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Ageing labour: How does demographic change affect regional human capital?

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Abstract

Human capital investments are frequently suggested as policy measure to cope with smaller and older labour forces caused by demographic change across Europe. However, the availability and composition of human capital is fundamentally intertwined with demographic structures, especially at a regional level. This paper analyses how ageing is related to the regional composition of human capital for 332 German regions between 1996 and 2010. The findings show that labour force ageing is associated with lower educational attainment, and that older labour forces have higher shares of traditional vocational degrees. On a national level, education expansion still sufficiently compensates for the effects of population ageing, but regional human capital composition shows distinct trends.

***Keywords*:** demographic change, human capital, regional labour markets, regional development

***JEL Codes*:** R10, R12, R23, J21, J24

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1. INTRODUCTION

Demographic change, characterised by trends of population ageing and a slow-down of population growth, holds significant challenges for European labour markets. The working-age population decreases relative to the population above retirement age and changes in composition. This process threatens the sustainability of unfunded (pay-as-you-go) pension systems (e.g. Börsch-Supan, Härtl, & Leite, 2016) and could affect per-capita economic growth (e.g. Bloom, Canning, & Fink, 2010; Lee, 2016). Besides increasing labour market participation, productivity increases may help compensate for a smaller and older labour force. For this reason, human capital investment takes on a central role in policy suggestions to cope with the labour market effects of demographic change (e.g. Börsch-Supan, 2003; Crespo Cuaresma, Loichinger, & Vincelette, 2016). However, due to differences in human capital across age groups as well as migration patterns, demographic change is itself intertwined with the availability and composition of human capital. This is especially relevant at a regional level because labour markets are locally defined and regions differ markedly in their demographic structures. Using the case of Germany, this paper investigates how population ageing is related to the regional composition of human capital.

Population ageing affects the structure of the labour market both quantitatively and qualitatively. The European working-age population is projected to decrease on average by 0.3% per year until 2060 with some countries experiencing much larger effects (EC, 2015). While there are certainly fewer labour market entrants, they may also differ from the retirees that they are replacing: education expansion over time implies that younger cohorts are generally more highly educated than older ones. On a regional level, though, the available supply of labour is influenced by the education choices of the local population, its age structure, and by in-and out-migration. Thus, even though the average educational attainment may be rising steadily, regional differences in human capital may persist or even increase.

The relevance of human capital as a driver of economic growth is well-documented in a range of influential studies (e.g. Barro, 2001; Mankiw, Romer, & Weil, 1992). Despite the prominent role of human capital in policy suggestions for coping with an ageing and shrinking labour force, few studies have so far addressed the interrelations between population ageing and human capital itself, especially

at a regional level. The existing literature focuses either on the role of demography in individual-level educational attainment (e.g. cohort studies such as Fertig, Schmidt, & Sinning, 2009) or on describing regional patterns of human capital development, degree of convergence and its consequences (e.g. Brunow & Hirte, 2009a, 2009b; Gregory & Patuelli, 2015; Südekum, 2008, 2010).

The main contribution of the paper to the existing literature is twofold. To the authors' knowledge, there are no empirical studies investigating the relationship between demographic change and the regional availability and composition of human capital. Moreover, human capital is usually approximated with broad measures, e.g. the proportion of population with a tertiary education degree, which neglect a large portion of the human capital effectively employed in the labour market, especially for countries with a strong vocational training system, such as Germany.

Most industrialised countries face rapidly ageing populations as well as prospects of population decline (Reher, 2007) and consequences of demographic change have already begun manifesting in some places. Due to increasing life expectancy coupled with very low fertility rates (around 1.4 children per woman) since the 1970s, Germany is already experiencing pronounced population ageing. The median age increased from 37 years in 1990 to 45 years in 2013 (Destatis, 2015) making the German population the oldest one in Europe (EC, 2015). Although these trends are expected to continue in the future, the degree of population ageing experienced so far implies that Germany provides a valuable context to study the consequences of demographic change.

This paper uses the German case to analyse the role of population ageing in explaining regional differences in the human capital composition for 332 districts between 1996 and 2010. It combines regression analyses on the relative shares of six different educational degrees with more exploratory methods to investigate different regional pathways of investing in human capital. It proceeds as follows. The literature background is presented in the following Section 2. In Section 3 the German educational context, the dataset and methods are described. Regression results are discussed in Section 4, while further extensions to the empirical analysis are presented in Section 5, before the conclusions.

2. BACKGROUND

2.1 Human capital and regional growth

Human capital is widely acknowledged as a central driver of economic growth. It is thought to contribute to innovation, creativity and technological progress. Its relevance for urban and regional growth has been demonstrated in a range of studies (e.g. Florida, Mellander, & Stolarick, 2008; Gennaioli, La Porta, Lopez-De-Silanes, & Shleifer, 2013; Qian, Acs, & Stough, 2013);the literature particularly emphasises the role of urban areas as knowledge centres shaped by and continuously attracting highly-skilled individuals (Faggian & McCann, 2009; Storper & Scott, 2009). Human capital externalities – i.e. when social returns to education exceed private returns, for instance due to productivity spillovers (Moretti, 2004) – may explain urban wage premia (Glaeser & Maré, 2001; Glaeser & Resseger, 2010; Rauch, 1993), and thus also city growth (Glaeser, Scheinkman, & Shleifer, 1995; Simon & Nardinelli, 1996). Human capital availability may also increase regional firm formation (Acs & Armington, 2004; Qian et al., 2013) and employment growth (Shapiro, 2006; Winters, 2013).

Factor mobility and the role of local characteristics – i.e. migration flows from peripheral to core regions – can cause unbalanced redistribution of human capital across space, thus failing to act as income equalizing mechanisms as indicated in standard economic theory (Iammarino, Rodríguez-Pose, & Storper, 2018). On the one hand, highly-skilled workers cluster specifically in places with high initial human capital – e.g. due to learning externalities (Peri, 2002), social (Kemeny, Feldman, Ethridge, & Zoller, 2016) and professional networks (Breschi & Lissoni, 2009), or highly-skilled entrepreneurs' hiring preferences (Berry & Glaeser, 2005); the knowledge spillovers they may generate, however, suffer from strong distance decay effects (e.g. Moreno, Paci, & Usai, 2005). On the other hand, interregional labour migration has remained sluggish in most advanced economies, and worrying restrictive regulations on immigration are proliferating internationally (e.g. Livi Bacci, 2017). Even if the attracting factor is not initial human capital but some other agglomeration force (e.g. Betz, Partridge, & Fallah, 2016), the outcome may nevertheless be increasing polarisation of human capital and rising within-country inequality. In a context of demographic change, understanding the economic geography

of the relationship between ageing and shrinking labour force and availability and composition of skills appears still a challenge.

The demographic changes in the German labour force are driven by the ageing of the disproportionally large baby-boom generation (birth cohorts roughly between 1955 and 1969), which was the last generation before fertility rates dropped below replacement level. The German Federal Statistical Offices (2009) predict the size of the labour force to fall on average by 11.6% between 2005 and 2030. Even assuming increasing participation rates and considerable net migration, a decreasing German labour force potential seems unavoidable (Fuchs, Söhnlein, & Weber, 2011). Simultaneously, the labour force is rapidly ageing especially as long as the baby boom generation is still of working age.

Human capital is relevant here for two reasons. First, a shrinking working-age population leads to a variety of social and economic challenges which could reduce economic growth (e.g. Bloom et al., 2010; Lee, 2016). Börsch-Supan (2003, 17) argues, based on the projected smaller share of German working-age population, that "annual productivity gains need to increase by a third if we are to experience the sustained levels of growth to which we are accustomed". Thus, by increasing productivity, human capital increases may help offsetting the effects of a shrinking working force and a growing retired population. Second, there are concerns that an older labour force may be inherently less productive. Studies of innovation behaviour over the life-course suggest an inverse U-shaped relationship between age and innovation (for a review see Frosch, 2011), scientific output (Jones, Reedy, & Weinberg, 2014), and entrepreneurial activity even at a regional level (Bönte, Falck, & Heblich, 2009). Moreover, Meyer (2009) finds that firms in ICT- intensive sectors are less likely to adopt new technologies if they employ a higher share of older workers; the latter may exhibit reduced absorptive capacity for technology (Prskawetz et al., 2007). Thus, human capital investment may also be instrumental in compensating for potential reductions in productivity of older work forces.

A related stream of literature concerns the question of convergence or divergence in human capital across space. For the US, empirical evidence seems to suggest divergence in human capital across cities (e.g. Berry & Glaeser, 2005; Wheeler, 2006). In contrast, for West Germany, Südekum (2008, 2010) finds that highly-skilled cities saw faster employment growth overall, but that high-skilled employment

is characterized by convergence. In a broader analysis of human capital based on educational attainment, Tarazona (2010) shows that human capital convergence among East and West Germany may coincide with divergence within West Germany. In particular, convergence seems to be driven by falling human capital levels in East Germany, which is supported also by literature on East-West brain drain due to skill-selective migration (e.g. Brücker & Trübswetter, 2007; Hunt, 2006; Melzer, 2013).

2.2 Demographic change and regional human capital accumulation

Through its potential effect on labour productivity, innovation and creativity, human capital investment is one of the primary policy tools suggested to cope with demographic change. However, demographic change itself affects the level and type of human capital by changing the size and composition of the working-age population. On the one hand, assuming stable participation rates, smaller young cohorts will not be sufficient to replace retiring cohorts. There are concerns that retirement of large cohorts (e.g. baby boomers) could lead to knowledge loss if not managed effectively (Hipp & Verworn, 2011). The increasing average age of the labour force may also impede updating of human capital because only a small share of new graduates enters the labour market. This emphasises the need for continuous on-the-job and life-long learning to ensure that the human capital stock is constantly upgraded. On the other hand, due to the global trend of expansion in secondary and tertiary education, labour market entrants are on average more highly educated than retirees.

Potential reasons for the global education expansion are supply-driven societal factors such as the democratisation of access to higher education (Schofer & Meyer, 2005) and changes in the labour demand in the context of skill-biased technological change (e.g. Katz & Autor, 1999). The effect of technical change on the task content of occupations (Autor, Levy, & Murnane, 2003) causes shifts in the skill distribution of human capital over time and space (e.g. Scott, 2010). For West Germany, Spitz-Oener (2006) shows that changes in the task content of occupations account for up to 36% of the increase in the share of high-skilled employees between 1979 and 1999. Additionally, education expansion has been an explicit policy goal for the European Union in the context of the Lisbon Strategy and Europe 2020, which benchmarks a goal of 40% of 30-34 year-olds having completed tertiary education (EC,

2010)[1]. Considering the trend of education expansion, a theoretical link between human capital and population ageing can be established: the degree of ageing affects the impact of education expansion on the availability of human capital. We would thus expect that regions with an older labour force have relatively lower levels of human capital, ceteris paribus. In terms of composition, because education expansion strongly affects the share of young people completing tertiary education, the labour force of strongly ageing regions would be characterised by lower educational attainment.

The relationship between population ageing and human capital availability is especially relevant at a subnational level because of large regional heterogeneity in demographic and labour market trends (Boschma & Fritsch, 2009; Scott, 2010). In general, migration propensity is higher among the young and well-educated (e.g. Bucher & Heins, 2001). Skill-selective migration has been shown to react to both wage premia (Borjas, Bronars, & Trejo, 1992) as well as employment differentials (Arntz, 2010; Arntz, Gregory, & Lehmer, 2014), and the determining factor may differ among age groups, e.g. young Germans being more sensitive to wages and less sensitive to unemployment rates than older workers (Hunt, 2006). Such skill- and age-selective migration would imply sorting of individuals across regions, which could simultaneously affect regional age and composition of human capital.

The existing empirical literature on regional human capital patterns pays limited attention to the role of demographic structure. Tarazona (2007) calculates a regional age-specific index of human capital for 2001 and concludes that age structure does not explain regional disparities. Brunow and Hirte (2009b) consider the age structure of regionally available human capital and find age-specific differences in productivity, but draw this conclusion from a cross-section thus not capturing the process of population ageing. Gregory and Patuelli (2015) present an exploratory spatial data analysis that suggests clustering and polarization between German regions in terms of age structure, share of creative professionals and innovative performance.

Besides relatively little concern for the relevance of demographic change in regional human capital accumulation, the existing literature largely builds on the distinction between high- and low-skilled

[1] This target has already almost been reached, with 39.1% of 30 to 34 year-olds in the EU-28 having attained tertiary degrees in 2016, although considerable differences across space remain (Eurostat, 2017).

human capital and predominantly focuses on the prevalence of university degrees. Although clearly relevant and advantageous in terms of data availability, the high/low skill dichotomy neglects the large variation within human capital. This is evident especially for countries with strong vocational training systems like Germany, where measuring only the share of university degrees neglects the substantial human capital content of vocational degrees.

This paper adds to the existing literature by investigating the link between labour force ageing and human capital composition across different educational degree types, illustrating the regional heterogeneity in human capital development under conditions of demographic change. It should be noted that the nature of the analysis is exploratory and descriptive. Age- and skill-selective migration implies that causality between age structure and human capital will likely go in both directions. This work does not attempt to isolate migration effects but rather considers migration as a driving factor for regional population ageing, as its main aim is to establish the existence of a relationship rather than proving its causal effect.

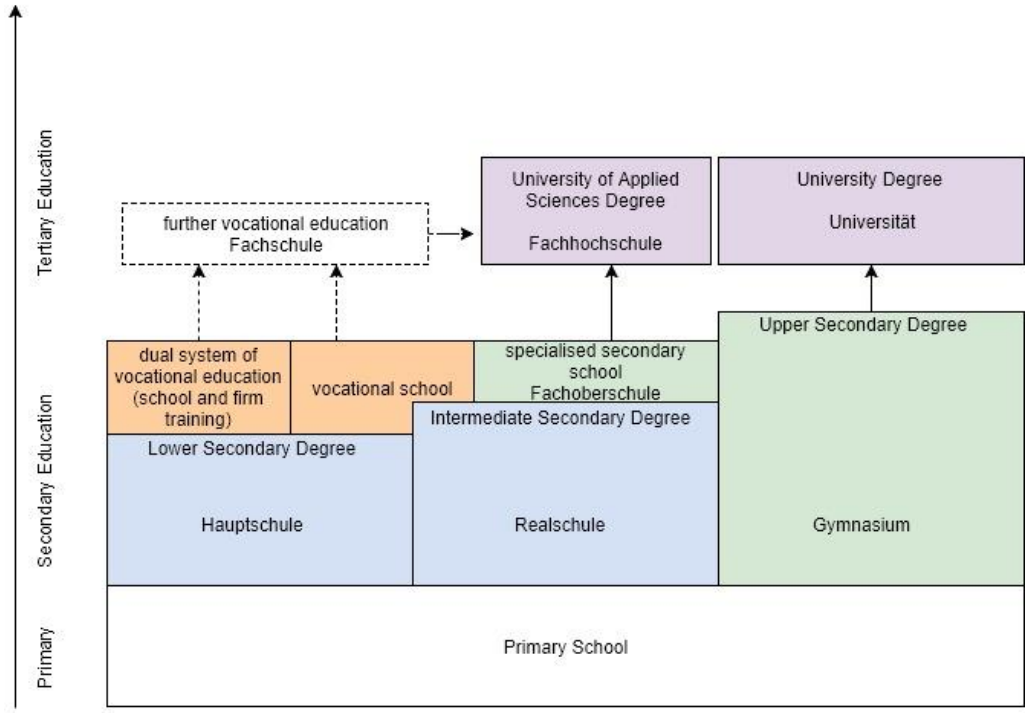
3. METHODOLOGY

3.1 The German education system

To analyse human capital in the German context, a short overview of the education system is necessary[2] (Figure 1). After primary school, students enter secondary schools for one of three degree types: lower secondary degree (*Hauptschulabschluss*), intermediate secondary degree (*Realschulabschluss*), and upper secondary degree (*Abitur*). A lower secondary degree takes 5 years after which students may begin vocational school or enter the dual system of vocational training[3]. An intermediate secondary degree takes 6 years and, after further secondary education, gives access to tertiary education at a university of applied sciences (*Fachhochschule*) or in specific subjects at universities. The upper secondary degree (8-9 years of secondary schooling) is the only degree that grants direct access to universities[4].

[2] See KMK (2015) for details.
[3] The dual system of vocational training does not have educational prerequisites. Thus, students who do not obtain a secondary degree are still eligible for vocational training.
[4] In some circumstances, a vocational degree allows further qualification (e.g. Fachschule), which grants access to tertiary education.

Figure 1: Schematic representation of German education system



Education policy is a responsibility of the Federal States and details of the system therefore differ within Germany, but this does not affect comparability of qualifications. Furthermore, the German Democratic Republic (GDR) had a distinct education system, which is reflected for example in the fact that East Germany has higher shares of university graduates. However, the data does not allow tracing where individuals completed their education and we therefore rely on the equivalence of vocational and educational qualifications that was set out in §37 of the reunification treaty.

Dual vocational training takes on a prominent role in the German education system and implies that students are trained both within a company and at a vocational school (*Berufsschule*). The combination of on-the-job training and both general and specialised vocational education are meant to equip apprentices with a degree, specific skills, and job experience. Powell and Solga (2011) argue that the German prevalence of vocational training (c.f. the Anglophone emphasis on higher education) is supported by cultural values associated with the concept of vocation as well as risk aversion, since an apprenticeship can be more secure and less costly than tertiary education (because apprentices earn a salary).

As a result, vocational training is attractive even for those who could attend university. More than half of any age cohort begins vocational training, and in 2012 24% of current apprentices had previously obtained entrance qualifications for higher education (KMK, 2015, 139). The prevalence of vocational education limits the size of the higher education sector with only 26% of 25-34 year-olds having completed tertiary education compared to an OECD average of 38% in 2012 (OECD, 2012, 3). Moreover, tuition fees play a limited role in the costs of tertiary education in Germany since university has traditionally been free[5]. Even in the period between 2007 and 2014 when universities in some Federal States charged tuition fees, the amounts were low in international comparison (€500 per semester), and research on the causal effects of German tuition fees generally does not find significant effects on enrolment behaviour (e.g. Bruckmeier & Wigger, 2014).

3.2. Data

The data source used to calculate regional human capital levels is the Sample of Integrated Labour Market Biographies 1975-2010[6]. It is a 2% sample of the administrative social security database recording for instance gender, age, educational attainment, occupation, employment status and region of workplace. The data considers only private sector employees and excludes civil servants, the self-employed and students because these groups do not fall under the compulsory social security cover (*versicherungspflichtige Beschäftigte*).

We restrict the sample to individuals of at least 30 years because the skill composition for younger individuals does not seem to be representatively captured in the data. Since the dataset is based on those employed, there is selection bias with respect to education because the observed individuals chose to work instead of continuing education. As a consequence, only a very small share of those under 30 in the dataset have attained a university degree (2.6% compared to 7.6% for above 30-year olds in 1996). Comparing this age group to the older ones thus introduces bias, which is why we disregard individuals under 30 years. The education data was imputed based on the strategy suggested by Fitzenberger,

[5] Tuition fees at public universities were banned by Federal law until 2005. As of 2014, all states that had imposed fees have abolished them again. Fees still apply in some cases, e.g. a second undergraduate degree, for long-term or non-EU students in certain Federal States.

[6] Data access was provided via a Scientific Use File supplied by the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB).

Osikominu, and Völter (2006) to address inconsistencies. After imputation and excluding observations with missing data, the underlying micro data set comprised 7.1 million observations on 800,000 individuals between the ages of 30 and 62.

The first employment spell per individual and year was aggregated to the regional level and used to calculate regional human capital measures described below. For reasons of anonymity, the regions represented in the SIAB have a population of at least 100,000, which is why the SIAB7510 regions combine some smaller districts to a district region, whereas larger districts appear as independent regions. The 332 SIAB regions are thus based on, but do not perfectly correspond to, the 412 districts (NUTS3) in Germany of 2010. The proportions of employees by educational attainment, mean age, and gender shares from the aggregated SIAB7510 file were combined with data on regional socio-economic characteristics from the Federal Statistical Offices (Regional Database Germany) and the BBSR (INKAR). Due to missing variables for six regions in 1996 and 1997 the final dataset is an unbalanced panel of 4968 observations.

3.3 Method

Based on Figure 1 above, human capital can be broken down to the shares of six educational degrees (Table 1) which are reported by employers. The six degree types are defined by the highest level of education completed and distinguish between vocational and higher education. The first type (D1) is only primary, lower secondary or intermediate secondary education and no further qualification, whereas the second type (D2) has a completed vocational qualification. Similarly, the third type (D3) refers to only an upper secondary degree and no further qualification, while the fourth type (D4) has both an upper secondary degree and a completed vocational degree. The fifth type (D5) is a degree from a university of applied sciences, and the sixth type (D6) is a university degree. Note that the types increase with the implied level of education except for D2 and D3 which cannot be ranked. For D5 and D6, an upper secondary education degree is not recorded but implied, since it is a requirement for higher education. As only the highest level of qualification is recorded, no information on vocational education is available for individuals with D5 or D6.

Table 1: Six qualification types of German human capital

	Primary/ Lower/ Intermediate Secondary Education	Upper Secondary Education	Completed Vocational Training	Higher education	Duration in years (Tarazona, 2010)
D1	✓				9
D2	✓		✓		12
D3	✓	✓			13
D4	✓	✓	✓		15
D5	✓	or equivalent*	-	University of Applied Sciences	17
D6	✓	or equivalent*	-	University	19

*The SIAB7510 dataset does not record secondary school attainment or vocational training for individuals with higher education. Upper secondary or an equivalent degree (*Fachabitur*) is a prerequisite for higher education

These six qualification types allow more detailed insight into the composition of human capital than a dichotomy of high- and low-skilled based on tertiary education. However, the information is clearly still relatively broad since no information about the precise type of degree within the categories is available: thus, the six education types should be understood as exemplary and relative categories rather than expressions of skill content.

To represent the composition of human capital, the share D(i) of employees with each of the six degree types (i=1,…6) is calculated per region and year. To investigate the relationship between population age structure and human capital composition two different approaches are implemented. First, we consider the availability of aggregate human capital as measured by the average years of schooling per region. The indicator (HC) uses the average years spent in education by degree type (i.e. D1 to D6) and weighs them by the share of employees with this degree in the region.

$$HC_r = \sum_{i=1}^{6} years\ of\ education\ in\ degree * D(i)_r \quad (1)$$

The average duration of degrees correspond to those used in Tarazona (2010) (see Table 1, last column). While roughly in line with the formalised schooling requirements, these durations are not particularly accurate and do not account for changes in the institutional frameworks. However, as the indicator is used here to compare regional differences in human capital using the same benchmarks, the confounding effects of the choice of education duration are likely negligible.

The age of the labour force is measured via its mean age as extracted from the SIAB7510. Measures such as the share of population above 65 years, which is often used to capture ageing, are not necessarily informative of the age structure of the labour force, which is why mean age is the preferred proxy for this analysis.

The relationship between human capital and age structure is modelled using a fixed effect panel model for the 332 regions and time period 1996 to 2010.

$$\ln(HC)_{rt} = \beta_0 + \beta_1 mean\ age_{rt} + \beta_3\ controls_{rt} + \theta_r + \mu_t + \varepsilon_{rt} \quad (2)$$

Following Tarazona (2010), we use the logarithm of the human capital indicator as dependent variable. The main variable of interest, mean age, enters as a level for ease of interpretation. Standard errors are clustered at the region-level and both region and time fixed effects are included to control for unobserved heterogeneity. While time-invariant factors are subsumed into the fixed effect, we control for other regional characteristics: GDP per capita, unemployment rates, the share of services (in value added), the share of female employees, and net migration (normalised by population).

Equation (2) allows testing whether the amount of accumulated human capital differs with regions' age structures, but neglects two relevant aspects discussed in the literature. First, the average years of education are an aggregate measure, which obscures the source of changes within the human capital endowment. Thus, we extend the analysis to consider the composition of human capital across the six different educational degrees:

$$D(i)_{rt} = \beta_0 + \beta_1 mean\ age_{rt} + \beta_3\ controls_{rt} + \theta_r + \mu_t + \varepsilon_{rt} \quad (3)$$

Equation (3) uses the relative share of each of the six educational degrees as dependent variable. While this approach avoids the generalization of an aggregate index such as in (2), it also implies that

regressions for (3) need to be run for each D(i) separately. Although each regression is separately valid, it should be noted that the coefficients across the six regressions add up to zero: when using relative shares as dependent variable, an increase in one share naturally implies a corresponding decrease in another.

The two models described in (2) and (3) allow investigating if the age of the regional labour force is correlated with different availability and composition of human capital. However, these models cannot distinguish whether regional differences are only due to the age composition or whether sorting mechanisms are also at work. To address this issue, we consider the model proposed in (3) but only for the age group 30-39, i.e. using the share of employees with a specific degree among those aged 30-39 ($d(i)_{30\text{-}39}$).

$$D(\mathrm{i})_{30-39_{rt}} = \beta_0 + \beta_1 mean\ age_{rt} + \beta_3\ controls_{rt} + \theta_r + \mu_t + \varepsilon_{rt} \qquad (4)$$

(4) allows comparing whether the human capital composition of the same age group varies with the regional age structure. Since (4) controls for age composition, the remaining effect of mean age on human capital is thus attributable to other factors such as regional differences in educational choice or migration.

4. RESULTS

4.1 Descriptive Analysis

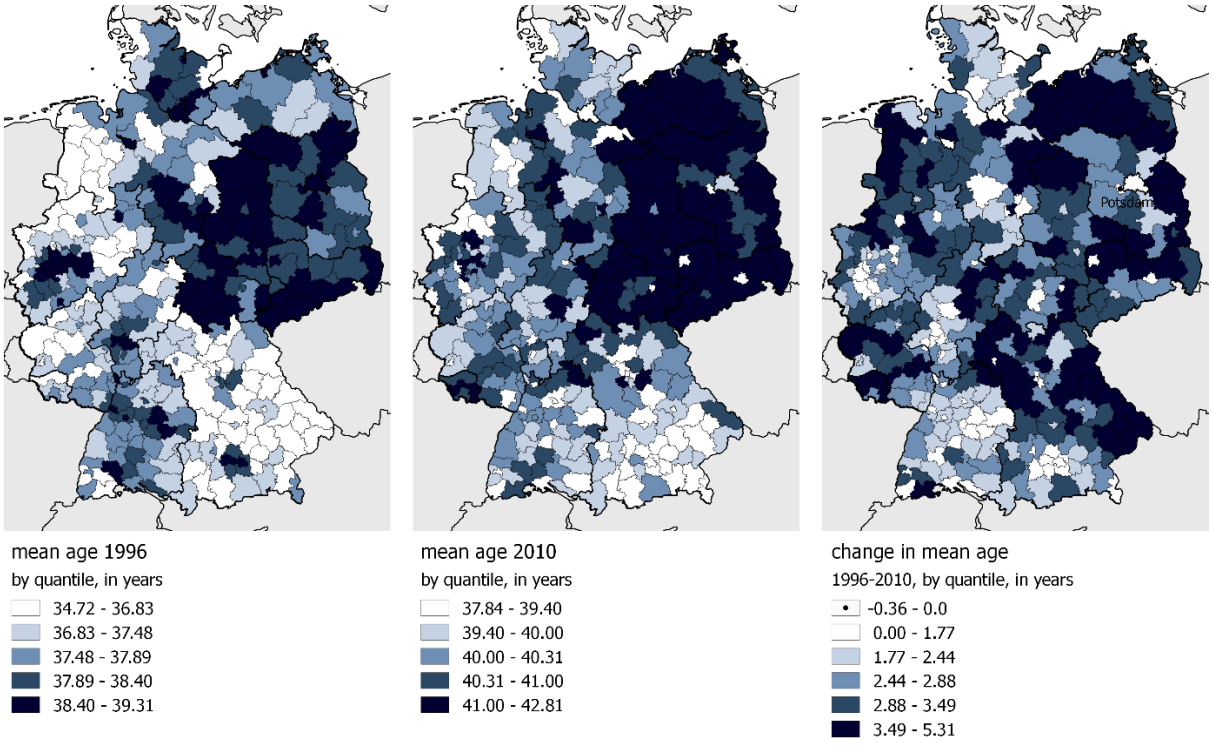
Table 2 reports summary statistics for relevant variables. The dominant trend of population ageing is clearly visible in the German labour force (Figure 2). The national mean age of the labour force sample increased by almost 3 years between 1996 and 2010 and in all regions but one: only the city of Potsdam, capital of the Federal State Brandenburg and adjacent to Berlin, recorded a lower average age in 2010 (39.0) than 1996 (39.3). Although ageing is a national trend, the spatial distribution of the age structure clearly shows a concentration of relatively old regions in the East of Germany, especially in 2010 (mid-panel of Figure 2). Nevertheless, there are also smaller clusters of old regions in the West, especially in Saarland and the Ruhr area, both affected by deindustrialisation. Moreover, the degree of population

ageing (Figure 2, right) is considerably less concentrated: strongly ageing regions are located throughout Germany and more in the west and south-east than in the former GDR.

Table 2: Summary statistics

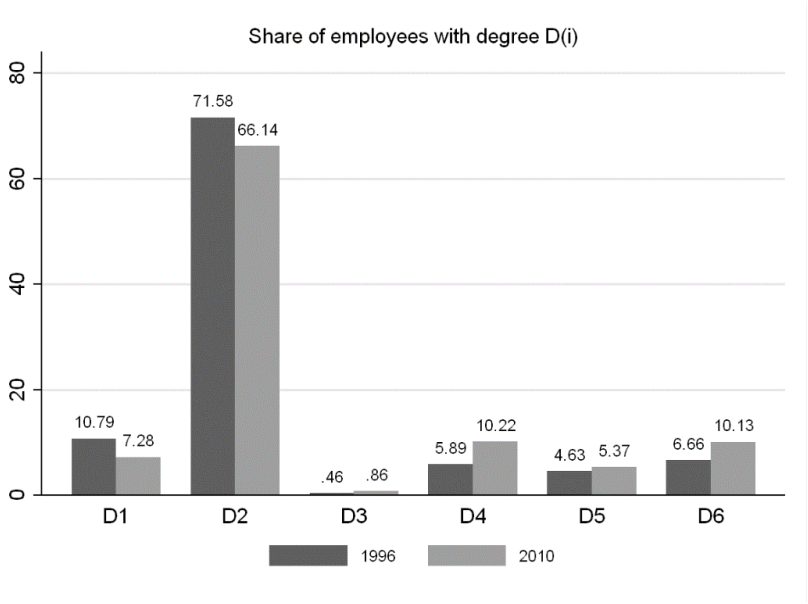
variable	obs	mean	std. dev	min	max
mean age	4968	38.771	1.205	34.638	42.837
Δ mean age$_{1996\text{-}2010}$	4968	2.887	0.988	-0.211	5.387
HC	4968	12.627	0.443	11.567	14.604
Δ HC$_{1996\text{-}2010}$	4968	0.481	0.210	-0.179	1.004
D1	4968	9.122	4.377	0.348	23.992
Δ D1$_{1996\text{-}2010}$	4968	-4.271	2.485	-12.092	1.552
D2	4968	72.358	6.924	43.393	88.013
Δ D2$_{1996\text{-}2010}$	4968	-3.425	4.143	-14.669	7.991
D3	4968	0.459	0.409	0.000	2.890
Δ D3$_{1996\text{-}2010}$	4968	0.264	0.359	-1.149	1.927
D4	4968	7.052	2.572	1.751	17.607
Δ D4$_{1996\text{-}2010}$	4968	3.853	1.641	-1.009	8.538
D5	4968	4.320	1.675	0.629	13.064
Δ D5$_{1996\text{-}2010}$	4968	0.786	1.050	-2.880	4.640
D6	4968	6.688	3.726	0.719	24.647
Δ D6$_{1996\text{-}2010}$	4968	2.794	1.938	-2.880	9.679
GDP p.c.	4968	24.725	9.814	10.752	83.520
unemployment	4968	10.494	4.776	1.900	27.700
service	4968	65.996	10.017	27.981	94.632
female	4968	47.418	4.875	26.511	59.469
net migration	4968	0.129	0.578	-3.598	4.288
urban	4968	0.564	0.496	0.000	1.000
east	4968	0.191	0.393	0.000	1.000

Figure 2: Mean age of the employed labour force: 1996, 2010, and change 1996-2010



The comparably large role of vocational training is visible in Figure 3. Although D2 is decreasing over time, it remains the single most common degree in the national average. Moreover, Figure 3 clearly illustrates the national trend of education expansion: the shares of D1 and D2 fell between 1996 and 2010, whereas the other shares rose. In particular, D4 (upper secondary and vocational training) and D6 (university degree) increased markedly. It should be noted that the reported share of D6 in the employed labour force is much lower than estimates of the entire population with tertiary education in Germany. This is partially caused by the fact that the used data source is employees covered in the social security database, which excludes current (unemployed) students as well as the self-employed and public servants.

Figure 3: Human capital composition in 1996 and 2010



4.2 Regressions

Table 3 presents the results of fitting the regressions (2), (3) and (4). The first column uses the average years of schooling as dependent variable, i.e. an aggregate measure of human capital. The coefficient on mean age is negative and highly significant. On average, an increase in mean age by one year is associated with a decrease of 0.4% in the average years of schooling. If we understand the average years of schooling as a measure of the aggregate human capital level, this suggests that regions with an older age structure may indeed have lower levels of human capital, ceteris paribus.

Table 3: Baseline regression results

VARIABLES	(1) lnHC	(2) D1	(3) D2	(4) D3	(5) D4	(6) D5	(7) D6	(8) $D1_{30-39}$	(9) $D2_{30-39}$	(10) $D3_{30-39}$	(11) $D4_{30-39}$	(12) $D5_{30-39}$	(13) $D6_{30-39}$
mean age	-0.004***	-0.001	1.066***	-0.075***	-0.390***	-0.123***	-0.478***	-0.055	1.482***	-0.143***	-0.357***	-0.207***	-0.721***
	(0.001)	(0.103)	(0.155)	(0.014)	(0.066)	(0.043)	(0.069)	(0.123)	(0.228)	(0.038)	(0.127)	(0.076)	(0.108)
ln GDP p.c.	-0.010*	0.476	2.586**	-0.193	-2.103***	-0.257	-0.510	-0.572	2.538	-0.254	-0.650	-1.233*	0.171
	(0.005)	(0.771)	(1.223)	(0.126)	(0.596)	(0.334)	(0.682)	(0.971)	(1.744)	(0.328)	(1.169)	(0.676)	(0.966)
unemployment	0.001***	-0.091***	-0.142***	0.004	0.076***	0.053***	0.100***	-0.109***	0.070	0.022**	-0.060	0.017	0.060
	(0.000)	(0.024)	(0.038)	(0.004)	(0.018)	(0.011)	(0.022)	(0.036)	(0.056)	(0.011)	(0.038)	(0.023)	(0.037)
net migration	0.001**	0.193**	-0.675***	0.021**	0.187***	-0.058	0.331***	0.048	-0.870***	0.093***	0.427***	-0.082	0.385***
	(0.001)	(0.087)	(0.096)	(0.009)	(0.055)	(0.047)	(0.074)	(0.093)	(0.160)	(0.027)	(0.114)	(0.068)	(0.108)
services	-0.000	0.001	0.016	-0.002	-0.001	-0.009	-0.004	-0.026	0.022	-0.002	0.036	-0.020	-0.011
	(0.000)	(0.016)	(0.022)	(0.003)	(0.012)	(0.008)	(0.012)	(0.021)	(0.036)	(0.007)	(0.024)	(0.015)	(0.020)
female	0.000**	-0.045**	-0.001	0.002	0.036***	0.004	0.004	-0.040	0.022	-0.003	0.005	0.022	-0.005
	(0.000)	(0.023)	(0.028)	(0.003)	(0.013)	(0.012)	(0.014)	(0.026)	(0.046)	(0.007)	(0.031)	(0.016)	(0.026)
Constant	2.664***	12.802***	27.012***	3.748***	23.685***	9.270***	23.482***	17.423***	7.696	6.621***	19.927***	15.797***	32.536***
	(0.027)	(4.767)	(7.569)	(0.687)	(3.321)	(2.051)	(3.511)	(5.454)	(10.697)	(1.827)	(6.417)	(3.919)	(5.558)
Observations	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968
R-squared	0.819	0.673	0.426	0.218	0.793	0.263	0.619	0.170	0.576	0.267	0.607	0.090	0.378
no. of regions	332	332	332	332	332	332	332	332	332	332	332	332	332
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

To see how this aggregate result translates into the relative prevalence of different educational degrees, the next six columns of Table 3 decompose this effect into each of the different education shares. Mean age is insignificant for D1 and significantly positive for D2. In contrast, it is negatively significant for the other four educational degrees. Thus, labour force ageing seems to be negatively associated with the prevalence of degrees that are usually considered "high-skilled", especially tertiary education (D5 and D6). Instead, regions with older age structures on average have higher shares of D2, i.e. lower or intermediate secondary degrees and vocational training. An increase in mean age by one year is on average associated with a 1.07 percentage point increase in employees with such traditional vocational degrees (D2) and a 0.48 percentage point decrease in the share of employees with a university degree (D6).

The recent trend of education expansion implies that younger individuals on average have higher educational attainment. Thus, the results of columns 2 to 7 are partially explained by differences in the composition of the labour force alone. To condition out this effect, columns 8-13 show the results of estimating the same model but restricting the sample to individuals aged 30-39: indeed, signs and significances are the same as for the whole sample. Thus, the results suggest not only that regions with an older labour force have relatively lower shares of higher education and larger shares of traditional vocational degrees, but that individuals aged 30-39 are relatively more likely to have tertiary education in regions with younger labour forces, indicating that there might be sorting of individuals or different incentives influencing educational choice.

For the regional characteristics included as controls, unemployment and net migration emerge as interesting covariates. Unemployment is significantly positive for the average years of schooling indicator (HC), and for D4, D5 and D6, although this significance disappears when restricting the age groups of the sample. Regions with higher unemployment rates thus exhibit higher levels of human capital both in terms of the aggregate HC indicator and with respect to the share of employees having completed higher education degrees. While at first glance counterintuitive, it should be noted that the human capital data used in the analysis refers only to employed individuals. The finding is thus in line with the notion that higher-skilled individuals may be less threatened by unemployment.

Net-migration is significantly positive for HC, D1, D3, D4 and D6. Thus, regions experiencing strong in-migration (relative to outmigration and to total population) on average seem to have higher availability of human capital (as measured by average years of schooling) and also higher shares of D1, D3, D4 and university degrees (D6). In contrast, the coefficient is significantly negative for D2. Due to data availability, it cannot be established whether this is due to the migrants' characteristics, sorting of migrants across regions or other factors.

Table 4 shows the results of the regressions including dummies for urban regions and for regions in the East of Germany (excluding Berlin) as interaction terms of mean age. The interaction between the urban dummy and mean age is consistently of opposite sign than the mean age coefficient, indicating that human capital and its composition are less sensitive to changes in mean age in urban than in rural regions. For example, column 3 shows that the associated increase in employees with degree D2 is 0.77 percentage points smaller in urban than in rural regions. Similarly, the associated decrease in the share of employees with university degrees (column 7) is 0.29 points smaller in urban than in rural regions.

The interaction term of mean age and the East dummy is significantly negative in column 1, indicating that ageing is associated with larger decreases in aggregate human capital in East Germany than in the West. In contrast to the baseline results, introducing the interaction term for East German regions yields significantly negative coefficients on mean age for D1, i.e. the degree type with the shortest duration of education, and significantly positive interaction terms: older labour forces on average seem to have a smaller share of D1 in West Germany but a larger share in East German regions. Moreover, the interaction terms for D5 and D6 are significantly negative, indicating that the same increase in mean age is on average associated with a larger fall in employees with higher education in the Eastern than in the Western regions. It should be emphasized that the strong emphasis on higher education in the education system of the GDR implied that regions in the East of Germany have traditionally exhibited relatively high shares of tertiary education. Indeed, Brunow and Hirte (2009b) identify the levels of higher education in East Germany as overeducation, due to many highly-educated East Germans permanently working in lower-skilled jobs. However, results such as those presented here, but also in Tarazona (2010), show that East Germany seems to experience less education expansion than West Germany.

Table 4:Regression results urban versus rural and East versus West

VARIABLES	(1) lnHC	(2) D1	(3) D2	(4) D3	(5) D4	(6) D5	(7) D6	(8) $D1_{30-39}$	(9) $D2_{30-39}$	(10) $D3_{30-39}$	(11) $D4_{30-39}$	(12) $D5_{30-39}$	(13) $D6_{30-39}$
mean age	-0.004***	-0.013	1.254***	-0.082***	-0.477***	-0.133***	-0.549***	-0.058	1.646***	-0.163***	-0.435***	-0.186**	-0.805***
	(0.001)	(0.108)	(0.154)	(0.014)	(0.066)	(0.045)	(0.070)	(0.124)	(0.231)	(0.037)	(0.129)	(0.078)	(0.110)
urban* age	0.002***	0.049	-0.770***	0.028**	0.357***	0.042	0.294***	0.016	-0.675***	0.082***	0.319***	-0.086	0.344***
	(0.000)	(0.089)	(0.111)	(0.012)	(0.048)	(0.033)	(0.049)	(0.111)	(0.181)	(0.031)	(0.106)	(0.065)	(0.092)
ln GDP p.c.	-0.007	0.522	1.854	-0.166	-1.764***	-0.217	-0.230	-0.556	1.896	-0.175	-0.347	-1.315*	0.498
	(0.005)	(0.768)	(1.145)	(0.123)	(0.562)	(0.331)	(0.662)	(0.981)	(1.706)	(0.324)	(1.168)	(0.671)	(0.960)
unemployment	0.001***	-0.096***	-0.064*	0.002	0.039**	0.049***	0.070***	-0.110***	0.139**	0.014	-0.093**	0.026	0.025
	(0.000)	(0.026)	(0.036)	(0.004)	(0.018)	(0.012)	(0.022)	(0.036)	(0.057)	(0.011)	(0.038)	(0.024)	(0.037)
net migration	0.001	0.184**	-0.541***	0.016*	0.125**	-0.065	0.280***	0.045	-0.753***	0.078***	0.372***	-0.067	0.325***
	(0.001)	(0.088)	(0.095)	(0.009)	(0.052)	(0.046)	(0.071)	(0.092)	(0.162)	(0.027)	(0.114)	(0.069)	(0.106)
services	-0.000	0.002	-0.003	-0.002	0.008	-0.008	0.003	-0.025	0.005	0.000	0.045*	-0.022	-0.002
	(0.000)	(0.016)	(0.021)	(0.003)	(0.011)	(0.008)	(0.012)	(0.021)	(0.036)	(0.007)	(0.024)	(0.015)	(0.020)
female	0.000	-0.046**	0.026	0.001	0.023*	0.002	-0.007	-0.041	0.045	-0.006	-0.006	0.025	-0.017
	(0.000)	(0.023)	(0.028)	(0.003)	(0.013)	(0.012)	(0.014)	(0.027)	(0.048)	(0.007)	(0.031)	(0.016)	(0.026)
Constant	2.639***	12.121**	37.742***	3.352***	18.717***	8.688***	19.380***	17.201***	17.106	5.477***	15.477**	16.996***	27.743***
	(0.027)	(4.700)	(7.196)	(0.705)	(3.172)	(2.012)	(3.538)	(5.758)	(10.448)	(1.882)	(6.427)	(3.919)	(5.732)
R-squared	0.827	0.674	0.465	0.223	0.807	0.264	0.634	0.170	0.584	0.273	0.611	0.091	0.388

	(1) lnHC	(2) D1	(3) D2	(4) D3	(5) D4	(6) D5	(7) D6	(8) $D1_{30-39}$	(9) $D2_{30-39}$	(10) $D3_{30-39}$	(11) $D4_{30-39}$	(12) $D5_{30-39}$	(13) $D6_{30-39}$
mean age	-0.002***	-0.329***	1.103***	-0.071***	-0.318***	-0.053	-0.333***	-0.310**	1.657***	-0.139***	-0.524***	-0.127	-0.557***
	(0.000)	(0.106)	(0.163)	(0.015)	(0.068)	(0.042)	(0.067)	(0.133)	(0.242)	(0.041)	(0.136)	(0.078)	(0.110)
east*age	-0.008***	1.207***	-0.136	-0.017	-0.264***	-0.257***	-0.533***	0.940***	-0.646***	-0.013	0.616***	-0.295***	-0.602***
	(0.001)	(0.069)	(0.127)	(0.011)	(0.056)	(0.052)	(0.071)	(0.097)	(0.209)	(0.031)	(0.122)	(0.089)	(0.121)
ln GDP p.c.	0.001	-1.183	2.774**	-0.170	-1.740***	0.097	0.223	-1.864*	3.426*	-0.235	-1.497	-0.828	0.998
	(0.004)	(0.757)	(1.278)	(0.127)	(0.587)	(0.331)	(0.633)	(0.975)	(1.813)	(0.337)	(1.187)	(0.659)	(0.934)
unemployment	0.000*	0.041*	-0.157***	0.003	0.047**	0.025**	0.042**	-0.006	-0.000	0.021*	0.007	-0.016	-0.006
	(0.000)	(0.022)	(0.039)	(0.004)	(0.019)	(0.011)	(0.021)	(0.035)	(0.058)	(0.011)	(0.037)	(0.024)	(0.037)
net migration	0.001*	0.271***	-0.683***	0.020**	0.170***	-0.075*	0.297***	0.109	-0.913***	0.092***	0.467***	-0.101	0.345***
	(0.000)	(0.062)	(0.098)	(0.009)	(0.050)	(0.043)	(0.062)	(0.081)	(0.163)	(0.027)	(0.108)	(0.065)	(0.098)
services	0.000*	-0.034**	0.020	-0.002	0.007	-0.002	0.011	-0.053**	0.041	-0.002	0.019	-0.012	0.006
	(0.000)	(0.015)	(0.023)	(0.003)	(0.012)	(0.008)	(0.011)	(0.020)	(0.037)	(0.007)	(0.024)	(0.015)	(0.020)
female	-0.000***	0.072***	-0.014	0.001	0.010	-0.021*	-0.048***	0.051*	-0.041	-0.005	0.064**	-0.006	-0.063**
	(0.000)	(0.023)	(0.030)	(0.003)	(0.014)	(0.011)	(0.013)	(0.029)	(0.050)	(0.008)	(0.031)	(0.018)	(0.026)
Constant	2.637***	17.062***	26.530***	3.689***	22.754***	8.362***	21.602***	20.742***	5.415	6.574***	22.101***	14.756***	30.412***
	(0.023)	(4.266)	(7.670)	(0.695)	(3.307)	(2.043)	(3.292)	(5.170)	(10.730)	(1.859)	(6.402)	(3.898)	(5.408)
R-squared	0.863	0.740	0.427	0.219	0.797	0.293	0.648	0.222	0.580	0.267	0.617	0.101	0.396
Observations	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968
No. of regions	332	332	332	332	332	332	332	332	332	332	332	332	332

Including Year Fixed Effects; robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1,

5. DISCUSSION AND EXTENSIONS

Our regressions indicate that labour force ageing goes hand in hand with changes in human capital. Regions with older labour forces show lower aggregate human capital when measured by average years of schooling. Additionally, older labour forces have relatively higher shares of "traditional" vocational degrees (D2), and lower shares of tertiary education degrees (D5, D6). Limiting the sample to only employees aged 30-39 showed that changes in human capital are not completely explained by the age composition but that other factors, e.g. sorting of individuals or regional differences in educational choice are at work.

How large is the role of demographic change relative to these other factors that influence the human capital composition? While we cannot pinpoint the exact source of changes in human capital, it is possible to roughly estimate the amount of change that is attributable only to variation in the age composition of the labour force. Using a shift-share approach (e.g. Loveridge & Selting, 1998), we project a hypothetical human capital composition for 2010 solely based on demographic shifts and compare these projected changes to the actual ones. We calculate the relative shares of each degree type by age group in 1996 and 2010, using three age groups: 30-39, 40-49 and above 50. We then assume that the relative shares of degrees per age group are constant over time, i.e. if 6.7% of the age group 30-39 recorded a university degree in 1996 we assume that the same share of 30-39 year-olds will hold a university degree in 2010. However, due to demographic change, the sizes of the age groups change between 1996 and 2010. Applying the education shares from 1996 to the age group sizes in 2010 thus yields a predicted human capital composition that is only based on demographic shifts.

Table 5 shows the result of this calculation for the national average human capital composition. The demographic shifts alone would have increased the shares for D1 and D2 while decreasing the other shares relative to the 1996 values. Moreover, the national average years of schooling would have decreased from 12.56 in 1996 to 12.51 in 2010. Comparing the projected to the actual shares of the degrees in 2010 shows that demographic change alone suggests opposite trends to those actually recorded. However, relative to the actually realised shifts in the human capital composition, the changes predicted by shifts in the age structure are small. Thus, other factors, i.e. the systematic increase in

educational attainment among graduate cohorts in the last 20 years, have so far been sufficient to offset any demographic effect on human capital, at least for the German national average.

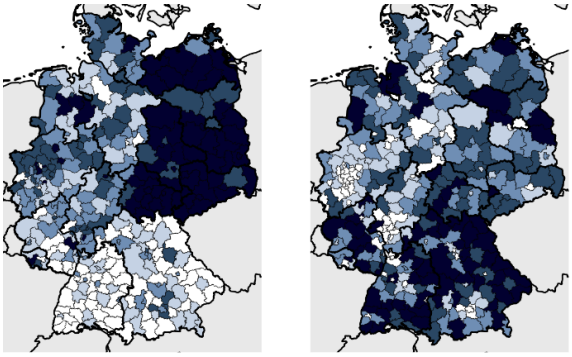
Table 5: National average shift-share decomposition

Share of degree type	D1	D2	D3	D4	D5	D6	HC
observed 1996	10.8	71.6	0.5	5.9	4.6	6.7	12.56
observed 2010	7.3	66.1	0.9	10.2	5.4	10.1	13.07
actual change 1996-2010	-3.5	-5.5	0.4	4.3	0.8	3.4	0.51
projected 2010	11.3	71.9	0.4	5.4	4.6	6.4	12.51
contribution demographic change	+0.5	+0.3	-0.1	-0.5	0.0	-0.3	-0.05
residual change	-4.0	-5.8	+0.5	+4.8	+0.8	+3.7	+0.61

However, considering only the average changes disguises a large degree of regional heterogeneity. The fact that urban and rural and East and West German regions seem to differ significantly in the relation between age structure and human capital was already established based on the significant interaction terms in Table 4. It is worthwhile to take a closer look at how regions' human capital composition has been changing over time in an explorative descriptive analysis. The maps in Figure 4 present the change in each of the six degree types for the whole time period, i.e. 1996-2010. Geographical patterns in the changes in human capital are clearly discernible, with especially the East of Germany showing distinct trends.

While each of these six maps can be interpreted individually, Figure 4 also shows the results of a simple k-means cluster analysis based on the changes in the six degree types. Such cluster typologies can be criticised on grounds of being rather arbitrary statistical constructs; however, the four emerging groups allow identifying interesting common trends and facilitate the parallel analysis of changes in the six degree types. In particular, comparing the maps and the summary statistics by cluster in Table 6, helps tracing four different types of regional human capital trajectories.

Figure 4: Maps of changes in degree shares (1996-2010) by quantile and cluster map

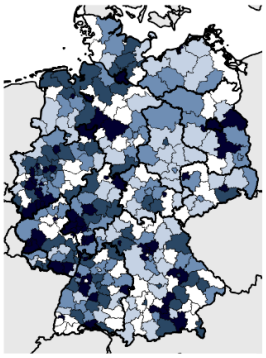


change share d1 1996-2010

-12.1 - -6.6
-6.6 - -4.6
-4.6 - -3.4
-3.4 - -2.0
-2.0 - 1.6

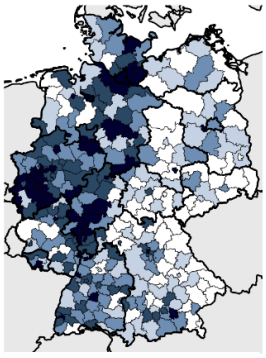
change share d2 1996-2010

-14.7 - -6.7
-6.7 - -3.9
-3.9 - -2.2
-2.2 - 0.0
0.0 - 8.0



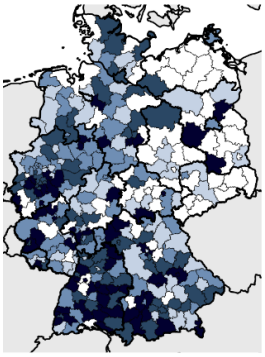
change share d3 1996-2010

-1.1 - 0.0
0.0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1.9



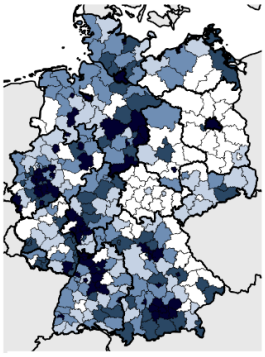
change share d4 1996-2010

-1.01 - 2.38
2.38 - 3.42
3.42 - 4.31
4.31 - 5.35
5.35 - 8.54



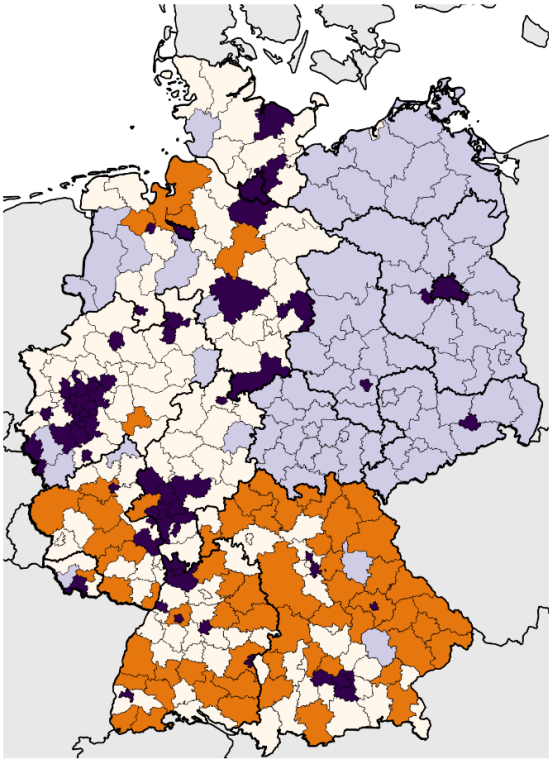
change share d5 1996-2010

-2.88 - 0.00
0.00 - 0.55
0.55 - 1.03
1.03 - 1.50
1.50 - 4.64



change share d6 1996-2010

-2.88 - 1.41
1.41 - 2.22
2.22 - 3.00
3.00 - 4.05
4.05 - 9.68



Clusters based on change in d(i) 1996-2010

cluster 1
cluster 2
cluster 3
cluster 4

Table 6: Summary statistics by Cluster

cluster		Δ D1	Δ D2	Δ D3	Δ D4	Δ D5	Δ D6	Δ mean age	urban	east	count
1	mean	-3.018	-9.520	0.586	5.686	1.085	5.181	2.041	0.985	0.044	68
	sd	1.511	2.315	0.389	1.233	0.846	1.719	1.005	0.121	0.207	
	min	-7.682	-14.669	-0.255	2.750	-1.884	1.829	-0.211	0	0	
	max	1.552	-6.678	1.571	8.538	3.357	9.679	4.579	1	1	
2	mean	-1.758	-1.854	0.109	2.494	0.039	0.970	3.384	0.200	0.800	75
	sd	1.079	1.707	0.209	0.844	1.089	1.489	0.808	0.403	0.403	
	min	-4.742	-5.651	-0.380	0.595	-2.880	-2.880	0.938	0	0	
	max	1.089	2.534	0.735	4.806	4.004	3.970	5.350	1	1	
3	mean	-7.567	1.916	0.084	2.656	0.835	2.077	3.222	0.333	0	63
	sd	1.670	2.000	0.297	1.234	0.858	1.146	0.903	0.475	0	
	min	-12.092	-0.670	-1.149	-0.201	-1.908	-0.150	1.113	0	0	
	max	-4.376	7.991	0.680	5.037	2.720	6.565	5.387	1	0	
4	mean	-4.779	-3.732	0.270	4.263	1.038	2.940	2.883	0.667	0.008	126
	sd	1.649	1.659	0.322	1.153	1.015	1.026	0.815	0.473	0.089	
	min	-10.183	-6.554	-0.349	-1.009	-1.485	1.027	0.698	0	0	
	max	-0.866	-0.889	1.927	6.626	4.640	5.845	4.928	1	1	
Total	mean	-4.265	-3.422	0.263	3.850	0.783	2.790	2.888	0.563	0.193	332
	sd	2.488	4.145	0.359	1.643	1.052	1.941	0.989	0.497	0.395	
	min	-12.092	-14.669	-1.149	-1.009	-2.880	-2.880	-0.211	0	0	
	max	1.552	7.991	1.927	8.538	4.640	9.679	5.387	1	1	

Cluster 1 refers predominantly to urban regions, especially in the West of Germany but also including Berlin, Potsdam, Halle and Dresden in the East. These regions on average experienced the smallest increases in mean age between 1996 and 2010. The share of "traditional" vocational training degrees (D2) fell substantially (9.5 percentage points), while D4, D5 and D6 especially increased. Cluster 1 thus refers to highly agglomerated urban regions with a comparatively low degree of population ageing that shift away from traditional vocational degrees in favour of higher education. Arguably, increases in human capital in terms of a high-skilled/low-skilled dichotomy as common in the literature, describe this type of upskilling.

Cluster 2 comprises most East German regions and some in the West, e.g. in Lower Saxony; 80% of the regions in cluster 2 are classified as rural. This cluster experienced strong labour force ageing, with mean age increasing by 3.38 years between 1996 and 2010, and relatively small changes to human capital composition. More specifically, this cluster recorded the smallest decrease in D1 and the smallest increases in higher education (D5 and D6). The degree expanding the most for cluster 2 is D4 (upper secondary degree and vocational training), although even this average increase of 2.4 percentage points

is below the national average. Across the four clusters, cluster 2 is characterised by the lowest amount of education expansion and some of these regions may have experienced a down-skilling of the available labour force. Indeed, 17 regions in this cluster recorded decreasing shares of university graduates between 1996 and 2010 in contrast to the national trend. As pointed out before, the starting level of human capital in East Germany was relatively high, which may explain the relatively small changes. However, considering the potential of human capital in dealing with demographic challenges, continuous investment should be occurring even in regions with relatively high starting values. Indeed, Anger and Plünnecke (2010) argue that East Germany may struggle to cover the demand for future university graduates caused by academics retiring as well as keeping up with expanding demand due to structural changes of the labour market. The changes in the human capital composition illustrated in Figure 4 are in line with this concern.

All regions in cluster 3 are located in West Germany. Two-thirds of this cluster are rural regions and the cluster is geographically concentrated especially in South Germany. These regions experienced similarly strong ageing as cluster 2 with mean age increasing by 3.22 years between 1996 and 2010. However, in contrast to cluster 2, cluster 3 shows a pronounced fall in the share of employees with only secondary education D1 (7.5 percentage points). In contrast to the national trend, cluster 3 records increasing shares of D2 (lower/intermediate secondary degree and vocational training), on average by 1.92 percentage points. Whereas all other clusters on average see this degree decline, regions in cluster 3 expand in the dimension of vocational training; it shows also some expansion in higher education, as the share of university degrees increases by 2.1 percentage points. However, considering only higher education as an indicator of human capital investment would likely categorize regions in this cluster as lagging, whereas the shift away from D1 and towards D2 and higher degrees clearly indicates some upskilling of the human capital composition. Although ageing to a similar degree, human capital in the regions of cluster 3 seems to expand more consistently than in cluster 2.

The final cluster 4 refers almost entirely to West German regions and two-thirds of these are strongly industrialised urban regions. Although cluster 4 experiences some ageing, it is on average less severe than for clusters 2 and 3. The changes to the human capital composition of this cluster are close to the

national average, which is also caused by the fact that this cluster is the largest in size, thus serving as a benchmark for the trends of human capital development in the other three clusters.

Clearly, the cluster analysis presented here is descriptive and qualitative, but it complements the regression results presented in the previous section. A closer look at how regional human capital compositions have changed over time shows that human capital investment takes on different forms. Young, urban regions experience a strong expansion in tertiary degrees, most likely because they attract highly-skilled (and young) labour but perhaps also because they incentivise investments in higher education. In contrast, in more rural regions with older age structures, especially in the South of Germany, vocational training maintains its important role in shaping the human capital composition (Filippetti, Guy, & Iammarino, 2018). These different pathways to human capital investment are of course closely related to regional industry structures and the demands of local employers.

These broad changes also illustrate that some regions do not seem to experience an education expansion in any direction. Especially regions of the former GDR, traditionally shaped by high shares of university graduates, seem to stagnate or even experience a down-skilling of the labour force. Whether this is simply a consequence of post-reunification transition, a by-product of economic convergence, or a symptom of population ageing, remains open to debate.

6. CONCLUSION

The aim of this paper was to investigate the interrelation between demographic ageing and regional human capital composition. Analysing a panel dataset of 332 German district-regions for 1996 to 2010 yields three main conclusions. First, the regression analyses illustrate a systematic relationship between labour force age and the prevalence of specific educational degrees. Average years of education, an aggregate measure of human capital, decreases with mean age of the employed labour force. Additionally, regions with older labour forces are on average shaped more by vocational degrees and less by higher education. This finding holds even when comparing the prevalence of degrees within the same age group (30-39 years).

Second, quantifying the contribution of population ageing to changes in the skill composition shows that, as expected theoretically, ageing hinders education expansion. However, between 1996 and 2010 the pronounced expansion in educational attainment in Germany was more than sufficient to compensate for the negative effects of demographic shifts. From a perspective of advocating human capital investment to cope with ageing and shrinking working-age populations, this result is encouraging. However, it also illustrates that policy aimed at increasing human capital needs to expand educational attainment continuously in order to compensate for the effects of population ageing.

Third, taking a closer look at the geographical patterns of changes in the human capital composition highlights a substantial degree of regional heterogeneity. While young, urban regions are expanding tertiary education, some ageing regions see increases in vocational training degrees. Moreover, other strongly ageing regions, especially in East Germany, seem to stagnate rather than expand human capital.

The starting point of this paper was the realisation that human capital investment is widely suggested as the prime policy measure to address future challenges of population ageing, and more generally to stimulate regional economic growth. Our results suggest that achieving increased regional human capital depends on the local age structure. This is important from a policy perspective because sorting of individuals by skill level may undermine efforts to increase regional human capital. Moreover, the degree of population ageing may itself hinder the effectiveness of investment in human capital, with strongly ageing regions requiring larger changes in educational attainment in order to compensate for the negative effect of the age structure.

Recent research on Europe has shown that the interaction of economy-wide forces and regional structural characteristics generated a geography made up of countries, regions and city-regions that are at different structural positions in the wider economy's ladder of value creation, and form different development 'clubs', each with different challenges and opportunities (Iammarino et al., 2018). Such regional development clubs require diversified and flexible policy approaches, i.e. place-sensitive policies, to maximise economic development in each territory and generate opportunities to be reaped by the local populations. Our results align with the call for such a differentiated development policy

approach across a geography that shows (within-country) high heterogeneity in both levels and trajectories of the key variables behind economic growth.

Although investment in tertiary education – as well as in R&D– play an undoubtedly important role when trying to increase labour productivity in the face of a shrinking and ageing labour force, this may not necessarily imply that such policies will trigger growth everywhere, and may actually even impair it in some places. In the face of increasing economic challenges of demographic change (as especially in East German regions, in this study) and considerable outmigration of young and skilled people, the results of this paper suggest that investment in human capital may not be delivered as a part of national (or European) education expansion but requires more targeted efforts. Depending on the initial human capital composition, but also crucially on regional characteristics and degree of population ageing, benchmarks such as the Europe 2020 aim of 40% 30-34 year olds with higher education, may therefore not automatically translate into increases in human capital. Additionally, although human capital investment is often understood to mean increases in higher education, there may be other pathways to develop human capital able to support place-specific economic growth and development. In this sense, the example of regions in South Germany expanding in vocational degrees illustrates that regional labour markets may have different demands and conditions governing the type of human capital investment necessary. The relationship between demographic shifts and regional human capital certainly requires more in depth and comparative research to be done in the future.

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