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Age and Productivity – Evidence from Linked Employer Employee Data

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Nontechnical Summary

In most Western, industrialised countries the workforce is ageing rapidly. Medical research on the relationship between individual performance and age suggests that an ageing workforce could have severe negative consequences on the economic performance of the affected countries. In order to assess the possible consequences of an ageing workforce, this paper measures the impact of changes in the age structure of establishments on productivity using representative linked employer-employee panel data. We take into account that the levels as well as the changes in the age structure of establishments and their production are likely to be determined simultaneously. We apply appropriate statistical methods and test their validity rigorously. In addition, we include several crucial establishment and workforce characteristics that are correlated with productivity and age shares. To summarise, our estimates suggest that some of the previeous studies underestimates the impact of older age groups on productivity. Most of the existing studies suggest a decline in productivity beyond the age of 40. However, we find that establishment productivity increases with the share of employees until the age group 50-55 years and decreases only slightly afterwards. In addition, the inclusion of additional establishment and employee characteristics has a remarkable impact on the shape of the age productivity pattern. Based on our results, we do not find an indication that the ageing workforce will necessarily lead to a decline of the welfare of the industrialised economies because on average the age productivity profile is essentially flat. Finally, our estimates suggest that there is considerable variation in the age productivity profile amongst the establishments in the economy. This is a sign of big differences in the impact of age on the productivity amongst the establishments.

Das Wichtigste in Kürze

Das Durchschnittsalter der Arbeitnehmer stieg in einem Großteil der westlichen Industrienationen über die letzten Jahre stetig an. Medizinische Forschung über die Beziehung zwischen individueller Leistungsfähigkeit und Alter deutet darauf hin, dass eine alternde Bevölkerung weitreichende negative Konsequenzen für die wirtschaftliche Leistungsfähigkeit der betroffenen Länder haben könnte. Um die Auswirkungen alternder Werktätiger abschätzen zu können, untersucht diese Studie die Auswirkungen von Veränderungen in der Altersstruktur von Betrieben auf deren Produktivität. Die Studie stützt sich dabei auf repräsentative Paneldaten, bei denen Informationen von Betrieben mit denen ihrer Arbeitnehmer verknüpft sind. Wir berücksichtigen hierbei, dass sowohl das Niveau als auch die Veränderungen in der Altersstruktur von Betrieben vermutlich gleichzeitig mit der Produktion bestimmt werden. Wir verwenden geeignete statistische Methoden und testen ihre Validität. Zudem fügen wir unseren Schätzungen wichtige Betriebs- und Beschäftigtencharakteristiken hinzu, die sowohl mit der Produktivität als auch den Altersanteilen korreliert sind. Die meisten Studien zu diesem Thema finden eine Abnahme der Produktivtät ab einem Alter von 35 bis 40 Jahren. Unsere Untersuchung zeigt jedoch, dass die Unternehmensproduktivität mit dem Anteil an Arbeitern in der Altersgruppe bis 50 - 55 kontinuierlich ansteigt und danach nur leicht abfällt. Unsere Schätzungen weisen auf mögliche Verzerrungen der Ergebnisse früherer Studien zu diesem Thema hin, da diese entweder Endogenität, Zeitabhängigkeit oder Informationen wie Dauer der Betriebszugehörigkeit und Qualifikation sowie den Zustand des Kapitals nicht berücksichtigen. Unsere Ergebnisse deuten außerdem auf erhebliche Unterschiede bei den Alters-Produktivitätsprofilen zwischen den Betrieben hin. Dies bedeutet, dass sich die Alterszusammensetzung sehr unterschiedlich auf die jeweilige Produktivität der Betriebe auswirkt.

Age and Productivity – Evidence from Linked Employer Employee Data◆

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Abstract

In most Western, industrialised countries the workforce is ageing rapidly. In order to assess the possible consequences of an ageing workforce, this paper measures the impact of changes in the age structure of establishments on productivity using representative linked employer-employee panel data. We take into account that the levels as well as the changes in the age structure of establishments and their production are likely to be simultaneously determined and apply dynamic GMM methods. We find that establishment productivity increases with the share of employees until the age of 50-55 and only decreases slightly afterwards. Our findings suggest that previous estimations are biased because they either do not take into account endogeneity, time dependencies, or crucial information correlated with age shares and productivity. Large standard deviations point to important variation in the age productivity profile among establishments.

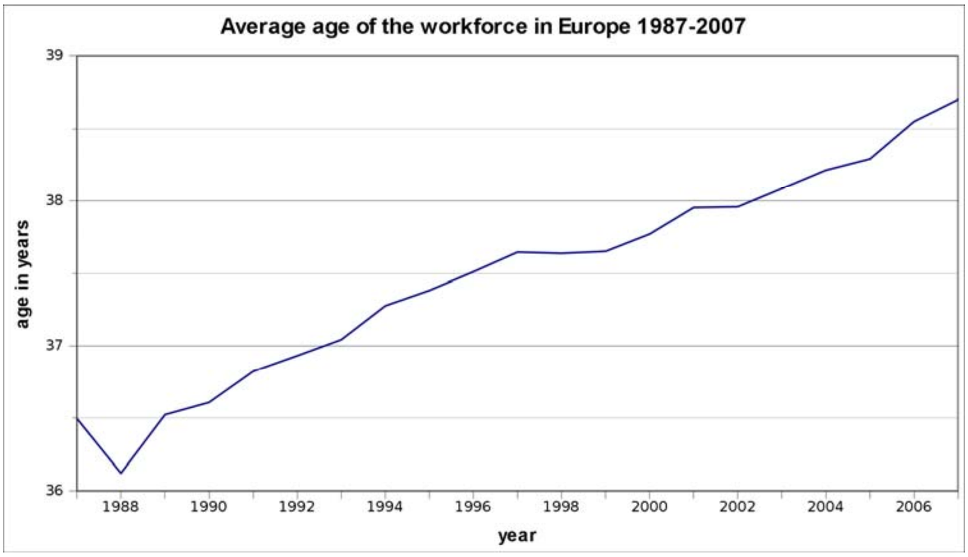
Key-Words: ageing workforce, age, productivity, LEED, system GMM

JEL Codes: J11, J14, J21

1 Introduction

In most industrialised economies, the age of the workforce is growing quickly over the recent years (OECD, 2008) and this trend is likely to continue (Toosi, 2007).

Figure 1: Average Age of the Workforce in Europe 1987-2007



Source: own computations based on OECD (2009).

There are several reasons for this increase. First, the regular retirement age has been increasing in several industrialised countries during the last years and is bound to be increased in other countries.[1] Second, labour force participation of young people decreased during the last years. For example, according to OECD statistics for the population between 15 and 24 years of age the labour force participation has been decreasing between 1987 and 2007 from 56% to 45% in Europe and from 68% to 59% in the US (OECD, 2009). Third, low birth rates reduced the relative size of the younger cohorts in many countries.

In the field of medicine and psychology, many contributions show that the relationship between age and performance indicators depends very much on the performance dimension investigated. For example, most dimensions of physical performance decline

[1] For example, the legal retirement age has been increased for Denmark (2006) Germany (2007), Italy (2007), and the United Kingdom (2006).

constantly with age for virtually all types of measures, at least beyond the age of 30 to 35 years (Stones and Kozma, 1985). For psychological performance, however, the picture is mixed (Ng and Feldman, 2008) and there seem to be various productivity related dimensions of psychological performance that show a positive relationship with age in the workforce (Waldman and Avolio, 1986; Mc Evoy and Cascio, 1989; Sturman 2003). Since each firm has specific needs with respect to the skills and knowledge of its employees, these results indicate that the effects of an ageing workforce on productivity are likely to vary between firms. In order to assess the effects of an ageing workforce for the welfare of an economy, it is helpful to know the average relationship between the age of the workforce and establishment productivity.

During the last years several attempts have been undertaken to study the relationship between age and establishment productivity. Many of these studies suffer either from poor data with respect to number of observations, explanatory variables or missing time dimensions. Moreover, to our knowledge the obvious danger of reverse causality between age structure and productivity has so far only been tackled by few studies (e.g. Aubert and Crépon, 2006, Malmberg et al., 2008). Finally, we argue that all of the previous studies suffer from at least one form of misspecification: Either they apply parametric assumptions about the functional forms of the age productivity profile that are difficult to defend, they suffer from dynamic misspecification, or do not include crucial information correlated with productivity and age shares.

In this paper, we estimate the age-productivity profile on the establishment level. More specifically, we estimate the marginal productivity impact of labour for different age groups. Similar to Aubert and Crépon (2006), we derive our estimates in a Cobb-Douglas production function framework. In our estimations, we take unobserved heterogeneity and simultaneity of the age structure and the production decision into account. We compare the results from between, within and GMM (instrumental) estimates and test the validity of the hypotheses used in the different specifications. In order to control for the characteristics of the establishments as well as the characteristics of the employees we use German representative linked employer-employee panel data entailing an unusually rich list of possible control variables. Our data set combines a panel survey on the establishment level with employment register data. We find considerable differences between the age productivity profiles depending on the estimation strategy and explain them. We further demonstrate that the addition of employer and employee characteristics considerably changes the age-productivity pattern measured. In our preferred specification we find that establishment productivity does increase with the share of workers in older age-groups until the age of 50-55 years. We do not find a meaningful decline of the productivity until the age of 60 years. This is different from most existing studies that find inverse u-shaped age productivity profiles. Moreover, our results point to considerable variation in the relationship between age and productivity amongst firms.

The remainder of this paper has the following structure. The next section provides an overview of issues that have been discussed in the literature on the impact of age on establishment productivity. In the third section we discuss our empirical estimation strategy and the fourth section provides the used representative linked employer-employee panel data set. The fifth section contains the empirical evidence on the impact of age on productivity and the impact of the estimation strategy and section six concludes.

2 Background

During recent years there has been a growing interest in the causal relationship between workforce age and establishment productivity and there have been several attempts to estimate the age-productivity-profile on the basis of firm/establishment level data[2]. It is the aim of this section to provide a summary of crucial issues that have been discussed in this literature. For exhausting reviews of the recent literature we refer to Börsch-Supan et al. (2005), Gelderblom (2006), and Skirbekk (2008).

We start our summary with specification issues of the statistical model. A central question is how the age-effect should be specified. We basically find two different approaches in the literature. One way is the inclusion of a *parametric function of the*

[2] Alternatives are estimations of the age-productivity profiles on the basis of managers´ ratings of employees in a firm and directly measuring the quantity and quality produced where an individual´s output is readily observable. These approaches might either suffer from discrimination or are not easy to generalise, however (Ilmakunnas et al., 2007).

average age (e.g. Grund and Westergaard-Nielsen, 2005, Ilmakunnas and Ilmakunnas, 2008). However, it appears that this approach puts a heavy load on the underlying parametric assumptions and the age-productivity profile. The age of peak performance is here mainly determined by the curvature of the relationship between average-age and productivity. The frequently reported inverted u-shaped relationship between age and productivity could, for example, be the outcome of restrictive parametric assumptions. To avoid these problems, the most common solution is the use of the share of the workforce for different age-classes (e.g. Hellerstein and Neumark, 1995; Haltiwanger et al., 1999; Hellerstein et al., 1999; Crépon et al., 2003). This allows for an unconstrained relationship between age of the workforce and productivity.

Simultaneity of the explained production output and the explanatory inputs can lead to biased estimates of the parameters of interest. In order to overcome this problem two approaches have been applied in the literature. The first is the use of lagged observations in order to instrument current values of the inputs (e.g. Crépon et al., 2003; Daveri and Maliranta, 2007; Lallemand and Rycx, 2009). The application of dynamic panel models provides a way to use lagged values as instruments in an efficient way (see also Aubert and Crépon, 2006). A different way to overcome the simultaneity problem is to derive the estimation approach from structural assumptions about the underlying economic process. Olley and Pakes (1996) and Levinsohn and Petrin (2003) provide such models for the estimation of standard production functions including labour, capital and investments or intermediate inputs. Currently there exist only few studies that apply the second approach for the estimation of age-productivity profiles (Hellerstein and Neumark, 2004; Dostie, 2006). We discuss some issues of these structural models in section three.[3]

The dynamic specification of the production function, i.e. the dependence of the production output of the output in previous periods, is an issue that has been ignored by most applications so far. Prskawetz et al. (2006) provide the only application that specifies a dynamic production function. Blundell and Bond (2000) and Bond (2002) however emphasise the importance of correct dynamic specifications and propose a

[3] See Ackerberg et al. (2006) for a discussion of the relationship between dynamic panel and structural approaches.

model where productivity shocks are allowed to be serially correlated for general production functions.

Now we discuss some issues that concern the data that are used for the estimation of age-productivity profiles. The availability of longitudinal data is important for the estimation of age productivity profiles. This is especially true in the likely case where the age and quality of the capital stock or the age of the establishment correlate with the age structure of the workforce. Older workers frequently work with older, less productive capital endowment (because the endowment at their employer is older or because they work in teams with older capital than teams with younger members), Malmberg et al. (2008). Firms change their age structure over time while they have to learn their optimal age structure and those firms with a better workforce age structure survive (Haltiwanger et al. 2007). In a cross section or between establishments analysis this would lead to an underestimation of the productivity of old workers because the coefficient of the share of older employees is negatively biased by unobservable third factors such as the quality of capital or establishment age. More generally, longitudinal data or within establishment comparisons correct for biases induced by unobservable time-invariant third factors that are correlated with certain age groups and establishment productivity (Crépon et al., 2003; Aubert and Crépon, 2006).

In addition to the use of methods that are based on longitudinal data, there are several observable establishment and workforce characteristics that should be included in the estimation model because they are likely to be correlated with age and that may have an effect on the productivity of the establishment. Some of these characteristics have been controlled for in recent studies. For example, Ilmakunnas and Maliranta (2005) show the sensitivity of age-productivity profiles to the quality of capital and education data. Malmberg et al. (2008) include the age of the firm as an indicator for the vintage (and productivity) of capital used. Daniel and Heywood (2007) and Schneider (2007) argue that it is necessary to control for the tenure of the workers. Some productivity effects may stem from tenure instead of age because higher tenured employees had the opportunity to accumulate firm specific human capital. In addition, higher tenured employees tend to have a better match between their human capital endowment and the requirements of the employer and they are therefore a positively selected group

(Gelderblom, 2006; Zwick, 2008). Various studies have tried to control for the heterogeneity of the age or the age dispersion inside a firm because age mixed teams might be beneficial for certain work processes (Veen, 2008; Ilmakunnas and Ilmakunnas, 2008). Differences in productivity between age groups might also stem from systematic increases in qualification levels obtained between different cohorts (Haegeland et al., 1999). The human capital endowment of the cohorts strongly increases over time, in most industrialised countries. This is also the case in Germany, where acceptance numbers to universities increased, especially during the 1970s as a consequence of the so-called qualification offensive.

In this study, we apply panel GMM estimators in order to account for endogeneity bias at the age productivity profile. We specify a dynamic production function and use the share of the workforce in different age classes to measure the effect of age on establishment productivity. Our analysis is based on a large and representative matched employer-employee panel dataset that allows us to control for all workforce and establishment characteristics mentioned above and show their impact on the estimation results.

3 Estimation Strategy

In this section, we first outline the specification of the production function that we estimate. Afterwards we discuss different estimation strategies and some implications. Similar to Aubert and Crépon (2006), we start from a structural Cobb-Douglas production function. Assuming perfect substitution among workers, one can write the production function per head, for establishment *j* in period *t* as:

$$\ln(p_{j,t}) \approx c + \beta \ln(k_{j,t}) + \sum_{i-\{0\}} (1-\beta)\left(\frac{a_i}{a_0} - 1\right)\left(\frac{L_i}{L}\right)_{j,t} + \varepsilon_{j,t} \qquad (1).$$

Value added (sales minus intermediate inputs) per head *p* is explained by capital per head *k* and the fraction of the number of employees in age groups *i*, L_i of the total number of employees in the establishments *L*. Here, a_i is the marginal product of age group *i*; a_0 is the marginal product for the reference age group. We use age classes in five year brackets and only report the coefficients of employees between 20 years of age and 60 years of age. The estimates for the other age classes are summarised in a separate variable but are not reported because they are likely to reflect unobserved characteristics of employees at the fringes of the age distribution - very young employees and very old employees are usually specific individuals. In addition, they represent only a small fraction of the population of all employees.[4]

This specification, however, is likely to provide an oversimplified view on the production process. For example, additional workforce characteristics such as the composition of the labour force with respect to education, tenure, age variance and qualification or establishment characteristics such as the technical state of the capital stock, sector or export activities should have an impact on the outcome. Moreover the production in one time period might be a function of the production in previous periods. Therefore, we also apply estimations where the production function is extended in two important ways. First, we allow for additional explanatory variables X_j and include a broad range of relevant establishment specific. Second, we specify a dynamic model where the production of one year is allowed to be a function of its past values:

$$\ln(p_{j,t}) \approx c + \sum_{k} \alpha_k \ln(p_{j,t-k}) + \beta \ln(k_{j,t}) + \sum_{i-\{0\}} \gamma_j \left(\frac{L_i}{L}\right)_{j,t} + \phi X_{j,t} + \varepsilon_{j,t} \qquad (2).$$

We consider various ways of estimating the production function. In a first step, we estimate pooled ordinary least squares (OLS) of equation (1) and (2). However, the OLS estimates are likely to be miss-specified because the value added and the age structure might be determined simultaneously (Griliches and Mairesse, 1998). Successful establishments for example recruit more workers and job entrants tend to be younger than those who leave the enterprise (Heywood et al., 2009; Zwick, 2008). In addition, the variation between the establishments is likely to drive the results and we can only observe part of the heterogeneity between establishments (Prskawetz et al., 2006) – establishments with better industrial relations might be able to bind their employees longer, for example, while they enjoy a higher productivity (Addison et al.,

[4] In 2005, the last year of our observation period only 3.5% of the employees is younger than 20 years and only 3.8% is older than 60 years old (OECD, 2005).

2009). Finally, the age structure might have lagged effects on value added because establishments react not immediately to the need to improve relative productivity of their ageing workforce.

In a next step we switch from a between estimation to a within estimation using Fixed Effects. They sweep out unobserved time-invariant heterogeneity. When it comes to the estimation of our production functions, Fixed Effects estimates are no panacea for simultaneity problems, however. Simultaneity may arise since, within a firm, also changes of production and age structure between years are likely to be determined in the same period. An example is that an increase in production is associated with the hiring of workers. Since hirings are likely to be predominantly in young age classes, this will lead to a simultaneous change of production and age structure – and consequently the estimates can not be interpreted as an effect of a change of the age structure on productivity. The latter arguments suggest that neither OLS nor Fixed Effect estimates are likely to be particularly useful for the estimation of age productivity profiles. This is the case since both approaches are not able to cope with the presence of simultaneity between the age structure and productivity.

In order to control for the described endogeneity problems, we apply static and dynamic GMM estimators (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). The basic idea of these estimators is to use lagged levels as "internal instruments" for contemporary differences and lagged values of differences of the same variable as internal instruments for contemporary levels. Generally speaking, the underlying assumption is that contemporary shocks that may affect productivity and the age structure of the workers are orthogonal to the past level of capital and the age structure of the establishment (Aubert and Crépon, 2006).

To derive a valid set of instruments, we start with a "difference GMM" (Arellano and Bond 1991) specification, where we instrument the equation in differences by lagged values of the explanatory variables.[5] Our panel data set contains observations for up to 9 years and provides a large set of potentially available instruments. Since the number

[5] We use the orthogonal deviation transform in order to purge the fixed effects. For a discussion of this approach see Arellano and Bover (1995) or Roodman (2007).

of available instruments exceeds the number of instrumented variables, we test the overidentifying restriction by applying the Sargan/Hansen test.

It is likely that recent lags have a greater explanatory power and it is therefore desirable to include the smallest lag that still satisfies the orthogonality conditions. The set of valid lags depends on the nature of the explanatory variables. For example, strict exogenous variables do, by assumption, not require the use of lagged variables whereas predetermined or endogenous variables require at least a lag of one or two periods, respectively. In practice, we start by the assumption of endogenous variables with a lag of high order and test gradually the validity of instruments that are based on recent lags. Since the model is overidentified we can apply the abovementioned Sargan/Hansen test in order to check statistically whether the recent lags are valid instruments.

In a further step we also apply "system GMM" estimations. Roughly speaking, here the set of equations from "difference GMM" is augmented by additional equations in levels. The differences of the explained variables provide instruments for the equation in levels and the set of available moment conditions can be augmented accordingly. For a discussion of the underlying economic assumptions that are behind these additional instruments, we refer to Arellano and Bover (1995), Blundell and Bond (1998) and Bond (2002). Again, the validity of the additional instruments and hence the underlying assumptions can be tested by means of the Sargan/Hansen tests.

Blundell and Bond (2000) and Bond (2002) have recently put an emphasis on correct dynamic specifications for the identification of the parameters of interest. We include the one and two year lag of the explained variable to allow for dependence of productivity on its recent values. We apply a test for autocorrelation in the disturbance terms appropriate for GMM panel estimates (Arellano and Bond, 1991) to check the presence of serial correlation in order to test the dynamic specification of the model.

To summarise, we apply dynamic GMM methods and use lagged values of the explanatory variable to instrument contemporary values. In order to find the correctly specified model, we start with moment conditions that require relatively mild assumptions and augment the set of instruments step by step. The validity of the additional instruments is tested by means of the Sargan/Hansen test for overidentifying restrictions. We also apply the test for serial correlation in the disturbance term in order to check whether the dynamic specification of the model is correct.

Blundell and Bond (2000) propose a different specification of the production function. Applying their model would boil down to equation (2) without the lagged dependent variables included; instead, the error term $\varepsilon_{j,t}$ is composed of a serially uncorrelated error term $m_{j,t}$ and, in addition, of an element $v_{j,t}$ that depends on its lagged value of the previous period:

$$v_{j,t} = \alpha v_{j,t-1} + e_{j,t} \qquad |\alpha| < 1 \qquad (3)$$

In this model, $v_{j,t}$ can be interpreted as a productivity shock that is allowed to be autoregressive. The dynamic (common factor) specification of this model can be consistently estimated by GMM methods (see also Bond, 2002). This implies the estimation of an unrestricted model, where the first lag of all input factors and the explained variable are included. The estimates of this unrestricted model are related to the parameters of interest, via several, known, non-linear (common factor) restrictions. In order to derive the estimates of the underlying model, we impose these restrictions by the means of minimum distance estimates. The validity of the common factor restriction and hence the model can be tested within the minimum distance framework (Hempell, 2006). We estimate the Blundell and Bond (2000) type of specification. In our case, the restrictions are clearly rejected at the 1% level. We conclude that the Blundell and Bond (2002) type of model cannot be applied in our case.[6]

Olley and Pakes (1996)[7] (OP) and Levinsohn and Petrin (2003)[8] (LP) propose different, more structural approaches for the estimation of production functions. They start from assumptions about the economic behaviour and timing of information and input decisions by firms and derive their estimation methods based on these assumptions. Bond and Söderbom (2005) and Ackerberg et al. (2006) question the identification of these approaches, even for cases where the underlying economic assumptions are

[6] The estimates and the test results for the system GMM Minumum Distance Estimator (MDE) are available on request.

[7] For an empirical application of Olley and Pakes on age-productivity profiles, see Hellerstein and Neumark (2004).

fulfilled. Their main concern is identification because there are problems of collinearity in the first step estimations of the labour coefficient and material input coefficient for LP or the investment coefficient for OP. Ackerberg et al. (2006) (ACF) propose an estimation procedure to solve these issues that assumes a strict time schedule for the decisions on material inputs/investments, labour, and capital. We think, however, that the assumptions that are required for the OP/LP/ACF-type of estimations are likely not to hold in our case. First, the assumption that productivity shocks are the only unobservables entering the investment function (OP) or the intermediate input (LP) rules out the existence of optimisation and measurement errors. Both errors are likely to be present in real world data, at least to some extent. Second, the identification of the OP/LP/ACF-models builds on assumptions about the (unobserved) timing of information about productivity shocks and the timing of input decisions for the different inputs. While these assumptions may be reasonable for specific industries, it seems to be an easy exercise to invalidate the same assumptions for other industries. Therefore it is problematic to apply these models for the estimation of production functions for the economy as a whole. Additionally, in this paper, age differences of the labour force are a focus of the analysis and employment protection, skill shortages or industrial relations could lead to complex timings with respect to employment decisions for different age groups. For example, older employees are stronger protected by labour law or by agreements against dismissals and for example works councils have a say who is dismissed and hired (Addison et al., 2009). To summarise, we think that key assumptions of the OP/LP/ACF-models do not apply in our case. Therefore, we believe that these models are not helpful for the evaluation of representative age productivity profiles in this study.

4 Data

In order to estimate the impact of the age structure on establishment productivity, this paper uses the waves 1997-2005 of the linked employer-employee data set (LIAB) of the *Institute for Employment Research (IAB).*[9] We use a version of the LIAB that provides one observation per year for establishment characteristics and virtually all

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[8] For an application of Levinsohn and Petrin (2003) on age-productivity profiles, see Dostie (2006).
[9] The German name is "*Institut für Arbeitsmarkt- und Berufsforschung*".

employees of the observed establishments on June 30th of the respective year (see Jacobebbinghaus, 2008 for details).[10] On the establishment level, the LIAB uses the representative survey data of the IAB establishment panel. This panel entails questions on value added, investments, industrial relations, sector, average employee characteristics and expectations of the managers. The establishment data are linked by the means of a common identifier to the administrative files for the employees. The employee data set uses official data of the IAB employment register. Yearly information on wages, qualification, gender, tenure, experience, and age can therefore be linked to the employer data. Altogether our version of the LIAB covers almost 7 million employees and more than 8,500 establishments.

Only establishments with more than five employees are included and in order to increase the homogeneity of the sample further, the public sector, the non-profit sector and the financial sector are excluded. In order to have a proxy for the capital stock, we use the yearly information on investment and the depreciation rates on the two-digit sector level according to the perpetual investment method (Zwick, 2004). For the starting value, we use the average of real investment and divide it by the sum of the depreciation rate and the average growth rate of investment (Hempell, 2006). Capital in the next period is then calculated by capital in the previous period plus investment and minus depreciation. About eight percent of the establishments never report an investment during our observation period. We apply two different strategies to cope with these missings. On the one hand, we delete the establishments that never report investments. On the other hand, we impute the missing values for capital stocks. Applying a sensitivity analysis, both empirical strategies lead to similar results, though. The results reported in this paper are derived with the imputed capital stocks.

Individual tenure and experience are censored in some cases. For employees in West Germany we know the exact date for experience and tenure since January 1st 1975 and for East Germany the dates are known since January 1st 1990. For observations before these dates the censored date is given. This means that between 16% (1997) and 10% (2005) of the West German and between 46% (1997) and 27% (2005) of the East

[10] Confusingly, this version of the LIAB-data is called “cross section version”, despite the fact that the data set provides panel data.

German employees have censored values. We account for censoring by multiply imputing their values (compare Gartner, 2005). We define 20 cells for different gender, qualification (five groups), and nationality. For each cell, censored Tobit regressions are estimated separately including the covariates tenure, tenure squared, age, age squared, a dummy for East Germany and the level of education. Yearly imputation of the values for experience and tenure could lead to excess variance in these variables and therefore, for each employee, only the first value for tenure and experience is imputed. For each additional year the employee stays in the same establishment we update the value for experience and tenure by adding one year to the value of the last year.

Since we are interested in the productivity per head we have to compute the amount of the input factors per head. To cope with workers that have only part-time contracts we count each part-time employed worker by one half. Apprenticeships are included but their share is controlled for because they can be expected to have a lower productivity - they only work four or three days per week. For a short description of the variables and their mean values, we refer to Table 1 in the appendix.

5 Results: The Age-Productivity Profile

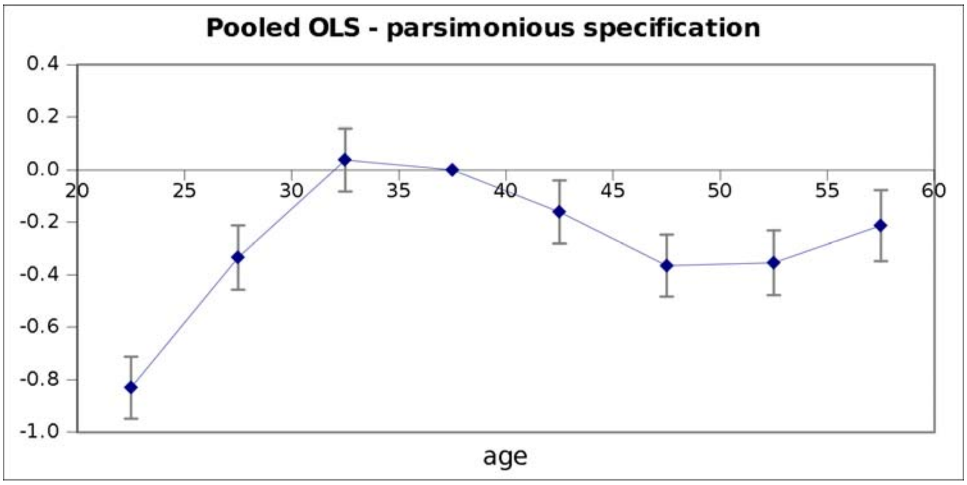
In this section we summarise our findings concerning the age-productivity profile. As mentioned in section three, we present the results for 5-year age classes from 20-60 years of age. For the results of the control variables we refer to the tables in the appendix.

The pooled OLS estimation without further explanatory variables leads to an age-productivity pattern that is comparable to existing results in the literature (Aubert and Crépon, 2006). Figure 2 provides a visual representation of the age-productivity profile obtained by pooled OLS. In this case, the age productivity profile increases until the age group 30-35 years, then decreases until the age group from 45-50 years and finally increases again. Most age groups have a significantly smaller productivity than the reference group.

In the past, several authors have argued that it is necessary to control for workforce and establishment characteristics in order to avoid biases in the age-productivity profile, however. According to the arguments collected in our background section, we include gender, nationality, share of apprenticeships, age variance, qualification groups, average tenure, and technical conditions of the equipment, the share of part-time workers, an export dummy, and the economic sector.

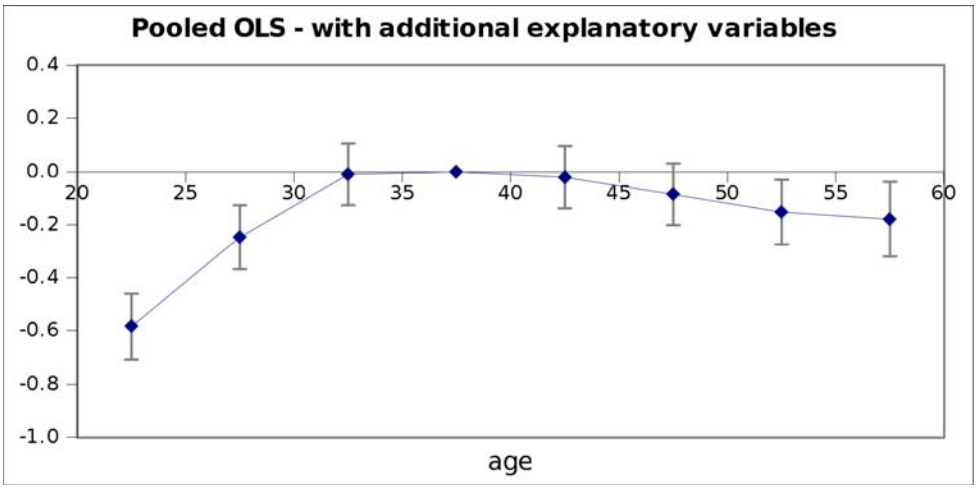
Figure 3 illustrates the age-productivity profile for the pooled OLS-estimates, after the inclusion of additional explanatory variables. Controlling for these variables, the total impact of age decreases considerably. Moreover the age group with the maximum productivity shifts to the age group 35-40 years. The productivity of workers older than 40 years is now decreasing slightly and the inverse u-shaped age effect for the old workers that we have found in Figure 2 is smaller, compare Figure 3. Note that the Arellano and Bond (1991) test for autocorrelation in the disturbance terms provides an indication for the presence of serial correlation, which could point to a dynamic misspecification.

Figure 2: OLS estimates without explanatory variables



Note: 95% confidence intervals are indicated by the bars.

Figure 3: Pooled OLS estimates with explanatory variables

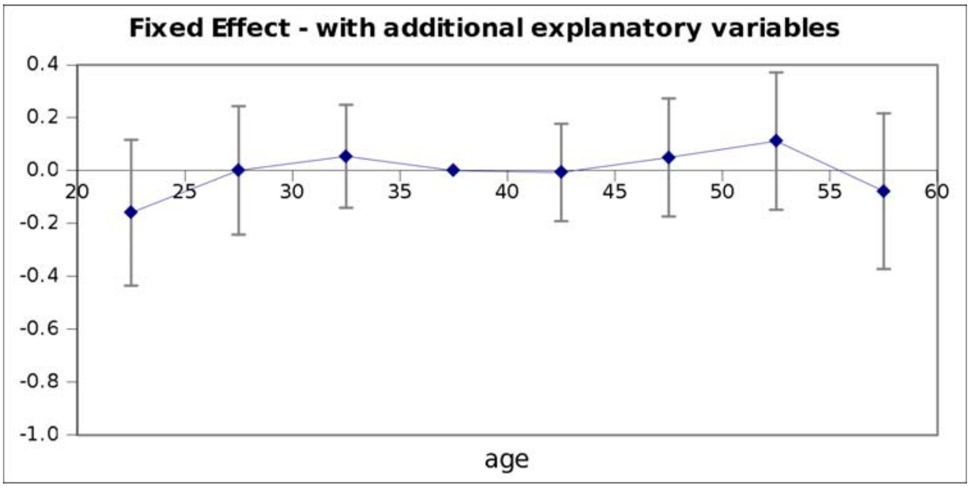


Note: 95% confidence intervals are indicated by the bars.

The Fixed Effects estimator leads to an essentially flat age-productivity profile;[11] see Figure 4 and Table 4. However, as argued in section 3, the pooled OLS as well as the Fixed Effects estimator are likely to suffer from endogeneity problems.

[11] Most covariates are insignificant and small in this specification - this is also found for example by Haltiwanger et al. (1999) when they go from a cross section to a fixed effects specification.

Figure 4: Fixed Effects with explanatory variables

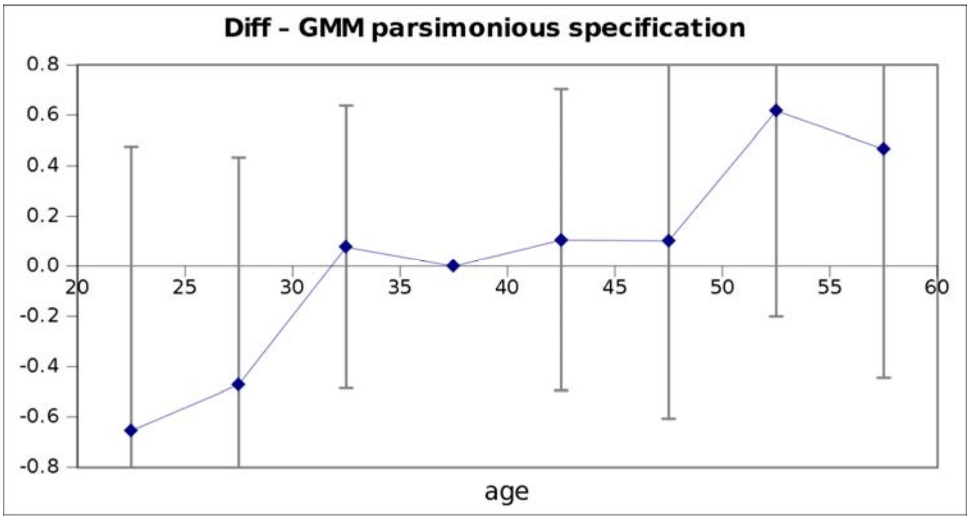


Note: 95% confidence intervals are indicated by the bars.

In order to cope with the endogeneity problem of age shares in productivity estimations, we apply panel GMM methods. Since one of our concerns is a correct specification of the dynamics of this model, we explore different dynamic specifications and use the Arellano and Bond (1991) test for autocorrelation in the disturbance terms as a specification test. As explained in section 3, we start with a Blundell and Bond (2000) type of specification, where productivity shocks are allowed to be autoregressive. In practice this boils down to the estimation of an unrestricted model. The parameters of the underlying, restricted model can then be derived by the means of minimum distance estimates. However, the implied common factor restrictions are clearly rejected at the 1% level. In the next step, we include the lags of the dependent variables into the model. Roughly speaking, this specification implies that the levels of productivity are autocorrelated. We find that the model with two lags of the dependent variable included provides a satisfying result in the sense that the test for remaining autocorrelation in the residual provides the required pattern. As expected we find a significant negative effect parameter for the AR(1) in the residuals (see Roodman, 2006) but no indication for AR(2) in the residuals.

We again first estimate a “parsimonious” version of the Difference GMM model, without the control variables mentioned above. We find that the productivity increases up to the age group 50-55 years and hardly declines afterwards. In addition, the variance of the estimates increases and we do not find a significant effect of age relative to the reference group. Next, we estimate the Difference GMM model with the additional control variables. In our preferred specification, we include the lags before t-3 for the variables of our parsimonious specification and the lags t-2 – t-5 for the additional control variables. We find that the age productivity profile differs from the parsimonious specification in the following ways: the negative effect of the share of young workers is less pronounced and the increase in productivity between the age groups 35-40 and 50-55 becomes almost linear. With this specification, we find that the productivity of the age group 50-55 years is significantly higher at the 10% level than the productivity of the age group 30-35 years, compare Figure 6 and Table 6. Our results suggest that there is ample variation in the age-productivity profile amongst establishments in the economy.[12] In order to test the validity of the instruments, we apply the standard Sargan/Hansen tests of overidentifying restriction separately for the variables of interest and for the control variables. Our tests indicate that all instruments are fine. Also the test for autocorrelation in the residuals indicates that the model is correctly specified.

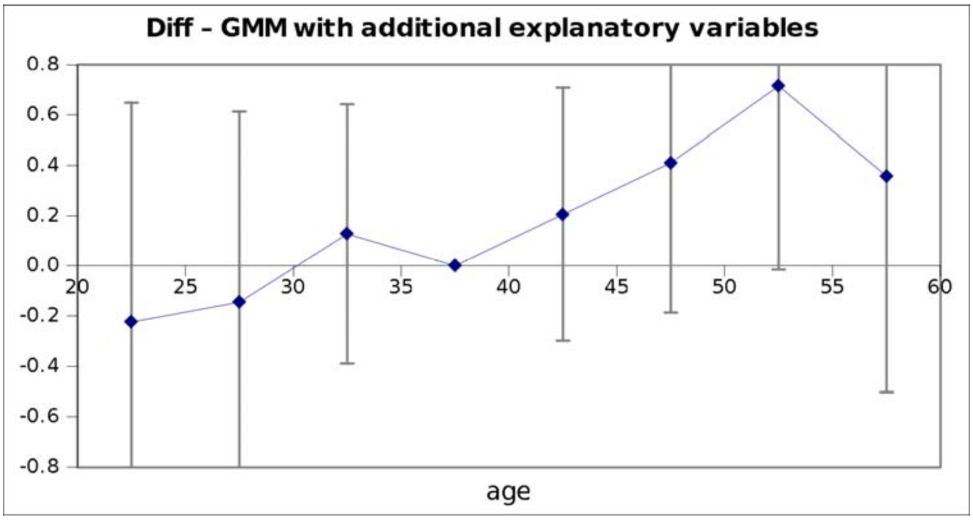
Figure 5: Dynamic diff-GMM estimates without explanatory variables



Note: 95% confidence intervals are indicated by the bars.

[12] Compare also Haltiwanger et al. (1999) who come to a similar conclusion.

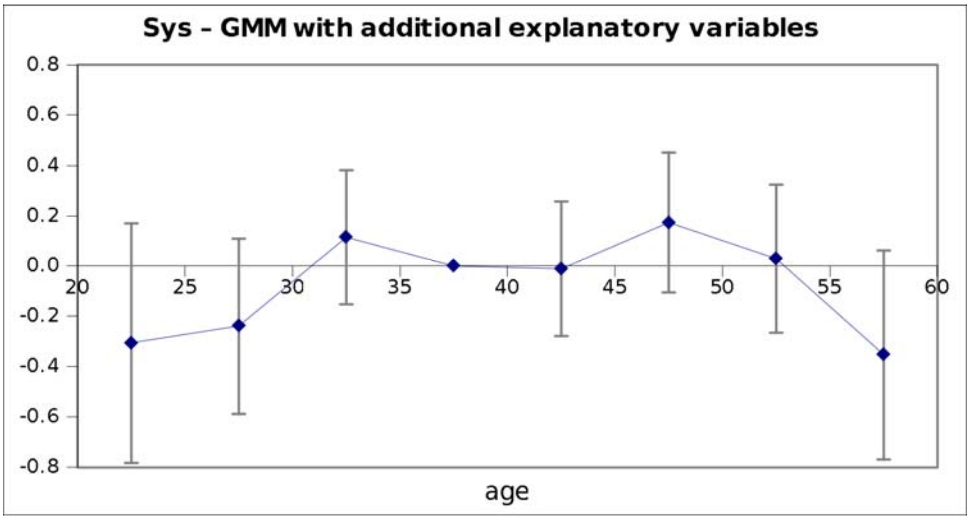
Figure 6: Dynamic diff-GMM estimates with explanatory variables



Note: 95% confidence intervals are indicated by the bars.

Finally, we also estimate System GMM estimates where we include additional moment restrictions. As described above, we cannot find any specification where the additional instruments have not been rejected by the Sargan test for overidentifying restriction. On the basis of this test we prefer the specification for Difference GMM, the results of the System GMM estimates are reported in Figure 7 and Table 7.

Figure 7: Dynamic Sys-GMM estimates with explanatory variables



Note: 95% confidence intervals are indicated by the bars.

Blundell and Bond (1998) point to the danger of biased results induced by weak instruments when applying Difference-GMM methods (Staiger and Stock, 1997) and also demonstrate that this approach is problematic when the data series are close to a unit root. We check the key variables that have been used for the estimates and the hypothesis of a unit root in the series is rejected at any common significance level on the basis of a Dickey-Fuller Test. In addition, we use a large data set that contains information on several thousand establishments for up to 9 time periods. This should help to reduce the problems that are induced by finite samples. Finally we would like to point to the fact that there is plenty of variation in the age structure of the establishments. This is partly a consequence of exogenous reasons, since during the observation period the age structure for the workforce strongly changes, partly due to demographic reasons. Figure 8 (in the appendix) provides the age structure of the employees in our data for different years. One can clearly see how the cohorts move through the age groups – the dip in the post war age cohorts grows slowly out of the workforce. This movement should have a remarkable effect on the age structure of the establishments.

In order to check the sensitivity of our analysis to specific aspects of our data set or specifications, we run several tests. The static specifications of the production function have been rejected since our specification test indicated autocorrelation in the residuals. As mentioned above, also the dynamic specification of Blundell and Bond (2000) has been rejected on the basis of a statistical test. One could also be concerned by the fact that the average tenure of the employees in the establishments is highly correlated with the age structure and that the high standard errors are a consequence of this correlation. In order to check whether this indeed is an issue, we estimate the final model without the tenure variable. The general picture does not change, however, and we decide to include tenure in the set of control variables for the preferred set of estimates. We also check the sensitivity of the results with respect to the size of the establishments – we exclude all establishments with more than 150 employees. Our results also seem not to be sensitive with respect to this change in the sample.

To summarise, our estimates suggest that OLS underestimates the impact of older age groups on productivity. In addition, the inclusion of additional establishment and employee characteristics has a remarkable impact on the shape of the age productivity pattern. Based on our results, we do not find an indication that the ageing workforce will necessarily lead to a decline of the welfare of the industrialised economies because the age productivity profile is essentially flat. The large standard errors indicate however that there is considerable variation in the age productivity profile amongst the establishments in the economy.

6 Conclusions

This paper shows that establishment productivity increases with the share of employees until the age of 50-55 years and only decreases slightly afterwards. Our findings suggest that previous estimates may be biased since they either do not take into account endogeneity of the age share, time dependencies, or essential information correlated with productivity and age shares such as workforce tenure, the technical state of capital, and qualification.

Large standard deviations point to important variation in the age productivity profile among establishments in the economy. This observation is in line with medical research that suggests that the age-profiles depend on the specific type of work. Another explanation could be that there might be important variation in the way firms try to prevent potential negative effects of ageing or exploit the specific capabilities and experience of old workers.

Our estimation approaches are the first steps in the direction of a comprehensive study of the relation between age and productivity. They illustrate that the estimation results of previous papers might be biased if endogeneity and unobserved heterogeneity between establishments are not taken into account. The rigorous application of well known statistical specification tests proofs to be helpful to determine a valid specification.

Several existing papers have investigated how the age-productivity profiles might differ between establishment groups and for different personnel measures chosen by the management such as flexible working time for older employees, specific training for older employees, or mixed age teams. An interesting new step therefore will be to differentiate between the age productivity profiles of for example small and large, old and young firms, different sectors or establishments pursuing different personnel measures for their older members of their workforce.

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Table 1: Descriptive statistics of variables used

Variable	Average Value	Description
Log (value added) per head	10.84	Log of (sales minus value of intermediate goods) per head
Log (capital)	10.09	Log of (capital) per head
Women	0.36	Dummy, 1 if gender is female
Germans	0.95	Dummy, 1 if nationality is German
Apprenticeships	0.05	Dummy, 1 if the employee follows an apprenticeship training
Unskilled	0.17	Dummy, 1 if not formally qualified
Lowskilled	0.29	Dummy, 1 formally qualified worker
Highskilled	0.02	Dummy, 1 formally qualified worker in leading position
White-collar	0.36	Dummy, 1 if white-collar worker
Parttime	0.14	Dummy, 1 if worker has a part-time contract
Good equipment	0.70	Dummy, 1 if the establishment indicates that their equipment/capital-stock is in good shape
Average tenure	7.12	Tenure in years of the employee in the establishment
Average employee age	39.91	Average age of employees
Age-dispersion	10.31	Standard deviation of age
Exporting	0.22	Dummy, 1 if establishment indicates that it is exporting
Number of workers	202.70	Number of workers per establishment expressed in full-time equivalents
East-German	0.38	Dummy, 1 if the establishment is in east Germany
Sector		50 Sector dummies derived from the 2 level NACE-classification

Table 2: Pooled OLS - parsimonious specification

Dependent variable: log(value added)

Variable	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
log(capital)	0.14	0.00	44.08	0.00	0.13	0.15
age_(20,25]	-0.83	0.06	-13.79	0.00	-0.95	-0.71
age_(25,30]	-0.33	0.06	-5.35	0.00	-0.46	-0.21
age_(30,35]	0.04	0.06	0.61	0.54	-0.08	0.16
age_(40,45]	-0.16	0.06	-2.61	0.01	-0.28	-0.04
age_(45,50]	-0.37	0.06	-6.07	0.00	-0.48	-0.25
age_(50,55]	-0.35	0.06	-5.64	0.00	-0.48	-0.23
age_(55,60]	-0.21	0.07	-3.08	0.00	-0.35	-0.08
_cons	9.71	0.07	136.47	0.00	9.57	9.85
50 sector dummies included						
9 year dummies included						

Number of obs = 32572
F(63, 32508) = 113.02
Prob > F = 0.0000
R-squared = 0.1779
Root MSE = 0.68237

Arellano-Bond test for AR(1): z = 62.41 Pr > z = 0.0000
Arellano-Bond test for AR(2): z = 48.09 Pr > z = 0.0000

Table 3: Pooled OLS - with additional explanatory variables

Dependent variable: log(value added)

Variable	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
log(capital)	0.12	0.00	38.32	0.00	0.12	0.13
age_(20,25]	-0.58	0.06	-9.24	0.00	-0.71	-0.46
age_(25,30]	-0.25	0.06	-3.99	0.00	-0.37	-0.13
age_(30,35]	-0.01	0.06	-0.16	0.88	-0.13	0.11
age_(40,45]	-0.02	0.06	-0.34	0.74	-0.14	0.10
age_(45,50]	-0.08	0.06	-1.44	0.15	-0.20	0.03
age_(50,55]	-0.15	0.06	-2.43	0.02	-0.27	-0.03
age_(55,60]	-0.18	0.07	-2.47	0.01	-0.32	-0.04
women	-0.06	0.01	-7.01	0.00	-0.08	-0.05
Germans	-0.07	0.02	-4.05	0.00	-0.10	-0.04
apprenticeships	0.04	0.02	2.06	0.04	0.00	0.07
unskilled	-0.06	0.01	-5.21	0.00	-0.08	-0.03
highskilled	0.04	0.03	1.60	0.11	-0.01	0.09
whitecoll	0.12	0.01	12.58	0.00	0.10	0.14
parttime	0.03	0.01	1.91	0.06	0.00	0.06
good equipment	0.07	0.01	8.47	0.00	0.05	0.08
average tenure	0.01	0.00	7.12	0.00	0.01	0.01
age-dispersion	-0.01	0.00	-3.42	0.00	-0.01	0.00
exporting	0.14	0.01	14.32	0.00	0.12	0.16
number of workers	0.00	0.00	6.15	0.00	0.00	0.00
East-german	-0.29	0.01	-33.95	0.00	-0.31	-0.28
constant	10.08	0.07	135.61	0.00	9.93	10.22
50 sector dummies included						
9 year dummies included						

Linear Regression

Number of obs = 32497

F(76, 32420) = 139.71

Prob > F = 0.0000

R-squared = 0.2395

Root MSE = .65646

Arellano-Bond test for AR(1): z = 57.55 Pr > z = 0.0000

Arellano-Bond test for AR(2): z = 43.49 Pr > z = 0.0000

Table 4: Fixed Effect - with additional explanatory variables

Dependent variables: log(value added)

Variable	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Lag 1 of dep. var.	0.02	0.02	1.05	0.30	-0.02	0.05
Lag 2 of dep. var.	-0.10	0.01	-6.95	0.00	-0.13	-0.07
log(capital)	0.31	0.04	8.75	0.00	0.24	0.38
age_(20,25]	-0.16	0.14	-1.13	0.26	-0.43	0.12
age_(25,30]	0.00	0.12	0.01	0.99	-0.24	0.24
age_(30,35]	0.05	0.10	0.55	0.59	-0.14	0.25
age_(40,45]	-0.01	0.09	-0.07	0.94	-0.19	0.18
age_(45,50]	0.05	0.11	0.44	0.66	-0.17	0.27
age_(50,55]	0.11	0.13	0.84	0.40	-0.15	0.37
age_(55,60]	-0.08	0.15	-0.52	0.61	-0.37	0.22
women	-0.03	0.01	-2.94	0.00	-0.05	-0.01
Germans	-0.04	0.02	-1.99	0.05	-0.07	0.00
apprenticeships	0.00	0.02	0.12	0.90	-0.03	0.04
Unskilled	-0.01	0.01	-0.57	0.57	-0.03	0.02
highskilled	-0.02	0.03	-0.53	0.60	-0.08	0.04
whitecoll	0.01	0.01	0.81	0.42	-0.01	0.03
parttime	0.09	0.04	2.26	0.02	0.01	0.17
good equipment	-0.01	0.01	-0.92	0.36	-0.04	0.01
average tenure	0.01	0.01	1.42	0.16	0.00	0.02
age-dispersion	0.00	0.01	-0.60	0.55	-0.02	0.01
exporting	-0.01	0.02	-0.67	0.51	-0.06	0.03
number of workers	0.00	0.00	0.26	0.80	0.00	0.00
constant	8.53	0.47	18.15	0.00	7.61	9.45
9 year dummies included						

Fixed-effects (within) regression
Number of obs = 13302
F(29,4679) = 8.37
Prob > F = 0.0000
corr(u_i, Xb) = -0.3662
(Std. Err. adjusted)

Table 5: Diff – GMM parsimonious specification

Dependent variable: log(value added)

Variable	Coef.	Std.	t	P>|t|	[95% Conf. Interval]	
Lag 1 of dep. var.	-0.04	0.09	-0.46	0.65	-0.22	0.14
Lag 2 of dep. var.	-0.11	0.09	-1.23	0.22	-0.29	0.07
log(capital)	0.18	0.16	1.18	0.24	-0.12	0.49
age_(20,25]	-0.65	0.58	-1.13	0.26	-1.78	0.48
age_(25,30]	-0.47	0.46	-1.02	0.31	-1.38	0.43
age_(30,35]	0.08	0.29	0.27	0.79	-0.49	0.64
age_(40,45]	0.10	0.31	0.34	0.73	-0.49	0.70
age_(45,50]	0.10	0.36	0.28	0.78	-0.61	0.81
age_(50,55]	0.62	0.42	1.48	0.14	-0.20	1.43
age_(55,60]	0.47	0.47	1.00	0.32	-0.45	1.38
6 year dummies included						

Number of obs = 8588
Number of instruments = 150
Wald chi2(17) = 18.76, Prob > chi2 = 0.342

Arellano-Bond test for AR(1) in first differences: z = -2.76 Pr > z = 0.006
Arellano-Bond test for AR(2) in first differences: z = 0.20 Pr > z = 0.840

Instruments for orthogonal deviations equation:
GMM-type (missing=0, separate instruments for each period unless collapsed)
t-3 to t-8 for: logva logcapital age_25 age_30 age_35 age_45 age_50 age_55 age_60 age_99
Sargan test of overid. restrictions: chi2(133) = 141.44 Prob > chi2 = 0.292
Hansen test of overid. restrictions: chi2(133) = 132.11 Prob > chi2 = 0.505

Table 6: Diff – GMM with additional explanatory variables

Dependent variable: log(value added)

Variable	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Lag 1 of dep. var.	-0.02	0.06	-0.32	0.75	-0.13	0.09
Lag 2 of dep. var.	-0.18	0.05	-3.51	0.00	-0.28	-0.08
log(capital)	0.08	0.10	0.84	0.40	-0.11	0.27
age_(20,25]	-0.22	0.45	-0.50	0.62	-1.10	0.65
age_(25,30]	-0.15	0.39	-0.38	0.71	-0.90	0.61
age_(30,35]	0.13	0.26	0.48	0.63	-0.39	0.64
age_(40,45]	0.21	0.26	0.80	0.43	-0.30	0.71
age_(45,50]	0.41	0.30	1.35	0.18	-0.19	1.01
age_(50,55]	0.72	0.37	1.92	0.06	-0.01	1.45
age_(55,60]	0.36	0.44	0.82	0.42	-0.50	1.22
women	-0.09	0.06	-1.48	0.14	-0.20	0.03
Germans	-0.06	0.11	-0.52	0.60	-0.26	0.15
apprenticeships	0.04	0.09	0.45	0.65	-0.14	0.22
unskilled	-0.10	0.07	-1.33	0.18	-0.24	0.05
highskilled	0.03	0.13	0.24	0.81	-0.23	0.30
whitecoll	0.13	0.06	2.19	0.03	0.01	0.25
parttime	0.12	0.08	1.44	0.15	-0.04	0.28
good equipment	-0.03	0.05	-0.66	0.51	-0.13	0.06
average tenure	0.03	0.02	1.55	0.12	-0.01	0.08
age-dispersion	0.01	0.02	0.58	0.56	-0.03	0.06
exporting	0.07	0.10	0.67	0.51	-0.13	0.27
number of workers	0.00	0.00	1.28	0.20	0.00	0.00
6 year dummies included						

Number of obs = 8571

Number of instruments = 402

Wald chi2(29) = 66.03, Prob > chi2 = 0.000

Arellano-Bond test for AR(1) in first differences: z = -5.19 Pr > z = 0.000

Arellano-Bond test for AR(2) in first differences: z = 1.44 Pr > z = 0.149

Instruments for all orthogonal deviations equation:

Sargan test of overid. restrictions: chi2(373) = 387.51 Prob > chi2 = 0.292

Hansen test of overid. restrictions: chi2(373) = 374.02 Prob > chi2 = 0.475

Difference-in-Hansen tests of exogeneity of instrument subsets:

t-3 to t-8 for: logva logcapital age_25 age_30 age_35 age_45 age_50 age_55 age_60 age_99

Hansen test excluding group: chi2(223) = 226.58 Prob > chi2 = 0.421

Difference (null H = exogenous): chi2(150) = 147.44 Prob > chi2 = 0.544

t-2 to t-5 for: gender german apprent unskill highskill whitecoll parttime equip tenure agesd export workers

Hansen test excluding group: chi2(121) = 112.84 Prob > chi2 = 0.689

Difference (null H = exogenous): chi2(252) = 261.19 Prob > chi2 = 0.332

Table 7: Sys – GMM with additional explanatory variables

Dependent variable: log(value added)

Variable	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Lag 1 of dep. var.	0.42	0.03	15.5	0.00	0.37	0.47
Lag 2 of dep. var.	0.12	0.02	6.81	0.00	0.08	0.15
log(capital)	0.08	0.02	4.76	0.00	0.05	0.12
age_(20,25]	-0.31	0.24	-1.26	0.21	-0.78	0.17
age_(25,30]	-0.24	0.18	-1.35	0.18	-0.59	0.11
age_(30,35]	0.11	0.14	0.84	0.40	-0.15	0.38
age_(40,45]	-0.01	0.14	-0.08	0.94	-0.28	0.26
age_(45,50]	0.17	0.14	1.22	0.22	-0.11	0.45
age_(50,55]	0.03	0.15	0.19	0.85	-0.27	0.32
age_(55,60]	-0.35	0.21	-1.67	0.10	-0.77	0.06
women	-0.11	0.04	-2.46	0.01	-0.19	-0.02
Germans	-0.10	0.09	-1.15	0.25	-0.26	0.07
apprenticeships	0.06	0.07	0.77	0.44	-0.09	0.20
unskilled	0.07	0.05	1.29	0.20	-0.04	0.17
highskilled	-0.07	0.11	-0.65	0.52	-0.30	0.15
whitecoll	0.20	0.04	4.52	0.00	0.11	0.29
parttime	0.08	0.02	4.56	0.00	0.04	0.11
good equipment	0.02	0.04	0.41	0.68	-0.06	0.09
average tenure	0.01	0.01	1.04	0.30	0.00	0.02
age-dispersion	0.00	0.01	0.36	0.72	-0.02	0.03
exporting	0.09	0.04	2.19	0.03	0.01	0.17
number of workers	0.00	0.00	-0.98	0.33	0.00	0.00
6 year dummies included						

Number of obs = 13302

Number of instruments = 733

Wald chi2(29) = 613.57, Prob > chi2 = 0.000

Arellano-Bond test for AR(1) in first differences: z = -15.08 Pr > z = 0.000

Arellano-Bond test for AR(2) in first differences: z = -0.75 Pr > z = 0.454

Instruments for all orthogonal deviations equation and instruments for levels equation:

Sargan test of overid. restrictions: chi2(703) = 1343.50 Prob > chi2 = 0.000

Hansen test of overid. restrictions: chi2(703) = 714.10 Prob > chi2 = 0.377

Difference-in-Hansen tests of exogeneity of instrument subsets:

Equation in differences:

t-2 to t-5 for: logva logcapital age_25 age_30 age_35 age_45 age_50 age_55 age_60 age_99

Hansen test excluding group: chi2(493) = 490.41 Prob > chi2 = 0.524

Difference (null H = exogenous): chi2(210) = 223.69 Prob > chi2 = 0.246

t-2 to t-5 for: gender german apprent unskill highskill whitecoll parttime equip tenure agesd export workers

Hansen test excluding group: chi2(451) = 448.13 Prob > chi2 = 0.529

Difference (null H = exogenous): chi2(252) = 265.97 Prob > chi2 = 0.261

Equation in levels:

t-3 to t-5 for: logva logcapital age_25 age_30 age_35 age_45 age_50 age_55 age_60 age_99

Hansen test excluding group: chi2(583) = 592.51 Prob > chi2 = 0.383

Difference (null H = exogenous): chi2(120) = 121.59 Prob > chi2 = 0.442

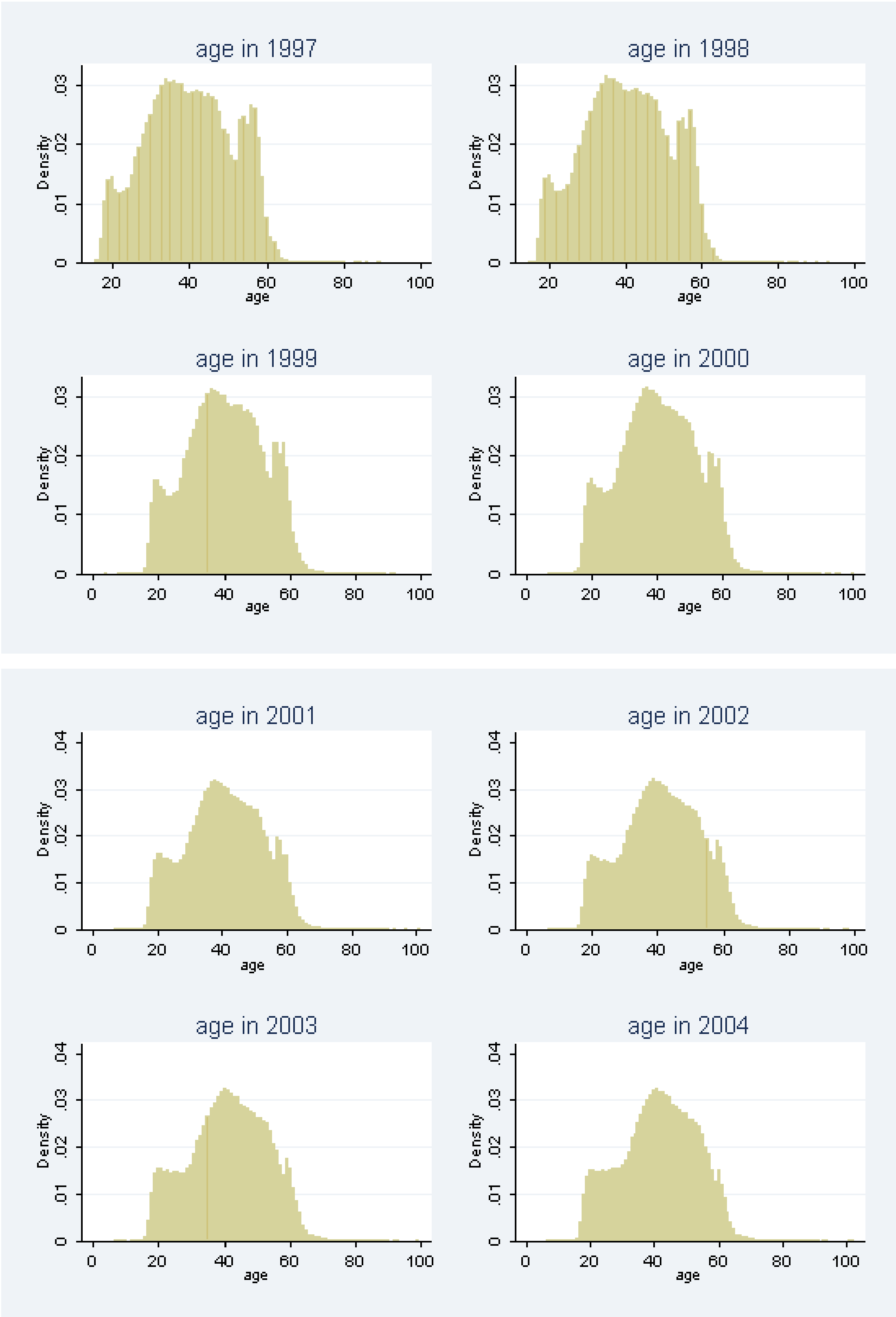
t-3 to t-5 for: gender german apprent unskill highskill whitecoll parttime equip tenure agesd export workers

```
  Hansen test excluding group:      chi2(559)  = 581.52  Prob > chi2 =  0.247
  Difference (null H = exogenous): chi2(144)  = 132.58  Prob > chi2 =  0.743
```

t for: jahr97 jahr98 jahr99 jahr00 jahr01 jahr02 jahr03 jahr04 jahr05

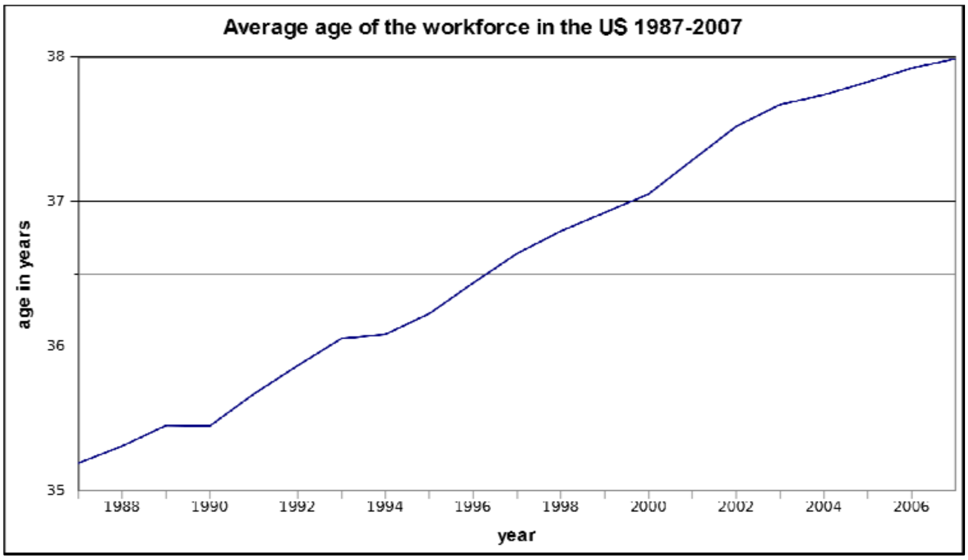
```
  Hansen test excluding group:      chi2(697)  = 707.72  Prob > chi2 =  0.381
  Difference (null H = exogenous): chi2(6)    =   6.38  Prob > chi2 =  0.382
```

Figure 8: Size of age cohorts between 1997-2000 and 2001-2004



Source: own computations based on the LIAB-data, waves 1997-2004

Figure 9: Average Age of the Workforce in the US, 1987-2007



Source: own computations based on OECD (2009).

Figure 10: Average Age of the Workforce in Germany, 1987-2007

Source: own computations based on OECD (2009).The break in the series in the years 2004/2005 is a consequence of methodological changes in the collection of the data.