 4 to7).

6 In particular, we do not expect to find the wave pattern as suggested by Verhoeven, Kemp and Peeters (2002) (this pattern would be present if β_4<0, β_6<0, and β_1>0 and /or (β_5>0 and β_7>0)).

table 5: List of variables used in the regression equation

Name	*Type*	*Label*
C	Dummy	Intercept
Age	Continuous	Age of firm
(Age-10)	Continuous	Age of firm -/- 10
(Age-20)	Continuous	Age of firm -/- 20
(Age-40)	Continuous	Age of firm -/- 40
(Age<10)	Dummy	Indicates whether firm is less than 10 years old
(Age>=20)	Dummy	Indicates whether firm is at least 20 years old
(Age>=40)	Dummy	Indicates whether firm is at least 40 years old
Int	Dummy	Integration
Sep	Dummy	Separation
Reorg	Dummy	Reorganisation
Text	Dummy	Textile, clothing, wood industry
Publ	Dummy	Publishing, printing, reproduction industry
Chem	Dummy	Chemical, oil, artificial material industry
Metal	Dummy	Metal industry
Mach	Dummy	Machine, apparatus industry
Other	Dummy	Other industries
Logwage	Continuous	Log(wage)

3.3.2 *The growth rate of productivity*

The equation that we use to examine the growth rate of productivity (equation 4) is very similar to the previous equation (equation 3). The dependent variable of equation 4 is the growth rate of productivity of firm i in year t ($GY_{i,t}$), but the independent variables in both equations overlap to a large extent. The only difference is that the growth rate equation includes an additional variable, which allows for a more specific test for the presence of a learning and / or selection effect. Both effects suggest that the prouctivity growth rate of sampled firms will be larger for firms with a relatively low productivity level in the previous period (such as young firms).This may be caused by a catch-up effect of underperforming firms (whinh can introduce the best practices from betre performing firms), or by increased exit rates for firms that are not able to catch up. To test for the presence of these effects, we have included the (log of the) relative productivity level in the previous period (relative to the average level of productivity within each sector; $Y\_rel_{i,t-1}$).

$$
\begin{aligned}
GY_{i,t} = {} & C + \varphi \cdot y\_rel_{i,t} + \beta_1 \cdot age_{i,t} \\
& + \beta_2 \cdot (age < 10)_{i,t} + \beta_3 \cdot (age < 10)_{i,t} \cdot (age_{i,t} - 10) \\
& + \beta_4 \cdot (age \geq 20)_{i,t} + \beta_5 \cdot (age \geq 20)_{i,t} \cdot (age_{i,t} - 20) \\
& + \beta_6 \cdot (age \geq 40)_{i,t} + \beta_7 \cdot (age \geq 40)_{i,t} \cdot (age_{i,t} - 40) \\
& + \gamma_1 \cdot int_{i,t-1} + \gamma_2 \cdot sep_{i,t-1} + \gamma_3 \cdot reorg_{i,t-1} \\
& + \delta_1 \cdot text_{i,t} + \delta_2 \cdot publ_{i,t} + \delta_3 \cdot chem_{i,t} \\
& + \delta_4 \cdot metal_{i,t} + \delta_5 \cdot mach_{i,t} + \delta_6 \cdot other_{i,t} + \delta_7 \cdot logwage_{i,t} + \varepsilon_{i,t}
\end{aligned}
\qquad (4)
$$

Again, we will test the null hypothesis that the estimated parameters do not differ significantly from zero, and we expect the following:

7 Learning and / or selection effects are present for older firms ($\phi > 0$).

8 The average growth rate of productivity differs between sectors (not all parameters δ_i will be equal to zero).

9 The average growth rate of productivity is not related with firm size ($\delta_7 = 0$) (controlling for a possible learning effect).

10 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).

11 Since we already control for a possible learning effect, productivity growth rate and age are not related for young firms ($\beta_2=0$ and $\beta_3=0$).

12 For elder firms, there is no relationship between age and growth rate of productivity ($\beta_i=0$ for i=1 and 4 to 7).

13 In particular, we do not expect to find the wave pattern as suggested by Verhoeven, Kemp and Peeters (2002) (this pattern would be present if $\beta_4<0$, $\beta_6<0$, and $\beta_1>0$ and /or ($\beta_5>0$ and $\beta_7>0$)).

3.3.3 *Estimation procedure*

The available data allows us to estimate equations (3) and (4) using different productivity indicators and different periods over time. Regarding the indicators, we will use the eight different indicators presented in the previous sections.

Regarding the time period, 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 information. 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.

4 Results

4.1 Introduction

In this chapter, we will use the available data to answer our research questions. The next section describes the distribution of firm productivity over age cohorts, for different years and different productivity indicators. After that, section 4.3 will present the results of the regression equations that we have estimated to determine to which extent firm age can explain differences in productivity between individual firms.

4.2 Productivity by age cohorts

In this section we present the distribution of productivity over age cohorts, using different productivity indicators. To determine to which extent this distribution depends on the choice for a specific indicator, we examine the correlations between the various indicators. If correlations are high, the distribution will be very similar for the different indicators, and it may be sufficient to present the distribution for a single indicator. Otherwise, it becomes important to pay attention to each of the individual indicators.

Not all indicators are alike

For each individual measurement period, we have determined the correlations between the four indicators for the level of productivity, and between the four indicators for the growth rate of productivity. Average correlations[1] are presented in table 6 and table 7.

table 6 Average correlations between different indicators for level of productivity

		Total factor productivity		*Labour productivity*	
		Value added	*Production*	*Value added*	*Production*
Total factor productivity	*Value added*	1			
	Production	0,81	1		
Labour Productivity	*Value added*	0,93	0,75	1	
	Production	0,38	0,12	0,43	1

The results indicate that three of the four indicators are similar, both regarding level and growth rate of productivity. The exception is the labour productivity of production: the average correlations of this indicator with the other indicators vary from 0.12 to 0.43 for the level of productivity, and from 0.52 to 0.57 for the growth rate. We have no explanation for the singular behaviour of this indicator, but it may be related to the fact that this indicator has the highest absolute value[2].

[1] Averaged over time.

[2] Output is represented by the largest of the two available output measures, while input is represented by the smallest of the available input measures.

table 7 Average correlations between different indicators for productivity growth rate

		Total factor productivity		*Labour productivity*	
		Value added	*Production*	*Value added*	*Production*
Total factor productivity	*Value added*	1			
	Production	0,80	1		
Labour Productivity	*Value added*	0,97	0,78	1	
	Production	0,52	0,57	0,54	1

We therefore use two different indicators to present the distribution of productivity over age cohorts: labour productivity of production and total factor productivity of production[1]. The distribution of the level of productivity over age cohorts is illustrated in figure 3 (based on the total factor productivity of production) and figure 4 (based on the labour productivity of production). Both figures show the average and variance of the respective indicators for the different age cohorts. Likewise, figure 5 and figure 6 illustrate the distribution of the growth rate of productivity over age cohorts.

No specific pattern for young firms...

Although our dataset includes firms from all age cohorts (including the age cohorts 0-4 and 5-9 years of age), this study especially looks at firms of at least 10 years of age. The reason for this choice is twofold. Firstly, for young firms the relation between age and productivity has already received relatively much attention. Secondly, our dataset is not suitable to examine young firms. This is due to the sample structure: our sample only includes firm of at least 20 employees. Since most firms start with only a few (if any) employees, the average size of the young firms in our sample is above the population average.

This is, in fact, true for all age cohorts in our sample (the average firm size of Dutch firms from the manufacturing firms is less than 20 employees). Nevertheless, it is especially relevant for the youngest firms, since for these firms the hypothesised relationship between age and productivity is related to firm size. Young firms start with a below-average level of productivity, after which they can catch up with the more mature firms in the sector (or exit the market). This catch-up effect not only results in an above-average growth rate of productivity, but may also result in a growth of firm size. The firms in our sample are already above average firm size, which suggests that they have already benefited from the catch-up effect and may already have caught up.

We therefore do not expect that the average productivity level of the young firms in our sample is below average, nor that their growth rate is above average. This is confirmed by the various figures in this chapter. Only one of the four different graphs shows the pattern that is generally found in other studies: the level of total factor productivity of production (figure 3) is below average for the youngest age cohort, and higher for the following two cohorts.

[1] Since the correlations between the other three indicators are relatively high, the choice for the second indicator is rather arbitrary. The distributions according to the other indicators can be found in Annex II.

figure 3 Total factor productivity of production (level) by age cohorts

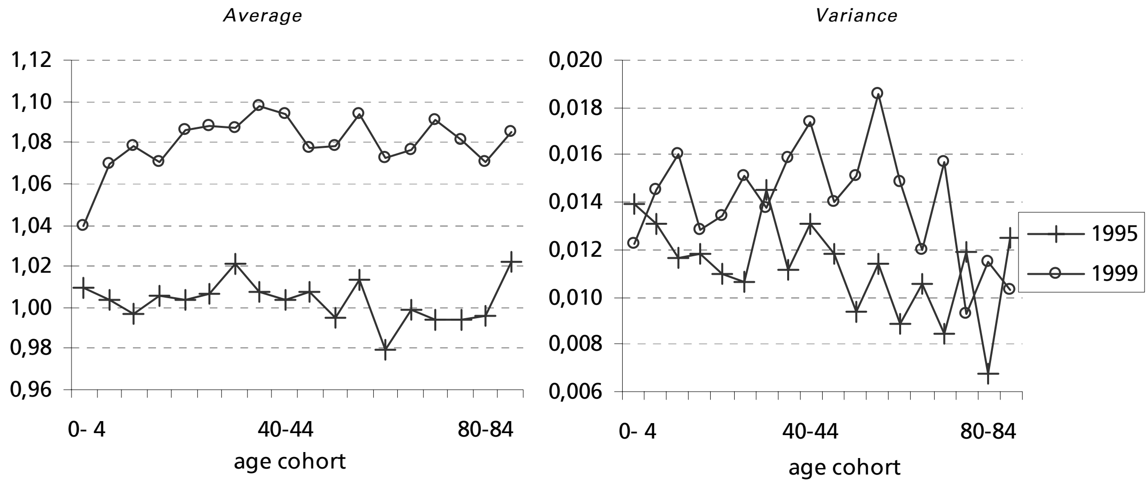


figure 4 Labour productivity of production (level) by age cohorts

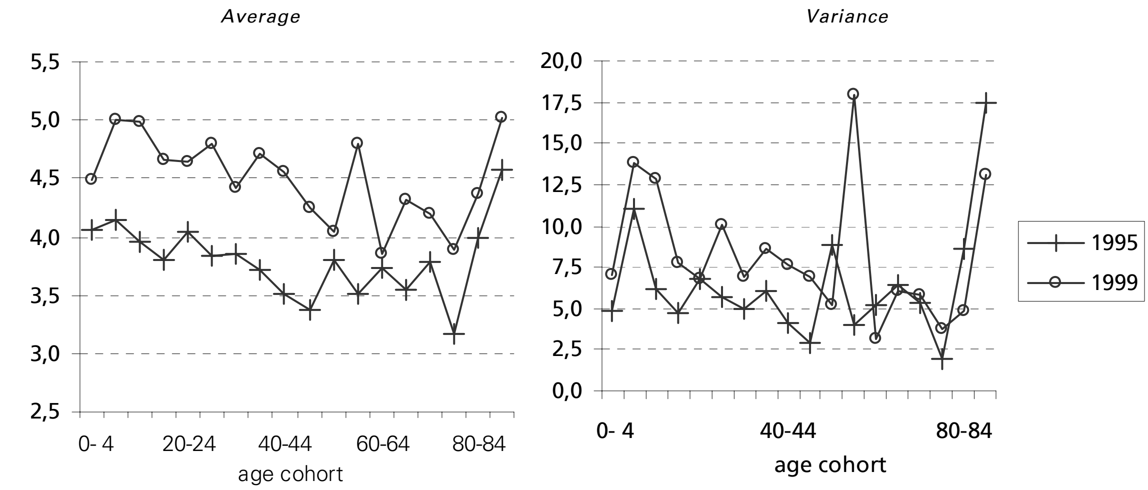


figure 5 Labour productivity of production (growth rate) by age cohorts

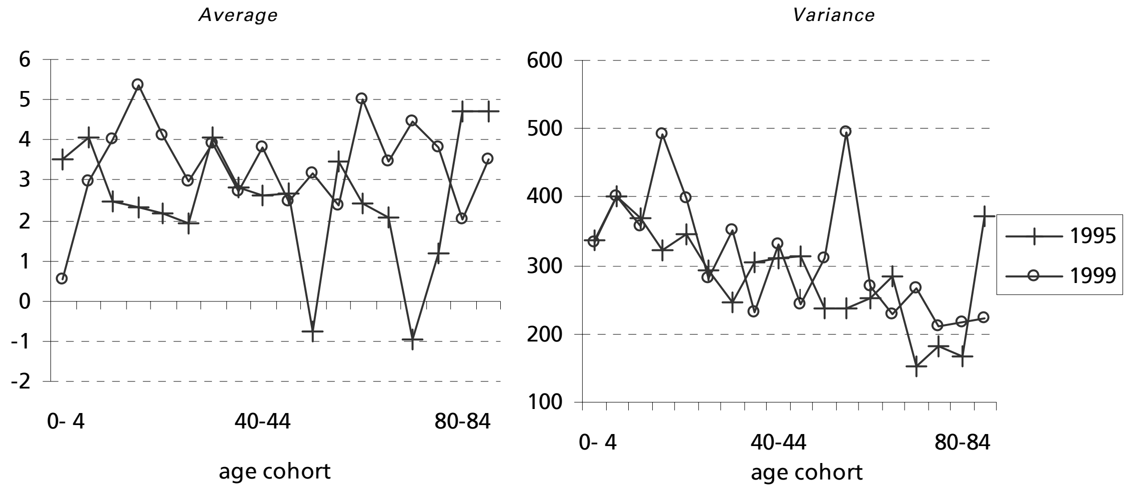
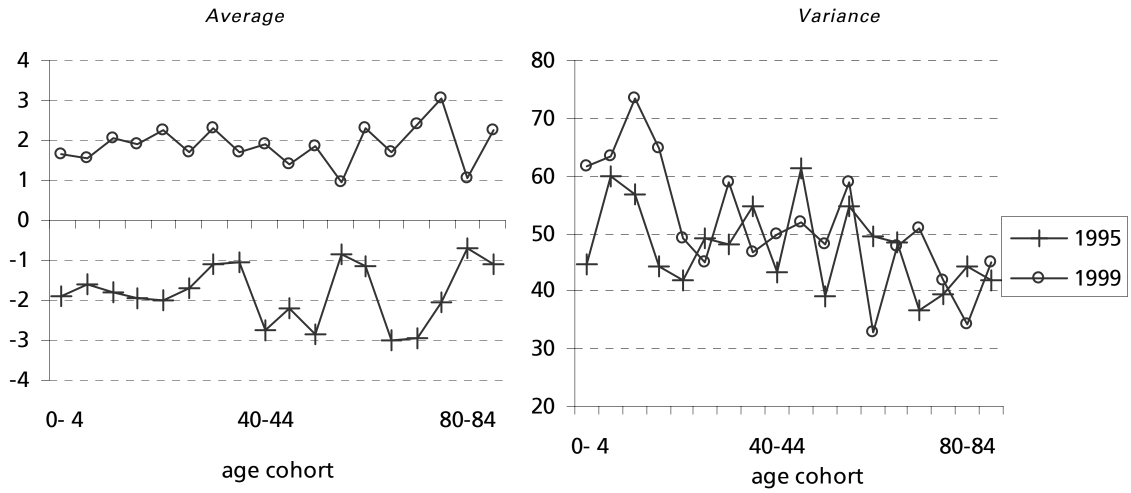


figure 6 Total factor productivity of production (growth rate) by age cohorts



... and no specific pattern for older firms either

Although some studies have found empirical evidence that suggests that age and productivity are related for older firms, the general view is that for these firms age and productivity are independent. The figures presented in this chapter do not challenge this view. Only one of the four figures indicates a specific relationship between age cohort and average level of productivity: according to figure 4, the labour productivity of production first declines with age cohort (for firms less than 50 years of age), and for elder firms (75 years and older) starts to increase again. This pattern differs from the patterns identified in previous studies.

Variation over time also suggests absence of cohort effects

If productivity is related to age cohorts, then we should be able to identify this relationship for most of the measurement periods on which we have data available. This suggests that for each of the eight productivity indicators that we have examined, the graphs for 1995 and 1999 should be highly correlated. To examine whether this is the case, we calculated (for each available indicator) the correlations between the two lines that represent the averages per age cohort for 1995 and 1999. This resulted in eight correlations that vary between –0.36 (figure 5) and 0.57 (figure 4), with an average of 0.03[1]. These low correlations do not support the notion of a relationship between productivity and age cohorts that is (even in the short run) consistent over time.

Productivity growth rates tend to converge

The idea that average productivity (level and growth rate) shows a systematic relationship with age cohorts, and that this relationship exists for different productivity indicators and different time periods, is not supported by the figures presented in this chapter. There are, however, indications that productivity growth rates tend to converge over time. We conclude this from the fact that the variance of productivity growth rates decreases over age cohorts (see e.g. figure 5 and figure 6). In particular, we have fitted 2nd degree polynomials into the eight available graphs[2], and determined whether the fitted lines showed a monotonic decrease. This turned out to be the case for all eight graphs.

We also applied this procedure to examine how the variance of the productivity levels changes over age cohorts. In this case, there is much less evidence of a negative relationship; out of the eight fitted polynomials, only one showed a monotonically decrease.

4.3 Productivity at firm level

4.3.1 *The level of productivity*

In the previous chapter we have presented the regression equation that we will use to examine the relationship between firm age and the level of productivity (equation 3). This equation has been estimated 20 times (using four different productivity indicators,

[1] The average correlation concerning the productivity level is 0.32, while the average correlation concerning the productivity growth rate is –0.27.

[2] The variance of productivity growth rates is available for four different indicators and two different years.

for five different years). The main results are presented in table 8 (regarding the most recent year) and table 9 (average results over all years). More elaborate tables (including the parameter estimates for all sector dummies and the standard deviations of all estimated parameters) are included in Annex III.

As expected, the productivity level of individual firms increases with firm size (as measured by logwage), and differs between sectors (see Annex III). This finding holds for all indicators and all years. Our other expectations are also confirmed by most or all of the estimation results.

First of all, we find support for a positive relationship between age and productivity for firms less than 10 years old. The parameter for the cross-product (Age<10)*(Age-10) is significantly positive for three of the four indicators used. In combination with an insignificant effect of the dummy variable (Age<10), this indicates that the level of productivity tends to be below average for firms less than 10 years of age. The level increases with firm age, and for firms of 10 years old there is no longer a difference with the average productivity of older firms. The size of this effect is, however, very limited, which explains why it is not present in the distributions presented in the previous section.

Next, there is no sign of an increasing or decreasing effect of age on the level of productivity throughout all age cohorts. There is also no support for the wave pattern that Verhoeven, Kemp and Peeters (2002) found in their dataset.

There is, however, some evidence of a relationship between age and productivity for older firms. For firms of at least 40 years of age, the average level of productivity tends to be somewhat smaller than for younger firms. At least, according the average results over the whole sample period. Although the parameter estimates of the dummy variable (Age>=40) are also negative for 1999, none of these estimates differ significantly from zero. This difference is probably due to the fact that fewer observations are available for a single measurement period. This can be concluded from the fact that the parameter estimates for the different periods have the same sign and the same order of magnitude. The effect is very small, suggesting that the productivity level for firms of at least 40 years is 1% to 4% below the average level (as represented by the intercept).

Both age effects (for firms less than 10 years and 40 years or more) are found for all indicators, except for labour productivity of production. This confirms the findings from the previous section, that this indicator differs from the other three.

Finally, as expected, structural changes such as integration, separation and reorganisation have no significant effect on the level of productivity.

table 8: OLS regression results for different indicators of the level of productivity (1999)

Variable	*labour productivity of value added*	*labour productivity of production*	*TFP of value added*	*TFP of production*
Intercept	1,824 **	7,946 **	1,362 **	1,070 **
Age	-0,011	-0,027	-0,003	-0,001
(Age<10)	-0,032	-0,033	-0,013	0,003
(Age<10)(Age-10)*	0,033 **	0,064	0,022 *	0,006 *
(Age>=20)	0,096 *	0,052	0,051	0,015
(Age>=20)(Age-20)*	0,011	0,012	0,003	0,001
(Age>=40)	-0,039	-0,094	-0,024	-0,010
(Age>=40)(Age-40)*	-0,001	0,009	-0,001	-0,001
Integration	0,064	0,556 *	0,058	0,023 *
Separation	0,007	-0,225	0,015	-0,003
Reorganisation	-0,090	0,355	-0,123	-0,022
log(wage)	0,044 **	0,295 **	0,013 *	0,003
R2	0,046	0,137	0,01	0,011
Valid observations	4.566	4.566	4.566	4.566

*: significant at 5% confidence level

**: significant at 1% confidence level

table 9: OLS regression results for different indicators of the level of productivity (1995-1999)

Variable	*labour productivity of value added*	*labour productivity of production*	*TFP of value added*	*TFP of production*
Intercept	1,525 **	6,917 **	1,180 **	0,995 **
Age	-0,001	0,000	0,002	0,001
(Age<10)	0,038	0,221	0,023	0,012 *
(Age<10)(Age-10)*	0,017 **	0,047	0,010 **	0,002 *
(Age>=20)	0,022	-0,046	0,009	0,003
(Age>=20)(Age-20)*	0,003	-0,011	0,000	0,000
(Age>=40)	-0,055 **	-0,161	-0,038 **	-0,009 *
(Age>=40)(Age-40)*	-0,002	0,009	-0,001	-0,001 **
Integration	0,006	0,133	0,010	0,007
Separation	0,020	0,196	0,002	-0,002
Reorganisation	-0,103	-0,005	-0,112 *	-0,024
log(wage)	0,059 **	0,355 **	0,027 **	0,008 **
Average R2[1]	0,052	0,129	0,016	0,044
Valid observations	22.041	22.041	22.041	22.041

[1]: *average of the results for the five different periods*

*: significant at 5% confidence level

**: significant at 1% confidence level

4.3.2 *The growth rate of productivity*

The main results of the various estimations of equation 4 are reported in table 9 and table 10[1].

Productivity growth rates differ between sectors, and the large and significantly negative effect of the relative level of productivity in the previous period clearly indicate the presence of learning and / or selection effects for older firms. Furthermore, the results support our expectations that there is no relationship between firm age and productivity. It is interesting to note that firms of at least 40 years of age have on average the same growth rate as younger firms. The difference in productivity levels between these two age groups is not accompanied by a difference in growth rates[2]. A possible explanation is that from a certain age onwards, firms are likely to change their strategy regarding the introduction of productivity-enhancing innovations: from leading the industry to following developments.

Contrary to our expectations, there is a consistently negative effect of firm size on productivity growth. While the level of productivity is higher for larger firms, their growth rate is smaller. This may also represent a learning effect, where smaller firms can catch up with their larger and more productive counterparts.

We also didn't expect to find that changes in the organisational structure of firms has such a limited effect on the growth rate of productivity. For integration we only find a significant effect for indicators that measure output by production, and only for the most recent year. Furthermore, this effect has the opposite sign of what we expected (but which is consistent with the findings by Huergo and Jaumandreu, 2004). In the case of integration, the parameter estimates tend to have the correct sign, but only one of the eight parameters presented in table 9 and table 10 is significantly different from zero.

Changes in the organisational structure are no prerequisite for changes in ownership and / or management. Management buy-outs of private or public limited enterprises and succession of the management of family firms are two examples which do not require structural changes. Since we have no information on management buy-outs or succession, we cannot test for their impact on productivity growth rates directly. One could argue that this can be tested indirectly, by including age dummies that identify specific age cohorts (as we have done). The underlying assumption is that changes in ownership / management are closely related to firm age (e.g. by assuming that succession mostly occurs within firms of 20-25 years of age and 40-45 years of age). As we already discussed in chapter two, we do not believe that this is an accurate assumption.

[1] More elaborate tables (including the parameter estimates for all sector dummies and the standard deviations of all estimated parameters) are included in Annex III.

[2] This is consistent with the finding that in the level-equation (equation 3) the parameter of the cross-term (Age>=40) * (Age-40) does not differ significantly from zero.

table 10: OLS regression results for different indicators of the growth rate of productivity (1999)

Variable	labour productivity of value added		labour productivity of production		TFP of value added		TFP of production	
Intercept	13,40	**	5,25		15,26	**	14,83	**
Y_rel	-3,13	**	-0,99	**	-4,50	**	-10,53	**
Age	0,01		0,22		-0,08		-0,03	
(Age<10)	-1,17		0,20		-1,18		-0,50	
(Age<10)*(Age-10)	0,07		0,11		0,18		0,10	
(Age>=20)	1,36		-1,55		2,02		0,63	
(Age>=20)*(Age-20)	-0,14		-0,31		-0,05		0,01	
(Age>=40)	-0,14		0,46		-0,43		-0,23	
(Age>=40)*(Age-40)	0,17		0,10		0,17		0,04	
Integration	-0,90		1,10		-0,59		0,09	
Separation	-0,28		-0,47		-0,31		-1,13	
Reorganisation	6,21		11,27	*	5,20		2,58	
log(wage)	-1,12	**	-1,23	**	-1,19	**	-0,40	**
R2	0,023		0,018		0,023		0,097	
Valid observations	4.586		4.586		4.586		4.586	

**: significant at 5% confidence level*

***: significant at 1% confidence level*

table 11: OLS regression results for different indicators of the growth rate productivity (1995-1999)

Variable	labour productivity of value added		labour productivity of production		TFP of value added		TFP of production	
Intercept	8,38	**	4,01	**	10,78	**	13,51	**
Y_rel	-4,68	**	-1,15	**	-6,97	**	-11,95	**
Age	0,10		0,13		0,07		0,01	
(Age<10)	0,92		0,33		0,84		0,12	
(Age<10)*(Age-10)	-0,01		-0,16		0,06		0,05	
(Age>=20)	-0,38		-0,69		-0,23		0,10	
(Age>=20)*(Age-20)	-0,10		-0,19	*	-0,06		-0,01	
(Age>=40)	-0,88		0,61		-1,05		-0,12	
(Age>=40)*(Age-40)	0,02		0,06		0,01		-0,01	
Integration	-0,10		0,30		-0,27		0,03	
Separation	1,27		2,44	*	1,16		0,44	
Reorganisation	-2,98		-0,65		-3,54		-0,78	
log(wage)	-0,46	**	-0,49	**	-0,47	**	-0,15	**
Average R2[1]	0,029		0,017		0,034		0,098	
Valid observations	22.049		22.049		22.049		22.049	

[1]: average of the results for the five different periods

**: significant at 5% confidence level*

***: significant at 1% confidence level*

5 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 also 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. Regarding the level of productivity, the study by Verhoeven, Kemp and Peeters (2002) suggests a wave relationship between age and productivity for the Dutch manufacturing industry.

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 very few indications of a relationship between age and productivity for the Dutch manufacturing industry. Our results show that both level and growth rate of productivity differ between sectors and vary with firm size: smaller firms tend to have a lower level and higher growth rate of productivity. The difference in productivity level may be caused by economies of scale and scope, while the difference in growth rates suggests that smaller firms are catching up. The negative relationship between productivity growth and the relative level of productivity in the previous period also indicates the presence of a learning and / or selection effect. 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.

We found no indication that this sector-specific productivity growth rate is related to firm age. Regarding the level of productivity, there are also very few indications of an age-effect. In particular, we didn't find the wave pattern that was suggested by Verhoeven, Kemp and Peeters (2002), who examined the same population (but used a different sample). Instead, we found support for the presence of an inertia effect: firms above 40 years of age tend to have a slightly lower productivity level than younger firms. The growth rate of these two groups, however, does not differ. Apparently, older firms are no longer in fore-front of their sector, but are still able to keep up with the younger firms.

These results depend only slightly on the specific indicator that is used to represent productivity. We have used four different indicators in our study. The development of labour productivity of production differs from the other three indicators, which are more or less similar. Regarding the relationship with firm age, the only difference is that the inertia effect cannot be identified when productivity is measured by the labour productivity of production. Otherwise, the conclusions are the same for all indicators.

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; large enough to identify a small inertia-effect concerning the level productivity.

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 separate the learning effect from the selection effect. 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.

Annex I Data considerations

Introduction

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. A firm is characterised by its autonomy with respect to the production process and by the sale of its goods or services to the market. A firm can consist of one or more juridical units or can be part of a larger juridical unit.
This annex contains detailed information on the usage of these data sources.

Production Statistics

The PS contain financial data on firms whose main economic activity lies within the manufacturing industry, consisting of the 2-digit industries 15 to 37 of the Standard Industrial Classification (SBI '93) . These industries are classified into 7 sectors (table 12). The variables that are used for this study are presented in table 13. This table also includes which price indicators have been used to deflate the variables of interest.

table 12 Sectors of manufacturing sector

Sector	*2-digit SBI classifications*
Food and tobacco industry	15,16
Textile, clothing, wood industry	17,18,19,20,21
Publishing, printing, reproduction industry	22
Chemical, oil, artificial material industry	23,24,25
Metal industry	27,28
Machine, apparatus industry	29,30,31,32,33,34,35
Other industries	26,36,37

Source: Statistics Netherlands, SBI '93

The PS also include the year of foundation of each firm. In several cases, the age of this legal entity may underestimate the economic age of the firm (i.e. how long the production process is in operation). This is for example the case if a firm is created by a merger between existing firms. Whereas the legal age is one year, the economic age of the newly created firm is much older.

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table 13 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 € 100.000 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

General Business Register

To obtain a better estimate of the economical age of firms, we have combined information from the PS with information from the GBR. Amongst others, the GBR includes information about various mutations in the structure and/or legal status of the firm. This information has been used to determine which type of mutation took place, and (if necessary) to recalculate the firm age. In addition, information about specific mutations is relevant in itself, since they refer to changes in the organisational structure that may affect the growth rate of productivity.

The remainder of this annex discusses how the available information on mutations in the GBR has been used to define three distinct indicators for organisational changes, and when and how the estimates of the economical age of firms have been improved.

Mutation codes

The mutation codes available in the GBR have been used to determine whether a firm has been involved in a reorganisation, a separation from other firms or an integration with other firms (table 14). In addition, if the mutation involves a removal from the GBR, the relevant firm is removed from the dataset as the balance sheet figures might not cover a complete financial year.

Notice that in some instances we also control for administrative mutations (which refer to mutations at a more disaggregate level, i.e. units within firms). This is because such mutations probably have an impact on balance sheet figures (as reported in the Production Statistics).

table 14 Mutation codes

Mutation	*Code*	*Integration*	*Separation*	*Reorganisation*	*Remove*
Add to register due to:					
- birth	11				
- merger	14	X			
- split off	15		X		
- dispersion	16		X		
- restructuring	17			X	
Remove from register due to:					
- death	22				X
- take-over	23				X
- merger	24				X
- dispersion	26				X
- restructuring	27				X
Keep identity in case of					
- take-over	33	X			
- split off	35		X		
- restructuring	37			X	
Add firm unit again (administrative)	71				
Add to register due to (administrative):					
- integration firm units	74	X			
- split off firm unit	75		X		
- dispersion of firm unit	76		X		
- restructuring of firm units	77				
Remove firm unit from register (administrative)	82				X
Remove firm unit from register due to: (administrative)					
- integration with other firm unit	83				X
- integration of firm units	84				X
- split off firm units	86				X
- restructuring of firm units	87				X
Other mutations:					
- (part of) other firm unit has been added to firm unit	93	X			
- part of firm unit has been split off	95		X		
- firm unit involved in restructuring	97			X	

Source: Statistics Netherlands, General Business Register.

The annual number of firms that reports an integration, separation or reorganisation is relatively small, as can be seen in table 15.

table 15 Firms in the Production Surveys with registered mutations

	'94 – '95	'95-'96	'96-'97	'97-'98	'98-'99
Sample size	4.398	4.329	4.305	4.431	4.586
Registered mutations:					
Integration	81	172	107	109	125
Separation	33	74	56	85	69
Reorganisation	2	54	36	44	17
Total	116	300	199	238	211

Source: own calculations, based on PS and GBR.

Based on firms for which observations are available for two consecutive years. The number of registered mutations only refers to the first year of each period.

Firm age

The age of each firm is defined as the year of foundation as registered in the GBR. If this is unknown, firm age is defined as the year of entrance into the GBR minus 1 (a new firm usually enters the register in the year after its foundation). Unfortunately, the year of entrance into the GBR is truncated at 1967; if firms entered the register before January 1967, the year of entrance was put on that date. For these firms, no valid Register date is available. If the year of foundation is unknown as well, the year of birth for these firms is unknown and coded as missing.

If the information from the GBR indicates integration, we have determined a fictional year of birth, and determined the age accordingly. In determining this fictional year of birth, we followed the following rules:
The year of birth of the relevant firm is calculated as the weighted average of the years of birth of all firms involved, where the weights are based on the number of employees.
If the relevant firm enters the register as a newly created firm, the year of birth of this firm is not taken into account in calculating the average year of birth.
If the relevant firm was already present in the register (e.g. in the case of a take-over or an integration of firm units), the year of birth of this firm is taken into account in calculating the average year of birth.
If the number of employees of one of the firms involved is unknown, we calculate the unweighted average instead of the weighed average.
If the year of birth of one of the firms involved is unknown, then the year of birth of the relevant firm cannot be calculated. In such cases, the year of birth is coded as missing (and thus, also, firm age).

Starting with the firms from the register 1993, we determine the years of birth of those firms. Then we update the dataset with the register 1994 as follows:
determine the birth date for new firms in the dataset.
recalculate the birth dates of existing firms that are involved in an integration in 1994.
We repeat this procedure for the years 1995 up to 1999.

Annex II Productivity by age cohorts

For each of the eight productivity indicators, this annex presents the development of average and variance over age cohorts.

Productivity level

figure 7 Labour productivity of value added (level) by age cohorts

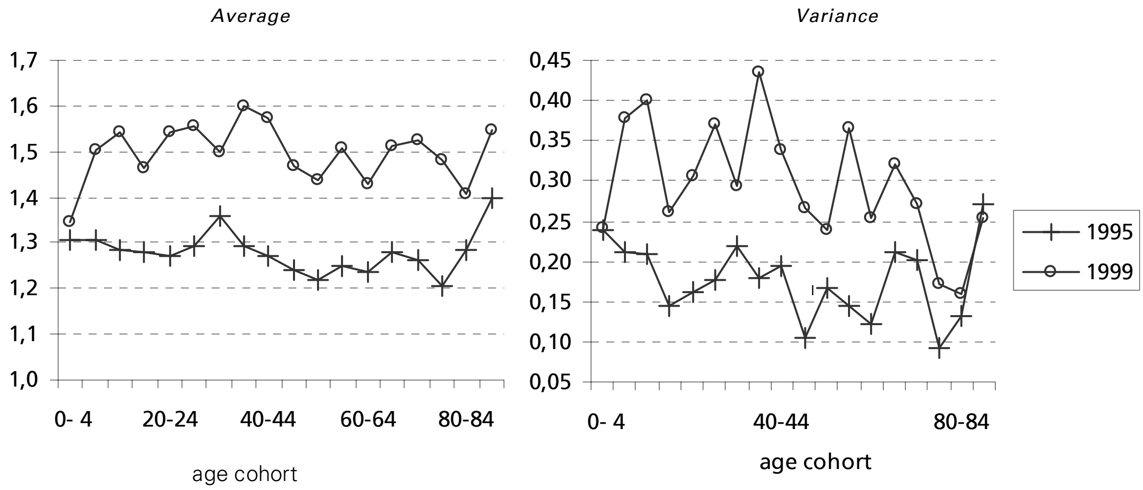


figure 8 Labour productivity of production (level) by age cohorts

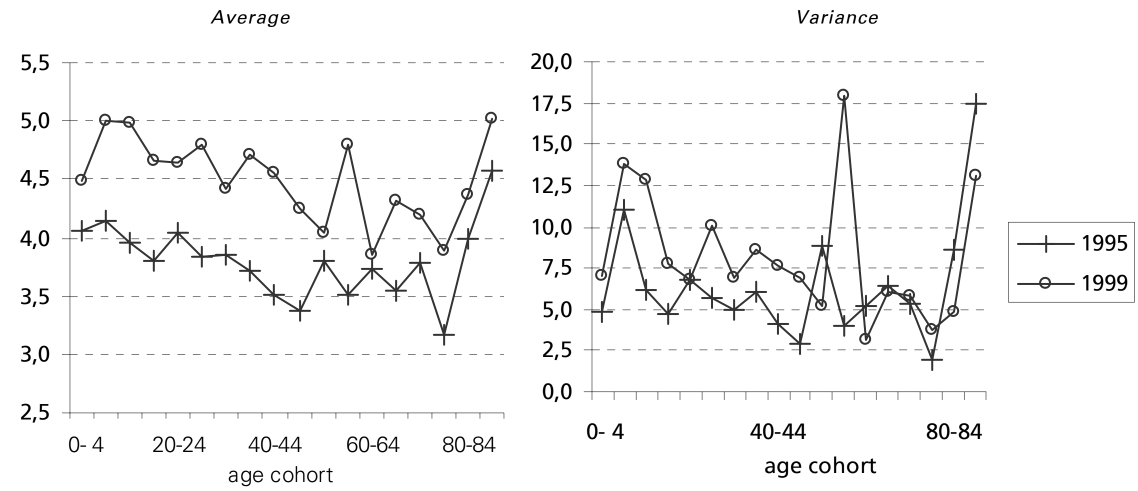


figure 9 Total factor productivity of value added (level) by age cohorts

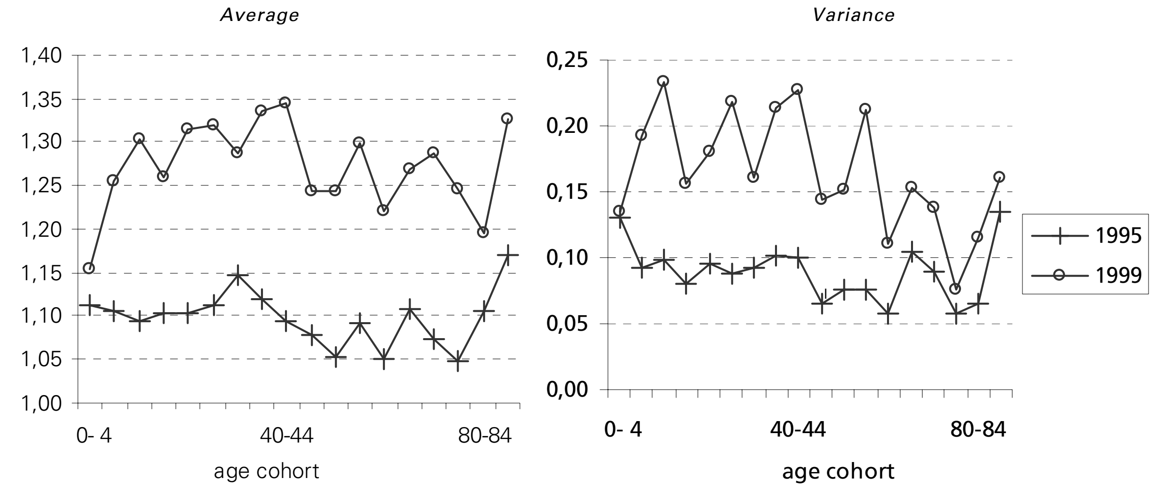
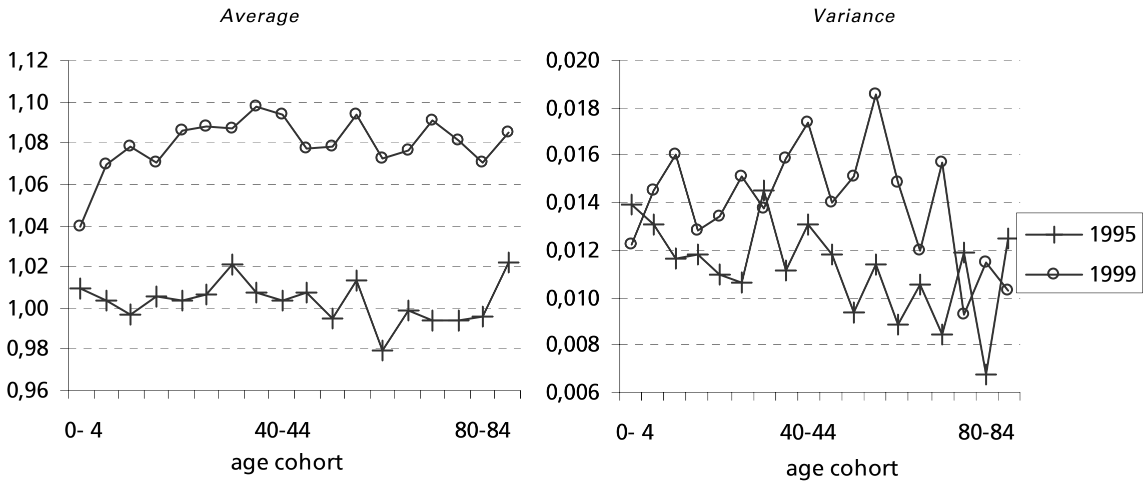


figure 10 Total factor productivity of production (level) by age cohorts



Productivity growth rate

figure 11 Labour productivity of value added (growth rate) by age cohorts

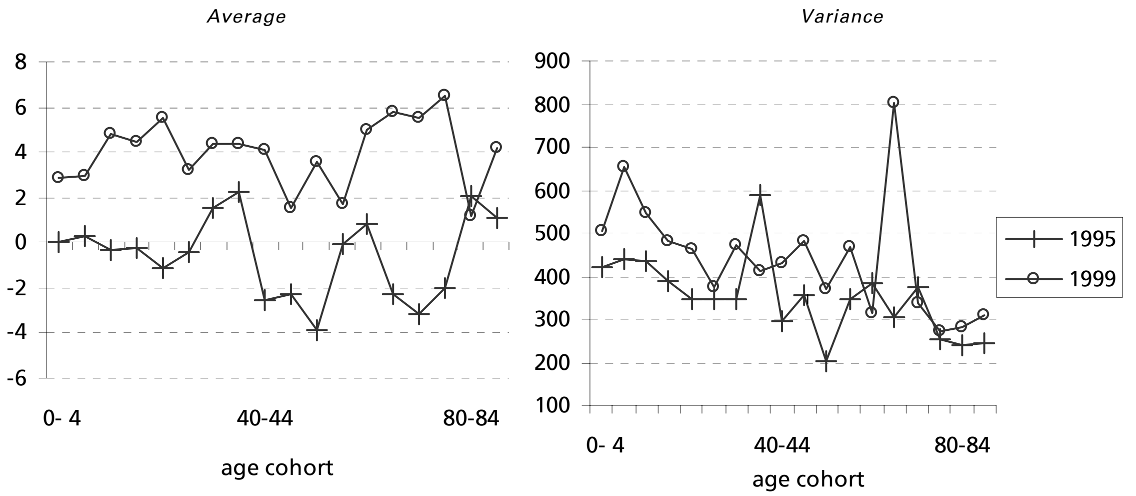


figure 12 Labour productivity of production (growth rate) by age cohorts

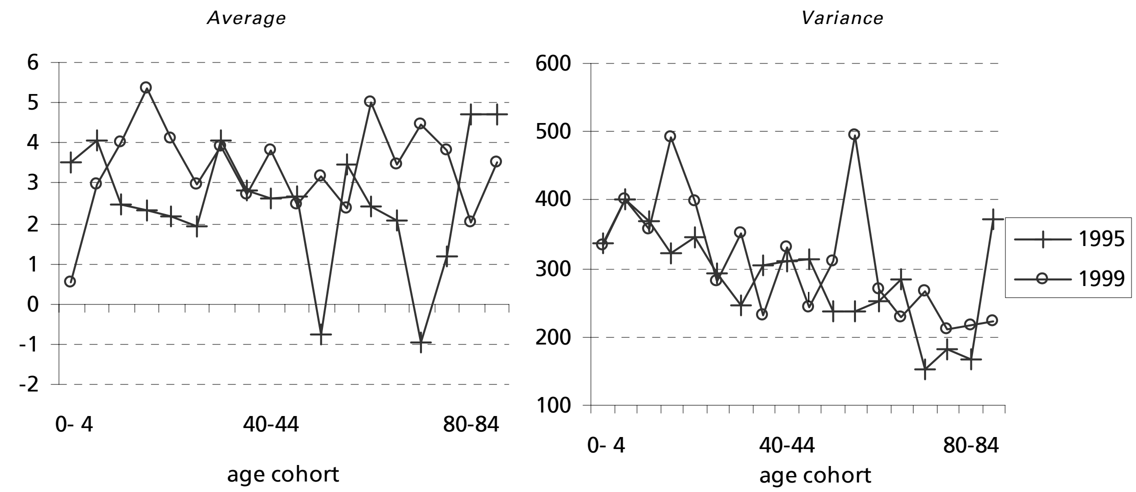


figure 13 Total factor productivity of value added (growth rate) by age cohorts

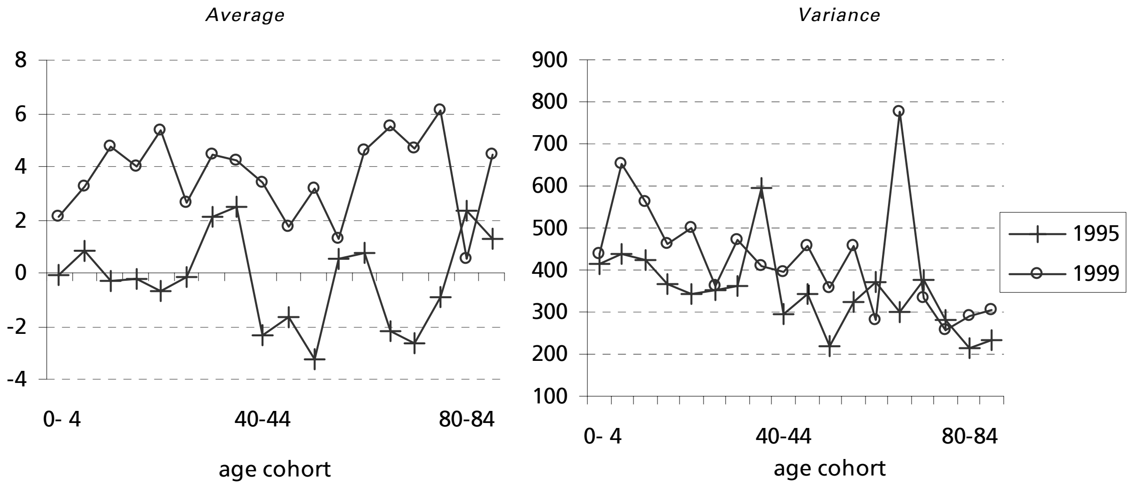
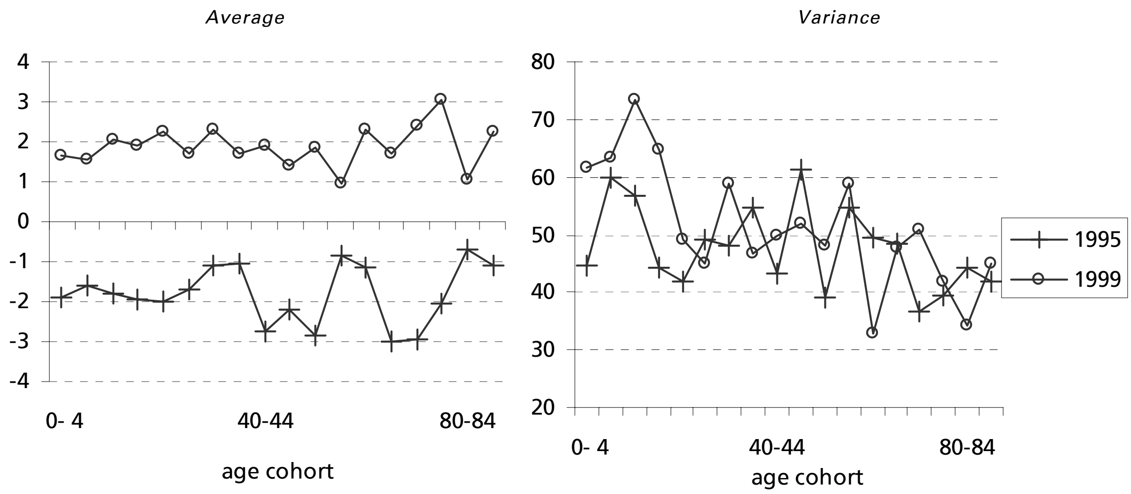


figure 14 Total factor productivity of production (growth rate) by age cohorts



Annex III Regression results

Equations (3) and (4) have been estimated separately for five consecutive years (1995 – 1999), using ordinary least squares. Instead of reporting the estimation results for all individual periods, we report results for the most recent year (t=1999; see table 16 and table 18) and average parameter estimates for all years (t=1995 to 1999; see table 17 and table 19). 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:

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

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

We want to make sure that for each year, differences in estimation results can only be explained by differences in the indicators that are used, and not by sample differences. For each year, we have therefore estimated each equation on the same subset of firms for which complete, valid and reliable data is available. For the estimations of equation (3) this implies a.o. that we only included firms for which valid and reliable information for all four indicators of the *level* of productivity is available. For the estimations of equation (4), we only included firms for which valid and reliable information for all four indicators of the *level and growth rate* of productivity is available.

table 16: OLS regression results for different indicators of the level of productivity (1999)

	labour productivity of value added		*labour productivity of production*		*TFP of value added*		*TFP of production*	
Variable	β_t	σ_t	β_t	σ_t	β_t	σ_t	β_t	σ_t
Intercept	1,824 **	0,0871	7,946 **	0,4402	1,362 **	0,0668	1,070 **	0,0187
Age	-0,011	0,0056	-0,027	0,0284	-0,003	0,0043	-0,001	0,0012
(Age<10)	-0,032	0,0516	-0,033	0,2607	-0,013	0,0395	0,003	0,0111
(Age<10)(Age-10)*	0,033 **	0,0126	0,064	0,0639	0,022 *	0,0097	0,006 *	0,0027
(Age>=20)	0,096 *	0,0407	0,052	0,2056	0,051	0,0312	0,015	0,0087
(Age>=20)(Age-20)*	0,011	0,0062	0,012	0,0311	0,003	0,0047	0,001	0,0013
(Age>=40)	-0,039	0,0456	-0,094	0,2307	-0,024	0,0350	-0,010	0,0098
(Age>=40)(Age-40)*	-0,001	0,0028	0,009	0,0141	-0,001	0,0021	-0,001	0,0006
Integration	0,064	0,0507	0,556 *	0,2565	0,058	0,0389	0,023 *	0,0109
Separation	0,007	0,0656	-0,225	0,3316	0,015	0,0503	-0,003	0,0141
Reorganisation	-0,090	0,1363	0,355	0,6892	-0,123	0,1045	-0,022	0,0293
log(wage)	0,044 **	0,0082	0,295 **	0,0416	0,013 *	0,0063	0,003	0,0018
Textile	-0,170 **	0,0342	-2,512 **	0,1731	-0,069 **	0,0262	0,001	0,0073
Publishing	-0,139 **	0,0361	-3,393 **	0,1827	-0,039	0,0277	0,026 **	0,0078
Chemical	0,079 *	0,0338	-1,711 **	0,1709	0,046	0,0259	0,028 **	0,0073
Metal	-0,174 **	0,0303	-2,985 **	0,1533	-0,025	0,0233	0,021 **	0,0065
Machine	-0,242 **	0,0284	-3,137 **	0,1438	-0,049 *	0,0218	0,014 *	0,0061
Other	-0,064	0,0353	-2,558 **	0,1783	-0,005	0,0270	0,022 **	0,0076
R2	0,046		0,137		0,01		0,011	
Valid observations	4.566		4.566		4.566		4.566	

*: significant at 5% confidence level

**: significant at 1% confidence level

table 17: OLS regression results for different indicators of the level of productivity (1995-1999)

	labour productivity of value added		*labour productivity of production*		*TFP of value added*		*TFP of production*	
Variable	$\overline{\beta}$	σ_β	$\overline{\beta}$	σ_β	$\overline{\beta}$	σ_β	$\overline{\beta}$	σ_β
Intercept	1,525 **	0,0365	6,917 **	0,2034	1,180 **	0,0270	0,995 **	0,0083
Age	-0,001	0,0024	0,000	0,0132	0,002	0,0018	0,001	0,0005
(Age<10)	0,038	0,0216	0,221	0,1207	0,023	0,0160	0,012 *	0,0050
(Age<10)(Age-10)*	0,017 **	0,0051	0,047	0,0284	0,010 **	0,0038	0,002 *	0,0012
(Age>=20)	0,022	0,0170	-0,046	0,0946	0,009	0,0125	0,003	0,0039
(Age>=20)(Age-20)*	0,003	0,0026	-0,011	0,0144	0,000	0,0019	0,000	0,0006
(Age>=40)	-0,055 **	0,0189	-0,161	0,1052	-0,038 **	0,0140	-0,009 *	0,0043
(Age>=40)(Age-40)*	-0,002	0,0012	0,009	0,0064	-0,001	0,0008	-0,001 **	0,0003
Integration	0,006	0,0215	0,133	0,1185	0,010	0,0159	0,007	0,0049
Separation	0,020	0,0291	0,196	0,1616	0,002	0,0215	-0,002	0,0068
Reorganisation	-0,103	0,0709	-0,005	0,3946	-0,112 *	0,0520	-0,024	0,0173
log(wage)	0,059 **	0,0034	0,355 **	0,0188	0,027 **	0,0025	0,008 **	0,0008
Textile	-0,117 **	0,0138	-2,239 **	0,0770	-0,026 *	0,0102	0,024 **	0,0032
Publishing	-0,054 **	0,0145	-3,008 **	0,0806	0,014	0,0107	0,048 **	0,0033
Chemical	0,103 **	0,0137	-1,465 **	0,0764	0,069 **	0,0102	0,060 **	0,0031
Metal	-0,129 **	0,0124	-2,742 **	0,0689	-0,002	0,0092	0,024 **	0,0028
Machine	-0,167 **	0,0115	-2,838 **	0,0640	-0,003	0,0085	0,041 **	0,0026
Other	0,003	0,0143	-2,415 **	0,0794	0,048 **	0,0106	0,057 **	0,0033
Average R2[1]	0,052		0,129		0,016		0,044	
Valid observations	22.041		22.041		22.041		22.041	

[1]: *average of the results for the five different periods*

*: *significant at 5% confidence level*

**: *significant at 1% confidence level* table 18: OLS regression results for different indicators of the growth rate of productivity (1999)

	labour productivity of value added			*labour productivity of production*			*TFP of value added*			*TFP of production*		
Variable	β_t		σ_t	β_t		σ_t	β_t		σ_t	β_t		σ_t
Intercept	13,40	**	3,4869	5,25		2,9368	15,26	**	3,4892	14,83	**	1,3504
Y_rel	-3,13	**	0,5688	-0,99	**	0,2611	-4,50	**	0,7290	-10,53	**	0,7433
Age	0,01		0,2213	0,22		0,1884	-0,08		0,2196	-0,03		0,0720
(Age<10)	-1,17		2,0304	0,20		1,7282	-1,18		2,0152	-0,50		0,6603
(Age<10)(Age-10)*	0,07		0,4990	0,11		0,4247	0,18		0,4952	0,10		0,1623
(Age>=20)	1,36		1,6024	-1,55		1,3638	2,02		1,5905	0,63		0,5212
(Age>=20)(Age-20)*	-0,14		0,2426	-0,31		0,2065	-0,05		0,2408	0,01		0,0789
(Age>=40)	-0,14		1,7999	0,46		1,5321	-0,43		1,7863	-0,23		0,5853
(Age>=40)(Age-40)*	0,17		0,1098	0,10		0,0935	0,17		0,1090	0,04		0,0357
Integration	-0,90		2,0201	1,10		1,7194	-0,59		2,0049	0,09		0,6570
Separation	-0,28		2,6991	-0,47		2,2976	-0,31		2,6786	-1,13		0,8776
Reorganisation	6,21		5,3868	11,27	*	4,5845	5,20		5,3471	2,58		1,7520
log(wage)	-1,12	**	0,3230	-1,23	**	0,2752	-1,19	**	0,3203	-0,40	**	0,1049
Textile	-9,11	**	1,3514	-6,36	**	1,1505	-8,72	**	1,3412	-3,26	**	0,4394
Publishing	-8,97	**	1,4097	-6,39	**	1,1999	-8,42	**	1,3992	-2,99	**	0,4585
Chemical	-7,66	**	1,3194	-5,22	**	1,1226	-7,20	**	1,3090	-5,01	**	0,4289
Metal	-5,72	**	1,1878	-2,87	**	1,0112	-5,27	**	1,1788	0,23		0,3862
Machine	-7,99	**	1,1080	-3,79	**	0,9432	-7,37	**	1,0996	-2,54	**	0,3603
Other	-6,22	**	1,3673	-2,35	*	1,1638	-5,95	**	1,3569	-2,69	**	0,4447
R2	0,023			0,018			0,023			0,097		
Valid observations	4.586			4.586			4.586			4.586		

**: significant at 5% confidence level*

***: significant at 1% confidence level*

table 19: OLS regression results for different indicators of the growth rate of productivity (1995-1999)

	labour productivity of value added			*labour productivity of production*			*TFP of value added*			*TFP of production*		
Variable	$\overline{\beta}$		σ_β	$\overline{\beta}$		σ_β	$\overline{\beta}$		σ_β	$\overline{\beta}$		σ_β
Intercept	8,38	**	1,5727	4,01	**	1,3277	10,78	**	1,5674	13,51	**	0,6107
Y_rel	-4,68	**	0,2537	-1,15	**	0,1088	-6,97	**	0,3198	-11,95	**	0,3469
Age	0,10		0,1004	0,13		0,0857	0,07		0,0994	0,01		0,0324
(Age<10)	0,92		0,9198	0,33		0,7853	0,84		0,9103	0,12		0,2970
(Age<10)(Age-10)*	-0,01		0,2184	-0,16		0,1863	0,06		0,2162	0,05		0,0703
(Age>=20)	-0,38		0,7198	-0,69		0,6144	-0,23		0,7123	0,10		0,2324
(Age>=20)(Age-20)*	-0,10		0,1097	-0,19	*	0,0936	-0,06		0,1086	-0,01		0,0354
(Age>=40)	-0,88		0,8028	0,61		0,6856	-1,05		0,7943	-0,12		0,2592
(Age>=40)(Age-40)*	0,02		0,0489	0,06		0,0417	0,01		0,0483	-0,01		0,0158
Integration	-0,10		0,9185	0,30		0,7863	-0,27		0,9085	0,03		0,2956
Separation	1,27		1,2592	2,44	*	1,0840	1,16		1,2455	0,44		0,4100
Reorganisation	-2,98		3,2300	-0,65		2,8284	-3,54		3,1848	-0,78		1,0740
log(wage)	-0,46	**	0,1436	-0,49	**	0,1224	-0,47	**	0,1420	-0,15	**	0,0464
Textile	-3,38	**	0,5865	-1,85	**	0,5007	-3,18	**	0,5804	-1,47	**	0,1891
Publishing	-2,96	**	0,6105	-2,30	**	0,5209	-2,66	**	0,6041	-1,34	**	0,1965
Chemical	-1,16	*	0,5794	-0,57		0,4944	-1,03		0,5732	-1,35	**	0,1867
Metal	-1,61	**	0,5227	-0,39		0,4463	-1,26	*	0,5173	-0,42	*	0,1685
Machine	-2,23	**	0,4848	-0,25		0,4140	-1,75	**	0,4797	-1,21	**	0,1562
Other	-2,97	**	0,5994	-1,49	**	0,5116	-2,72	**	0,5931	-1,41	**	0,1932
Average R2[1]	0,029			0,017			0,034			0,098		
Valid observations	22.049			22.049			22.049			22.049		

[1]: average of the results for the five different periods

**: significant at 5% confidence level*

***: significant at 1% confidence level*

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