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The Age-Productivity Pattern: Do Location and Sector Affiliation Matter?[1]

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Abstract

Current demographic developments are expected to challenge the sustainability of welfare in industrialised economies. Persistent low fertility levels and increasing survival rates to older age imply a decreasing share of younger individuals within the labour force that needs to support an increasing share of old people out of the labour force. We use matched employer-employee data for Austria at the firm level in order to study the link between the age structure and labour productivity and concentrate on the role played by regional location and sector affiliation. We apply multilevel estimation techniques in order to account for systematic variation of the age-productivity pattern with regard to these two dimensions. Our results indicate that the age-productivity pattern differs significantly across regions and across sectors and that sectoral differences are the more sizable source of heterogeneity in the link between the age structure and firm productivity.

JEL Codes: C21; J14; J24; J82; R11

Key-Words: Age-productivity profile, firm heterogeneity, employer-employee data, multilevel regression methods, regional variability, sectoral variability

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I. Introduction

The ongoing process of ageing does not only change the ratio between those working and those out of the labour force, but also leads to a shift in the age distribution of the labour force itself. The working population is thus expected to become smaller and older in the future. In our analysis we connect these demographic characteristics to the production side of an economy. For that purpose we focus on firms, which actually provide the setting for the production process. On the one hand firms represent an aggregate of single individuals' abilities, whereby these, on the other hand, are influenced by their interplay within a team structure as well as several firm characteristics. We build on former research (Mahlberg et al., 2013) and, using data for Austria, we aim at exploring how the relationship between the age structure of employees and firm productivity systematically differs depending on a firm's geographic location and/or its sector affiliation. We employ multilevel methods which allow us to account explicitly for region/sector-specific mean and slope effects in addition to the usual control variables included in empirical analysis which study the linkages between age structure and productivity. Such heterogeneity might hint at local labour market peculiarities or at industry specificities like sharing a similar type of technology leading to within-sector externalities or the demand for certain abilities related to age. For instance, Raspe and van Oort (2011) address the issue of within-sector externalities among others and Prskawetz and Lindh (2006) as well as Nordström Skans (2005) deal with the effects of local labour markets.

While previous attempts to unveil the link between age and labour productivity tended to find a hump-shaped age-productivity relationship (e.g. Hellerstein and Neumark, 1995; Haltiwanger et al., 1999; Lallemand and Rycx, 2009; Mahlberg et al., 2009; Vandenberghe et al., 2012), more recent analyses indicate a flat pattern for higher ages (e.g. Aubert and Crépon, 2006; Cardoso et al., 2011; Dostie, 2011; Göbel and Zwick, 2013; Mahlberg et al., 2013; Van Ours and Stoeldraijer, 2011). So far, the existing literature has systematically applied multivariate regression techniques to analyse this relationship empirically. Such an approach may not be appropriate if the data have different parameters in the framework of hierarchical or nested structures, which may indeed be the case for firm level data, as these are usually integrated in the economic structure of a region and an industrial sector. Since 'single-level' multivariate regression techniques do not account for systematic region/sector level differences, the respective coefficients might be imprecisely estimated due to the correlation of errors within groups. If local labour market or industry-specific externalities exist, firm performance has to be understood not only in terms of individual firm-specific characteristics, but also in relation to higher level structures. Hence, we make use of multilevel models to disentangle firm-specific effects from region-specific and sector-specific effects, assuming that the interaction of firms with their economic environments play an important role in shaping firm productivity.

Studies on firm productivity using multilevel methods have been conducted by Raspe and van Oort (2007) and by Fazio and Piacentino (2010). While the former link firm productivity to knowledge-intensive spatial contexts in the Netherlands, the latter investigate the spatial variability of the productivity of small and medium-sized enterprises in Italy. Furthermore Aiello et al. (2011) apply multilevel approaches to analyse how firms' characteristics and regional factors affect total factor productivity in Italian manufacturing firms, van Oort et al. (2012) investigate the impact of location on firm survival and firm growth in the Netherlands and Zuluaga and Forero (2011) study the effects of regional context and regional knowledge spill-overs on the innovative performance of industrial firms in Columbia.

In this study we extend the analysis from Mahlberg et al. (2013) by applying multilevel regression techniques in order to study the relationship between the age structure of the workforce and labour productivity. To our knowledge, this approach – including the sectoral and regional environment into a study on the age-productivity correlation at the firm level - has never been applied before. Our results indicate that the heterogeneity of the linkage between age structure and productivity is dominated by industry effects (as opposed to region effects). The estimated models suggest that the uncertainty surrounding the effect of the share of older employees on productivity is large and do not support a robust negative effect.

Our analysis is related with the recent contribution by Kunnert et al. (2012), which analyses the age-productivity relationship for Austrian regions. This work is based on aggregated subnational data, with observations at the level of federal states (NUTS-2-regions) as well as judicial districts (NUTS-3-regions). Their findings yield a statistically significant hump-shaped relationship between the age structure of the population and changes in labour productivity. The estimated productive peak is rather flat and negative effects appear at a rather high age.

The paper is structured as follows. Section 2 introduces the theoretical framework and the estimation methodology, before we describe our data in Section 3. The empirical results are presented in Section 4 and Section 5 concludes.

II. Theoretical framework and empirical implementation

The aim of our empirical analysis is to explain differences in labour productivity (measured as value added per employee) across firms based on differences in the age structure of workers. We assume that production at the firm level can be represented by a Cobb-Douglas production function with technology, capital and differentiated labour as factors of production. In the spirit of Crépon et al. (2002), we express total labour input of a firm as the weighted sum of various types of (perfectly substitutable) employees, whose productivity differential is assumed constant across firms. This setting allows us to express value added per employee for each firm as a function of capital per employee, the relative shares of labour input by various characteristics and a set of firm specific characteristics (for a detailed derivation of the resulting regression equation of output per employee see Mahlberg et al., 2013).

We apply a multilevel specification (see e.g. Hox, 2010) to the resulting regression model which relates value added per employee to the set of explanatory variables. Such a modelling choice has the advantage of explicitly assessing the fact that the firm level data we use violate the assumption of independence (Corrado and Fingleton, 2012). We hypothesise that firms sharing the same external environment (i.e. located in the same region or belonging to the same sector) are more similar in their behaviour (as reflected in the elasticities to be estimated) than firms that do not share the same external environment (i.e. firms in different regions or different sectors) because of shared agglomeration externalities. Following Jones (2004), there are two distinct advantages to multilevel models. First, multilevel models offer a natural way to assess contextuality, or the extent to which a link exists between the macro level and the micro level. Second, multilevel analysis allows us to incorporate unobserved heterogeneity into the model by including random intercepts and allowing relationships to vary across environments, i.e. group or higher level units, through the inclusion of random coefficients. Whereas ‘standard’ regression models are designed to model an overall mean coefficient, multilevel analyses focus on additionally modelling group level variances or standard errors respectively explicitly. This kind of complexity can be captured in a multilevel framework through the inclusion of random coefficients in addition to the 'usual' fixed effects.

We apply a two-level model where firms constitute the first level and regions, sectors or sectors-by-regions (i.e. the interaction of region and industry) constitute the second (or group) level. To analyze hierarchical data, we explicitly assume potential parameter heterogeneity for each group to predict the outcome variable *Y* using the explanatory variables *X*,

$$Y_{ij} = \beta_{0j} + \sum_{k=1}^{K} \beta_{kj} X_{kij} + e_{ij} \qquad (1)$$

where the outcome variable Y_{ij} is labour productivity (i.e. value added per employee) of the *i*-th firm (*i* = 1 … *I*) nested in the *j*-th (*j* = 1 … *J*) group. The explanatory variable X_{kij} is the *k*-th characteristic (*k* = 1 … *K*) of the *i*-th firm belonging to the *j*-th group. In this regression equation, β_{0j} is the group-specific intercept, β_{kj} the group-specific regression coefficient for the *k*-th firm characteristic X_{kij} and e_{ij} is the 'usual' error term assumed to fulfil the standard assumptions for the normal linear regression model. Intercepts and slopes vary thus across regions, sectors or sectors-by-regions (depending on the definition of the grouping used) and are treated as random coefficients. Hence, specific values for the intercept and the slope coefficients for the firm characteristics can be considered as group characteristics.

Across all groups, the regression coefficients β_j follow a distribution with a constant (group-specific) mean and variance. The next step in the hierarchical regression model is to explain the variation of the regression coefficients β_j as follows:

$$\beta_{0j} = \gamma_{00} + u_{0j} \qquad (2)$$

and

$$\beta_{kj} = \gamma_{k0} + u_{kj} \qquad (3)$$

The u-terms u_{0j} and u_{kj} in equations (2) and (3) are (random) error terms defined at the group-level which are assumed to have a mean of zero and to be independent from the residual errors e_{ij} at the firm level. The variance of the residual errors u_{0j} is denoted as $\sigma^2_{u_0}$, and the variance of the residual errors u_{kj} is specified as $\sigma^2_{u_k}$. The covariance between the residual error terms u_{0j} and u_{kj} is generally assumed to be nonzero. Note that in equations (2) and (3) the regression coefficients γ_{00} and γ_{k0} are not assumed to vary across groups. Because they apply to all groups, they are referred to as fixed coefficients. All between-group variation left in the β coefficients is assumed to be residual error variation. This is captured by the group-specific error terms u_{0j} and u_{kj}.

Our model can be written as a single regression equation by substituting equations (2) and (3) into equation (1). From this procedure we obtain equation (4).

$$Y_{ij} = \gamma_{00} + \sum_{k=1}^{K} \gamma_{k0} X_{kij} + u_{0j} + \sum_{k=1}^{K} u_{kj} X_{kij} + e_{ij} \qquad (4)$$

The term $(\gamma_{00} + \sum_{k=1}^{K} \gamma_{k0} X_{kij})$ in equation (4) contains the fixed coefficients. It is generally termed the fixed (or deterministic) part of the model. The term $(u_{0j} + \sum_{k=1}^{K} u_{kj} X_{kij} + e_{ij})$ in equation (4) contains the random error terms, and it is generally termed the random (or stochastic) part of the model. Under the maintained assumption of Gaussian errors, the specification given by (4) can be estimated in a straightforward manner using maximum likelihood methods.

III. The Matched Employer-Employee Data Set

Our analysis is based on a matched employer-employee panel data set for Austria encompassing information for 19.633 firms[2] over the years 2002 to 2005.[3] The data are predominantly obtained from the *Structural Business Survey* (carried out by Statistics Austria) as well as the *Main Association of Austrian Social Security Institutions* ('Hauptverband der Sozialversicherungsträger') and offer the advantage of combining information at the employee level with firm level characteristics. While the aggregated employees' age structure within a firm (as measured by the share of workers in the age groups younger than 30 years, 30 to 49 years, and older than 49 years) constitutes the characteristic of interest for our research question, value added per employee is the indicator of labour productivity used and serves as the dependent variable. We additionally control for age concentration and tenure, as well as gender shares within a firm, part-time employment and types of occupation, firm size (both linearly and as a squared variable), age and capital intensity (both linearly and as a squared variable), whether a firm is of multi-plant type or not and to which sector (NACE[4]-sections) it belongs to as well as where it is regionally located in terms of the Austrian federal states (NUTS[5]-level 2).[6] We differentiate between NACE-sections C to F for the industry and construction sector as well as NACE-sections G to K for the market-oriented service sectors. Tables 1 and 2 present the distribution of firms by region and sector, while Figures 1 and 2 presents the corresponding average age shares.

[2] Due to missing values in some of the model variables, we lose some observations and end up with a sample of 16,639 firms for the econometric analysis.

[3] We thank Statistics Austria for performing the matching process as well as valuable support. Please note, that Statistics Austria holds the copyright for the data used.

[4] NACE (Nomenclature of economic activities) is a code that represents the classification of economic activities within the European Union. For details see European Commission (2002) and Statistics Austria (2003).

[5] NUTS is an abbreviation for "Nomenclature des unités territoriales statistiques". This is a system of hierarchically organised territorial units for statistical purposes that was established by Eurostat in collaboration with the member states and must be used according to the European Commission (2011). It divides the territory of the EU into territorial units on 3 levels, which normally consist of entire administrative units or groupings of such units. In Austria NUTS-level 2 represents the federal states.

[6] Please see the Appendix for further details regarding the definition of variables.

Table 1: Distribution of firms – included in the analysis - with respect to regions, i.e. NUTS-categories.

NUTS 11	NUTS 12	NUTS 13	NUTS 21	NUTS 22	NUTS 31	NUTS 32	NUTS 33	NUTS 34
2,64%	16,90%	20,56%	5,63%	12,25%	17,96%	8,49%	9,96%	5,61%

Note: NUTS 11 … Burgenland, NUTS 12 … Lower Austria, NUTS 13 … Vienna, NUTS 21 … Carinthia, NUTS 22 … Styria, NUTS 31 … Upper Austria, NUTS 32 … Salzburg, NUTS 33 … Tyrol, NUTS 34 … Vorarlberg

Table 2: Distribution of firms – included in the analysis - with respect to sectors, i.e. NACE-categories.

NACE C	NACE D	NACE E	NACE F	NACE G	NACE H	NACE I	NACE J	NACE K
0,44%	24,40%	0,44%	16,52%	30,19%	6,76%	7,99%	1,44%	11,82%

Note: NACE C … Mining and quarrying, NACE D … Manufacturing, NACE E … Electricity, gas and water supply, NACE F … Construction, NACE G … Wholesale and retail trade, NACE H … Hotels and restaurants, NACE I … Transport, storage and communication, NACE J … Financial intermediation, NACE K … Real estate, renting and business activities

As Figures 1 and 2 indicate, the average age structure across firms within regions or sectors respectively is not uniform, with higher fluctuations across industries than federal states. To the extent that firms employ their workers according to the needs of the sector and are potentially constrained by local labour markets, this may indicate that both levels (regions and sectors) may introduce heterogeneity into the relationship between the employees' age structure and labour productivity.

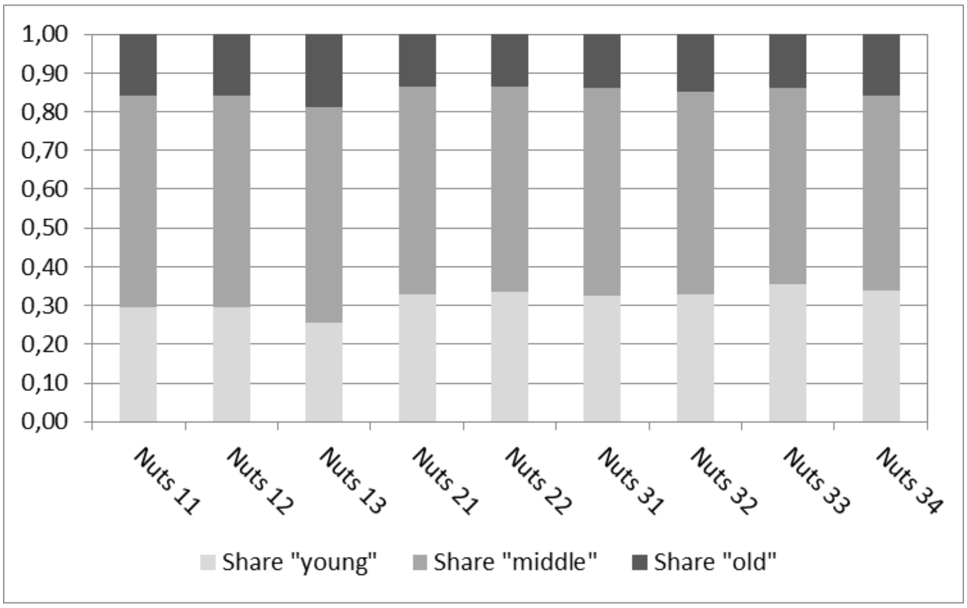

Figure 1: Mean age distribution across regions, i.e. NUTS-categories.

Note: Share "young" … Age < 30years, Share "middle" … 30years ≤ Age < 50years, Share "old" … Age ≥ 50years

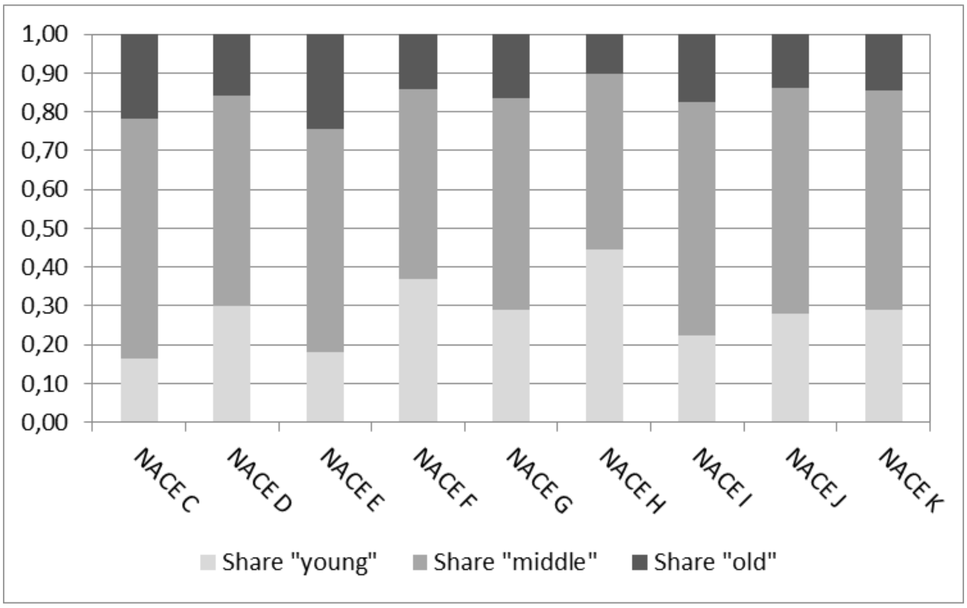

Figure 2: Mean age distribution across sectors, i.e. NACE-categories.

Note: Share “young” … Age < 30years, Share “middle” … 30years ≤ Age < 50years, Share “old” … Age ≥ 50years

Joining up the respective distributions of sampled firms across regions or sectors yields further interesting insights at a more detailed level and at the same time introduces our third level of analysis, which is sectors (regions) by regions (sectors). As Figure 3 indicates firms belonging to NACE D, F and G rather occupy an identical share in Burgenland, while the distribution of firms in Vienna is dominated by NACE G and K, whereas NACE D and G are the dominating sectors in Upper Austria. Turning the picture around, we see from Figure 4 that the highest share of hotels and restaurants (NACE H) can be found in Tyrol (NUTS 33), while Vienna occupies the largest proportions of financial intermediation (NACE J) as well as real estate, renting and business activities (NACE K).

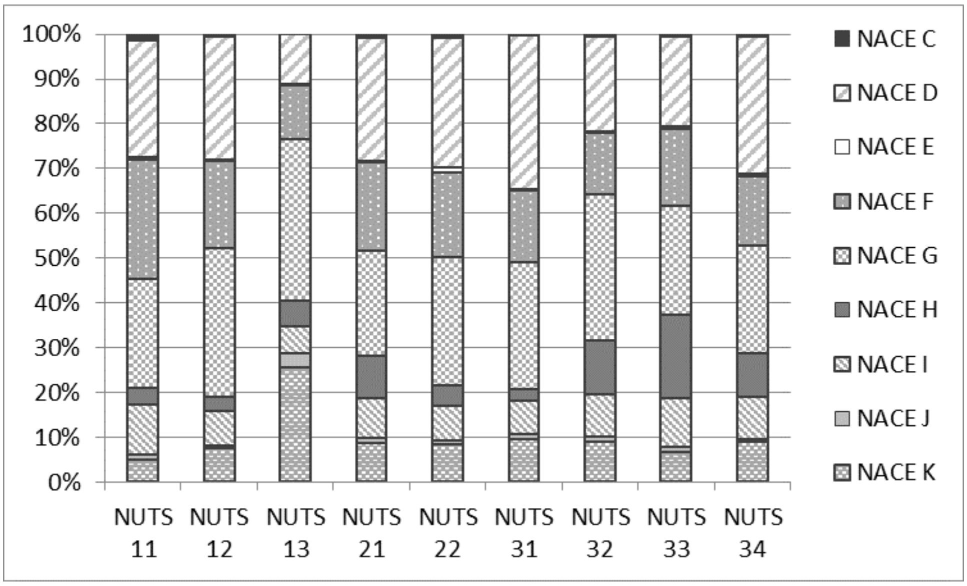

Figure 3: Distribution of firms within sectors across regions

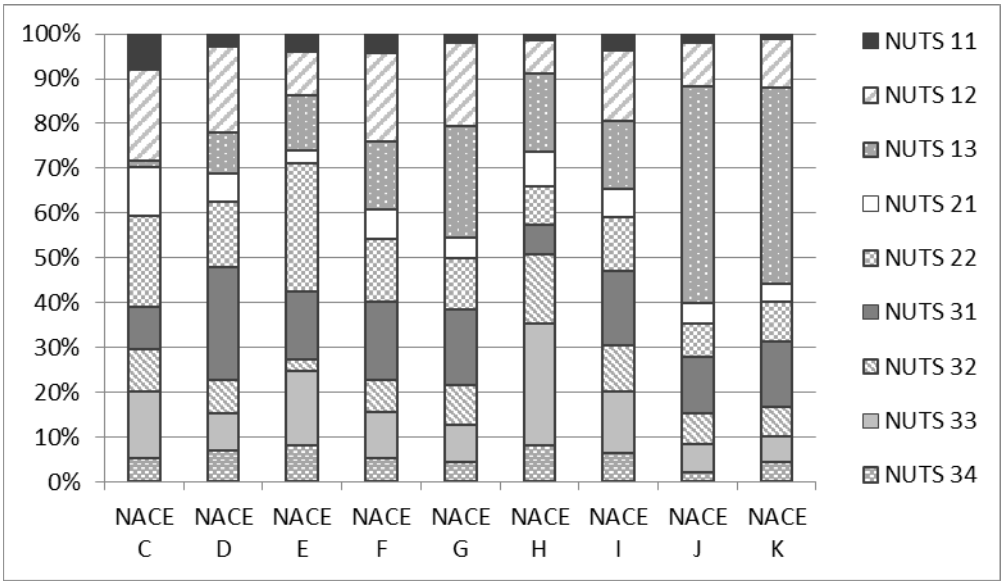

Figure 4: Distribution of firms within regions across sectors

IV. Results

In this section, we present the results of estimating multilevel regression models to study the linkage between age structure and productivity at the firm level in Austria. Following Mahlberg et al. (2013), we regress (log) value added per employee in 2005 (end year of the observation period) on the explanatory variables for 2002 (the beginning of the period) in order to partly account for potential endogeneity problems emanating from reverse causality between the productivity variable and the explanatory covariates. The set of independent variables includes the natural logarithm of value-added per employee in 2002, the three age-share variables, the Herfindahl index for age shares as a measure of age concentration, six tenure-share variables, the natural logarithm of the size of the firm (both linearly and as a squared variable), the natural logarithm of the firm's age, a dummy controlling for multi-plant firms, the natural logarithm of the stock of net fixed assets (both linearly and squared), the share of workers in various occupations as well as gender shares and the share of part-time workers.

In order to check for potential group level effects in the framework of an age productivity pattern at the firm level, we differentiate the relationship between the age composition and labour productivity by federal states (NUTS level 2)[7] on the one hand and by sectors (NACE-1-digit) on the other as well as by sectors-by-regions (i.e. an interaction of region and industry). The aim is to identify whether the age-productivity profile within firms systematically depends on the regional location or the sector affiliation. In particular, we identify group-level slopes for the age share variables, which constitute our main interest, as well as for the age concentration and lagged labour productivity.[8]

In the description of our results we distinguish between the mean relations (i.e. so called fixed effects) over all observations across all groups (regions, sectors or sectors-by-regions respectively) and the group-specific relations (i.e. the random effects), which indicate deviations from the overall mean. Finally, the sum of these two components constitutes the total relation.[9]

Table 3: Estimation results for labour productivity

Variable	Regions	Sectors	Sectors-by-regions
Fixed part			
Ln (value added per employee)	0.46***	0.51***	0.47***
	(0.01)	(0.03)	(0.01)
Share of employees			
Aged under 30	-0.06*	-0.06	-0.06
	(0.04)	(0.05)	(0.04)
Aged over 49	0.08	-0.07	0.05
	(0.05)	(0.10)	(0.05)
Herfindahl index	0.18***	0.12	0.18***
	(0.05)	(0.08)	(0.05)
Proportion of			
Tenure ≤ ¼ year	-0.12***	-0.13***	-0.15***
	(0.04)	(0.04)	(0.04)
¼ year > Tenure ≤ 1 year	-0.10***	-0.10**	-0.11***
	(0.03)	(0.03)	(0.03)
2 years > Tenure ≤ 5 years	-0.01	-0.02	-0.01
	(0.03)	(0.03)	(0.03)
5 years > Tenure ≤ 10 years	-0.00	-0.00	-0.01
	(0.04)	(0.04)	(0.04)
Tenure > 10 years	-0.06	-0.07	-0.06
	(0.04)	(0.04)	(0.04)
Ln (size of firm)	-0.08***	-0.08***	-0.09***

[7] As our data are available at the firm level, we can also identify so-called "multi-plant" firms, but our source data does not allow us to explicitly allocate the plants, which in fact carry out the business and might be the entities that are indeed impacted by the regional and industrial environment.

[8] Differences in the autoregressive dynamics of productivity caused by the regional and/or industrial environment last variable would be embodied in the differences implied for the parameter associated to lagged labour productivity.

[9] Positive group-specific relations imply that the coefficient of the respective group is above the mean coefficient corresponding to the full sample and negative ones imply that the coefficient is below.

	(0.02)	(0.02)	(0.02)
Ln (size of firm)^2/100	1.21***	1.10***	1.25***
	(0.20)	(0.20)	(0.20)
Ln (age of firm)/100	-0.22	-0.43	-0.33
	(0.46)	(0.46)	(0.46)
Multi-plant	-0.07***	-0.07***	-0.07***
	(0.01)	(0.01)	(0.01)
Ln (fixed assets per employee)	-0.01**	-0.00	-0.01
	(0.01)	(0.01)	(0.01)
Ln (fixed assets per employee)^2/100	0.80***	0.64***	0.73***
	(0.07)	(0.07)	(0.07)
Proportion in occupation			
Self-employed	-0.47***	-0.47***	-0.47***
	(0.07)	(0.07)	(0.07)
Blue-collar (incl. homeworkers)	-0.36***	-0.35***	-0.37***
	(0.02)	(0.02)	(0.02)
Apprenticeship	-0.95***	-1.01***	-0.96***
	(0.06)	(0.06)	(0.06)
Proportion of			
Female employees	-0.23***	-0.22***	-0.23***
	(0.02)	(0.02)	(0.02)
Proportion of			
Part-time	-0.29***	-0.29***	-0.29***
	(0.03)	(0.03)	(0.03)
Constant	2.63***	2.38***	2.50***
	(0.09)	(0.13)	(0.07)
Random part			
$\sigma^2_{\text{value-added per employee}}$	0.01**	0.09	0.03***
$\sigma^2_{\text{share of young}}$	0.03**	0.09	0.12**
$\sigma^2_{\text{share of old}}$	0.08**	0.21***	0.16***
$\sigma^2_{\text{Herfindahl}}$	0.05**	0.16	0.04
$\sigma^2_{\text{constant}}$	0.02**	0.30	0.08***
σ^2_{ε}	0.49**	0.48	0.48***
Wald Test	12,494.75***	1,923.31***	7,935.33***
Log likelihood	-11,598.87	-11,514.42	-11,597.85
Number of Observations	16,639	16,639	16,639

Significance levels: * 10%, ** 5%, *** 1%

Note: The share of prime-aged employees, the share of employees with job tenure of one to two years, the share of male employees and the shares of white-collar as well as the share of full-time workers are chosen as reference categories.

The mean coefficients for the share of young employees shown in Table 3 are insignificantly negative (except for the regression by regions, where the relation is weakly significant). For the share of old workers, on the other hand, the mean coefficient estimates by federal states and by sectors-by-regions turn out to be insignificantly positive, whereas that of the regression by sectors is insignificantly negative.

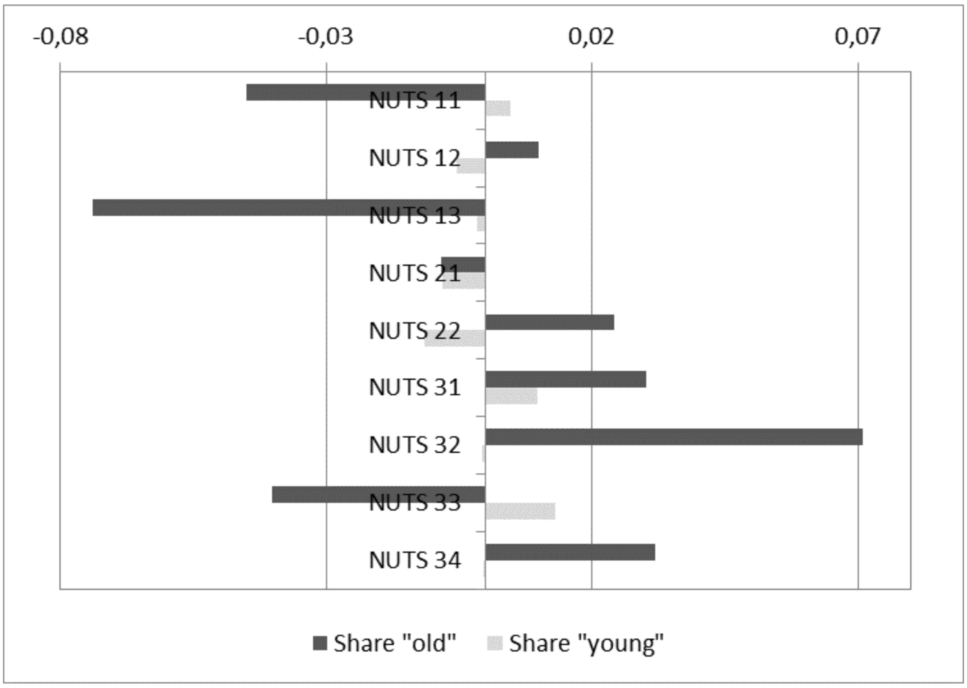

Figure 5: Age-productivity profile across states (deviations from the mean slope)

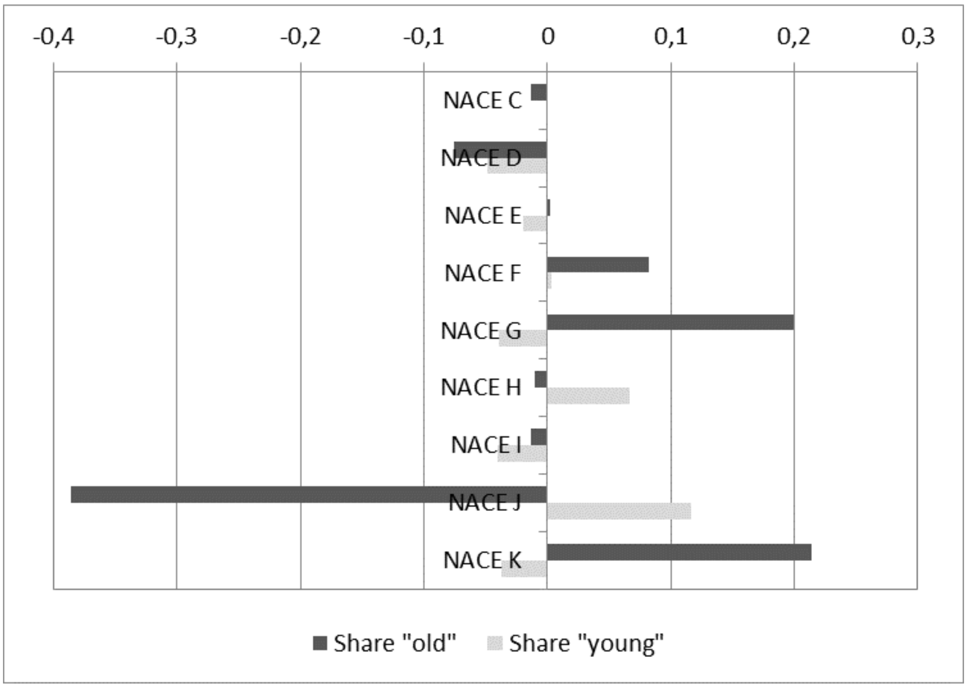

Figure 6: Age-productivity profile across sectors (deviations from the mean slope)

Deviations from mean slopes, which correspond to the random effects, differ strongly across regions as well as sectors. While overall group-specific differences are slightly more pronounced across sectors than regions (note the different scales in Figure 5 and Figure 6), the old age pattern is clearly more distinct than the young age pattern. We find positive deviations from the mean for the share of old aged employees in Lower Austria (NUTS 12), Styria (NUTS 22), Upper Austria (NUTS 31), Salzburg (NUTS 32) as well as Vorarlberg (NUTS 34) and negative group level effects in Burgenland (NUTS 11), Vienna (NUTS 13), Carinthia (NUTS 21) and Tyrol (NUTS 33) (Figure 5). Having a look at the share of old employees across industrial sectors (Figure 6) we find visible deviations with a positive sign for real estate, renting and business activities (NACE K), wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (NACE G) and construction (NACE F), while the coefficient for financial intermediation (NACE J) and manufacturing (NACE D) are clearly negative. As regards the share of young employees, deviations are altogether more moderate, although one may mention a positive slope for hotels and restaurants (NACE H) as well as financial intermediation (NACE J).

The overall mean or fixed coefficients for the other explaining variables differ only very slightly across the three regression analyses. With respect to the tenure variable – which allows us to disentangle ‘pure’ age effects from the length of stay within a firm – the coefficients indicate that higher shares of employees in short tenure intervals (as compared to a share of employees within a tenure interval of 1 to 2 years) is negatively associated with labour productivity. With regard to the age concentration of the employees, we find that less diversity favours labour productivity. The mean effect disappears once that heterogeneity in the effect of the variable is allowed to differ across sectors, which implies that such a result may be driven by the role played by age diversity as a driver of productivity in particular sectors. Firm age, on the other hand, does not appear to be a significant determinant of labour productivity, while the organisational form in terms of being a multi-plant enterprise or not shows a slightly negative link with labour productivity. The negative effect of firm size (as measured by the number of employees) on productivity is reduced for relatively larger firms, a pattern which is also found for capital intensity, proxied in the model by fixed assets per employee.

In relation to the reference category of white-collar workers, the three other occupational groups are negatively related to productivity, with the share of employees in apprenticeship showing the most negative coefficient. A higher share of female employees and part-time workers, which often goes along with each other, has a negative impact on productivity. These results confirm the findings in Mahlberg et al. (2013) and expand them by assessing the spatial and sectoral heterogeneity explicitly.

Table 4: Age group coefficients (deviations from the mean slope) in a sectors-by-regions breakdown

Federal state	Sector	Share of employees	
		Aged under 30	Aged over 49
Burgenland (NUTS 11)	Mining and quarrying (NACE C)	0,0054	-0,0050
	Manufacturing (NACE D)	0,0572	-0,0715
	Electricity, gas and water supply (NACE E)	-0,0010	-0,0098
	Construction (NACE F)	0,0063	-0,0184
	Wholesale and retail trade (NACE G)	0,0608	-0,0211
	Hotels and restaurants (NACE H)	-0,0175	0,0039
	Transport, storage and communication (NACE I)	-0,0224	0,0013
	Financial intermediation (NACE J)	-0,0226	0,0216
	Real estate, renting and business activities (NACE K)	0,0103	0,0071
Lower Austria (NUTS 12)	Mining and quarrying	-0,0077	0,0083
	Manufacturing	-0,0739	-0,1233
	Electricity, gas and water supply	-0,0015	0,0106
	Construction	0,0467	-0,0175
	Wholesale and retail trade	-0,0165	0,1979
	Hotels and restaurants	-0,0237	-0,0180
	Transport, storage and communication	-0,0194	-0,0443
	Financial intermediation	0,0389	0,0331
	Real estate, renting and business activities	0,0401	-0,0414
Vienna (NUTS 13)	Mining and quarrying	-0,0027	-0,0156
	Manufacturing	0,0367	-0,0952
	Electricity, gas and water supply	0,0035	0,0411
	Construction	0,0584	0,0056
	Wholesale and retail trade	-0,0177	-0,0864
	Hotels and restaurants	-0,0498	0,0187
	Transport, storage and communication	0,0194	-0,0741
	Financial intermediation	0,2267	-0,2760
	Real estate, renting and business activities	-0,0971	0,0141
Carinthia (NUTS 21)	Mining and quarrying	0,0072	0,0227
	Manufacturing	-0,0974	0,0292
	Electricity, gas and water supply	0,0051	0,0091
	Construction	0,0073	0,0175
	Wholesale and retail trade	0,0633	-0,0780
	Hotels and restaurants	-0,0140	0,0248
	Transport, storage and communication	-0,0118	-0,0105
	Financial intermediation	0,0094	0,0227
	Real estate, renting and business activities	-0,1058	0,0073
Styria (NUTS 22)	Mining and quarrying	0,0059	-0,0135
	Manufacturing	-0,0903	-0,0268
	Electricity, gas and water supply	-0,0130	0,0028
	Construction	0,0283	-0,0567
	Wholesale and retail trade	-0,0057	0,1583
	Hotels and restaurants	-0,0183	-0,0233
	Transport, storage and communication	-0,0180	0,0418
	Financial intermediation	0,0254	-0,0001
	Real estate, renting and business activities	-0,0017	-0,0178
Uppe r Austr	Mining and quarrying	-0,0017	0,0114
	Manufacturing	-0,0582	-0,0642
	Electricity, gas and water supply	0,0049	0,0136

	Construction	0,0566	0,0311
	Wholesale and retail trade	0,1241	0,1648
	Hotels and restaurants	-0,0284	-0,0271
	Transport, storage and communication	0,0350	-0,0039
	Financial intermediation	-0,0001	0,0364
	Real estate, renting and business activities	-0,1408	-0,0244
Salzburg (NUTS 32)	Mining and quarrying	0,0034	-0,0160
	Manufacturing	0,0222	-0,0143
	Electricity, gas and water supply	-0,0010	-0,0035
	Construction	-0,0097	0,0502
	Wholesale and retail trade	-0,0571	0,2152
	Hotels and restaurants	0,0852	-0,0640
	Transport, storage and communication	-0,1114	0,0571
	Financial intermediation	0,0509	-0,0289
	Real estate, renting and business activities	-0,0271	0,0298
Tyrol (NUTS 33)	Mining and quarrying	0,0091	0,0273
	Manufacturing	0,0090	0,0661
	Electricity, gas and water supply	0,0045	0,0239
	Construction	-0,0133	-0,0107
	Wholesale and retail trade	0,0215	-0,1564
	Hotels and restaurants	0,0386	-0,0081
	Transport, storage and communication	0,0907	-0,1012
	Financial intermediation	0,0456	0,0110
	Real estate, renting and business activities	-0,0324	0,0487
Vorarlberg (NUTS 34)	Mining and quarrying	0,0028	0,0046
	Manufacturing	0,0045	-0,0822
	Electricity, gas and water supply	0,0023	0,0008
	Construction	-0,0121	0,0138
	Wholesale and retail trade	-0,1293	0,1134
	Hotels and restaurants	0,0362	-0,0087
	Transport, storage and communication	-0,0636	0,0010
	Financial intermediation	0,0218	0,0120
	Real estate, renting and business activities	0,0050	0,1260

In addition, we explore the age-productivity pattern considering a group level defined in terms of a breakdown of sectors-by-regions in order to get some deeper insights into the reasons that may lie behind the group differences across regions. Overall, the picture of age-productivity relations at this finer group level is rather heterogeneous (see Table 4, which shows the estimated coefficients – to be interpreted as deviations from the mean effect – by sector and region). In Burgenland (NUTS 11) the slightly positive coefficient of the share of young employees, which indicates a smaller negative effect of this age group, originates from NACE D (manufacturing) and NACE G (wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods), whereas the clearly negative coefficient of the share of old employees emanates from NACE D. To a large part the economic structure in Burgenland consists of NACE D and G (see Figure 3). In Lower Austria (NUTS 12), the slightly negative coefficient of the share of young employees is mainly related to the effects in

NACE D and, to a lesser extent, from NACE G (where the aggregated effect of the old age variable is positive), which constitute the largest sectors in the region. The slightly positive coefficient of the share of old employees is linked to NACE G. In Vienna (NUTS 13) the coefficients of the share of young employees for the individual sectors tend to neutralise each other, so that the overall effect is almost zero. The clearly negative coefficient of the share of old employees may be ascribed to NACE G. The strongly negative coefficient corresponding to NACE J (financial institutions) does not strongly influence the overall linkage observed at the aggregate level, since this sector is rather small (in terms of the number of firms) relative to other sectors in Vienna. The moderate negative coefficient of the share of young employees in Carinthia (NUTS 21) appears to be due to NACE D and that of the old employees to NACE G, which shows a negative effect in contrast to many other federal states. As can be seen in Figure 3, these two sectors are the two largest in Carinthia, followed by NACE F (construction). The opposite sign of the coefficients of NACE F soften the negative effects of the two other strong sectors. In Styria (NUTS 22) the slightly negative coefficient of the young employees originates mainly form NACE D, which is one of the two largest sectors in terms of the number of firms. The positive coefficient of the old employees comes from a clearly positive effect of NACE G which is moderated by slightly negative coefficients of the two other big sectors NACE D and F. In Upper Austria (NUTS 31) the links between productivity and young as well as old employees are positive due to the clearly positive coefficient of NACE G which constitutes the second largest sector. The positive effect of NACE G is weakened by the slightly negative effect of the largest sector (NACE D). The large positive coefficient of the share of old employees in Salzburg (NUTS 32) originates almost exclusively from the clearly pronounced positive effect of NACE G. In Tyrol (NUTS 33) the slightly positive coefficient of the young employees may obviously be traced back to NACE G as well as NACE H which are the two largest branches. The negative coefficient of the share of old employees originates mainly from NACE G. In Vorarlberg (NUTS 34) the positive effect of the old employees once more stems from the clearly positive coefficient of NACE G. The negative coefficient of NACE D mitigates the positive one of NACE G. All in all, we see that NACE G (wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods) and to a lesser extent NACE D (manufacturing) seem to be the determining sectors for the overall coefficient of age shares on regional level for almost all Austrian federal states, since in most cases these two sectors are the largest in the respective regional economy.

The results of the analysis indicate that parameter heterogeneity in the age-productivity gradient is a pervasive phenomenon in our firm-level dataset for Austria. Such an insight implies that aggregate results will tend to mask sector-specific and region-specific effects which drive the relationship that is found if a global, homogeneous relationship is assumed.

V. Conclusions

In this paper we extend the analysis in Mahlberg et al. (2013) by considering the possibility of a systematic variation of the age-productivity pattern in Austria depending on the regional location and/or sectoral affiliation of a firm. While the overall age-productivity pattern in an average firm appears rather similar to the findings in Mahlberg et al. (2013), our results yield some interesting insights on the heterogeneity in the linkage between age structure and productivity implied by geographical location and sector affiliation. First, age effects at the industry level are of a higher magnitude than at the regional level. The industrial environment, thus, appears to play a more important role for a firm's age-productivity pattern than the spatial neighbourhood. The dependence of the age-productivity gradient on sectoral characteristics indicates that the heterogeneity of the relationship probably emanates from the role that age plays as a determinant of certain abilities and that local labour markets are less important as a constraint to productivity improvements. Second, the random effects for the share of old employees are more pronounced than for the share of young employees and not of a uniform pattern. Hence, we are not able to discern a generally negative association between the share of old employees and labour productivity. Finally, we find varying age effects at the group level if we distinguish the sectors by regions. Particularly this finding would deserve deeper attention in terms of further research. The heterogeneous age-productivity pattern found in this study should be taken into consideration in future research on the age-productivity relation. In particular, relaxing the parameter homogeneity assumption which is standard in most econometric models on age-productivity patterns at the firm level should become a rule more than an exception in future empirical research.

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Appendix

Definitions of selected independent variables

The age-share describes the share of employees in a certain age interval measured in years. We distinguish employees aged less than 30, aged between 30 and 49 and aged over 49 years.

The age concentration is measured by the Herfindahl index for age shares.

Tenure is defined as time spent working in the current firm (job experience[10]).[11] The variable is constructed making use of three variables in the data set: i) the length (in number of days) of employment during the current year, ii) the length of (the same) employment until the end of the previous year, and iii) the length of an earlier employment having ended before the current year (but after the beginning of 2002) and being upright until the current kind of employment relationship has started - within the same firm. Unfortunately the tenure variable is systematically left-censored before 2002, as we cannot track changes that have taken place before that date.

The size of a firm corresponds to the average number of employees, who have been working in a certain firm within the considered year.

Firm age is defined as the number of years since the firm's foundation.

Capital intensity is measured by net fixed-assets per employee. Data on net fixed-assets are taken from the national accounts data of Statistics Austria. These data are available only at the industry level. In order to make them suitable for our data set, we have disaggregated them to the firm-level. As in Harhoff (1998), for the first year (2002) net fixed assets of each firm was computed by dividing the aggregate industry level capital stock among firms according to their share in total industry investment in order to obtain a starting value for the capital stock time series. For subsequent years, the usual perpetual inventory method was used exploiting firm-specific investment data from the Structural Business Survey and industry-specific depreciation rates from the National Accounts.

The share of part-time workers is the share of workers working below the 'normal' working hours according to the wage agreement of the respective industry.

Moreover, we include a multi-plant dummy which is 1 for firms which run more than one plant.

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[10] Since data on educational attainment of employees are not available, potential work experience (= age minus years of education minus six) cannot be computed.

[11] For details regarding the construction of the tenure variable see Freund et al. (2011).

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