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Ageing, Productivity and Wages in Austria: evidence from a matched employer-employee data set at the sector level[1]

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Abstract

In this paper we analyse the link between the age structure of the labour force and average labour productivity at the intermediate level of economic sectors. The analysis is based on a panel data set ranging over six years (2002-2007) and covers the sectors of mining, manufacturing and market oriented services in the Austrian economy. Our results exhibit a positive correlation of the share of older employees and productivity, while we cannot find any evidence for a significant relationship of the share of younger employees and productivity. Moreover, the estimated age-wage pattern does not hint at an over-payment of older employees.

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Key-Words: ageing workforce, production function, age-productivity profile, age-wage pattern

Word count: 10,995

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I. Introduction

Low levels of fertility, increasing survival to older ages and moderate levels of migration will lead to population ageing in most industrialized countries. While population shrinkage might not set in immediately, the age structure of the population and in particular the age structure of the workforce will grow older in the near future. Will an ageing and possibly shrinking workforce be able to maintain economic growth, social security systems and prosperity? An important pre-requisite to face future demographic challenges will be the capability to increase productivity. Recent research on the interrelationship of ageing and productivity is conducted at various levels of analysis; the individual (e.g. Skirbekk, 2008), the firm (e.g. Aubert and Crépon, 2006; Göbel and Zwick, 2009) as well as the country (e.g. Lindh and Malmberg, 1999; Prskawetz *et al*., 2007) level. From our point of view it is the sector level, which seems to be under-explored up to now and offers some potential to gain new insights on ageing and productivity within a "special" economic aggregate. Hence, we aim at contributing to industry level[2] research in order to close the literature gap with respect to a connection between ageing and labour productivity.

Based on a cross-section matched employer-employee data set in 2001 for Austrian firms our previous study (Mahlberg *et al*., 2009) showed that there is a hump-shaped age-productivity pattern. The share of employees aged 15 to 29 years as well as the share of employees aged 50 years and older are negatively correlated with a firm's value added per employee as compared to the share of middle-aged (30 to 49 years) employees. In addition, ordinary least squares (OLS) regression estimates yield, that training has a positive impact on average labour productivity at the firm level (with a lag of two years). However, the training effect vanishes as soon as we control for sector heterogeneity in terms of sector dummies. These results indicate that although value added is actually produced within firms, it is the industrial affiliation, which matters as well.

The aim of the current study is, whether a similar age-productivity pattern – as we have observed at the firm level - may be found at the industry level as well. It is important to note, that the sector level presents an economic aggregate over firms. Hence, we deal with a kind of intermediate level between a firm and a country. It is therefore less intuitive in which way the age structure might be correlated to productivity within an economic sector. At the firm level this correlation is more obvious since a firm's value added is produced – among various other input factors - with human capital of different age groups. At the macro level it is aggregate labour, consumption and savings (or investment) behaviour that determines overall GDP.

A potential age-productivity link at the sector level may offer important insights for countries that undergo a fundamental transition in their economic structure. As we will explain, there are indeed some sectors, which are characterised by a rather young age structure of their employees, as well as other industries, for which the opposite is true. While we might capture differences in the slowly moving age structure across sectors, the short time span of our data will not allow for capturing changes in the age structure within sectors. The industry level also offers an interesting political perspective, since wage negotiations between employer and employee representatives usually take place at the sectoral level. Since there does not exist a "one size fits all" policy in terms of the age-productivity correlation, investigations at various levels of an economy are essential.

Different types of R&D efforts are taken at the firm level. Human capital investments are at the firm level as well. However, these activities have not only impacts to the productivity of the investing firms but also generate knowledge spillovers to other firms of the same industry which are difficult to be taken into account at the firm level studies. Hence, studies on R&D and productivity are indeed also conducted at the industry level, e.g. Bönte

[2] In this paper we consider the terms industry and sector as synonyms.

(2003), Cameron (2000) and Verspagen (1995). Analysis on productivity effects of a firm's training activities provided to their employees (e.g. Dearden *et al*., 2006; Kuckulenz, 2006), which are actually conducted at the industry level, point to the importance of externalities in terms of knowledge spillovers among firms within one economic sector. Although we cannot directly control for training (of different age groups) in this paper, a correlation between training and labour productivity might exist and implicitly show up in the coefficients on the age-productivity correlation. While the group of trained employees consists of younger employees as a rule, Bellmann and Leber (2008) show, that the elderly in small and medium sized firms run the risk of being “under-trained”. Hence, age effects might also capture effects that actually emanate from training, but cannot separately be controlled for due to data restrictions. As Levinsohn and Petrin (1999) point out, productivity increases at the industry level may not necessarily be traced back to “real” productivity increases at the firm level. It is rather the contrary: Their results show that decreases in “real” productivity at the firm level account for the largest part in productivity decreases at the industry level, whereas productivity increases at the industry level are mainly due to shifts of output shares from less to more productive firms (cf. OECD 2001, p. 120).

In addition to the age-productivity correlation at the industry level, we aim at addressing the discussion on overpayment of older employees, which is supposed to purely rely on age as well as job tenure, i.e. seniority wage schemes, and is potentially not justified by productivity increases over age to an equal degree.

While Hellerstein *et al*. (1999) cannot find any evidence for an over-payment of old employees at the firm level, Crépon *et al*. (2002) find opposite results. Following Dostie (2006), who bases his analysis on individual wages, this outcome may depend on the level of detail in the measurement of labour supply. Additionally, Kuckulenz (2006) shows at the industry level, that apart from labour productivity also wages may be positively influenced by training activities. It is therefore of interest whether at the industry level an age-productivity correlation is accompanied by an age-wage correlation of the same or opposite sign or whether the age structure is not at all correlated with wages.

One advantage of a sector level analysis as opposed to the firm level is, that there “is a lot of noise in firm data which partly washes out in the aggregates” (Mairesse and Mohnen, 1994, p. 835). Furthermore, our data set covers also small enterprises which are underrepresented in most employer-employee data sets. Small enterprises present the majority of enterprises in Austria and other developed economies. However, switching from the firm to the industry level is accompanied by various aggregation effects with regard to the age structure as well as to productivity. As descriptive analysis indicate (cf. Freund *et al*., 2010), the average age distribution across firms within one economic sector does not necessarily coincide with the overall age distribution within the same industry, i.e. abstaining from averaging over firms. This may probably be traced back to the possibility of completely heterogeneous as well as partly strongly concentrated age distributions across different firms within one economic sector.

Thus, we need to keep in mind that the level of analysis (sector vs. firm or region or country level) might explain differences in the age-productivity profile. For instance, at the firm level, the negative correlation between the share of younger employees and productivity is rather stable, while the correlation between the share of older employees and productivity is rather small and might even vanish if one properly accounts for time-invariant unobserved heterogeneity and endogeneity between firms. At the macro level, however, it is rather the share of young employees that seems to be less stable.

As for the current analysis a panel data set across sectors of mining, manufacturing and market oriented services over the period 2002 to 2007 is available, we will be able to apply appropriate panel data estimation techniques. The econometric framework will be more closely related to applications at the firm level (cf. Aubert and Crépon, 2006; Göbel and

Zwick, 2009) instead of common empiric economic growth models at the country-level (cf. Lindh and Malmberg, 1999; Prskawetz *et al*., 2007).

The paper is structured as follows: Section 2 reviews the relevant literature. In section 3 we introduce the theoretical model. A description of the data is presented in section 4. Results of the empirical application are summarized in section 5, while the last section (section 6) concludes.

II. State of the Art

In the following we present a brief overview of research focusing on the three main aspects of our study: the choice of the industry level as the unit of analysis, estimates on the age-productivity pattern and estimates on the age-wage profile.

Level of analysis

Following Levinsohn and Petrin (1999) aggregate productivity changes at the industry level may be explained through various arguments. Firstly, increases of real productivity at the firm level being based on learning processes, which take place within firms, lead to cumulated productivity growth at the industry level. Secondly, the pure redistribution of market shares, i.e. either the expansion of efficient firms, for instance, may also lead to changes in aggregate industry level productivity. Based on different estimation methods their empirical findings[3] are, that productivity decreases at the firm level are predominantly responsible for declining productivity at the sectoral level, whereas shifting output shares from less to more productive firms mainly lead to a productivity increase at the sector level.
Consequently, the observation of industries becoming more productive may not necessarily be traced back to an increase of real productivity at the firm level. Moreover, aggregate industry productivity might rise while it could obviously be even the opposite development for firm level productivity.

Pöschl *et al*. (2009) show that export effects, which apparently are industry-specific, may play an important role in determining productivity.[4] They analyse the “export premia” for Austrian firms, which turns out to be industry-specific.[5] Based on descriptive statistics they find, that the “intensive margin” (= exports per firm) may matter more for overall exports than the “extensive margin” (= number of exporting firms). For the overall manufacturing sector a so-called bimodal distribution is found with a predominant number of firms, which are either not or highly engaged in exports. This distribution can be explained by comparative disadvantages of non-exporting and comparative advantages of exporting firms. On a more disaggregated level the prevalent pattern is, that most exporting firms (with exports > 0) have an export share above 50% of total sales, which mirrors the Austrian situation of a “small open economy” (Pöschl *et al*., 2009, p. 15) being geographically located in the centre of the European Union. The overall cumulative distribution shows, that a small share of firms accounts for the largest part of exports. Overall, although again characterised by heterogeneity among industries (as well as certain exceptions) exporting firms turn out to be larger than non-exporting Austrian firms in terms of sales, employment, their wage sum as well as investment. Moreover, “size” increases with export intensity implying small-scale non-

[3] Levinsohn and Petrin (1999) use an annual unbalanced panel data set for 6,665 Chilean plants ranging from 1979 to 1986 encompassing eight 3-digit level industries.
[4] The direction of causality between exports and productivity in the literature does not seem to be clear-cut up to this point.
[5] The authors consider 4,952 to 6,326 firms in the manufacturing sector (NACE D) on 23 2-digit-levels in the period 1997-2006 based on data of the structural business survey. They point to the methodological change in 2002 and construct two subsamples with regard to time intervals.

exporters. An export premium is - albeit smaller, but - also found with respect to labour productivity defined as production value or wages per employee as well as investment intensity averaged over the period 2002-2006. Summing up these findings, an analysis of the age-productivity relationship at the sectoral level is warranted as it might control sector specific export premia in a more proper way.

Two papers addressing the industry as opposed to the firm level with respect to the question on wage vs. productivity effects of age are Dearden *et al*. (2006) and Kuckulenz (2006). Based on a labour decomposition with respect to trained versus untrained employees, Dearden *et al*. (2006) explore the causal relationship of training at the workplace and productivity (= “direct measure”) on the one hand as well as training at the workplace and wages (= “private return”) on the other hand.[6] While the training impact is significantly positive for both of the dependent variables, it is larger for productivity than for wages. Comparing their regression estimates for the latter with respective results at the individual level leads to the authors' conclusion of positive training externalities among firms, which are located within the same industrial sector.

The same approach is followed by Kuckulenz (2006), who analyses to which extend training effects are split up between the employer - in terms of higher productivity - and the employees - in terms of higher wages.[7] High-skilled as well as young employees show a comparably high training participation. The author finds that productivity is significantly and positively influenced by present and past training activities as well as the share of employees in all age groups older than 17-20 years.[8] Moreover, the wage per employee is positively correlated with present training activities as well as with the shares of employees in all age groups older than 17-20 years except for age groups 26-30 and 36-40. Kuckulenz (2006) draws two conclusions: Firstly, since the respective training coefficient from the productivity regression exceeds the one from the according regression on wages, the employer as well as the employees benefit from training activities. Secondly, there obviously exist “knowledge spillovers” (p. 20) among firms within one sector, which is revealed by a comparison with results at the firm level (Zwick 2005).

The overall age-productivity relation found in Dearden *et al*. (2006) and Kuckulenz (2006) does not follow a specific pattern at the sector level with the exception of a negative correlation between productivity and the youngest age group as compared to the other age groups.

Summing up, the studies by Dearden *et al*. (2006) and Kuckulenz (2006) hint towards knowledge spillovers across firms within sectors. Hence, a study of the age-productivity and age-wage profile at the sectoral level is warranted as it will take these spillovers into account. Moreover, from our point of view externalities among enterprises which are economically active in the same industrial field might also occur due to further kinds of knowledge spillovers that are not necessarily based on training activities. Besides education, which we shall separately control for, these could arise from human capital in terms of experience, potentially being incorporated in the age distribution of the labour force. This has to be kept in mind when interpreting the coefficients on the age-productivity and age-wage correlation coefficients.

Further investigations with respect to productivity at an intermediate level refer to a geographical decomposition. Tang and MacLeod (2006) show that older employees are, on average, less productive than younger employees and that labour force ageing has a modest negative direct impact on productivity growth in Canada. Brunow and Hirte (2009) provide evidence that there are age specific human capital effects in Germany and that a temporary

[6] They make use of 94 industries in the British economy excl. the service sector over the period 1983-1996.
[7] She considers 58 German industries over a time interval of seven years (1996-2002).
[8] Age share dummies are a relatively crude way of measuring age, as probably in each sector nearly every age group may be found.

increase in regional productivity could occur during the demographic transition. Kunnert *et al*. (2010) find a hump-shaped age-productivity pattern for Austria.

Age-productivity and age-wage patterns

Studies based on employer-employee data sets in various countries that try to explain labour productivity through changes in the age structure of the employees found a hump-shaped age pattern. However, by referring to longer panel data time series and by applying advanced econometric methods that take unobserved heterogeneity into account and control for “simultaneity” of the dependent (= labour productivity) and independent (= age structure) variables, the coefficient on the share of older workers looses significance.

Malmberg *et al*. (2008) find a hump-shaped age effect on value added per employee as long as they do not consider unobserved fixed effects. Their results reveal a negative correlation of older employees and productivity, which is true for large as well as small firms. Having a closer look at the situation within an average firm over time shows a completely different picture: A negative productivity connection is shown for younger employees, while the coefficient for older employees even turns around its sign and prime-aged employees are of less importance.

Also Göbel and Zwick (2009) [9] show the sensitivity of the age-productivity correlation by applying different estimation techniques ranging from pooled ordinary least squares (POLS) estimation, fixed effects estimators (FE) to system generalized method of moments (GMM) regressions that control for possibly existing simultaneity (= endogeneity) of the regressors and labour productivity. The authors finally conclude that labour productivity on the establishment level peaks in the age group of 50-55 years and decreases only slightly for higher ages.

Also country level studies generally confirm a hump-shaped age-productivity relation. Interestingly, it is the negative impact from the young age group, which seems to be less stable in at the country level (Lindh and Malmberg, 1999; Prskawetz *et al*., 2007).

An additional aspect taken up in the literature is the role of the age structure of employees on the firm’s wage sum. Recalling the theory of Lazear (1979) these studies investigate whether a higher share of older workers indeed leads to a higher wage sum supporting the hypothesis of wages rising with age. While Hellerstein *et al*. (1999) find that higher wages of employees above the age of 35 years are justified by their higher productivity as compared to their youngest counterparts, Crépon *et al*. (2002) find for French manufacturing firms increasing wages over age, whereas productivity decreases again from age 35 onwards supporting the hypothesis of overpayment at higher and / or under-payment at younger ages.

In contrast to Hellerstein *et al*. (1999) or Crépon *et al*. (2002), Dostie (2006) builts the wage equation upon the individual level. He cannot reject the hypotheses of wages and productivity to be equal, when measuring labour by hours worked, while based on crude employee counts the different results of age structure on productivity vs. wages hints towards deferred compensation to the benefit of older men with a degree and at the expense of younger men holding at least an undergraduate degree. The general age-productivity as well as age-wage patterns indicate an overall concave shape with a maximum in the middle-aged group of ≥35 years and ≤55 year old men and women.

Summing up, assuming that efficient and inefficient, entering and exiting or exporting and non-exporting firms are characterised by a systematically different age structure of their employees, this may lead to a divergent outcome with regard to the age-productivity or age-wage pattern at the industry level as compared to the average firm. The fact that the pattern

[9] Their linked employer-employee panel data set encompasses the years 1997-2005 for approximately 8,500 German establishments with nearly 7 Mio. employees.

might also be traced back to reverse causality of age and productivity, additionally challenges the econometric set-up. As former research has shown, there are various potential factors which are supposed to be correlated with labour productivity at the industry level motivating our analysis. It turns out that the formerly found hump-shaped age-productivity pattern strongly depends on the estimation method applied, availability of control variables, respective data source as well as the analytical level and the way of measuring wages as well as labour supply. In the end, dealing with different economic levels opens some space for different compensatory and / or aggregation effects, in terms of knowledge spillovers for instance, being at work.

III. Theoretical Model

We start with a Cobb-Douglas production function with the input factors capital and labour. The latter factor is decomposed by age as well as further labour force characteristics such as gender, occupation, etc.

In the basic model capital K_i and labour L_i^* within a sector i are combined with a technology parameter A (= Solow residual) resulting in the level of output Y_i[10]:

$$Y_i = K_i^{\alpha} L_i^{*\beta} A \tag{1}$$

As the age structure of the workforce is a central element of our analysis, we particularly focus on the definition of labour L_i^*, which may be modelled in different ways. Following Crépon *et al*. (2002), we decompose total labour input L_i^* within a sector into a weighted sum of various types of employees k, which are perfectly substitutable and implemented by an additive sum[11]. The weights are represented by an individual productivity parameter λ_{ik}.

$$\begin{aligned} L_i^* &= \textstyle\sum_{k=0}^{m} \lambda_{ik} L_{ik} \\ &= \lambda_{i0} L_{i0} + \sum_{k=1}^{m} \lambda_{ik} L_{ik} \\ &= \lambda_{i0}\, L_i \left(1 + \sum_{k=1}^{m} \left(\frac{\lambda_{ik}}{\lambda_{i0}} - 1\right) \frac{L_{ik}}{L_i}\right) \end{aligned}$$

$$\ln(L_i^*) = \ln(\lambda_{i0}) + \ln(L_i) + \ln\left(1 + \textstyle\sum_{k=1}^{m} \gamma_{ik} \frac{L_{ik}}{L_i}\right) \tag{2}$$

where λ_{i0} is the productivity of the reference group of employees, and $\gamma_{ik} = \frac{\lambda_{ik}}{\lambda_{i0}} - 1$ denotes the relative productivity difference between an employee of type k and the reference group of employees.[12] We assume the productivity differential to be constant across sectors, i.e. $\gamma_{ik} \equiv \gamma_k$.

In a next step we postulate constant returns to scale, i.e. $\alpha + \beta = 1$. Taking logs of equation (1) and substituting L_i^* (equation (2)) into equation (1) yields:

[10] For simplifying reasons we abstain from time subscripts in the following.

[11] An alternative way in order to abstain from the assumption of perfect substitutability would be to implement a Cobb-Douglas type aggregate of labour, see e.g. Prskawetz *et al*. (2008).

[12] This term is similar to the "relative (marginal) productivity differential" of a trained worker compared to an untrained worker $\frac{\mathrm{MP_T\text{-}MP_U}}{\mathrm{MP_U}}$ in Konings and Varnomelingen (2009), p. 5.

$$\ln(Y_i) = \alpha\ln(K_i) + (1-\alpha)\ln(\lambda_{i0}) + (1-\alpha)\ln(L_i) + (1-\alpha)\ln\left(1+\sum_{k=1}^{m}\gamma_k \frac{L_{ik}}{L_i}\right) + \ln(A) \quad (3)$$

Considering that the expression for $\ln(\lambda_{i0})$ is captured within the constant term *c*, subtracting $\ln(L_i)$ from both sides and implementing the approximation $ln(1+x)\approx x$, which in fact holds for $x \ll 1$, leads to the equation of output per employee[13] for each sector that will be estimated in section 5.

$$\ln\left(\frac{Y_i}{L_i}\right) = c + \alpha\ln\left(\frac{K_i}{L_i}\right) + (1-\alpha)\sum_{k=1}^{m}\gamma_k \frac{L_{ik}}{L_i} + \delta\ln(X_i) + u_i \quad (4)$$

where u_i represents the error term being the remaining part of *A* that cannot be explained with the help of further sector-specific explanatory variables X_i [14]. Note that the term on the absolute number of employees $\ln(L_i)$ drops out. Moreover, from equation (4) it follows that the estimated (age) share coefficients are composed of the Cobb-Douglas parameter α as well as the relative productivity differentials γ_k.

The empirical analysis of the age-wage correlation[15] follows analogously to the productivity estimation. Gross wages and salaries per employee at the industry level W_i/L_i are modelled as a function of capital intensity K_i/L_i, different types of labour L_{ik}/L_i and further explanatory variables X_i. In this case the empirical estimation is based on the following equation:

$$\ln\left(\frac{W_i}{L_i}\right) = c + \alpha\ln\left(\frac{K_i}{L_i}\right) + (1-\alpha)\sum_{k=1}^{m}\gamma_k \frac{L_{ik}}{L_i} + \delta\ln(X_i) + u_i \quad (5)$$

Within the wage regression we explain the average wage at the sector level by exactly the same variables that enter the production function. This specification permits to compare the impact of age on wages per employee and productivity and to test whether old employees are overpaid or not. One could argue that firm variables such as capital intensity should be excluded from the wage equation in competitive labour markets. However, these variables are typically quite informative in wage equations, either because they are picking up some measure of unobserved labour quality (Hellerstein and Neumark, 1999) or because of departures from perfect competition. In either case, omitting such variables is likely to cause bias on the age variables and our baseline specifications will include them (cf. Dearden *et al*., 2006).

IV. Data

Composition of the Data Set

We base our study on a newly created panel data set that contains yearly employer-employee data for 2002-2007. It emerged from matching industry level data from the structural business statistics of Statistics Austria with data from the Main Association of Austrian Social Security Institutions ("Hauptverband der Sozialversicherungsträger"), being augmented with information from the national accounts of Statistics Austria and the micro census of Statistics Austria as illustrated in Figure 1.

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[13] Note that we are consistent with our empirical approach (see Section 5) in dividing output and capital through L_i instead of L_i^*.

[14] In fact, X_i may encompass several sector specific characteristics *j:* $\sum_{j=1}^{n}\delta_j\ln(X_{ij})$.

[15] Although average wages rather present an approximate measure, especially at the present level of analysis we prefer it as opposed to individual wages in order to achieve best possible comparability with the productivity outcome.

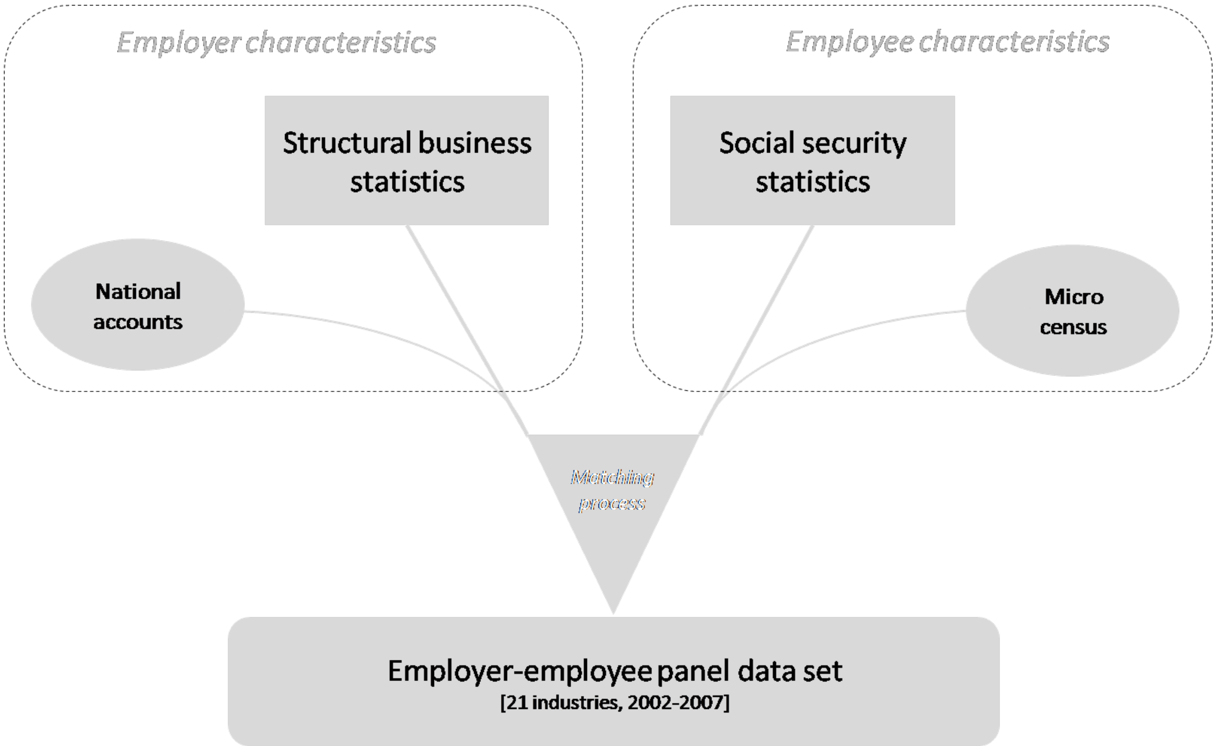

Figure 1. Merging procedure

Our sector characteristics are collected from the structural business statistics of Statistics Austria, which are publicly accessible. The underlying survey is conducted yearly and provides data concerning the structure (single-plant vs. multi-plant firm), sector affiliation, employment, investment activities and performance of enterprises at the national and regional level in a breakdown by economic branches in accordance with OeNACE classification[16]. It encompasses the economic branches of production (C "Mining and quarrying", D "Manufacturing", E "Electricity, gas and water supply", F "Construction") and selected sections of the service sector (G "Wholesale and retail trade; repair of motor vehicles and motorcycles, personal and household goods", H "Hotels and restaurants", I "Transport, storage and communication", J "Financial intermediation", K "Real estate, renting and business services"). Not included in the survey are the sectors "Agriculture, hunting and forestry" and "Fishing" (NACE A and B) as well as "Public administration and defence; compulsory social security", "Education", "Health and social work", "Other community, social and personal service activities", "Activities of households" and "Extra-territorial organizations and bodies" (NACE L to Q). The structural business statistics is based on the structural business survey which collects economic characteristics of approx. 35,000 enterprises in each year. The outcome of this primary data collection together with certain administrative data (social security data, value added tax data, income tax data, etc) is used to estimate the indicators of firms not included in the survey. To yield the final statistics the data of individual firms are aggregated to sector data. The structural business statistics covers characteristics of the whole firm population in the investigated sectors. These sector data are

[16] NACE (Nomenclature of economic activities) is a code that represents the classification of economic activities within the European Union, while OeNACE accords to the Austrian version. While all other levels of OeNACE are identical with the corresponding levels of NACE an additional hierarchical level - the national sub-classes - was added to represent the Austrian economy in a more detailed and specific way. For details see European Commission (2002) and Statistics Austria (2003). Based on the classification of our data we use the OeNACE version of 2003.

used in our study. The statistics contains amongst others the following indicators: value added, investments, gross wages and salaries, no. of employees, number of self-employed persons, number of white-collar workers, number of blue-collar workers, number of apprentices, number of home workers and number of part time workers.[17] All variables (except for employment) are deflated to constant prices of 2005 by the harmonized consumer price index taken from Statistics Austria. In addition, data on net fixed capital are taken from the national accounts of Statistics Austria.[18, 19] The data serve as a measure of capital stock and are valued at replacement cost of 2005.

The workforce characteristics emerge from social security data. These data are collected by the Main Association of Austrian Social Security Institutions and provide information on age, gender, and social status (white-collar worker vs. blue-collar worker) of individuals employed in the firms of the considered sectors.[20, 21] Self-employed persons and public servants are excluded from our data set.[22] Temporary agency workers ("Zeitarbeiter") are assigned to temporary employment companies and not to the firms they actually work for. All persons with other atypical employment relationships like service contracts ("Werkvertrag") are also not linked to their actual employer.[23] Data on educational attainment are taken from micro census of Statistics Austria and added to the data set.

All of the four data sources mentioned above contain a sector identifier which allows linking these four data sets at the sectoral level. The matched data set is aggregated to 21 sectors[24] and covers all firms of the Austrian firm population as well as all employees working in the investigated sectors. The data represent approximately 276 thousand firms and 2.5 million employees per year on average. With regard to the industry level our panel data set is constructed to be balanced.

While the structural business statistics is based on yearly averages (with regard to the number of employees), social security data and micro census count every single employee, who has ever been working in one of the included firms. This issue is of special importance, when these two data sets are related to one another for analytical purposes. As already stated, all variables have been aggregated across firms per sector.

[17] These data are directly taken from the publications on the structural business statistics of Statistics Austria. For further details on sample selection, methods of extrapolation etc. in structural business statistics see e.g. Statistics Austria (2009b).

[18] These data were provided by Statistics Austria. For details on the computation procedure of net fixed capital see Schwarz (2002) and Statistics Austria (2009a, p. 154).

[19] Direct information on the stock of fixed assets is not available at the appropriate level. Values from the balance sheets of companies cannot be used because they are based on a completely different valuation method (cf. Schwarz, 2002).

[20] Hofstätter *et al*. (2009) emphasise two decisive characteristics of social security data: Firstly, these are based on employment relationships inclusive the possibility of several of these being attributed to one person. Secondly, every single employment period regardless of its length is recorded without any kind of smoothing.

[21] The Main Association of Austrian Social Security Institutions provided us with these data for our particular research purpose. Thus, except for the manufacturing sector (NACE D), where data are available on a lower aggregate, i.e. subsections, the provided information is aggregated to NACE sections. Data on NACE DF ("Manufacture of coke, refined petroleum products and nuclear fuel") are not available from Statistics Austria due to secrecy reasons.

[22] Basically social security data contain all employees (white-collar and blue-collar workers, home workers, apprentices, full-time and part-time workers) and self-employed persons. The data set we received for our particular research purpose is, however, restricted.

[23] Since labour productivity is calculated based on the structural business statistics, while age shares emanate from social security data, this imbalance might theoretically lead to a bias of the results. For instance, self-employed persons contribute to value added, whereas they do not count for the age distribution. We assume that this does not lead to a systematic bias.

[24] As information on workforce characteristics based on social security data have been aggregated to NACE sections, we have proceeded analogously with respect to the data on firm characteristics. Except for NACE section D (manufacturing) that has been disaggregated more strongly to its according subsections.

Descriptive Statistics

A summary of descriptive statistics of our data (mean values, standard deviations, minima and maxima for selected characteristics) is presented in Table 1 below.

In terms of *value added per employee, gross wages and salaries per employee* and *net fixed assets per employee* the sectors are substantially different from each other.[25] With respect to value added per employee sectors C (Mining and quarrying), E (Electricity, gas and water supply) and J (Financial intermediation) present the most productive industries while sector H (Hotels and restaurants) is the least productive sector. In terms of *gross wages and salaries per employee* sectors E (Electricity, gas and water supply) and DG (Manufacture of chemicals, chemical products and man-made fibres) show the highest numbers and sector H (Hotels and restaurants) the lowest. Regarding the *capital stock* sector E (Electricity, gas and water supply) and also sector K (Real estate, renting and business activities) are of extraordinary size, which is highlighted when concentrating on per capita figures. Clearly, both of these industries are particularly capital intensive.

The *modernity of capital stock* is defined as the ratio of net to gross fixed assets. Data on net as well as on gross fixed assets are taken from national accounts. This measure expresses the percentage of those assets which are not depreciated and thereby provides information about the ageing process of fixed assets. The higher these values the less capital stock is depreciated and thus, high values indicate a sector using relatively recent equipments. On average, modernity amounts to 0.60. The disparities between sectors are quite small. The least modern (0.54) sector is DL (Manufacture of electrical and optical equipment), while the most modern (0.71) industry is industry K (Real estate, renting and business activities).

Intangible assets contain the stock of software as well as the value of concessions, industrial and similar rights and assets as well as licenses in such rights and assets. The proportion of these types of assets amounts to around 2% of the whole capital stock on average. In the majority of sectors this share is at most 5%, while sector J (financial institutions) stands out with a share of 12%.

The category of *micro, small and medium-sized enterprises* (SME) is made up of enterprises employing fewer than 250 persons.[26] All firms employing 250 employees and more are referred to as large enterprises. With respect to the share of SME the discrepancy between sectors are minor. In most of the sectors more than 90% of enterprises belong to the category of SME, reflecting the shape of the Austrian firm environment. Sector DF (Manufacture of coke, refined petroleum products and nuclear fuel) is the only sector which is less dominated by SME.

The *age composition of the workforce* at the industry level is captured by three age shares: young (15 to 29 years), middle-aged (30 to 49 years) and old (50+ years). In terms of this indicator the differences between sectors are remarkable as well. While for instance the sectors H (Hotels and restaurants) and K (Real estate, renting and business activities) are rather young, the opposite holds for sectors C (Mining and quarrying) and E (Electricity, gas and water supply). An inter-temporal comparison shows that the Austrian workforce went through a slight ageing process with an increase of nearly one year on average during our observation period. Although part of the ageing process is identical for all industries due to a common demographic trend as well as Austria-specific pension policies, we additionally observe an ageing trend that varies across sectors, which might be due to industry- and age-specific workplace requirements, for instance.

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[25] Sector specific results are not shown in Table 1 but can be obtained from the authors on request.

[26] This definition is similar to that of the European Commission (2003). The Commission's definition not only contains limits of staff headcounts but also financial ceilings (for annual turnover and annual balance sheet total). Since we do not have access to these financial indicators, we solely adopt the staff headcount limit.

Educational levels are grouped by attainment into (a) basic education (up to nine years), (b) upper secondary education with medium skill attainment, which includes apprenticeships and short cycle vocational education (ten to twelve years of schooling), (c) upper secondary education with higher skill attainment, which encompasses the Austrian gymnasium and its equivalents, such as vocational colleges (twelve to thirteen years of schooling) and (d) tertiary education including postgraduate studies, teacher training colleges, etc. The medium skill upper secondary education (referred to as 'lower secondary education' in the tables) is the most prevalent category with a mean share of 59%. The differences between sectors are again remarkable. A closer look at the distribution of education shares across sectors reveals the following: The sector with the highest share of basic education is NACE DC (Manufacture of leather and leather products) and the lowest share of employees having only basic education can be observed for sector E (Electricity, gas and water supply). Sector C has the highest share of lower secondary educated employees, while it has the lowest share in industry K. Sector J (Financial institutions) reaches the highest share of upper secondary education and sector DC (Manufacture of leather and leather products) the lowest. The best educated workforce can be found in sector K (Real estate, renting and business activities), where the share of tertiary educated persons is highest. The sector employing the lowest share of academics is sector DD (Manufacture of wood and wood products).

TABLE 1

Descriptive statistics

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
Sector Characteristics				
Value added per employee (in TEUR)	71.06	33.80	25.68	184.31
Wages and salaries per employee (in TEUR)	30.51	8.32	11.82	47.82
Net fixed assets per employee (in TEUR)	210.43	264.04	57.54	1,171.76
Modernity of fixed assets	0.60	0.04	0.54	0.71
Proportion of				
Tangible assets	0.98	0.02	0.88	1.00
Intangible assets	0.02	0.02	0.00	0.12
Proportion of				
Small and medium sized enterprises	0.98	0.04	0.75	1.00
Large enterprises	0.02	0.04	0.00	0.25
Employee-characteristics				
Proportion of employees				
Aged under 30 ('young')	0.29	0.05	0.16	0.43
Aged 30 to 49 ('prime-aged')	0.55	0.03	0.46	0.62
Aged over 49 ('old')	0.17	0.04	0.10	0.30
Proportion of				
Basic education	0.19	0.07	0.05	0.46
Lower secondary education	0.59	0.09	0.32	0.77
Upper secondary education	0.15	0.07	0.04	0.40
Tertiary education	0.07	0.05	0.01	0.24
Proportion in occupation				
Self-employed	0.06	0.05	0.00	0.21
White collar	0.39	0.19	0.10	0.90
Blue collar	0.51	0.18	0.05	0.73
Apprenticeship	0.04	0.02	0.01	0.09
Home worker	0.00	0.00	0	0.01
Proportion of				
Male employees	0.69	0.16	0.41	0.88

Female employees	0.31	0.16	0.12	0.59
Proportion of				
Part-time	0.11	0.06	0.02	0.28
Full-time	0.89	0.06	0.72	0.98

Within the employee distribution based on the s*ocial security status* (= type of *occupations*) we find huge differences among sectors as well. White-collar and blue-collar workers in general constitute the largest parts. While white-collar workers dominate in sectors DG (Manufacture of chemicals, chemical products and man-made fibres), DL (Manufacture of electrical and optical equipment), E (Electricity, gas and water supply), G (Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods), J (Financial intermediation) and K (Real estate, renting and business activities), blue-collar workers constitute the largest share in sector C (Mining and quarrying), the major divisions of sector D (Manufacturing) and sector H (Hotels and restaurants). The highest share of apprenticeships is found in sector F (Construction industry), which is positively correlated with the share of young employees as well as employees with lower secondary education.

Moreover, Table 1 depicts that the differences in terms of *gender shares* are again noticeable. A closer look at the data reveals that sector H (Hotels and restaurants) is clearly dominated by women, which is also the case for sector DB (Manufacture of textiles and textile products) as well as sector DC (Leather and leather products). Industries with a rather balanced gender structure (over age groups) are sectors G (Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods), J (Financial intermediation) and K (Real estate, renting and business activities).

We also observe considerable differences in terms of the *share of part time workers* the differences are again considerable. Its distribution over sectors coincides with that of female employees which obviously confirms that part time work is female in Austria.

Before switching to the empirical investigation of the conditional correlation of age and mean value added as well as age and wages per employee at the industry level, a first hint with respect to a potential (a) age-productivity profile and (b) age-wage pattern is offered by Figure 2. While the respective patterns are quite similar, the figure shows the unconditional pair-wise correlation between the respective age share and labour productivity as well as between the respective age share and wages per employee. The picture points towards a negative correlation of the share of young employees and labour productivity as well as wages within an industry. It turns to a positive sign for prime-aged and old employees.

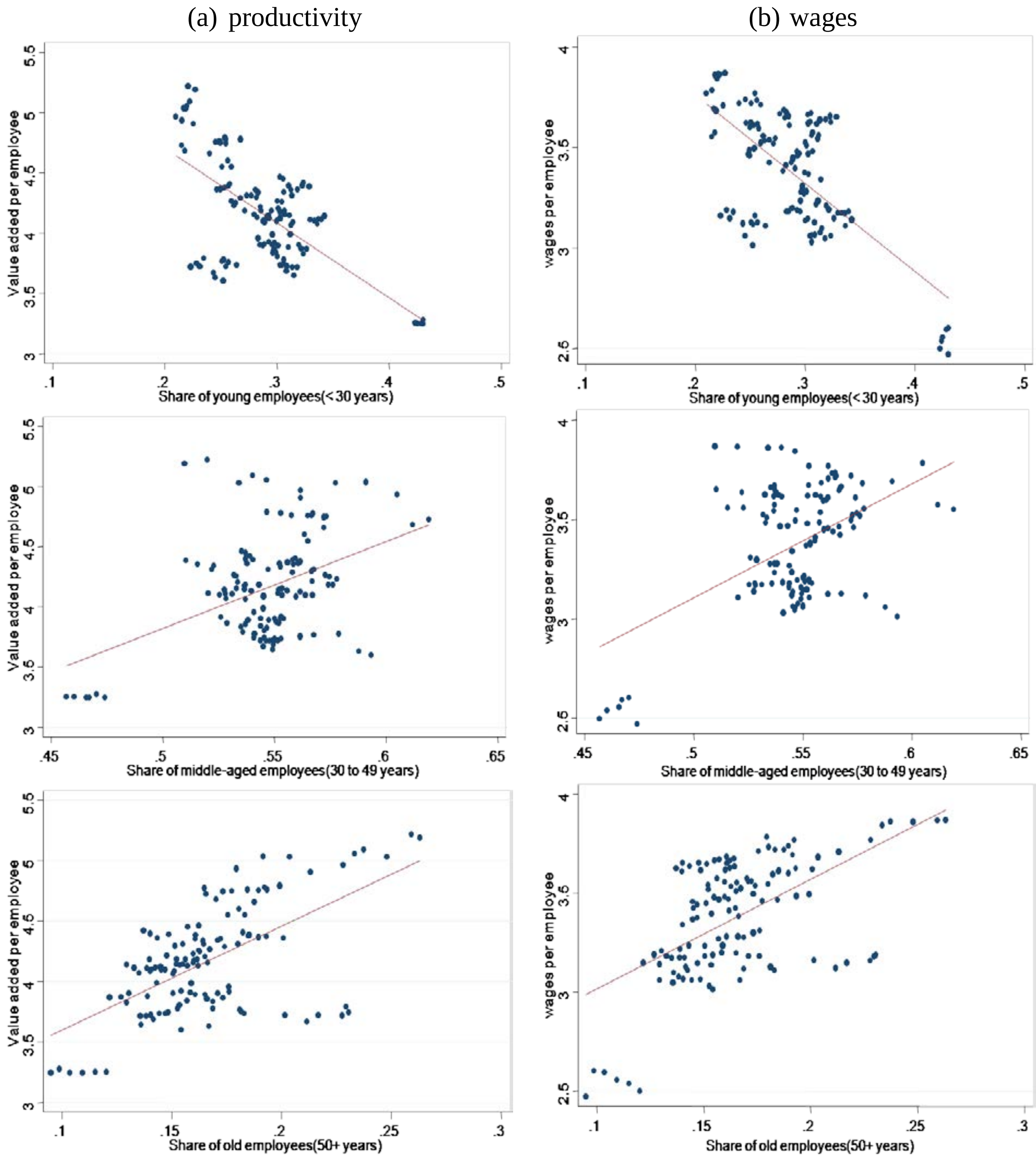

Figure 2. Unconditional correlation of age shares and labour productivity as well as age shares and wages per employee

V. Results

Productivity and wages

This section concentrates on the implementation of our theoretical model. The dependent variables are (the natural logarithm of) labour productivity and (the natural logarithm of) wage per employee at the sector level. Labour productivity is based on the aggregate value added for each sector divided by the overall number of employees within the respective industry. Similarly, wage per employee is defined as gross wage and salaries of each sector divided by the according number of employees. Labour productivity as well as wages per employee are regressed on three age-share variables, four education shares, the share of gender, sector-specific variables such as the modernity of capital stock (the ratio of gross to net fixed assets per employee measured by a continuous variable), the proportion of intangible assets (measured by a continuous variable), and the share of large firms (measured by a continuous variable). A further set of variables encompasses the share of employees in various occupations as well as the share of part-time workers and six time dummy variables. Reference categories are represented by the shares of prime-aged employees, employees with only basic education, male employees, tangible assets, small and medium sized enterprises as well as the shares of blue-collar workers as well as full-time workers and the time dummy variable for 2002. In general, our cross-section comprises 21 industrial sectors, which are sectors C (Mining and quarrying) to K (Real estate, renting and business activities) on one-digit level, while sector D (Manufacturing) is broken down on two-digit level.[27] The longitudinal dimension ranges from 2002 to 2007. Moreover, data restrictions only allow controlling for a limited number of independent variables.

For the following analysis we applied pooled ordinary least squares estimates (POLS) as well as classical panel data estimation techniques such as fixed effects (FE), random effects (RE) and between effects (BE) estimates, which allow to control for individual time-invariant effects. In the process of POLS estimations we tested for heteroscedasticity by applying the Breusch-Pagan / Cook-Weisberg and the Szroeter's tests. Both tests clearly confirm heteroscedasticity. Furthermore, by using the Wooldridge test for autocorrelation in panel data (cf. Wooldridge, 2002)[28], the model is positively tested for serial correlation, i.e. first-order autocorrelation of residuals is detected. Both problems are solved by applying a feasible generalized least squares (FGLS) estimation, so that Table 2 presents the results from our preferred estimation method entailing reliable t-statistics among others.[29] The regression coefficients on the age categories presented in the subsequent tables indicate the marginal effect of an increase in the respective share, assuming that the omitted share adjusts. To calculate the effect of an increase in the share of old employees, assuming that the share of young employees adjusts, one can take the difference between the two coefficients.

TABLE 2

Estimation results on labour productivity as compared to average wages

Variable	*Productivity*	*Wages*
Proportion of employees		
Aged under 30	0.086	0.080
Aged 30 to 49 (ref.cat.)	-	-
Aged over 49	2.339*	2.669***
Proportion of		
Basic education (ref.cat.)	-	-
Lower secondary education	0.238*	0.156
Upper secondary education	0.060	0.224
Tertiary education	0.173	1.072***
Proportion of		
Male employees (ref.cat.)	-	-
Female employees	-0.563***	-0.954***

[27] As already mentioned above, NACE subsection DF (Manufacture of coke, refined petroleum products and nuclear fuel) is excluded, since data are not available.
[28] The test has been implemented in Stata by Drukker (2003). The according command is called “xtserial”.
[29] We trace the diverging results across estimation methods back to the respective application itself as well as the small number of observations and short time dimension entailing hardly any variance within the age distribution.

Net fixed assets per employee	0.209***	-0.005
Modernity of fixed assets	-0.854	-1.395***
proportion of		
Tangible assets (ref.cat.)	-	-
Intangible assets	3.797***	0.119
proportion of		
Small and medium sized enterprises (ref.cat.)	-	-
Large enterprises	1.881*	1.754***
Proportion in occupation		
Self-employed	-1.472*	-1.577***
White collar	0.503***	0.147*
Blue collar (ref.cat.)	-	-
Apprenticeship	-0.446	-1.462*
Home worker	-15.803***	-9,837***
Proportion of		
Part-time	-0.523†	-0.470*
Full-time (ref.cat.)	-	-
Constant	4.018***	3.922***
Number of observations	126	126

Significance levels: † 10%, * 5%, ** 1%, *** 0.1%
Dependent Variables: value added per employee (productivity regression) and wages per employee (wage regression). Dummy variables are included to account for time-fixed effects.
We apply FGLS and take into account heteroscedasticity and autocorrelation of residuals.

While we cannot find any significant effect of the share of young employees as compared to the reference group of prime-aged employees, the coefficient for the share of old employees is significantly positively related to labour productivity. This outcome might result from a positive selection effect of employees at higher ages (cf. Aubert and Crépon, 2006). In general the Austrian labour market is characterised by a rather low effective retirement age, so that those employees older than 50 years, who are still in the labour market, may be the productive ones.

Several papers (e.g. Crépon *et al.*, 2002) argue, that the productivity and the wage profile diverge over age, i.e. young employees tend to be under-paid, while older employees are usually over-paid, which is either denoted as “deferred compensation” (cf. Dostie, 2006) or “seniority wage schemes” as prevalent in countries like Austria or Germany, for instance. In contrast to this, our results at the industry level are more in line with Hellerstein *et al.* (1999) or Cardoso *et al.* (2010) by not only finding, that the share of old aged employees is positively related to labour productivity at the industry level, but also by showing, that the respective age wage relation seems not to diverge significantly from the age-productivity profile. From our point of view particularly the latter finding presents a decisive insight, as wage negotiations among unions and employers’ representatives usually take place at the sector level. Comparing the conditional correlation of the share of old aged employees and average wages with the respective correlation of old aged employees and labour productivity as shown in Table 2 reveals, that these are not significantly different from each other[30]. Thus,

[30] The equality between the age effects on labour productivity and wages can be tested by comparing the estimated coefficients. This is done by regressing the difference between (the natural logarithm of) labour productivity and (the natural logarithm of) aggregate wages per capita (= productivity-pay gap) on the same set of regressors as the production function and the wage equation. The estimated coefficients for the age shares correspond to the difference between the coefficients of the production function and the wage equation. Based on this proceeding we cannot reject the null-hypotheses that the coefficient for the share of old employees within the productivity-pay-gap regression is equal to zero.

our results reject the hypothesis of deferred compensation or seniority wage schemes. At least at the industry level such a correlation cannot be supported.[31, 32]

With regard to education it is only the share of employees with upper secondary education with medium skill attainment (referred to as "lower secondary education" in Table 2), which has a significantly different – and positive – effect on labour productivity as compared to the share of employees with only basic education. In contrast to labour productivity, the mean wage at the sectoral level is positively associated with the share of tertiary educated employees, while for the other levels of education no significant association can be found.

Compared to the share of males, an increasing share of women is associated with decreasing labour productivity and decreasing wages per employee, which might be due to the fact that females often tend to work part-time. Unfortunately, we are not able to control for hours worked, but include the share of part-time workers being significantly negative and of equal size as well. Due to individual fixed costs part-time workers are relatively more expensive for firms than full-time workers. Moreover, a higher number of part-time employees by definition reduces output as well as wages per employee as compared to a smaller number of full-time employees being faced with value added and wages per capita of identical size.

Regarding sector-specific characteristics the modernity of the capital stock seems to be of minor importance for labour productivity, while it interestingly is negatively correlated with wages per employee. The proportion of intangible assets on total net fixed assets has a positive coefficient. A sector seems to be more productive if it has a bigger stock of software and concessions, industrial and similar rights, which is obviously not the case for wages per employee. For the proportion of large enterprises the coefficient is significantly positive indicating that sectors with many large enterprises are better off, which might hint towards economies of scale. Moreover, large enterprises tend to pay higher wage.

While a rising share of self-employed persons leads to decreasing productivity and wages per employee, an increase in white-collar workers compared to blue-collar workers is positively associated with productivity and wages per employee. At the same time sectors employing a higher share of apprentices and a higher share of home workers pay smaller wages per employee.

Sensitivity analysis

In order to verify the robustness of our results from the regression analyses, we perform several checks. Firstly, we conduct the regression analysis excluding sector J (Financial institutions), since "the measures of capital and value added have a different meaning than in the other sectors" (Göbel and Zwick 2010, p. 10). This change of our sample does not essentially alter our main findings.

Secondly, we perform the regression analysis without taking into account the observations of sector H (hotels and restaurants) which can be considered as outlier due to its extraordinary low productivity and its extraordinary high share of young employees as well as low share of old employees. Again, our findings are robust to this change in the sample.

Thirdly, we exclude our measures of capital stock (net fixed assets per employee) as well as capital quality (modernity of fixed assets and proportion of intangible assets) as regressors from the right hand-side of the wage equation. In this respect we follow a couple of

[31] Of course, this way of interpretation assumes the correlating group of employees being also the directly affected one, which might be particularly questionable at this level of aggregation.

[32] We are aware of the fact, that pure age should actually be disentangled from tenure effects, which unfortunately is not properly possible up to now.

studies in the relevant literature (e.g. Crepon *et al*., 2002; Hellerstein and Neumark, 2007; Hellerstein *et al*., 1999; Iranzo *et al*., 2008; van Ours, 2009). This equation at the sector level is consistent with the individual level Mincer (1974) wage equations. Under perfect competition in the labour market, wages do not vary systematically across sectors, so that regressing the average wage on a constant and indicators of workforce quality produces consistent estimates. Again, we cannot observe any noteworthy changes compared to the results presented in Table 2.

Finally, we are able to substantiate our hypothesis of a positive old age selection effect driving our results to a certain degree: One of our robustness checks encompasses a regression based on smaller 5-year age groups leading to a significantly positive coefficient for the age group 60+, while both age groups below (50 to 54 and 55 to 59) do not show any significant impact on labour productivity. Comparing the wage profiles for a certain cohort at different ages, i.e. at two different points in time, reveals, that wages for those, who remain in the labour forces at higher ages, have already been higher on average in the past, than of those employees leaving the labour force earlier.[33] Finally, pure pair-wise unconditional correlation coefficients for 5-year age groups again show a significantly positive connection of the share of tertiary educated employees and the share of 60+ years old employees, while the four younger age groups preceding the 60+ years age group are either not or even negatively correlated with labour productivity.

VI. Conclusions

In this paper we present results from our analysis on the link between labour force ageing and labour productivity at the industry level. Except for NACE section D (manufacturing), that has been disaggregated in more detail, our data are available at the level of NACE categories C to K in the Austrian economy over the period 2002 to 2007.

Summing up the results of our analysis, we find a positive effect of the share of old employees (50 years and older) on labour productivity as well as on the average wage in each sector. Firstly, this outcome might be traced back to a positive selection effect of employees at higher ages. In general the Austrian labour market is characterised by a rather low effective retirement age, so that those employees older than 50 years, who are still in the labour market, may be the productive ones. Secondly, our results do not yield any evidence for an over-payment of old employees as compared to their correlation with productivity. Furthermore we find no evidence for a significant impact of the share of young employees (29 years and younger) on productivity. Thus, being faced with population ageing we should exploit the opportunities, which are offered by the awareness of at least some part of the elderly age groups being characterised by a positive productivity effect. As shown by Göbel and Zwick (2010) for Germany, productivity of older employees may be supported by specific measures for old employees, for instance. An increase of this population group staying in the labour force would lead to a positive effect in terms of increasing contributions to as well as decreasing benefits from the social security system at the same time. In addition, since our empirical results do not yield any evidence for a potential over-payment of old employees, the potential concern of a lopsided burden for employers does not necessarily seem to be reasonable considered at the industry perspective. In addition, this finding is also important from a political point of view, when it comes to wage bargaining at the sector level.

In previous work (Mahlberg *et al*., 2010) we have shown that a firm's training intensity may vary across industries. These results lend support to our approach in this paper to conduct the study on age-productivity and wage-productivity at the industry level. Furthermore, first insights of our study on age-productivity and wage-productivity patterns at the firm level

[33] We are very grateful to René Böheim for providing us these results.

(based on a panel data of 16,742 firms from 2002 to 2005) hint towards the importance of sector-specific effects since our findings differ depending on whether an enterprise carries out its business in the manufacturing or in the service sector.

To our knowledge neither the age-productivity nor the age-wage relationship has ever been analysed at the intermediate economic aggregate of industrial sectors (in Austria) before. Our current findings in combination with our past and preliminary results at the firm level not only close a gap in the literature, but also point towards its reasonable implementation.

Besides clear hints for a positive selection effect of the elderly, we cannot definitely exclude, that the findings might be driven by knowledge spillovers among firms within the same industrial sector. While these could be based on training effects for instance, which we cannot separately control for due to data restrictions, and might particularly stimulate labour productivity at higher ages, further research would be needed in order to disentangle various possible driving factors in more detail.

We are not explicitly able to exclude reverse causality[34] being one possible driving force of our results. This would mean that firms, which are characterised by rather low productivity, have to send older employees, who are not highly productive anymore, into early retirement. The reason behind may be the fact, that these firms are not able to compensate high costs of older employees – being caused by wages rising with age. Such an argument may be relevant for the Austrian labour market that is characterised by a senior wage scheme as well as a comparatively low retirement age within Europe.

One drawback of our study is the scarcity regarding data diversity compared to firm level data. The industry level, which we analytically focus on, seems to be not as tangible as the firm or the country level, for instance. Further research might address the identification of determinants influencing the employment of older employees in Austria, since also a sector's workforce is not exogenously given, but determined endogenously by a single firm or its competitive environment respectively. Additionally, our findings might also be traced back to measurement issues, as we are unfortunately not able to account for hours worked (cf. Dostie, 2006), but just rely on employee counts instead. Slightly more disaggregated data (e.g. to the NACE divisions) would be more suitable for our analysis entailing the advantage of a rising number of observations. Implementing constant returns to scale may be rather strict as well. While it allows for consistency in the transformation of the production function, this assumption contradicts the regression outcome for the net fixed assets (i.e. capital) coefficient.

[34] Unfortunately, the number of observations is too low, so that we would lose too many degrees of freedom by applying an Instrumental Variable (IV) or General Method of Moments (GM) approach.

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