Labour force ageing and the composition of regional human capital

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Abstract

Human capital investments are frequently suggested as a 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 324 German regions between 2000 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 development

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

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1. INTRODUCTION

Demographic change, characterised by simultaneous trends of population ageing and slow growth, holds significant challenges for European economies. Due to shrinking cohort sizes, the working-age population is decreasing relative to the population above retirement age and changing 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 rises may help compensate for a smaller and older labour force. For this reason, human capital investment takes on a central role in policy recommendations to cope with the labour market effects of demographic change (e.g. Crespo Cuaresma, Loichinger, & Vincelette, 2016; Kotschy & Sunde, 2018). 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 subnational level because labour markets are locally defined, and regions differ markedly in their demographic structures. Thus, if we consider increasing human capital a valid policy response to maintain productivity of ageing populations, we need to understand the regional processes of human capital development in a context of demographic change. Using the case of Germany, this paper investigates and quantifies the contribution of labour force ageing to the availability and composition of employed regional human capital.

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. Yet, on a regional level, the available supply of labour is influenced by education choices and labour force participation 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 interrelation between age structure and human capital has attracted attention mainly within the field of demography. This is reflected for instance in recent population projections that extend conventional estimations on the basis of age and gender structures by including educational attainment (Lutz, Butz & KC, 2014; European Union, 2018). Although the relevance of human capital as a driver of economic growth is well-documented in a range of influential studies (e.g. Mankiw, Romer, & Weil, 1992; Barro, 2001), few studies have so far addressed the relationship with population ageing, especially at a subnational level. The existing literature focuses either on the role of demography in individual-level educational attainment (e.g. Fertig, Schmidt, & Sinning, 2009) or on describing regional patterns of human capital development, degree of convergence and its consequences (e.g. Südekum, 2008; Brunow & Hirte, 2009a, 2009b; Gregory & Patuelli, 2015; Franklin, 2019).

This paper contributes to the literature by emphasising the process of population ageing as an explanatory factor in differential development of human capital availability and composition at the regional level. It presents an in-depth and multi-method analysis of the relationship between regional labour force ageing and changes in the amount and type of employed human capital for German districts between 2000 and 2010. Instead of relying on the widely used dichotomy of "low-skilled" versus "high-skilled" labour (usually defined as the share of population with tertiary education), we consider the composition of human capital along five distinct educational degrees. This allows a detailed regression-based analysis, testing whether age structure explains systematic shifts in aggregate human capital as well as the relative prevalence of specific kinds of degrees. Conceptualising human capital as comprising both academic and vocational education also uncovers a large amount of regional heterogeneity in human capital development, e.g. among rural and urban, and East and West German regions. Moreover, we quantify the relative contribution of workforce ageing to changes in human capital to examine whether and to what extent education expansion in Germany is hindered by demographic change.

While most industrialised countries face ageing populations and prospects of population decline (Reher, 2007), Germany is already experiencing pronounced ageing due to increasing life expectancy and very low fertility rates since the 1970s. According to the UN World Population Prospects (2019), Germany's median age of 45.9 years in 2015 make it the second oldest country in the world and therefore a valuable early example of potential future effects of global demographic changes on human capital availability and composition.

This paper proceeds as follows. The literature background is presented in the next Section 2. Section 3 describes the German educational context, whilst data and methods are reported in Section 4. Sections 5 presents the results of a descriptive, a regression-based and a cluster analyses, whilst Section 6 reports a conclusive discussion.

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; Qian, Acs, & Stough, 2013; Marrocu & Paci, 2015); the literature particularly emphasises the role of urban areas as knowledge centres shaped by, and continuously generating and attracting, highly-skilled individuals (Faggian & McCann, 2009; Storper & Scott, 2009; Brown, Newbold & Beckstead, 2010; Storper, 2013). Human capital externalities (Moretti, 2004) – may explain urban wage premia (Glaeser & Maré, 2001; Glaeser & Resseger, 2010), 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 from peripheral to core regions – can cause unbalanced redistribution of human capital across space, failing to act as income equalizing mechanisms as indicated in standard economic theory (Iammarino, Rodríguez-Pose, & Storper, 2019). 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 (see e.g. Storper, 2018; Kemeny & Storper, 2020). Although human capital therefore takes a central role in discussions on spatial disparities, the relevance of a context of demographic change is rarely acknowledged. Understanding the economic geography of the relationship between ageing and shrinking labour force and availability and composition of human capital appears still a challenge.

The demographic changes in the German labour force are driven by the ageing of the disproportionally large baby-boom cohorts (born between 1955 and 1969), the last generation before fertility rates dropped below replacement level. As a consequence, the population of working-age is estimated to fall by 5 million (ca. 10%) between 2013 and 2030 and by up to 23% until 2060 (Destatis, 2015). Even assuming increasing participation rates and considerable net migration, a shrinking and ageing German labour force seems unavoidable.

These demographic changes hold a variety of challenges for growth and productivity (e.g. Bloom et al., 2010; Lee, 2016). In particular, there are concerns that an older labour force may be inherently less productive due to inverse U-shaped relationships between age and innovation (e.g. Frosch, 2011), scientific output (Jones, Reedy, & Weinberg, 2014), and entrepreneurial activity (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 new technology (Prskawetz et al., 2007). Although advancements in current and future generations' technological skills may protect them from experiencing productivity losses at the same rate as past cohorts, increases in productivity are still needed in order to compensate for the potential negative impacts of an older and smaller working-age population.

Human capital accumulation represents a central component to countering these negative effects. We can distinguish quantitative and qualitative approaches to increasing the amount of employed human capital. Policy initiatives aimed at increasing the size of the active workforce – e.g. by raising participation rates of women or minorities, retirement ages or immigration flows (Brunow & Faggian, 2018) – intend to use *more* of the human capital embodied in a regions' population. In contrast, a qualitative increase in human capital implies changes in the *type* of human capital available. Human capital investment, as defined by Becker (1962), refers to processes that increase the amount of a person's human capital, e.g. schooling, training or learning. From a regional perspective, such human capital investment may manifest itself in education expansion or upskilling of the labour force. Moreover, technological change, through processes of increasing automatization and robotization, represents a complementary pathway to human capital accumulation both quantitively and qualitatively, since it may compensate for labour scarcity (Acemoglu & Restrepo, 2017) or change the nature of job tasks and the human capital required to complete them (Susskind, 2019).

Meeting the challenges of an ageing population certainly requires a policy mix involving increased participation, immigration, life-long-learning and technology: this paper focuses on changes in human capital via increased educational attainment. Education may allow raising productivity even in contexts of contracting working-age populations and limited potential to further increase labour force participation. Indeed, Kotschy and Sunde (2018) suggest that education may dampen negative productivity effects of ageing more effectively than increasing female labour force participation or longer working hours. Although education can also refer to expanding human capital (or job experience) among older workers, such learning often takes place within firms and is not documented in official regional statistics. We therefore limit the following analysis of human capital to educational attainment as captured by obtained degrees.

2.2 Demographic change and regional human capital accumulation

While human capital investment through education is one of the primary policy tools suggested to cope with demographic change, the latter 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, young cohorts will not be sufficient to replace larger retiring cohorts. Retirement of the baby boom generation may require additional labour supply in certain sectors, but also raises concerns over potential knowledge loss if not managed effectively (Hipp & Verworn, 2011). Moreover, fewer labour market entrants also mean a smaller supply of workers with the most recent state of knowledge (e.g. university graduates), which could impede the updating of the human capital stock. 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.

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 demand of human capital over time and space (e.g. Scott, 2010). For West Germany, Spitz-Oener (2006) shows that changes in task content of occupations account for up to 36% of the increase in the share of high-skilled employees between 1979 and 1999. Progressing automatization and digitization may put especially jobs with low qualification requirements at risk, implying further changes in labour demand (Arntz, Gregory & Zierahn, 2016). 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].

From a demographic perspective, the trait of increased educational attainment is transmitted upwards through the age distribution: the composition of a population's education changes with cohort replacement as well as due to differences in cohort sizes (Rees, 2018). We would thus expect that regions with an older labour force have relatively lower levels of human capital, ceteris paribus. Moreover, since the education expansion concerns tertiary education especially, we would expect this type of degree to particularly reflect age structure.

This relationship between population ageing and human capital availability is especially relevant at a subnational level because of large heterogeneity in regional demographic as well as labour market conditions (Boschma & Fritsch, 2009; Scott, 2010). These disparities may be caused by locational

[1] This target is almost reached: in 2016, 39.1% of 30- to 34-year-olds hold tertiary degrees in the EU-28, although considerable differences across countries remain (Eurostat, 2017).

differences in the likelihood of attaining specific educational levels as well as migration patterns (Waldorf, 2009; Brown et al., 2010). Skill- and age-selective migration further implies sorting of individuals across regions, which could reinforce spatial disparities in human capital and age-structure.

More generally, the effect of population ageing on human capital availability is related to questions of regional polarisation of human capital. Divergence in human capital across cities is documented for the US (e.g. Berry & Glaeser, 2005; Wheeler, 2006; Franklin, 2017). In contrast, for West Germany, Südekum (2008) finds that highly-skilled cities saw faster employment growth overall, but that high-skilled employment is characterized by convergence. 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. Hunt, 2006; Brücker & Trübswetter, 2007; Melzer, 2013).

Nevertheless, 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 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 human capital, and predominantly focuses on the prevalence of university degrees. Although clearly advantageous in terms of data availability, the high/low skill dichotomy neglects the large variation within human capital especially for countries with strong vocational training systems like Germany. Moreover, equating human capital investment with university education expansion also disguises regional heterogeneity in human capital pathways: for some regions, lacking growth in higher education degrees may be a sign of distress or systematic regional disadvantage; for others, it may indicate alternative trajectories of education via vocational training that could be well-adapted to regional circumstances. In this sense, education increases to offset negative productivity effects of ageing may require different strategies, e.g. in urban versus rural regions, depending on the local relevance of academic rather than vocational human capital.

This paper adds to the existing literature, first, by explicitly studying the interrelation between labour force ageing and the accumulation and composition of employed human capital at a regional level. Education expansion represents a potential policy to offset anticipated reductions in labour force size and productivity, but the required extent of the expansion depends on the relationship between ageing and human capital. Our analysis contributes to the understanding of the net effects of ageing on regional availability and relative prevalence of specific types of human capital. It also allows quantifying the counteracting effects of education expansion and ageing. Second, the paper introduces a more detailed conceptualisation of educational attainment, distinguishing not only university degrees but also vocational training. We can therefore identify and examine regional heterogeneity in paths of human capital development which hold lessons for appropriate regional development policies in times of demographic change. The nature of our analysis is exploratory and descriptive and does not attempt to identify causal directions but rather to establish the existence of the relationship between ageing and human capital composition, and its regional variation.

3. 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

[2] See KMK (2017) for details.
[3] Students who do not obtain a secondary degree are also eligible for vocational training.

takes 6 years and, after further secondary education, gives access to tertiary education at a university of applied sciences (*Fachhochschule*) or in specific university subjects. The upper secondary degree (8-9 years of secondary schooling) is the only degree that grants direct access to universities.

[Figure 1 about here]

Education policy is a responsibility of the Federal States and details of the system therefore differ within Germany. 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 factual equivalence of vocational and educational qualifications across current and past regional systems.

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 equip apprentices with a degree, specific skills, and job experience. Powell and Solga (2011) argue that the German prevalence of vocational training is supported by cultural values associated with the concept and status 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 2014 26% of apprentices had previously obtained entrance qualifications for higher education (KMK, 2017, 142). The prevalence of vocational education limits the size of the higher education sector: in 2015 only 30% of 25-34-year-olds had completed tertiary education compared to an OECD average of 42% (OECD, 2017, 51). Tuition fees play a limited role in the costs of tertiary education in Germany since university has traditionally been free[4]. 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

[4] Tuition fees at public universities were banned by Federal law until 2005. By 2014, all states that had imposed fees abolished them again. Fees still apply in some cases, e.g. second undergraduate degrees, for long-term or non-EU students.

of German tuition fees generally does not find significant effects on enrolment behaviour (e.g. Bruckmeier & Wigger, 2014).

4. METHODOLOGY

4.1 Data

Regional human capital levels are calculated from the Sample of Integrated Labour Market Biographies (SIAB7514)[5]. It is a 2% sample of the German administrative social security database but excludes public servants and the self-employed since these groups are not covered under compulsory social security. We restrict the sample to full-time employment spells that include the 30th of June in each year[6]. We further exclude individuals under 30 years as their educational attainment does not seem to be representatively captured. Since the dataset is based on those employed, there is selection bias among younger age groups because the observed individuals chose to work instead of continuing education. As a consequence, only a small share of those under 30 years hold a university degree (in 2000: 2.9% for ages 20-29, 9.7% for 30-39), which is why we disregard younger individuals. The education data was imputed based on the strategy suggested by Fitzenberger, Osikominu, and Völter (2006) to address inconsistencies. After imputation and excluding observations with missing data, the underlying micro dataset comprised 3.2 million observations on 560,000 individuals between the ages of 30 and 62.

Education per individual and year was aggregated to district regions and used to calculate the human capital measures described below. The SIAB dataset uses NUTS3 regions but combines regions with a population below 100,000 for reasons of anonymity. The 326 SIAB regions are thus based on, but do not perfectly correspond to, the 401 German districts (NUTS3). The proportions of employees by educational attainment, mean age, and gender shares were combined with data on regional characteristics from the Federal Statistical Offices (Regional Database Germany). After excluding

[5] Data access was provided via a Scientific Use File supplied by the Research Data Centre of the German Federal Employment Agency at the Institute for Employment Research. We restrict the dataset to 2000 to 2010 because a change in the occupational code in the SIAB7514 prohibits distinguishing D4 from D5 after 2010.
[6] For individuals with several spells at the cut-off date, we choose the first if the regions of employment are identical. 2515 observations with full-time employment in more than one region were dropped.

observations with missing control variables, the final dataset covers 324 regions between 2000 and 2010[7].

4.2 Operationalisation

Based on Figure 1, human capital can be broken down to six educational degrees which are reported by the employers. The six degree types are defined by the highest level of education completed and distinguish between vocational and higher education. The minimum educational attainment (D1) is only primary, lower secondary or intermediate secondary education, whereas the second type (D2) additionally includes a completed vocational qualification. While it is possible to distinguish between an upper secondary degree with no further qualifications (D3a) and one with vocational training (D3b), we report these degrees jointly as D3 in our analysis. This is because type D3a does not occur frequently (only 1.6% of the sample) and is intuitively close to D3b. The final two degree types refer to higher education: D4 is a degree from a university of applied sciences, whereas D5 is a university degree. For D4 and D5, an upper secondary education degree is not recorded but implied, since it is a requirement for tertiary education. As only the highest qualification is recorded, information on vocational training is not available for individuals with D4 or D5.

These qualification types allow more detailed insights into the composition of human capital than the dichotomy high/low-skilled based on tertiary education frequently used in the literature. Yet, the indicators are still relatively broad since no information about the precise type of degree within the categories is available and the content of qualifications may change over time. Thus, the 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 of the five degree types (i=1,…5) is calculated by region and year. To investigate the relationship between population age structure and human capital composition two different approaches are implemented. First, we consider an aggregate index that is meant to capture general availability of human capital but not its composition. The degrees are qualitatively different categories which prohibit simple aggregation: it is not clear how

[7] The 2 SIAB regions excluded for missing observations are Göttingen and Osterode am Harz in Lower Saxony.

much "more" human capital is in a university degree than in a degree from a university of applied sciences. Thus, we construct an aggregate human capital index (HC) based on the average time spent in education (in years). We convert each degree (D1 to D5) into their respective duration in education years (corresponding to those used in Tarazona (2010) and presented in Figure 1) and weight them by the share of employees with each degree in the region.[8]

$$HC_r = \sum_{i=1}^{5} years\ of\ education\ in\ degree * \ D(i)_r \quad (1)$$

Converting the degrees to education years does not address the problem of the different content of the degree types but it yields a measure of the aggregate time invested in education. As such, average years of schooling is a widely used indicator of human capital, applied for instance by Lutz et al. (2014). However, this aggregate measure relies on strong assumptions on the years of education and obscures the source of changes within the human capital endowment. As a second approach, we therefore use the regional shares of the five degree types D(i) as separate dependent variables.

Population age structure is measured here via the mean age of the labour force as extracted from the microdata. Measures such as the share of population above 65 years, which are commonly used to capture ageing at a population level, are not necessarily informative of the age structure of the labour force, which is why mean age is the preferred proxy for this analysis.

4.3 Empirical specification

The relationship between human capital and age structure is modelled using a long difference specification for 324 regions and the time period 2000 to 2010.

$$\ln{(HC)_{r,2010}} = \beta_0 + \beta_1 \Delta\ mean\ age_{r,2000-2010} + \beta_2\ \ln{(HC)_{r,2000}} + \beta_3\ controls_r + \varepsilon_r \quad (2)$$

We control for the initial level of human capital (in 2000), mitigating also the threat of time-invariant unobserved factors[9]. We further control for a range of regional characteristics: GDP per capita in 2000; GDP growth; change in unemployment rates; change in the share of services; population growth; and

[8] In calculating HC, we account for the different years of education required for degrees D3a and D3b respectively.

[9] We cannot exclude the possibility of time-variant unobserved factors, such as institutional changes in this specification. However, results are robust to specification as a fixed-effects panel model and available upon request.

dummies for urban regions and former East Germany (excluding Berlin). To consider alternative channels affecting human capital we also control for whether the region has a university (accounting for local access to higher education), and changes in the shares of both female employees (proxying female participation rates) and of non-German residents (as a rough proxy for international migration). The variable list is presented in the Appendix.

We extend the analysis to consider the composition of human capital across the different educational degrees:

$$\Delta\, D(i)_{r,2000-2010} = \beta_0 + \beta_1\, \Delta\, mean\ age_{r,2000-2010} + \beta_2\, D(i)_{r,2000} + \beta_3\, controls_r + \varepsilon_r \qquad (3)$$

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, since the shares add up to 100%.

The two models 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 ($D(i)_{30\text{-}39}$).

$$\Delta\, D(\mathrm{i})_{30-39_{r,2000-2010}} = \beta_0 + \beta_1\, \Delta\, mean\ age_{r,2000-2010} + \beta_2\, D(i)_{r,2000} + \beta_3\, controls_{r,2000} + \varepsilon_r \qquad (4)$$

Since (4) controls for age composition by restricting the dependent variable to the same age group, the remaining effect of ageing on human capital is attributable to other factors such as regional differences in educational choice or migration.

4.5 Robustness checks

Due to the interrelated nature of migration and age structure, there are concerns of endogeneity with respect to the main variable of interest, ageing. The primary channel for this endogeneity is likely selective migration both with respect to age and skill-levels. To alleviate this concern, we propose instrumental variable specifications as robustness check. In the absence of well-accepted instruments for population ageing, a viable option is to instrument the degree of population ageing between 2000 and 2010 using historical age structures. In this sense, and under the assumption that migration is not dependent on historical age structures, it can be argued that a region's previous age structure is predictive of current population ageing but does not include the effect of age-selective migration.

Unfortunately, historical population age structures at the district level are difficult to obtain. Regional-level data for re-unified Germany only starts in 1995, which is an insufficient time lag. As a compromise, we implement a separate IV specification for regions in the former West Germany only, which allows using historical census data. We use the share of population between 7 and 15 years in 1970 as an instrument for population ageing between 2000 and 2010. Individuals of this age group were born during the German baby boom, which is the predominant determinant of current population ageing. Thus, the census data allows forecasting population ageing through the regional extent of the baby boom.

5. RESULTS

5.1 Relative contribution of ageing and education expansion

The dominant trend of population ageing is clearly visible in the German labour force (Figure 2). Between 2000 and 2010, mean age of the employed labour force increased in all regions across Germany and on average by 2.5 years. 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 clusters of old regions in the West, especially in the Palatinate, Saarland and the Ruhr areas, affected by structural change and deindustrialisation. The degree of population ageing (Figure 2, right) is considerably less concentrated: strongly ageing regions are located throughout Germany, with the West ageing at a comparable rate as the East.

[Figure 2 about here]

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 2000 and 2010, whereas especially the share of university degrees (D5) rose. It should be noted that the reported share of D5 (university degree) in the employed labour force is lower than estimates of the entire population with tertiary education in Germany. This is because (unemployed) students, the self-employed and public servants are not represented in our dataset.

[Figure 3 about here]

How much of the change in Figure 3 can be explained by demographic change? 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 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 2000 and 2010, using three age groups: 30-39, 40-49 and above 50. Applying the education shares from 2000 to the age group sizes in 2010 thus yields a predicted human capital composition that is purely based on demographic shifts.

Table 1 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 D3 and D5 relative to the 2000 values. Moreover, the national average years of schooling would have decreased from 12.8 in 2000 to 12.7 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 real 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, seem to offset any demographic effect on human capital for the national average in the decade considered.

[Table 1 about here]

5.2 Regressions

Table 2 presents the results of fitting the regressions (2), (3) and (4). The first column uses our aggregate measure of human capital. The coefficient on mean age is significantly negative: on average, an increase in mean age by one year is associated with a decrease of 0.3% in the average years of education. If we understand the average time of education as a measure of the aggregate human capital level, this suggests that regions with an older age structure indeed have lower levels of human capital, ceteris paribus.

[Table 2 about here]

To see how this aggregate result translates into the relative prevalence of different educational degrees, the next five columns of Table 2 decompose this effect into each of the education degree shares. Labour force ageing is negatively associated with the prevalence of "high-skilled" degrees, especially university education (D5). 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 0.71 percentage point increase in employees with such traditional vocational degrees (D2) and a 0.39 percentage point decrease in the share of employees with a university degree (D5).

The trend of education expansion implies that younger individuals on average have higher educational attainment. Thus, the results of columns 2 to 6 are partially explained by differences in the composition of the labour force alone. To condition out this effect, columns 7-11 show the results of estimating the same model but restricting the sample to individuals aged 30-39. For this age group, the significantly positive coefficient on ageing disappears for the traditional vocational degrees (D2) but it holds and increases in size for university education (D5): regions where mean age increases by one year on average experience a 0.697 percentage point decrease in the share of employees with a university degree in the age group 30-39. 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. This result is in line with suggestion of sorting of population, with "younger" regions either creating or attracting relatively more workers with higher education.

With respect to other regional characteristics included as controls some interesting observations emerge. For economic structure, GDP per capita is highly significant and associated with higher aggregate education (column 1) and specifically tertiary education. Rising unemployment rates between 2000 and

2010 are associated with lower educational attainment. In contrast, neither GDP growth nor changes in the share of services emerge as significant predictors of human capital availability or composition.

Both population growth and the share of non-German population were included as rough proxies for (international) migration effects but overall we find no evidence for migration driving notable differences in the human capital composition beyond other regional controls. Similarly, in line with the observation that German universities are relatively evenly distributed geographically, the dummy variable for a university in the region is insignificant in our baseline results: it turns however significant for D5 in the age group 30-39, which would be in line with university regions retaining some of their graduates – at least in the short run. Changes in the share of female employees are mostly insignificant beyond a significantly negative coefficient for vocational degrees among 30-39-year olds.

The dummy variable for urban regions is significantly negative for D2 but positive for the other degree types (except D4) as well as the aggregate HC measure. This illustrates distinct human capital compositions for urban and rural regions, with urban regions experiencing much larger decreases in the share of traditional vocational degrees (D2). For the aggregate human capital indicator HC and for the share of university degrees, regions in West Germany on average experience larger increases than those in the East. While this indicates slower human capital accumulation in the East, it should be noted that the legacy of the GDR's education system implies that East Germany had relatively high educational attainment (especially tertiary) when compared to the West. 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. In this sense, the negative coefficients for East Germany could still be due to adjustment processes.

Results for the robustness check using an instrumental variable approach are presented in the Appendix. The OLS results from the full sample hold similarly for the limited West German sample: regional population ageing is associated with increases in vocational training degrees (D2) and decreases in university degrees, leading to decreasing aggregate human capital as measured by HC. The IV coefficient estimates are larger in magnitude than the OLS estimates. Moreover, for the age group 30-39, the IV results show a positively significant coefficient even for D2, which does not emerge in the

OLS but is consistent with our baseline findings. The coherence of results when excluding East German regions and when instrumenting the variable of interest give us further confidence in the robustness of our regression estimates.

5.3 Cluster analysis of regional human capital development

The regressions show that urban and rural, and East and West German regions seem to differ significantly in the availability and composition of human capital. It is worthwhile to take a closer look at the underlying regional heterogeneity in an explorative descriptive analysis. The maps in Figure 4 present the change in each of the five degree shares between 2000 and 2010. Geographical patterns in human capital variations are clearly discernible, with distinct trends especially for the East of Germany.

[Figure 4 about here]

While each map can be interpreted individually, Figure 4 also shows the results of a simple k-means cluster analysis based on the changes in the five 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 five degree types. In particular, comparing the maps and the summary statistics by cluster in Table 3, helps tracing four broad types of regional human capital trajectories.

[Table 3 about here]

Cluster 1 refers predominantly to urban regions, especially in the West of Germany but also including Berlin and Jena. These regions on average experienced the smallest increases in mean age between 2000 and 2010 and have the youngest labour force in 2010. The share of "traditional" vocational training degrees (D2) fell substantially (8 percentage points), whilst D5 (university degrees) rose sharply (5.1 percentage points). Cluster 1 thus refers to highly agglomerated urban regions with a comparatively low degree of population ageing, shifting 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 the majority of East German regions and some in the West, e.g. in Lower Saxony; 72% of the regions in cluster 2 are classified as rural. This cluster experienced the strongest labour force ageing, with mean age increasing by 2.72 years between 2000 and 2010, and relatively small changes to human capital composition. More specifically, cluster 2 recorded the smallest decrease in D1 and the smallest increases in higher education. The degree expanding the most is D3 (upper secondary degree with or without vocational training), although even this average increase of 2 percentage points is below the national average. Across the four clusters, cluster 2 is characterised by the lowest amount of education expansion. 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 addressing demographic challenges, continuous investment should be occurring even in regions with relatively high starting values.

All but two regions in cluster 3 are in West Germany. 60% of this cluster are rural regions and the cluster is geographically concentrated especially in South Germany. These districts also experienced strong ageing with mean age increasing by 2.55 years between 2000 and 2010. However, in contrast to cluster 2, cluster 3 shows a pronounced fall in the share of employees with degree D1 (4.5 percentage points) and an average increase in shares of D2. Whereas all other clusters on average see this degree decline, regions in cluster 3 even expand in the dimension of vocational training. Considering only higher education as indicator of human capital would likely categorise regions in this cluster as lagging (since university degrees are expanding at less than the national average). However, the strong decline in D1 with a shift towards D2 and higher degrees clearly indicates upskilling of the human capital composition. Although ageing to a similar extent, human capital in the regions of cluster 3 expands more consistently than in cluster 2 but on a different dimension (i.e. vocational degrees) than cluster 1.

The final cluster 4 includes mostly West German regions, 74% of which are urban regions often surrounding agglomerations (e.g. in the Ruhr area). Although cluster 4 experiences some ageing, it is slightly less severe than for clusters 2 and 3. Changes in the human capital composition of this cluster are close to the national average: this cluster is indeed 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 is merely descriptive, but it complements the regression results previously presented. 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 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 and even expands its important role in shaping the human capital composition. These different pathways to human capital investment are of course closely related to regional industry structures and the demands of local employers.

This broad picture also illustrates that some regions do not seem to experience an education expansion in any direction. Especially regions of the former GDR, traditionally characterised 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 the post-reunification transition, a by-product of economic convergence, or a symptom of population ageing, remains open to debate.

6. DISCUSSION AND CONCLUSION

The aim of this paper was to investigate the interrelation between demographic ageing and regional human capital composition. Analysing German district-regions for 2000 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. 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 2000 and 2010 the pronounced expansion in educational attainment in Germany was more than sufficient to compensate on average 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, although educational attainment is increasing at the national level, 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 ageing, and more generally to stimulate regional economic growth. It should be noted that we considered only human capital investment via formal education, whereas coping with demographic change certainly requires increasing labour productivity through multiple channels. This includes strategies to expand the working-age population, e.g. via immigration or postponing retirement, to encourage labour market access, e.g. among women or minorities, and to boost labour productivity in other ways, e.g. by emphasising on-the-job training and life-long-learning for older workers as well as exploring the productivity-enhancing role of technology. These policies for human capital accumulation are further intertwined with the relevance of education: for instance, education levels may differ by country of origin or gender of immigrants, progressing automatization and digitisation may change skill demands, and education is itself a contributing factor to innovation and fundamental restructuring of work in an ageing society. Further research on the interaction between population ageing and other pathways of human capital accumulation is needed, especially at the subnational level, addressing, for instance, the role of occupation- or task-based skills, automatization, or gender disparities.

Nevertheless, 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 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 diverse challenges and opportunities (Iammarino et al., 2019). 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 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 critical 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 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 here) and considerable outmigration of young and skilled people, our findings suggest that investment in human capital may not be delivered simply as part of a national (or European) education expansion but requires more targeted efforts. Depending on the initial human capital composition, but also crucially on regional structural features 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. More importantly, human capital investment is too often intended to boost higher education, whilst other skill upgrading pathways may be more suitable to support place-specific regional economic growth and development (Filippetti, Guy, & Iammarino, 2019). In this sense, the example of regions in South Germany expanding in vocational degrees illustrates that local labour markets may have different demands and conditions governing the type of 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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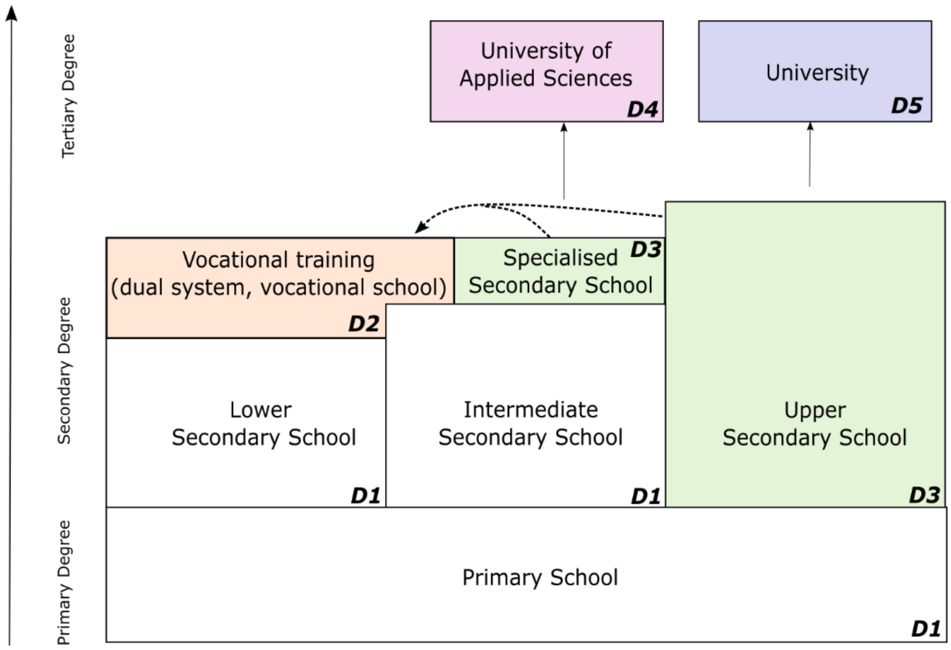
Figures & Tables

Figure 1: Schematic representation of German education system



	D1	D2	D3a	D3b	D4	D5
No secondary degree; lower or intermediate secondary degree.	✓	✓	✓	✓	✓	✓
Upper secondary degree.			✓	✓	✓*	✓*
Vocational Training		✓		✓	*	*
University of applied sciences					✓	
University degree						✓
Average duration of education (Tarazona, 2010)	9	12	13	15	17	19

*Secondary school attainment and vocational training is not recorded for individuals with higher education. Upper secondary or an equivalent degree (*Fachabitur*) is a prerequisite for higher education

Figure 2: Mean age of the employed labour force: 2000, 2010, and change 2000-2010

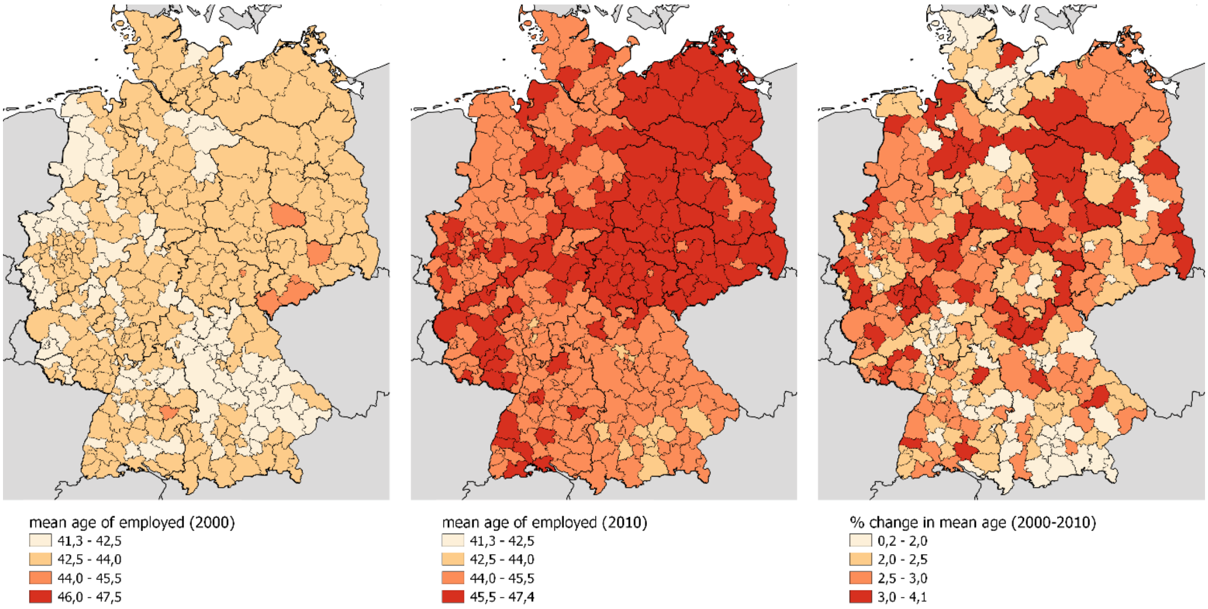


Figure 3: Human capital composition in 2000 and 2010

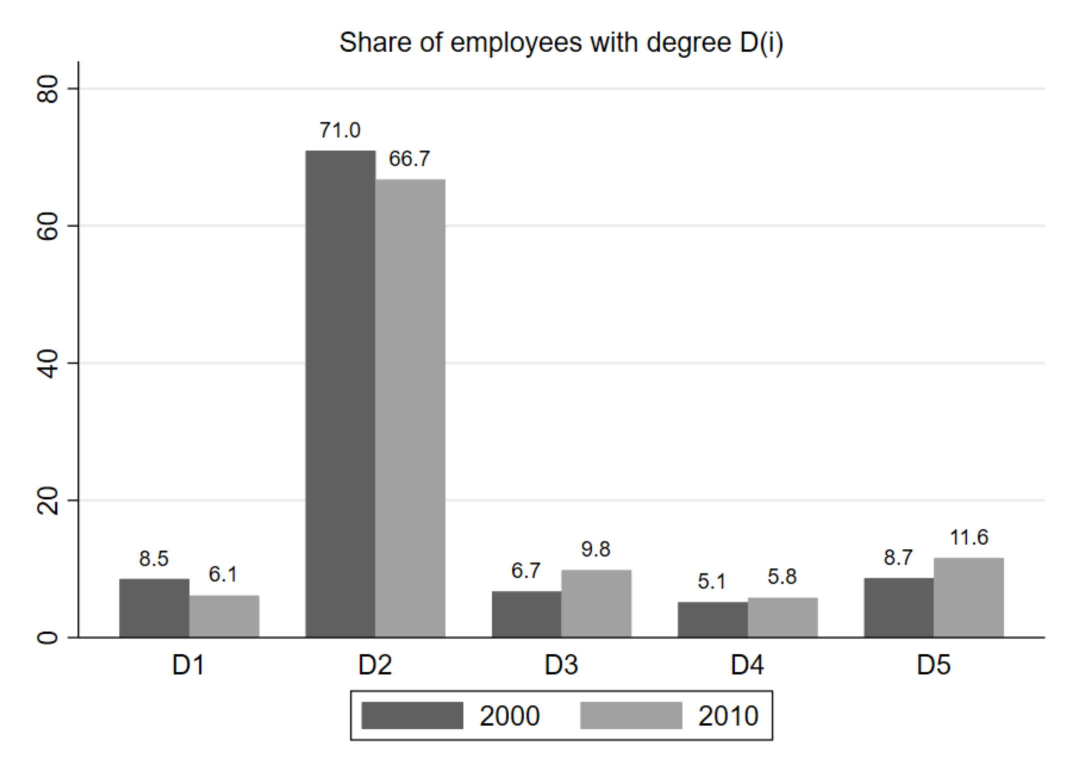


Table 1: National average shift-share decomposition

Share of degree type	D1	D2	D3	D4	D5	HC
observed 2000	8.5	71.0	6.7	5.1	8.7	12.8
observed 2010	6.1	66.7	9.8	5.8	11.6	13.2
actual change 2000-2010	-2.4	-4.3	3.1	0.7	2.9	0.4
projected 2010	8.8	71.5	6.1	5.1	8.4	12.7
contribution demographic change	0.3	0.5	-0.6	0.0	-0.3	-0.1
residual change	-2.7	-4.8	3.7	0.7	3.2	0.5

Table 2: Baseline regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
dep. variable	$lnHC_{2014}$	Δ D1	Δ D2	Δ D3	Δ D4	Δ D5	Δ $D1_{30-39}$	Δ $D2_{30-39}$	Δ $D3_{30-39}$	Δ $D4_{30-39}$	Δ $D5_{30-39}$
Δ mean age	-0.003***	0.208	0.714***	-0.155	-0.196**	-0.388***	0.325	0.346	0.144	-0.080	-0.697**
	(0.0009)	(0.1264)	(0.2502)	(0.1230)	(0.0936)	(0.1369)	(0.2306)	(0.4608)	(0.2649)	(0.1718)	(0.2735)
ln gdp $p.c._{2000}$	0.011***	-0.561**	-1.839***	-0.245	0.769**	1.613***	-1.464***	-1.005	-0.506	1.352***	2.688***
	(0.0027)	(0.2792)	(0.7008)	(0.2920)	(0.3330)	(0.4809)	(0.4715)	(1.3701)	(0.5870)	(0.5103)	(0.8096)
gdp pc growth	0.000	0.011	0.003	-0.003	0.008	0.005	0.012	0.031	-0.055***	0.008	0.025
	(0.0001)	(0.0075)	(0.0203)	(0.0072)	(0.0052)	(0.0110)	(0.0167)	(0.0354)	(0.0173)	(0.0105)	(0.0183)
Δ unemployment	-0.001**	0.229***	0.199	-0.034	0.007	-0.169**	0.387***	0.375	-0.248*	-0.033	-0.192
	(0.0005)	(0.0757)	(0.1290)	(0.0611)	(0.0537)	(0.0738)	(0.1414)	(0.2454)	(0.1438)	(0.0939)	(0.1617)
Δ services	0.000	-0.001	0.004	0.026	0.017	-0.012	-0.044	0.073	-0.022	-0.015	0.051
	(0.0002)	(0.0187)	(0.0456)	(0.0175)	(0.0151)	(0.0228)	(0.0386)	(0.0757)	(0.0415)	(0.0280)	(0.0450)
population growth	0.000	-0.017	-0.023	0.013	0.020	0.006	-0.013	-0.086	0.053	0.023	0.030
	(0.0001)	(0.0158)	(0.0337)	(0.0173)	(0.0124)	(0.0201)	(0.0334)	(0.0680)	(0.0449)	(0.0242)	(0.0432)
Δ foreign	-0.001	-0.089	0.155	-0.034	-0.096*	-0.114	0.015	-0.011	-0.308	-0.118	0.027
	(0.0009)	(0.0639)	(0.1701)	(0.0751)	(0.0562)	(0.1282)	(0.1207)	(0.2637)	(0.2013)	(0.1082)	(0.1717)
Δ female	-0.000	0.004	-0.093	0.049*	0.001	-0.025	0.109**	-0.307***	0.127*	-0.068*	0.067
	(0.0002)	(0.0267)	(0.0602)	(0.0260)	(0.0246)	(0.0327)	(0.0457)	(0.1164)	(0.0690)	(0.0410)	(0.0641)
university	0.002	-0.101	-0.672*	0.097	-0.066	0.358	-0.337	-2.143***	0.608	0.035	1.541***
	(0.0014)	(0.1555)	(0.3878)	(0.1843)	(0.1246)	(0.2406)	(0.2714)	(0.7755)	(0.4553)	(0.2583)	(0.4583)
urban	0.004***	0.640***	-1.667***	0.763***	0.137	0.514***	1.100***	-3.466***	2.061***	0.466*	0.889**
	(0.0014)	(0.1821)	(0.3851)	(0.1786)	(0.1383)	(0.1899)	(0.2922)	(0.7196)	(0.4021)	(0.2461)	(0.3677)
east	-0.018***	0.053	0.295	-0.305	-0.082	-1.925***	-0.330	-1.954	1.946**	-0.410	-0.447
	(0.0033)	(0.3602)	(0.7055)	(0.3509)	(0.3259)	(0.4313)	(0.6905)	(1.2400)	(0.8610)	(0.4951)	(0.7876)
dep. var_{2000}	0.947***	-0.392***	0.018	0.124***	-0.277***	0.042	-0.578***	-0.130**	-0.154**	-0.653***	-0.177***
	(0.0299)	(0.0353)	(0.0389)	(0.0393)	(0.0495)	(0.0385)	(0.0770)	(0.0548)	(0.0707)	(0.0620)	(0.0558)
Constant	0.057	5.727**	13.809	4.456	-5.572*	-13.773***	16.980***	14.766	9.635	-10.069*	-23.069***
	(0.0659)	(2.8943)	(9.1698)	(2.9976)	(3.3021)	(4.8749)	(4.9812)	(16.5643)	(5.9300)	(5.1284)	(8.1776)
Observations	324	324	324	324	324	324	324	324	324	324	324
R-squared	0.935	0.592	0.332	0.288	0.287	0.446	0.427	0.204	0.213	0.312	0.200

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

Figure 4: Maps of changes in degree shares (2000-2010) by quantile and cluster map

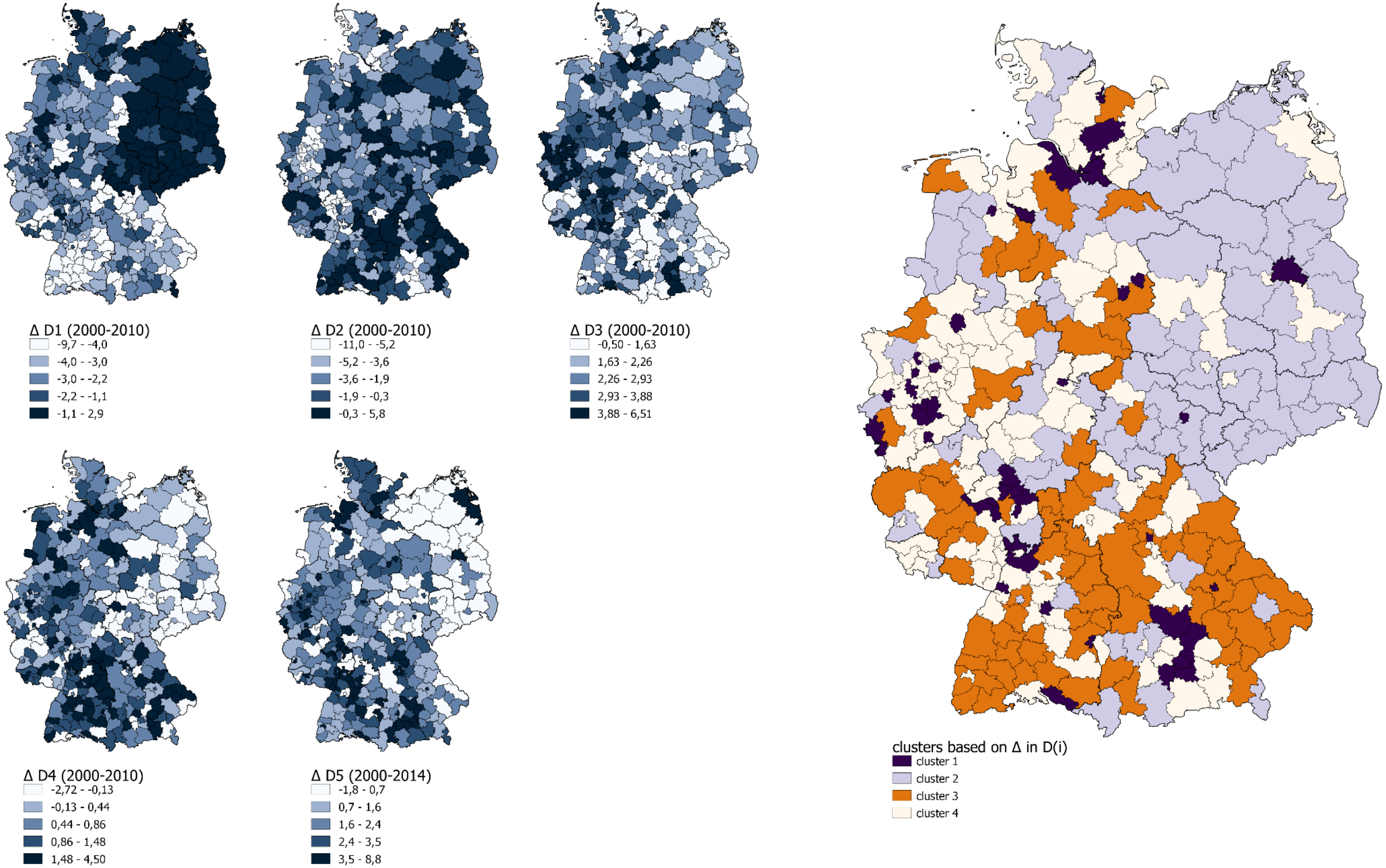


Table 3: Summary statistics by Cluster

cluster		Δ D1	Δ D2	Δ D3	Δ D4	Δ D5	Δ mean age	mean age_{2010}	count	% urban	% east
1	mean	-2.13	-8.01	3.97	1.05	5.13	1.91	44.68	43	90.7	2.3
	sd	1.43	1.55	0.94	0.98	1.53	0.53	0.54			
	min	-4.73	-10.96	0.92	-0.86	0.38	0.74	43.30			
	max	2.88	-5.04	6.01	4.41	8.81	2.97	45.98			
2	mean	-1.30	-1.59	2.03	0.16	0.71	2.72	45.77	89	28.1	53.9
	sd	1.05	1.24	0.86	0.88	1.04	0.61	0.73			
	min	-3.48	-4.74	0.17	-1.97	-1.36	0.99	43.56			
	max	1.54	1.97	4.62	2.27	2.83	3.97	47.38			
3	mean	-4.55	0.51	1.81	0.68	1.56	2.55	45.15	78	38.5	2.5
	sd	1.35	1.64	0.87	1.14	1.19	0.52	0.59			
	min	-9.72	-1.91	-0.50	-2.72	-1.83	1.42	43.33			
	max	-1.87	5.84	3.58	2.95	4.10	3.90	46.52			
4	mean	-2.71	-4.19	3.42	0.85	2.64	2.39	45.15	116	74.1	6.9
	sd	1.39	1.09	1.15	0.95	1.09	0.57	0.55			
	min	-6.56	-6.82	1.15	-2.10	0.50	0.24	42.98			
	max	1.06	-1.95	6.51	4.50	5.24	4.07	46.56			
Total	mean	-2.69	-2.86	2.72	0.64	2.18	2.46	45.26	326	55.2	18.1
	sd	1.76	3.02	1.29	1.03	1.81	0.62	0.70			
	min	-9.72	-10.96	-0.50	-2.72	-1.83	0.24	42.98			
	max	2.88	5.84	6.51	4.50	8.81	4.07	47.38			

Appendix

Appendix A: List of variables

Variable	Description	Source
HC	Average years of schooling as used in Tarazona (2010)	SIAB
D1	Share of employees with at most primary, lower secondary or intermediate secondary education.	SIAB
D2	Share of employees with primary, lower secondary, intermediate secondary education and completed vocational qualification.	SIAB
D3	Share of employees with upper secondary degree without (D3a) or with (D3b) vocational qualification.	SIAB
D4	Share of employees with a tertiary degree from a university of applied sciences.	SIAB
D5	Share of employees with a university degree.	SIAB
mean age	Mean age of the labour force	SIAB
ln GDP p.c.	ln of GDP per capita	INKAR
unemployment	Unemployment rate	INKAR
services	Share of services in total value added	RDG
pop. growth	Population growth	RDG
foreign	Share of non-German citizens	RDG
female	Share of female employees	SIAB
urban	Dummy for urban settlement type	INKAR
east	Dummy for regions of former GDR (Berlin coded as West)	
University	Dummy for public research university (obtained from German Rectors' Conference website)	
Data Sources		
SIAB	Sample of Integrated Labour Market Biographies 1975-2014 (SUF)	
RDG	Regional Database Germany (Federal Statistical Offices)	
BBSR	Federal Institute for Research on Building, Urban Affairs and Spatial Development	

Appendix B: Summary statistics

variable	mean	std. dev	min	max
mean age_{2000}	42.80	0.58	41.35	44.49
Δ mean $age_{2000-2010}$	2.45	0.62	0.24	4.07
HC_{2000}	12.57	0.44	11.82	14.18
Δ $HC_{2000-2010}$	0.34	0.18	-0.12	0.82
D1	8.91	4.17	0.72	20.99
Δ $D1_{2000-2010}$	-2.69	1.76	-9.72	2.88
D2	74.27	6.52	50.95	87.13
Δ $D2_{2000-2010}$	-2.87	3.02	-10.96	5.84
D3	5.61	2.08	1.57	14.22
Δ $D3_{2000-2010}$	2.72	1.30	-0.50	6.51
D4	4.49	1.71	0.64	11.81
Δ $D4_{2000-2010}$	0.65	1.03	-2.72	4.50
D5	6.71	3.97	1.63	25.19
Δ $D5_{2000-2010}$	2.19	1.81	-1.83	8.81
GDP $p.c._{2000}$	24123	10539	12200	80600
growth GDP $p.c._{2000-2010}$	24.02	11.10	-2.77	70.06
Δ unemployment $_{2000-2010}$	-1.93	2.19	-10.10	2.10
Δ $services_{2000-2010}$	1.58	4.00	-13.50	14.35
growth population $_{2000-2010}$	-0.97	5.38	-16.15	11.81
Δ $foreign_{2000-2010}$	-0.06	0.89	-3.06	6.99
Δ $females_{2000-2010}$	-0.19	2.35	-6.88	9.00
University	0.23	0.42	0.00	1.00
Urban	0.55	0.50	0.00	1.00
East	0.18	0.39	0.00	1.00

Observations: 324

Appendix C: Robustness check – instrumental variable approach

For West German regions only. Using population 7-15 years in 1970 as instrument for ageing.

dep. var.	$lnHC_{2014}$		Δ D1		Δ D2		Δ D3		Δ D4		Δ D5	
	(1) OLS	(2) IV 2nd	(3) OLS	(4) IV 2nd	(5) OLS	(6) IV 2nd	(7) OLS	(8) IV 2nd	(9) OLS	(10) IV 2nd	(11) OLS	(12) IV 2nd
Δ mean age	-0.004***	-0.013***	0.186	-1.176	0.716**	7.901***	-0.184	-1.838**	-0.149	0.420	-0.429***	-3.017***
	(0.0010)	(0.0049)	(0.1456)	(0.7312)	(0.2839)	(2.2650)	(0.1398)	(0.7566)	(0.1040)	(0.4483)	(0.1546)	(0.8472)
ln gdp $p.c._{2000}$	0.011***	0.009***	-0.657**	-1.124**	-1.614**	0.732	-0.240	-0.776	0.743**	0.912**	1.494***	0.737
	(0.0028)	(0.0032)	(0.2878)	(0.4602)	(0.7273)	(1.4765)	(0.3140)	(0.4823)	(0.3424)	(0.3752)	(0.5258)	(0.6489)
gdp pc growth	0.000	0.000	0.013	0.023**	0.023	-0.035	-0.010	0.001	0.008	0.003	0.003	0.023
	(0.0001)	(0.0001)	(0.0087)	(0.0107)	(0.0251)	(0.0413)	(0.0094)	(0.0119)	(0.0067)	(0.0072)	(0.0151)	(0.0192)
Δ unemployment	-0.001	-0.001**	0.285***	0.198*	0.221	0.569**	-0.070	-0.152*	0.058	0.086	-0.158*	-0.296***
	(0.0006)	(0.0007)	(0.1051)	(0.1179)	(0.1623)	(0.2676)	(0.0729)	(0.0908)	(0.0677)	(0.0704)	(0.0901)	(0.1115)
Δ services	0.000	0.000*	-0.005	0.013	0.021	-0.097	0.013	0.039	0.026	0.017	-0.006	0.035
	(0.0002)	(0.0002)	(0.0212)	(0.0238)	(0.0509)	(0.0904)	(0.0205)	(0.0274)	(0.0173)	(0.0178)	(0.0257)	(0.0357)
population growth	0.000	-0.000	-0.040*	-0.109**	-0.047	0.327**	-0.004	-0.090**	0.043***	0.071***	0.022	-0.110**
	(0.0002)	(0.0003)	(0.0234)	(0.0488)	(0.0458)	(0.1302)	(0.0213)	(0.0443)	(0.0159)	(0.0259)	(0.0257)	(0.0497)
Δ foreign	-0.001	-0.000	-0.087	-0.031	0.099	-0.145	0.003	0.061	-0.092	-0.109*	-0.110	-0.016
	(0.0010)	(0.0011)	(0.0686)	(0.0727)	(0.1557)	(0.2577)	(0.0698)	(0.0841)	(0.0573)	(0.0596)	(0.1333)	(0.1613)
Δ female	-0.000	-0.000	-0.002	-0.023	-0.070	0.054	0.039	0.013	-0.003	0.008	-0.031	-0.074
	(0.0003)	(0.0003)	(0.0316)	(0.0447)	(0.0690)	(0.1478)	(0.0307)	(0.0422)	(0.0289)	(0.0337)	(0.0376)	(0.0629)
university	0.002	0.001	-0.110	-0.224	-0.766*	-0.121	0.142	0.019	-0.063	-0.013	0.351	0.146
	(0.0016)	(0.0017)	(0.1773)	(0.2308)	(0.4368)	(0.7360)	(0.2079)	(0.2517)	(0.1378)	(0.1510)	(0.2586)	(0.3242)
urban	0.005***	0.006***	0.675***	0.753***	-1.811***	-2.449***	0.866***	1.022***	0.141	0.085	0.537***	0.766***
	(0.0015)	(0.0017)	(0.2023)	(0.2398)	(0.4128)	(0.7520)	(0.1904)	(0.2284)	(0.1547)	(0.1661)	(0.2052)	(0.2935)
dep. var_{2000}	0.945***	0.921***	-0.408***	-0.386***	0.031	-0.004	0.127***	0.086	-0.282***	-0.260***	0.054	0.022
	(0.0318)	(0.0361)	(0.0374)	(0.0424)	(0.0413)	(0.0676)	(0.0413)	(0.0556)	(0.0577)	(0.0597)	(0.0413)	(0.0550)
Constant	0.059	0.166*	6.929**	14.371**	10.186	-26.261	4.549	13.761**	-5.376	-8.379*	-12.520**	0.854
	(0.0701)	(0.0929)	(2.9726)	(5.7891)	(9.5662)	(19.7000)	(3.2300)	(6.1407)	(3.3852)	(4.2842)	(5.3117)	(7.5003)
Observations	265	265	265	265	265	265	265	265	265	265	265	265
R-squared	0.934	0.914	0.443	0.257	0.339	-1.061	0.268	-0.156	0.140	0.049	0.358	-0.255
F-stat 1st stage		16.45		16.86		17.05		15.70		15.96		18.40

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

Appendix C: Robustness check – instrumental variable approach (continued)

For West German regions only. Using population 7-15 years in 1970 as instrument for ageing.

dep. var.	Δ D1$_{30-39}$		Δ D2$_{30-39}$		Δ D3$_{30-39}$		Δ D4$_{30-39}$		Δ D5$_{30-39}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd	OLS	IV 2nd
Δ mean age	0.241	0.324	0.157	8.327***	0.034	-3.476**	0.131	0.833	-0.573*	-5.557***
	(0.2624)	(1.0040)	(0.5250)	(3.0879)	(0.2964)	(1.5902)	(0.1914)	(0.8110)	(0.2918)	(1.6202)
ln gdp p.c.$_{2000}$	-1.686***	-1.657***	-1.151	1.457	-0.787	-1.993**	1.441***	1.662***	2.826***	1.243
	(0.4762)	(0.5952)	(1.4263)	(2.1737)	(0.6066)	(0.9416)	(0.5195)	(0.5637)	(0.8277)	(1.3041)
gdp pc growth	0.009	0.009	0.062	-0.004	-0.057**	-0.030	-0.001	-0.007	0.024	0.064*
	(0.0166)	(0.0175)	(0.0425)	(0.0535)	(0.0226)	(0.0284)	(0.0130)	(0.0145)	(0.0244)	(0.0326)
Δ unemployment	0.529***	0.534***	0.274	0.670	-0.316*	-0.494**	0.020	0.052	-0.164	-0.427
	(0.1780)	(0.1823)	(0.3174)	(0.4459)	(0.1695)	(0.2165)	(0.1196)	(0.1219)	(0.1962)	(0.2707)
Δ services	-0.072*	-0.073*	0.121	-0.013	-0.055	0.001	-0.010	-0.021	0.077	0.157**
	(0.0390)	(0.0379)	(0.0798)	(0.1069)	(0.0494)	(0.0661)	(0.0322)	(0.0334)	(0.0487)	(0.0675)
population growth	-0.065	-0.061	-0.028	0.399**	-0.006	-0.191**	0.052	0.087*	0.029	-0.228**
	(0.0422)	(0.0677)	(0.0965)	(0.1964)	(0.0521)	(0.0933)	(0.0318)	(0.0495)	(0.0551)	(0.1067)
Δ foreign	0.066	0.062	-0.081	-0.353	-0.266	-0.138	-0.108	-0.129	0.006	0.190
	(0.1265)	(0.1276)	(0.2641)	(0.3457)	(0.1991)	(0.2275)	(0.1098)	(0.1137)	(0.1809)	(0.2388)
Δ female	0.090*	0.092*	-0.265*	-0.124	0.094	0.036	-0.064	-0.051	0.054	-0.028
	(0.0523)	(0.0540)	(0.1368)	(0.1924)	(0.0794)	(0.0985)	(0.0477)	(0.0512)	(0.0711)	(0.1186)
university	-0.306	-0.298	-2.126**	-1.405	0.420	0.122	-0.038	0.028	1.541***	1.109
	(0.3129)	(0.3136)	(0.8987)	(1.2159)	(0.5262)	(0.6289)	(0.2812)	(0.2948)	(0.5092)	(0.6971)
urban	1.180***	1.175***	-3.450***	-4.201***	2.006***	2.294***	0.306	0.244	0.883**	1.288**
	(0.3184)	(0.3139)	(0.7913)	(1.0759)	(0.4450)	(0.5004)	(0.2683)	(0.2718)	(0.4008)	(0.5609)
dep. var$_{2000}$	-0.602***	-0.602***	-0.134**	-0.168**	-0.075	-0.103	-0.616***	-0.600***	-0.179***	-0.211***
	(0.0829)	(0.0821)	(0.0585)	(0.0804)	(0.0768)	(0.0936)	(0.0664)	(0.0692)	(0.0572)	(0.0771)
Constant	19.857***	19.388***	16.071	-25.276	12.235**	32.174***	-11.298**	-15.096**	-24.735***	2.119
	(4.9701)	(7.5232)	(17.1739)	(28.5392)	(6.1544)	(12.2001)	(5.2290)	(6.5988)	(8.3489)	(14.9761)
Observations	265	265	265	265	265	265	265	265	265	265
R-squared	0.390	0.390	0.163	-0.511	0.145	-0.240	0.263	0.230	0.172	-0.608
F-stat 1st stage		17.33		18.15		17.81		16.61		19.20

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