Education, experience, and urban wage premium[*]

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Abstract

Cities have higher wages and more college-educated workers than less populated areas. We investigate the heterogeneity of the agglomeration effect and sorting with respect to education. The magnitude of static and dynamic agglomeration effects on wages in Norway is estimated for different educational categories. Using rich administrative data for the period 2003–2010 with experience data back to 1993, we find that college-educated workers have higher return to labor market experience accumulated in cities. The city wage premium of less educated workers is increasing in job tenure, while the college educated gain more from shifting jobs between firms. We address sorting by comparing distributions of worker fixed effects by level of education. The distribution of unobserved abilities is similar in cities and the rest of the country for workers with only primary and secondary education, while the distribution for workers with college education is shifted to the right in cities. Sorting with respect to unobserved abilities matters for college-educated workers, even when taking dynamic learning effects into account. Distinguishing between young and old workers, we find that differences in unobserved abilities are more important early in a worker's career.

Keywords: Agglomeration economies, sorting, education, worker experience, job tenure

JEL codes: J24, J31, J61, R12, R23

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[*] We appreciate discussions at the 2012 European Meeting of the Urban Economics Association, the 2012 North American Meeting of the Regional Science Association International, the 2013 Meeting of the Western Regional Science Association, the 2013 Congress of the European Economic Association, the Urban and Regional Economics seminar at LSE, the Labour Economics/Empirical Microeconomics workshop at the Norwegian School of Economics, and at the department seminar at Umeå School of Business and Economics, and comments from Ragnhild Balsvik, Nate Baum-Snow, Paul Cheshire, Jorge De la Roca, Steve Gibbons, Christian Hilber, Ana I. Moreno-Monroy, Jarle Møen, Henry Overman, Kjell Gunnar Salvanes, Olmo Silva, the editor, and two anonymous referees. We are grateful for the cooperation of Statistics Norway. This work was supported by the Research Council of Norway [grant number 255509].

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1. Introduction

The role that college-educated workers play in the productivity of cities has led to a literature dealing with "skilled cities" or "smart cities" (Glaeser and Saiz, 2004; Shapiro, 2006; Combes et al., 2008; Winters, 2011). The observed urban wage premium is partly explained by the urban concentration of college-educated workers. The studies deal with the static agglomeration effect and the methodological challenge of separating sorting from productivity. Recent contributions apply individual panel data and address the importance of the place and type of experience (Glaeser and Mare, 2001; Gould, 2007; Baum-Snow and Pavan, 2012) and derive dynamic agglomeration effects (De la Roca and Puga, 2016; Matano and Naticchioni, 2016). We extend this literature by combining data on experience and education to analyze agglomeration effects and sorting based on unobserved abilities across education groups.

We begin by estimating static and dynamic agglomeration effects for different education groups. City regions with more than 150,000 inhabitants are compared to regions in the rest of the country. Using rich administrative data for Norway for the period 2003–2010 with experience data back to 1993, we find that the initial urban wage premium increases with education level. This is in accordance with the static literature. Our contribution is to study the effects of experience and job tenure across education groups, and we show that college-educated workers have higher return to labor market experience accumulated in cities. The city wage premium of less educated workers is increasing in job tenure, while the college educated gain more from shifting jobs between firms. Furthermore, we address sorting by comparing distributions of worker fixed effects by level of education. The distribution of unobserved abilities is similar in cities and the rest of the country for workers with only primary and secondary education, while the distribution for workers with college education is shifted to the right in cities. Sorting with respect to unobserved abilities matters for college-educated workers, even when taking dynamic learning effects into account. Distinguishing between young and old workers, we find that differences in unobserved abilities are more important early in a worker's career.

Only a limited number of studies of agglomeration effects have individual data on education achievement, and they do not use worker fixed effects to identify the agglomeration effect. The existing analyses basically conclude that static agglomeration effects are higher for those with the highest education level. Wheeler (2001) shows how, in the United States, the effect is increasing with the level of education. Rosenthal and Strange (2008) find that the urban wage premium for workers with college degrees is higher than for other workers. Bacolod et al. (2009) conclude that the effect of population size increases monotonically with education level, although the difference in effect between workers with college and high school degrees is not statistically significant. Exceptions include Adamson et al. (2004), who find a nonlinear relationship between urban wage premium and education level, and Di Addario and Patacchini (2008), who find a negative correlation between return to higher education and regional population size. We consider identification when allowing for worker fixed effects and study how dynamic agglomeration effects vary across education groups.

Recent studies look at the importance of work experience in more detail. The analyses relate to a large empirical labor literature on the returns to experience, seniority, and job tenure, initiated by Topel (1991). Baum-Snow and Pavan (2012) offer model simulations separating between a wage level effect and variation in the return to experience across cities and abilities. They find that for college-educated workers living in large cities, the work experience effect is more important. De la Roca and Puga (2016) use register data from Spain to estimate the urban wage premium with identification based on movers, including the individual history of experience. They find that working in a larger city gives an immediate wage premium that is expanded over time when working in a large city. De la Roca (2011) looks at both initial and return migration. D'Costa and Overman (2014) show that workers with experience in cities have higher wage growth. Matano and Naticchioni (2016), using panel data for Italian workers, find that return to work experience in high-density regions is increasing over the wage distribution.

In addition to spatial sorting with respect to observable characteristics, the recent research also addresses sorting based on unobserved abilities using worker fixed effects. The methodology of testing for shift, dilation, and truncation when comparing distributions of worker fixed effects across locations is developed by Combes et al. (2012a). Combes et al.

(2012b) document sorting with respect to unobserved abilities in a static model, while De la Roca and Puga (2016) argue that sorting disappears when the value of experience is allowed to vary across city sizes. We study the heterogeneity of sorting within different educational categories.

The administrative register data cover hourly wages of the whole working population during 2003 to 2010, and include information about work experience dating back to 1993. We exclude part-time workers and workers in the public and primary sectors, producing a dataset with about 4.1 million worker-year observations in 54 industrial sectors, 350 occupations, 89 labor market regions, and about 140,000 firms. The main analysis focuses on the city wage premium in the largest city labor market regions in Norway, defined as having more than 150,000 inhabitants in 2010 and denoted as "cities". In our analyses we distinguish between Oslo and the six other large cities. Compared to regions outside the largest seven cities, Oslo's raw wage premium is 18.7%—reduced to 10.8% when controlling for observed worker characteristics, and 6.5% when including worker fixed effects. Alternative cutoffs defining cities are investigated, and a separate analysis uses a continuous population density variable. We study how the city wage premium and return to work experience and job tenure in cities depend on education level after controlling for industry, occupation, and unobservable time-invariant worker characteristics.

We find that college-educated workers benefit most from working in cities, and that the extra city wage premium they enjoy over low-educated workers is increasing with city work experience. The combined static and dynamic overall premium in Oslo is 17%, which consists of a static effect of 7% and an experience effect of 10% (at average experience of eight years). Primary-educated workers have a combined premium of 7%, while college-educated workers gain 14% in Oslo. We know of no other studies of the dynamic role of work experience using education data, but our result is consistent with variation across ability levels shown by De la Roca and Puga (2016) and over the wage distribution analyzed by Matano and Naticchioni (2016). We find that the city wage premium of low-educated workers is increasing in job tenure, whereas the premium of college-educated workers is increasing with job shifts. The wage premium for college-educated workers is reduced to 13% in Oslo when we take job tenure into account. Job tenure in cities has a detrimental effect on the wage premium of college-educated workers. The result is in accordance with the analysis of job change for skilled and unskilled workers by Matano and Naticchioni (2016). They identify unskilled workers using percentile of the wage distribution instead of education, and separate between high-density and low-density regions.

We address sorting by comparing distributions of unobserved abilities by level of education. In the aggregate, a static model shows sorting with respect to unobserved abilities consistent with the literature. When we allow the value of experience to differ with city size, we still have sorting, contrary to De la Roca and Puga's findings (2016). The sorting, based on worker fixed effects, is driven by the college educated. The distribution of worker fixed effects is similar in cities and the rest of the country for workers with only primary and secondary education. In an investigation separating between young and old workers, we find sorting only among the young. We begin by reproducing the findings of Combes et al. (2012b) in a static model, and find that sorting is more important in the old worker group. When we control for experience and allow for the value of experience to vary according to city size, the sorting among old workers disappears. Old workers in cities have accumulated more experience, which in turn is more valuable. Our interpretation is that differences in unobserved abilities are more important early in a worker's career.

Many studies of the agglomeration effect use a continuous population density variable, assuming that the effect is linear over an urban scale. Our OLS estimates show an elasticity of about 0.016–0.03, consistent with recent results. The dynamic elasticities increase from 0.026 for primary-educated workers to 0.043 for college-educated workers. Most authors addressing the endogeneity of population density using instrumental variables (IV) conclude that the endogeneity bias is negligible. We apply instruments of population density based on historical mines, as suggested by Leknes (2015). In this case, the IV estimates of density elasticities are somewhat higher than the OLS estimates. The IV-estimated dynamic elasticities vary from 0.041 for primary-educated workers to 0.054 for college-educated workers.

Our analysis extends the empirical evidence about the urban wage premium to a small European country, Norway. Available administrative registers allow for better databases than most studies, in particular for education. Norwegian cities are small by international comparison; the capital, Oslo, has about 600,000 inhabitants. However, the results show that the static city wage premium of Oslo and the six other large cities is comparable to the estimates found in datasets for other countries. D'Costa and Overman (2014) apply a similar cutoff definition of cities for the UK and reach basically the same result. The elasticity of wages with respect to population density has the same magnitude as comparable studies surveyed by Combes and Gobillon (2015).

The rest of the paper is organized as follows: section 2 discusses our econometric strategy and data. The estimates of the static city wage premium across education groups are presented in section 3. Section 4 moves on to dynamic agglomeration effects based on variations in returns to work experience and job tenure across locations. Section 5 deals with sorting on unobserved abilities, while section 6 presents an alternative analysis using a continuous population density variable. Section 7 summarizes our conclusions.

2. Econometric strategy and data

Based on information about commuting flows between municipalities, Statistics Norway divides Norway into 89 travel-to-work areas, denoted "economic regions". The economic regions conform to NUTS-4 regions, as defined by the European Union standard of regional levels. This level of aggregation captures functional regions understood as common labor markets. We define cities as labor market regions with more than 150,000 inhabitants in 2010, and thereby include the seven largest city regions. We separate out Oslo from the six other large cities. Alternative assumptions about the cutoff are shown in a check of robustness. Our definition is consistent with the standard understanding of large cities in Norway.

To identify static and dynamic agglomeration effects, we use data on hourly wages and worker characteristics from 2003–2010, with information on work experience dating back to 1993. The dataset is computed from three administrative registers: employment, tax, and education. The employment register links workers and firms, and gives information on work contracts for all employees. It includes the number of days worked, the type of contract[1], and the exact number of hours worked per week. We calculate the number of hours worked per year, which is combined with data on annual wage income from the tax register to give a measure of hourly wages for all employees. Information about work contracts dating back to 1993 is used to calculate work experience for each worker, using overall experience, experience by type of region (Oslo, the six other large cities, and the rest of the country), and experience in the worker's present firm (job tenure). Job change is measured with a dummy variable that equals 1 if the worker has changed firm affiliation in two consecutive years (without being out of the labor force), excluding job changes due to movement between region types. The education register covers the whole adult population and gives information about the highest completed education level in the beginning of October each year. We also have information on the age, gender, immigrant status, sector affiliation, occupation group, and home region of all individuals.

The original dataset consists of approximately 16.1 million worker-year observations and 2.8 million workers. We exclude workers below 25 years of age and above 65 years of age, totaling about 2.75 million worker-year observations. Since the productivity of resource-based sectors is unrelated to urbanization, we exclude the primary sectors of agriculture, fishing, and forestry. Since their wages are determined by national regulation, public sector workers (including those in public administration, education, and health care) are excluded. This reduces the dataset by about 4.7 million worker-year observations. Due to an incomplete history of work experience, foreign immigrants are also excluded (about 1.35 million observations). We concentrate on workers with full-time contracts (at least 30 hours per week). The tax register gives information on total annual earnings, rather than separate earnings for each work contract. Workers with more than two contracts during a year, as well as workers with one full-time and one part-time contract, are excluded. Workers with two full-time contracts are excluded if the number of days worked that year exceeds 455. This means that we allow for a maximum of three months of overlap between the two contracts. We also exclude workers with fewer than 30 working days during a year. These

[1] The employment register separates between three contract types: full-time contracts with at least 30 hours of work per week, part-time contracts with 20–29 hours of work per week, and part-time contracts with fewer than 20 hours of work per week.

restrictions reduce the dataset by about 1.3 million worker-year observations. Missing data on hours worked, level of education, or occupation group, together with exclusion of workers that changed education group after entering the labor market as full-time employees, further excludes approximately 1.75 million observations. Finally, to avoid extreme observations, we exclude the top and bottom 1% of the wage distribution. The final dataset includes about 500,000 workers every year during the period 2003–2010, giving a total of about 4.1 million worker-year observations in 54 industrial sectors, 350 occupation groups, 89 labor market regions, and about 140,000 firms. Workers can enter and leave the labor market during the eight-year period, and in total about 850,000 different workers are included.

Our main interest is differences across three subgroups of workers according to level of education: college (workers who have completed at least one year at college/university), secondary (workers who have completed at least one year of secondary education), and primary (workers with nothing more than compulsory schooling). About 18% of the workers have only a primary education, while workers with a secondary and college education account for 54% and 28% of the sample, respectively. Geographically, Oslo has 13% of the workers, the six other large cities 32%, and the rest of the country 55%. Cities have a higher share of college-educated workers (Oslo 52%, the six other large cities 32%, and the rest of the country 20%).

Table 1 shows descriptive statistics for hourly wages, work experience, job tenure, and job change across city size and education groups. The average worker in our dataset has an hourly wage of 289 NOK in constant 2010 prices (log 5.58) and has 8.1 years of work experience. The average job tenure is 4.4 years, and 7.3% of the worker-year observations indicate a job change. Among the 850,000 workers, 72% remain in the same firm from 2003–2010, while 21% and 5% change jobs once and twice, respectively, during the eight-year period. The raw wage differences for all workers show that Oslo and the six other large cities have higher wages than the rest of the country (19% and 13%, respectively, approximated by log differences). Wages of primary educated and secondary educated are, respectively, 40% and 27% below wages of college educated. Interestingly, college-educated workers in Oslo are not at the top; they have somewhat lower wages than college-educated workers in the other large cities. The high wages of the "oil capital", Stavanger, contributes to the high wages of the six other large cities. As discussed below, lower wages among college educated in Oslo may reflect a larger share of younger workers and women than in other cities.

Length of work experience is shorter in Oslo compared to the rest of the country, particularly among the college educated. This is related to the amount of time spent in university, as well as the number of young workers in the city. Accordingly, job tenure is longer outside cities, and college-educated workers have shorter tenure. Job changes are more frequent in larger cities and among the college educated. Twenty-five percent of workers with a primary education changed jobs at least once during the 2003–2010 period, compared to 29% of college-educated workers. This is analyzed in more detail by Leknes (2016).

Table 1 here

We begin with a hedonic regression of hourly wages for the period 2003–2010 that controls for observable worker characteristics, and includes sector, year, occupation, and worker fixed effects:

$$\ln w_{isot} = \alpha_1 \cdot city_{1,it} + \alpha_2 \cdot city_{2,it} + \mu_s + \varphi_o + \gamma_t + \eta_i + X_{it}\beta + \varepsilon_{isot} \qquad (1)$$

where w_{isot} is the hourly wage income for worker *i* in sector *s*, occupation *o*, and year *t*, and $city_{1,it}$ and $city_{2,it}$ are dummies for Oslo and the six other large cities respectively, with α_1 and α_2 as the corresponding city wage premiums. Sector, occupation, worker, and year fixed effects are represented by μ_s, φ_o, η_i and γ_t, respectively. The vector of observable worker characteristics (X_{it}) includes dummies for age (five-year intervals), as well as aggregate work experience since 1993 (calculated in days and expressed in years). β is a vector of parameters and ε_{isot} is an error term.

The city wage premiums $(\alpha_1$ and $\alpha_2)$ represent a mix of static and dynamic effects of working in cities. We allow the value of both work experience and job tenure to vary between Oslo, the six other large cities, and the rest of the country:

$$\ln w_{isot} = \alpha_1 \cdot city_{1,it} + \alpha_2 \cdot city_{2,it} + \mu_s + \varphi_o + \gamma_t + \eta_i + X_{it}\beta + \delta_1 \cdot \exp\_c_{1,it} + \delta_2 \cdot \exp\_c_{2,it}$$
$$+\delta_3 \cdot ten_{it} + \delta_4 \cdot ten_{it} \cdot city_{1,it} + \delta_5 \cdot ten_{it} \cdot city_{2,it} + \varepsilon_{isot} \qquad (2)$$

where $\exp\_c_{1,it}$ and $\exp\_c_{2,it}$ are work experience acquired by worker *i* up until time *t* in Oslo and the six other large cities, respectively, and ten_{it} represents years of experience in the worker's present firm.[2] If $\delta_1 > 0$, work experience in Oslo is more valuable than in the rest of the country, while returns on job tenure are higher in Oslo than in the rest of the country if $\delta_4 > 0$. Similar effects for the six other large cities are captured by δ_2 and δ_5. The immediate static city wage premiums are given by the estimated coefficients on the city dummies $(\alpha_1$ and $\alpha_2)$, while the wage premium after τ_1 years of work experience and τ_2 years in the present firm will be $\alpha_1 + \delta_1 \tau_1 + \delta_4 \tau_2$ and $\alpha_2 + \delta_2 \tau_1 + \delta_5 \tau_2$ for Oslo and the six other large cities, respectively.

3. Static city wage premium across education groups

Since most of the literature estimates static agglomeration effects, we start by estimating the static effect in order to compare Norway relative to other countries. The raw urban wage premium of Oslo is 18.7%, while the six other large cities have an average premium of 12.7%, shown in column 1 of Table 2. The rest of the country serves as a reference group. In a dataset for the UK, D'Costa and Overman (2014) find a raw urban wage premium of 14%. Their definition of city region is 100,000 inhabitants in a travel-to-work area, somewhat lower than the 150,000 cutoff chosen here. The estimated city wage gaps in the literature vary with city size structures, as expected.

[2] The regression also includes quadratic experience and tenure terms.

To control for observed heterogeneity, we run an individual-level regression over the whole sample, including all worker characteristics, as well as year, sector, and occupation fixed effects, but without worker fixed effects. The city effect is reduced to 10.8% for Oslo and 6.5% for the six other large cities, as seen in column 2. The education wage gap is about 6% from primary to secondary education and 18% from primary to college education. The male wage advantage is 14%. Experience matters, and the effect is non-linear. Wages increase with experience for the first 20 years, and one extra year of experience adds 1% to wages calculated at average experience (8.1 years).

The importance of unobserved characteristics has been a source of concern, and only a few studies have been able to follow movers between regions to control for the ability factor. The regression in column 3 includes worker fixed effects (as described by equation (1) in section 2). The city effect is 6.5% for Oslo and 4.5% for the six other large cities, when observable and unobservable worker characteristics are taken into account. It follows that about two-thirds of the city wage gap is accounted for by observable and unobservable worker characteristics. The result is similar to that found by Bütikofer et al. (2014) using a longer dataset for Norway. In the worker fixed effect regression, the effect of a year of experience increases to 6% (starting from the average number of years of experience, 8.1 years). The change in the experience coefficient when we introduce worker fixed effects indicates a negative correlation between ability and experience; ability matters more for the young. While the comparable city effect of D'Costa and Overman (2014) controlling for sorting is 2.3%, their controls are different and they do not include experience variables. Gould (2007) finds a somewhat lower reduction of the wage premium for white-collar workers, but a larger one for blue-collar workers. Glaeser and Mare (2001) produce worker fixed effect estimates that are about one-third of the raw wage gap.

Table 2 here

Our main interest is the separate city effects for each education group. When controlling for observed heterogeneity (columns 1–3, Table 3), the city wage effect for Oslo increases from 7.2% for primary-educated workers to 14% for workers with a college education, while the effect for the six other large cities varies from 4.4% for primary-educated workers to 9% for the college educated. When also controlling for unobservable characteristics of workers (columns 4–6, Table 3), the city effects are still increasing with education level, from 4.5% to 7.6% in Oslo and from 3% to 5.1% in the six other large cities. Hence, consistent with most American studies as well as the Swedish study by Andersson et al. (2014), we find that the city effect is increasing with education level. This result survives when worker fixed effects are included, although educational differences become smaller.

We calculate the importance of observable and unobservable factors in Oslo compared to the rest of the country (excluding the six large cities). Among primary-educated workers, the raw Oslo wage premium is 9.6%, and this is reduced to 7.2% when observable characteristics are taken into account (column 1)—and further to 4.5% when worker fixed effects are included (column 4). It follows that observable characteristics explain 25% of the raw premium, and that 28% are due to differences in unobservables. College-educated workers in Oslo have a raw premium of 10.5%. This premium increases to 14% when observables are included (column 3), including experience, sector composition, occupation, age, and gender. Observable characteristics of the workers cannot explain the wage premium in Oslo, and one would expect a lower wage premium given the large share of young workers and women and a large service industry. When worker fixed effects are included (column 6), the Oslo wage premium is reduced to 7.6%. Unobservables explain 61% of the raw wage gap. Unobservable characteristics are more important for the college educated, and the distribution of unobserved abilities is investigated further in section 5. More of the wage premium is explained by observables for the six other large cities, in particular since we capture the oil sector effect. The effects of observables and unobservables are roughly equal for all education groups.

Table 3 here

4. Dynamic agglomeration effects across education groups

The dynamics of agglomeration are related to the accumulation of experience. Our contribution is to analyze the dynamic effect for different education groups and to study the interaction between education level and job tenure. We have data for experience, job tenure, and job change. The three factors are clearly related and cannot be studied together. We have investigated various model specifications and report the inclusion of experience and job tenure below. The estimates of an alternative model including experience and job change are available from the authors.[3] It should be noted that while identification based on movers is important for the static agglomeration effect, in the estimation of the dynamic agglomeration effect based on experience and job tenure, we apply all observations. It follows that the effect of movers is a level effect across education groups, and it is less important for our analysis of experience and tenure comparing city regions and the rest of the country.

We allow the value of experience and job tenure to vary between cities and other regions in Table 4, based on equation (2) in section 2. For all workers (column 1, Table 4), the initial/static city effect is 7% in Oslo and 4.5% in the six other large cities, about the same as the estimated city effects without controlling for city experience or job tenure (see column 3, Table 2). The effects of experience and job tenure are both non-linear; experience is inverse U-shaped and job tenure is U-shaped in all regions and for all education groups. The effect of having experience from cities is of economic importance, and given the average experience of 8.1 years for all workers in all regions, the dynamic effect adds much to the Oslo wage premium. The total Oslo effect is about 17%, consisting of a static effect of 7% and an experience effect of 10% over the average eight years of work experience. In the six other large cities, the total effect is 10%, up from a static effect of 4.5%. For all city regions, the dynamic effect counts for 60% of the total urban wage premium. The result of this basic model is consistent with De la Roca and Puga's study (2016), where about half the total effect is accounted for by the dynamic element. In the aggregate, the return to job tenure is basically similar across regions, but has important variation across education groups, as shown below.

Table 4 here

[3] A set of tables describing alternative model specifications is available as an external online appendix: https://sites.google.com/site/hildegunnestokke/.

Columns 2–4 of Table 4 present separate results by education groups. The effect of city experience on wages is positive and increasing with education level. The estimated models are reformulated to test for the statistical significance of the differences across education groups. We find that the differences between primary- and college-educated workers and between secondary- and college-educated workers are statistically significant at the 1% level for all city effects (city premium, experience, and job tenure) (see external online appendix). While we do not know of other studies by education groups, this finding can be related to the use of worker fixed effects as measure of skills by De la Roca and Puga (2016). The interaction between job tenure and the city dummies is significantly positive for primary-educated workers and significantly negative for workers with a college education. Hence, working in cities makes experience in the same firm more valuable for workers without a college education, and less valuable for workers with a college education. Though the difference of the job tenure effect for primary- and college-educated workers has not been shown in the literature, Matano and Natacchioni (2016) show similar differences between the top and the bottom of the wage distribution for job change and separating between high- and low-density regions.

The static Oslo city wage premium is 4% for primary-educated workers, increasing to a dynamic effect of 7% when the experience effect in Oslo is added, and to 8.4% when job tenure in Oslo is included (all calculated at average years of experience and tenure for all workers). Although both experience and tenure add to the wage premium of primary-educated workers, experience is more important. For the college educated, the static premium is 8.2% and the dynamic effect increases to 14% when taking the more valuable experience in Oslo into account. When we allow the value of job tenure to vary across regions, the wage premium for the college educated in Oslo is reduced to 13%. Job tenure in cities is to the disadvantage of the college educated. This result is confirmed in an analysis of experience and job change, where we show that job change is to the advantage of college-educated workers in cities (available as external online appendix).

A consequence of the findings above is that the city wage premium trajectories depend on job tenure. Figure 1 shows the trajectories of the Oslo city wage premium for primary- and college-educated workers during the first 10 years after moving to the capital. We study two situations: workers with no job change during the 10-year period and workers with two job changes, after two years and five years, respectively. In the first situation, the Oslo city premium of primary-educated workers starts at 4% (the static city effect) and increases gradually to 8.5% after 10 years, whereas the Oslo city premium of workers with a college education increases from 8.2% to 13% (calculated based on the estimated coefficients of experience and tenure in Oslo, shown in Table 4). The return to experience is higher for the college educated, but in this alternative without job changes, the accumulated tenure works in the opposite direction. Hence, the difference between primary- and college-educated workers is about constant over time. In the second situation with two job changes during the 10-year period, the difference between primary- and college-educated workers increases over time, as shown by the dotted lines in Figure 1. The college educated gain from job changes, while the primary educated lose compared to prolonged job tenure.

Figure 1 here

We have chosen to estimate the city agglomeration effect distinguishing between Oslo and the six other large city regions in Norway (above 150,000 inhabitants). We investigate the robustness of this definition by introducing a cutoff population size of 100,000 and distinguishing between Oslo and twelve other cities. As expected, the Oslo wage premium is higher when the comparison is regions with fewer than 100,000 inhabitants. The main difference compared to a cutoff of 150,000 inhabitants (Table 4) is that the return to experience in cities outside Oslo is no longer increasing with education level. Our interpretation is that the higher return to experience for college-educated workers requires larger cities. Similarly, the different job tenure effects across education groups are reduced when we expand the set of cities. In an alternative with a city cutoff of 65,000 inhabitants and including a separate group of small cities (between 65,000 and 150,000 inhabitants), we find no extra gain of having experience in small cities for any of the education groups (see external online appendix).

A limitation of our analysis is that we only have worker experience data dating back to 1993, which is not the full history of worker experience for many workers. The analysis is repeated for a sample of workers for whom we have a full history of experience (workers born after 1967), which is presented in Appendix Table A.1. The main results regarding the higher return to experience in cities and increasing return to experience with education remain. The same applies to the result that job tenure is to the advantage of the primary-educated workers, while the college-educated benefit from job changes. The effects of experience and job tenure differ more across education groups in this sample of young workers. The effect of experience may be underestimated when all workers are included (Table 4) due to measurement error, but the differences may also follow from stronger effects early in a worker's career. Similarly, the effects of job change in cities are stronger when we concentrate on young workers with a full history of experience (see external online appendix).

Many studies concentrate on male workers, as women have a different relationship with the labor market. Although we have run the regressions of Table 4 excluding women, the results are the same as those reported above (see external online appendix).

A concern regarding the estimation of city size effects is the role of amenities motivating migration. Four types of amenities are extensively studied in the literature: school quality, cultural services, crime, and climate. We check the robustness of the results with respect to a set of amenity variables. The measure of school quality is based on Borge and Naper (2006). They estimate municipal fixed effects based on individual data of student achievement in English and with other relevant controls. The weighted municipal effects are aggregated to regional school quality. Cultural amenities are measured as net per capita regional spending on museums in the year 2010. Public safety is measured by the number of violent crimes per 1,000 inhabitants and as an average over the period 1994–2001. Finally, climate is represented by the average January temperature from 1994–2002. The amenity variables are measured at the regional level and cover all 89 labor market regions. The estimates of the city agglomeration effect, including the amenity variables, are presented in the external online appendix. The main difference in the estimates is a higher initial wage premium for Oslo. It follows that the dynamic wage premium for Oslo also increases. This finding is consistent with the migration equilibrium model, where workers are willing to give up earnings in order to have access to urban amenities. The effect is the same for workers born after 1967 as for workers born in 1967 or earlier. The wage premium of the six other large cities is not affected. The differences across education groups regarding experience and job tenure effects remain.

5. Sorting on unobservable abilities within education groups

We have shown above how workers are sorted based on observables, notably the differences with respect to education level. The college educated concentrate in cities. The next issue is spatial sorting on unobservables, in particular for different education groups. We use the estimated worker fixed effects from the wage regressions of Table 4 as a proxy of unobserved abilities. The analysis covers 850,000 different workers. The fixed effect of each worker is related to the region where the worker lived in 2010 or the last year available in the dataset. We compare distributions of unobserved abilities between cities (Oslo and the six other large cities) and the rest of the country using the methodology developed by Combes et al. (2012a). The distribution of worker fixed effects in cities is approximated by taking the distribution of worker fixed effects in the rest of the country, shifting it by an amount *A*, and dilating it by a factor *D*.[4] Table 5 reports estimated values of shift and dilation in different specifications.

We first consider the raw wage differences between cities and the rest of the country, given in the first row in panel A. The shift parameter is 13.6% and the dilation parameter is significantly higher than 1, which implies higher average wages and more dispersed wages in city regions. Comparing worker fixed effects estimated from a static model, the shift parameter equals 7.7%, indicating spatial sorting on average abilities over time (second row in panel A).[5] This is in accordance with Combes et al. (2012b) and De la Roca and Puga (2016). In a dynamic specification where the return to experience and job tenure are allowed to differ in cities and the rest of the country, the estimated worker fixed effects represent an unobserved ability when entering the labor market. As seen from the third row in panel A, the distribution of worker fixed effects from the dynamic model differs between

[4] We have tested for truncation in the comparison of two distributions, but it does not have any significant importance and is thus ignored in the analysis.

[5] To allow for comparison with the findings in Combes et al. (2012b), the static model is specified with age, sector affiliation, city dummies, and year fixed effects as the only controls.

cities and the rest of the country; the city region distribution is 4% to the right of the rest. This is in contrast to De la Roca and Puga's findings (2016); they conclude that there is no sorting when including homogenous or heterogeneous dynamic effects. We find significant differences in abilities across regions upon entering the labor market, and these come in addition to the experience effect in cities.

Table 5 here

Our contribution is to analyze the distributions of estimated worker fixed effects across education groups. In panel B, the estimated shifts and dilations of the distributions are shown for each of the education categories. For primary- and secondary-educated workers, the distributions are similar; there is no significant shift when comparing cities and the rest of the country. For the college educated, the distribution of unobserved abilities in cities is shifted 5% to the right compared to the rest of the country. The sorting based on worker fixed effects is driven by college-educated workers. Aggregate studies miss this heterogeneity. We show the comparison of worker fixed effects distributions between cities and other regions for the three education groups in Figure 2. As seen, the distributions for cities and the rest of the country are similar for primary-educated and secondary-educated workers, while the distribution for college-educated workers is shifted to the right for city regions. The larger dispersion in city regions observed for all workers disappears when we consider each education category (the estimated dilation parameters are not significantly different from 1). The observed heterogeneity with respect to education explains the higher dispersion in cities for all workers.

Figure 2 here

The effects discussed above may reflect generational effects or career development. We distinguish between young (those under 35 years of age) and old workers (those above 45 years of age). The age cutoff refers to the average age of the worker when included in the sample.[6] The results are documented in panel C of Table 5. We begin by reproducing, in a static model, the findings of Combes et al. (2012b) that sorting is more important in the old worker group. This is shown in the first and the second rows of panel C. There is a significant shift in the distributions between cities and the rest of the country for both young and old workers, but the shift is larger for the old workers (9.4% compared to 5.2% for the young). When we control for experience and job tenure and allow the value of experience and tenure to vary according to city size, the sorting among old workers disappears (comparing the third and fourth rows of panel C). This follows from old workers in cities having more experience and higher return to experience compared to old workers in the rest of the country. Our understanding is that differences in unobserved abilities are more important early in a worker's career. It should be noted that Combes et al. (2012b) estimate a fixed effect for average ability over time. We find that sorting matters for ability upon entering the labor market. The dilation parameter in the second column is significantly higher than 1 for old workers in both the static and the dynamic specification. The wage dispersion for old workers is larger in cities compared to the rest of the country.

6. Continuous population density

Some of the agglomeration literature—notably Ciccone and Hall (1996), Combes et al. (2008), and Mion and Naticchioni (2009)—studies the agglomeration effects using a continuous population density variable. These analyses have been concerned with the endogeneity of population density following Ciccone and Hall (1996), who introduced instrument variables based on historical population numbers. In addition to reverse causality, the IV strategy also addresses omitted variable problems. Lagged values of population density can be affected by permanent characteristics, and therefore influence present productivity. Recent studies have looked for alternative instruments. Geological characteristics are introduced by Combes et al. (2008), assuming that such characteristics influenced early agricultural production and human settlement without affecting the productivity of modern industries. We follow this IV strategy, but avoid instruments based

[6] The use of average age during the period studied introduces some noise in the estimates, but this is reduced by the fact that we have a 10-year gap between young and old workers. Despite this measurement error, we find significant differences between large and small cities.

on historical population data. We include natural characteristics as controls and use historical mines as instruments, as suggested by Leknes (2015). The spatial distribution of mineral resources predicts future population densities.

In Norway, the population size and population density of regions are strongly correlated, and we apply the population density variable to compare with the literature. We handle static and dynamic agglomeration effects as above, calculating the dynamic effect based on average years of experience and job tenure. The initial regional premium is estimated in individual regressions, including regional fixed effects for 89 labor market regions. The estimates are reported in Appendix Table A.2. As seen, the differences across education groups for work experience and job tenure in cities are consistent with the findings in Table 4. To calculate the medium-term premium, we add the wage effect of the average worker experience and job tenure in a region to the static wage premium. The learning effect is allowed to differ between Oslo, the six other large cities, and the rest of the country.

The identification of the agglomeration effect is based on a two-step approach, whereby the regional wage measures (initial and medium-term) are regressed on regional population density in the second step. Controls for regional area (in square kilometers) and several natural characteristics (mountain area share, slope, January temperature, wind speed, precipitation, and coastal length) are included in the model.[7] We concentrate on variation in urban density and drop the rural regions. The dataset covers 68 regions with more than 15,000 inhabitants. In the aggregate, the static and dynamic density elasticities equal 0.03 and 0.048 respectively, consistent with the literature as summarized by Combes and Gobillon (2015). We report OLS estimates across education groups in panel A of Table 6. The differences between education groups are similar to our analysis of city effects in Table 4, with the dynamic elasticities increasing from an elasticity of 0.026 for primary-educated workers to 0.043 for college-educated workers.

The first-stage effects of the instruments are shown in panel B of Table 6. Current regional population density is instrumented by the number of mines that operated in each region in

[7] Further descriptions of the natural regional characteristics are given in Leknes (2015).

the 12th to the 19th centuries. We also include two proxies for pre-mining regional population size as instruments: the number of graves from the early Iron Age (500 B.C.–500 A.D.) and the number of hoards with deposited noble metal artifacts (800–1100 A.D.). Historical mines, noble metal deposits, and Iron Age graves all have a statistically significant effect on the present population density. The *F*-statistic is about 28, well above the rule of thumb for weak instruments in the test suggested by Stock and Yogo (2005). The LM test with a null hypothesis of underidentification gives a clear rejection, with a p-value of 0.001. The Hansen J test checks the exogeneity of the instruments. The null hypothesis that instruments are uncorrelated with the error term is not rejected, with p-values well above 0.10. It follows that the instruments are valid. Though the test for exogenous population density gives somewhat varying results, exogeneity is not rejected at the 5% level for secondary- and college-educated workers.

Table 6 here

The IV estimates of the population density effect are reported in panel C of Table 6. The IV estimates of the density elasticity are somewhat higher overall and indicate a negative OLS bias. Most studies using historical population data as instruments conclude that there is no OLS bias. The literature has mostly been concerned with a possible upward bias due to endogeneity (migration responding to wages). Underestimation may result from omitted variables correlated with population density. Indeed, various mechanisms may be at work. In a migration equilibrium setting, amenities positively correlated with density may have negative effect on wages. Combes and Gobillon (2015) discuss the possibility that amenities attract workers and have a negative effect on labor productivity via higher land prices and factor substitution.

Although the density elasticities are still increasing with education level, the differences between the three education groups are smaller and not statistically significant. The IV-estimated dynamic elasticities vary from 0.041 for primary-educated workers to 0.054 for college-educated workers. Our interpretation is that the difference across education groups is not captured well with a continuous density variable. We have shown above that the experience effect does not differ between education groups when we use a city cutoff of

100,000 inhabitants. The differences between education groups are only important in larger cities. The effects are not linear in population density, as assumed in this type of analysis.

7. Concluding remarks

We have used register data for all full-time workers in the private sector in Norway (about 4.1 million worker-year observations) to study the city wage premium. Cities are defined as regions with more than 150,000 inhabitants. The individual panel data include observations of education levels and occupations, as well as labor market, employment sector, and firm level affiliation. The panel allows for the estimation of unobserved worker effects and identification of the city wage premium based on migration between regions. The main focus is the analysis of differences in city effects for wages across education groups, taking work experience into account.

The analysis includes the location and firm-specific work experience of the workers. Experience is distinguished between cities and the rest of the country. While the initial static wage premium is not affected by the inclusion of worker experience history, the experience effect adds to the medium-term wage effect, since experience in city regions is found to be more valuable. We show that the experience effect differs with respect to education; in particular, the college educated gain more from agglomeration. Job tenure in cities is found to be to the advantage of primary-educated workers, while college-educated workers, especially young workers, benefit from shifting between firms.

Furthermore, we address sorting on unobserved ability within education groups by comparing distributions of estimated worker fixed effects between cities and other regions. The distribution of unobserved abilities is similar in cities and the rest of the country for workers with only a primary or secondary education, while the distribution for workers with a college education is shifted to the right in cities. Sorting based on unobserved abilities matters for college-educated workers, even when taking dynamic learning effects into account. Distinguishing between young and old workers, we find that differences in unobserved abilities are more important early in a worker’s career.

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Table 1
Descriptive statistics

	All regions	Oslo	Six other large cities	Rest of country
Mean log hourly wages (in 2010 NOK)				
All workers	5.581	5.704	5.644	5.517
Primary-educated workers	5.405	5.474	5.444	5.378
Secondary-educated workers	5.531	5.599	5.582	5.496
College-educated workers	5.796	5.827	5.853	5.724
Work experience (in years)				
All workers	8.1	7.3	8.3	8.2
Primary-educated workers	8.0	7.6	8.2	7.9
Secondary-educated workers	8.4	8.0	8.5	8.4
College-educated workers	7.7	6.8	8.0	7.9
Job tenure (in years)				
All workers	4.4	3.6	4.4	4.6
Primary-educated workers	4.5	4.0	4.5	4.6
Secondary-educated workers	4.7	4.1	4.7	4.8
College-educated workers	3.7	3.2	3.8	4.0
Job change (share)				
All workers	0.073	0.081	0.075	0.07
Primary-educated workers	0.07	0.07	0.072	0.068
Secondary-educated workers	0.072	0.077	0.074	0.07
College-educated workers	0.077	0.086	0.078	0.072

Notes: We separate between the largest city Oslo, the next six large cities, and the rest of the country. Work experience and job tenure are calculated based on actual days worked from 1993 onwards (overall and at the worker’s present firm), expressed in years. Job change is a dummy that equals one if the worker has changed firm affiliation (without being out of the labor market), excluding job changes due to movements across region types (Oslo, six other large cities, rest of country).

Table 2
Estimation of static urban wage premium

Dependent variable	(1) Log hourly wage	(2) Log hourly wage	(3) Log hourly wage
Oslo	0.187***	0.108***	0.065***
	(0.0013)	(0.001)	(0.0018)
Six other large cities	0.127***	0.065***	0.045***
	(0.0009)	(0.0006)	(0.0017)
Experience		0.016***	0.074***
		(0.0002)	(0.0008)
$(\text{Experience})^2$		-0.0004***	-0.0007***
		(0.0000)	(0.0000)
Secondary education		0.057***	
		(0.0008)	
College education		0.184***	
		(0.0011)	
Male		0.144***	
		(0.0008)	
Year fixed effects	Yes	Yes	Yes
Sector fixed effects	No	Yes	Yes
Occupation fixed effects	No	Yes	Yes
Age controls	No	Yes	Yes
Worker fixed effects	No	No	Yes
Observations	4,131,194	4,131,194	4,131,194
Workers	850,412	850,412	850,412
R^2	0.10	0.44	0.82

Notes: The regressions are based on yearly data for all full-time workers in the private sector during 2003-2010. Sector fixed effects are at the two-digit level and include 54 sectors. Occupation fixed effects are at the four-digit level and include 350 occupations. The age controls are given as five-year intervals. Robust standard errors (clustered by workers) are given in parenthesis. *** indicates significance at the 1 percent level. All regressions include a constant term.

Table 3

Estimation of static urban wage premium by education group

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Log hourly wage	Log hourly wage	Log hourly wage	Log hourly wage	Log hourly wage	Log hourly wage
Education group	Primary	Secondary	College	Primary	Secondary	College
Oslo	0.072***	0.099***	0.14***	0.045***	0.05***	0.076***
	(0.0026)	(0.0015)	(0.0015)	(0.0059)	(0.003)	(0.0024)
Six other large cities	0.044***	0.06***	0.09***	0.03***	0.037***	0.051***
	(0.0014)	(0.0008)	(0.0014)	(0.005)	(0.0026)	(0.0026)
Experience	0.01***	0.01***	0.027***	0.062***	0.066***	0.094***
	(0.0005)	(0.0003)	(0.0005)	(0.0017)	(0.001)	(0.0015)
$(\text{Experience})^2$	-0.0001***	-0.0001***	-0.0007***	-0.0005***	-0.0005***	-0.0012***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Male	0.138***	0.151***	0.127***			
	(0.0018)	(0.0011)	(0.0013)			
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Occupation fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Age controls	Yes	Yes	Yes	Yes	Yes	Yes
Worker fixed effects	No	No	No	Yes	Yes	Yes
Observations	742,262	2,249,737	1,139,195	742,262	2,249,737	1,139,195
Workers	165,741	447,692	236,979	165,741	447,692	236,979
R^2	0.30	0.38	0.41	0.75	0.80	0.83

Notes: Explanatory variables are defined in the notes to Table 2. Robust standard errors (clustered by worker) are given in parenthesis. *** indicates significance at the 1 percent level. All regressions include a constant term.

Table 4

Estimation of urban wage premium, including experience and tenure by type of region

	(1)	(2)	(3)	(4)
Dependent variable	Log hourly wage	Log hourly wage	Log hourly wage	Log hourly wage
Education group	All	Primary	Secondary	College
Oslo	0.07***	0.04***	0.049***	0.082***
	(0.002)	(0.0068)	(0.0034)	(0.0028)
Six other large cities	0.045***	0.026***	0.036***	0.055***
	(0.0019)	(0.0053)	(0.0028)	(0.0028)
Experience	0.073***	0.068***	0.069***	0.091***
	(0.0008)	(0.0019)	(0.0011)	(0.0016)
$(\text{Experience})^2$	-0.0006***	-0.0006***	-0.0005***	-0.0011***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Experience in Oslo	0.021***	0.007***	0.008***	0.013***
	(0.0006)	(0.002)	(0.001)	(0.0009)
$(\text{Experience in Oslo})^2$	-0.001***	-0.0004***	-0.0005***	-0.0007***
	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Experience six other large cities	0.009***	0.003***	0.004***	0.009***
	(0.0005)	(0.0012)	(0.0006)	(0.0008)
$(\text{Experience six other large cities})^2$	-0.0003***	-0.0000	-0.0001**	-0.0002***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Job tenure	-0.003***	-0.006***	-0.004***	-0.001**
	(0.0002)	(0.0005)	(0.0003)	(0.0004)
$(\text{Job tenure})^2$	0.0001***	0.0001***	0.0001***	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Job tenure x Oslo	-0.000	0.003**	0.000	-0.003***
	(0.0005)	(0.0015)	(0.0007)	(0.0007)
$(\text{Job tenure})^2$ x Oslo	0.0000	-0.0001	0.0000	0.0001**
	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Job tenure x Six other large cities	0.001**	0.003***	0.001***	-0.002**
	(0.0003)	(0.0008)	(0.0004)	(0.0006)
$(\text{Job tenure})^2$ x Six other large cities	-0.0000*	-0.0001**	-0.0001*	0.0001
	(0.0000)	(0.0001)	(0.0000)	(0.0001)
Year fixed effects	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes
Occupation fixed effects	Yes	Yes	Yes	Yes
Age controls	Yes	Yes	Yes	Yes
Worker fixed effects	Yes	Yes	Yes	Yes
Observations	4,131,194	742,262	2,249,737	1,139,195
Workers	850,412	165,741	447,692	236,979
R^2	0.82	0.75	0.80	0.83

Notes: Experience in cities refers to work experience accumulated in the respective city group (the largest city Oslo or the six other large cities). Other explanatory variables are defined in the notes to Table 2. Robust standard errors (clustered by worker) are given in parenthesis. ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. All regressions include a constant term.

Table 5

Comparison of hourly wages and worker fixed effects distributions, seven largest cities vs. rest of country

	Shift ($\hat{A}$)	Dilation ($\hat{D}$)	R^2	Obs.
Panel A: Aggregate				
Log hourly wages	0.136***	1.064***	0.984	850,412
	(0.0037)	(0.0088)		
Worker FE, static premium	0.077***	1.068***	0.946	850,412
(specification as in Combes et al., 2012b)	(0.0069)	(0.0096)		
Worker FE, static and dynamic premium	0.04***	1.036***	0.809	850,412
(Table 4, column (1))	(0.0085)	(0.0099)		
Panel B: Across education groups				
Primary: Worker FE, static and dynamic premium	-0.001	0.997	0.045	165,741
(Table 4, column (2))	(0.0278)	(0.0225)		
Secondary: Worker FE, static and dynamic premium	0.013	0.999	0.859	447,692
(Table 4, column (3))	(0.0152)	(0.0121)		
College: Worker FE, static and dynamic premium	0.054***	0.985	0.887	236,979
(Table 4, column (4))	(0.0132)	(0.016)		
Panel C: Early vs. late in the career (aggregate)				
Young workers, below 35, static premium	0.052***	1.012	0.962	289,242
(specification as in Combes et al., 2012b)	(0.008)	(0.0179)		
Old workers, above 45, static premium	0.094***	1.088***	0.927	311,756
(specification as in Combes et al., 2012b)	(0.0084)	(0.0158)		
Young workers, below 35, static and dynamic premium	0.033***	0.984	0.922	289,242
	(0.0096)	(0.018)		
Old workers, above 45, static and dynamic premium	0.003	1.054***	0.705	311,756
	(0.0035)	(0.0163)		

Notes: The distribution of worker fixed effects in the seven largest cities is approximated by taking the distribution of worker fixed effects in the rest of the country, shifting it by an amount *A* and dilating it by a factor *D*. We estimate $\hat{A}$ and $\hat{D}$ both aggregate, within education groups, and within age groups. Bootstrapped standard errors are given in parenthesis (re-estimating worker fixed effects in 100 bootstrapped iterations based on 5% random samples with replacement). The methodology is developed and explained by Combes et al. (2012a). *** indicates significance at the 1 percent level (significantly different from 0 for $\hat{A}$ and from 1 for $\hat{D}$).

Table 6

Estimation of urban wage premium – continuous density variable

Panel A: OLS estimation

Dependent variable	Initial premium (regional indicator coefficients)			Medium-term premium (initial + mean years of experience and tenure)		
Education group	Primary	Secondary	College	Primary	Secondary	College
	(1)	(2)	(3)	(4)	(5)	(6)
Log population density	0.016***	0.03***	0.03***	0.026***	0.038***	0.043***
	(0.0047)	(0.0047)	(0.004)	(0.0049)	(0.0046)	(0.0052)
Log area	-0.01	0.009	0.003	-0.000	0.017*	0.016
	(0.0099)	(0.0087)	(0.0074)	(0.01)	(0.0086)	(0.0096)
Natural characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	68	68	68	68	68	68
R^2	0.65	0.69	0.75	0.70	0.75	0.78

Panel B: First stage IV estimation

Dependent variable	Log population density
Historical mines	0.2***
	(0.0538)
Noble metal deposits	0.144***
	(0.0367)
Iron Age graves	0.007***
	(0.0018)
Log area	-1.443***
	(0.1584)
Natural characteristics	Yes
Observations	68
R^2	0.83

Panel C: Second stage IV estimations

Dependent variable	Initial premium			Medium-term premium		
Education group	Primary	Secondary	College	Primary	Secondary	College
	(1)	(2)	(3)	(4)	(5)	(6)
Instrumented log population density	0.03***	0.038***	0.039***	0.041***	0.048***	0.054***
	(0.0076)	(0.0074)	(0.0064)	(0.0077)	(0.0076)	(0.0083)
Log area	0.008	0.019*	0.014	0.019	0.03***	0.031***
	(0.0122)	(0.0104)	(0.0093)	(0.012)	(0.0104)	(0.0122)
Natural characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	68	68	68	68	68	68
R^2	0.62	0.68	0.73	0.66	0.73	0.76
F-test weak identification	28.7	28.7	28.7	28.7	28.7	28.7
P-value LM test underident.	0.001	0.001	0.001	0.001	0.001	0.001
P-value Hansen J-test	0.209	0.464	0.165	0.837	0.503	0.134
P-value endogeneity test	0.022	0.151	0.052	0.023	0.113	0.075

Notes: The OLS, first stage and second stage regressions include the following regional natural characteristics: mountain area share, slope, January temperature, wind speed, precipitation, and coastal length.

Fig 1: Urban wage premium trajectories for primary- and college-educated workers, years after move to Oslo

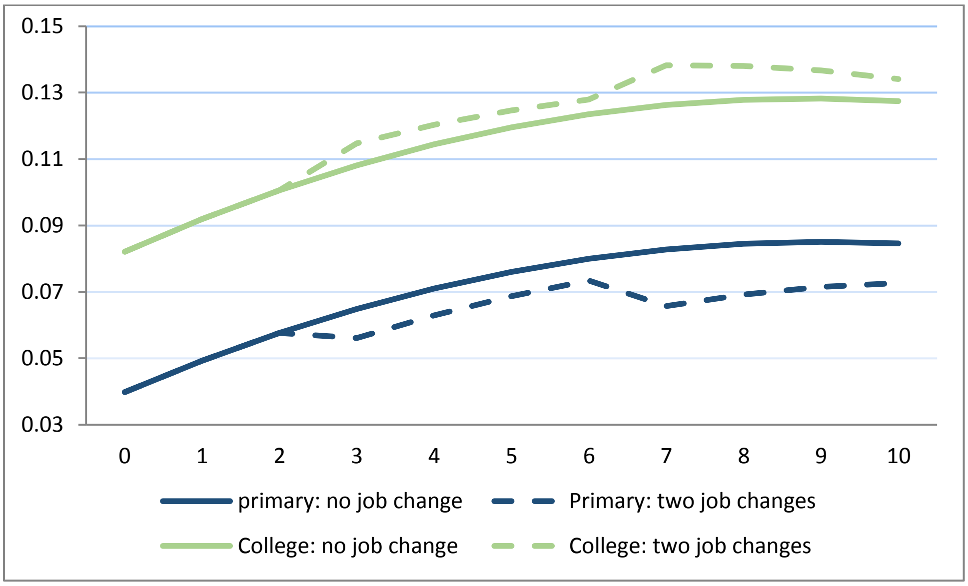
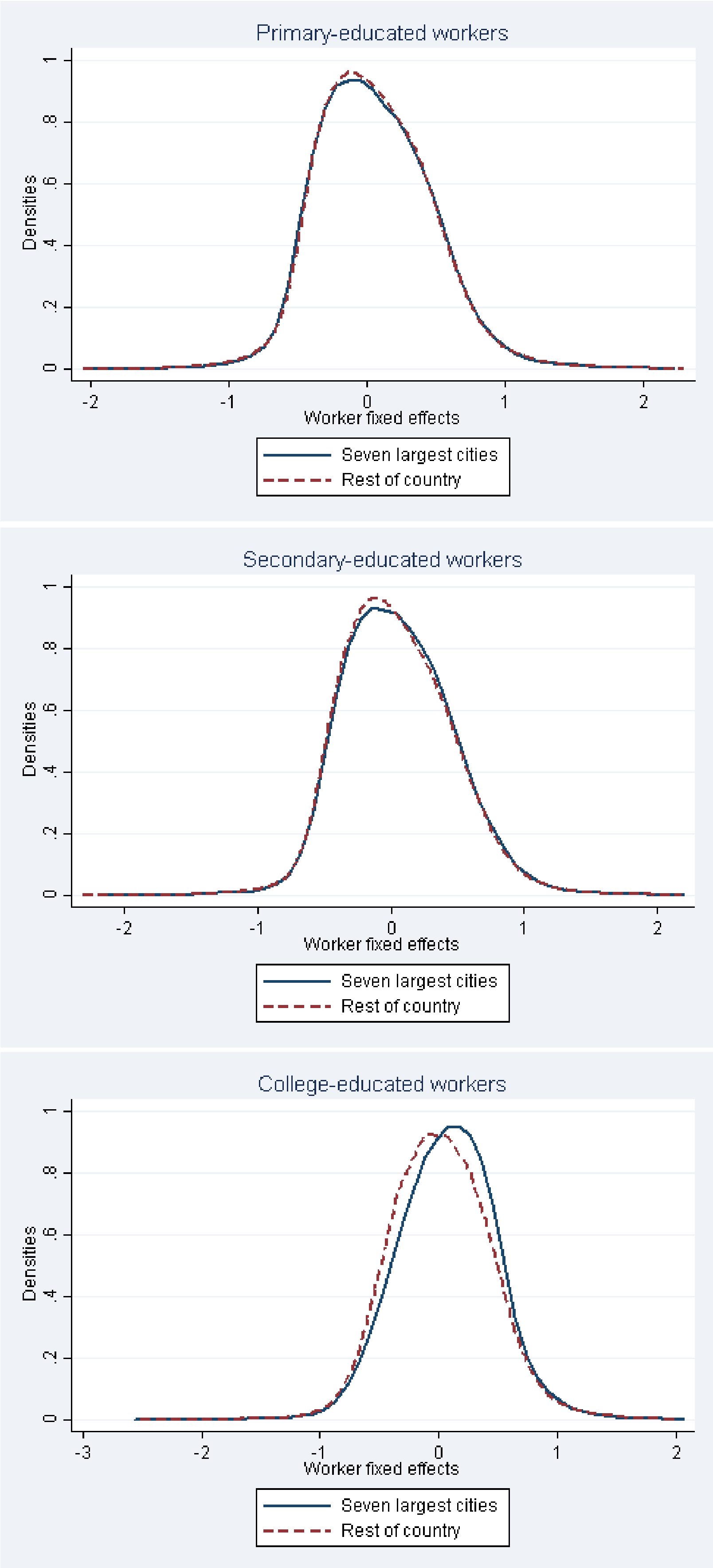


Fig 2: Comparison of worker fixed effects across education groups, cities vs. rest of country



Appendix Tables

Table A.1
Estimation of urban wage premium – young workers (born after 1967)

	(1)	(2)	(3)	(4)
Dependent variable	Log hourly wage	Log hourly wage	Log hourly wage	Log hourly wage
Education group	All	Primary	Secondary	Tertiary
Oslo	0.079***	0.046***	0.059***	0.087***
	(0.0025)	(0.0099)	(0.0044)	(0.0032)
Six other large cities	0.047***	0.026***	0.035***	0.056***
	(0.0023)	(0.0075)	(0.0035)	(0.0033)
Experience	0.086***	0.086***	0.077***	0.109***
	(0.0012)	(0.003)	(0.0016)	(0.0022)
$(\text{Experience})^2$	-0.0007***	-0.0009***	-0.0005***	-0.0014***
	(0.0000)	(0.0001)	(0.0000)	(0.0001)
Experience in Oslo	0.027***	0.008**	0.013***	0.016***
	(0.0009)	(0.0033)	(0.0015)	(0.0013)
$(\text{Experience in Oslo})^2$	-0.0014***	-0.0006***	-0.0008***	-0.0009***
	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Experience six other large cities	0.011***	0.001	0.003***	0.009***
	(0.0007)	(0.002)	(0.0009)	(0.0012)
$(\text{Experience six other large cities})^2$	-0.0003***	0.0001	0.0000	-0.0001
	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Job tenure	-0.005***	-0.012***	-0.006***	-0.002**
	(0.0004)	(0.0012)	(0.0005)	(0.0008)
$(\text{Job tenure})^2$	0.0001***	0.0004***	0.0002***	-0.0000
	(0.0000)	(0.0001)	(0.0000)	(0.0001)
Job tenure x Oslo	-0.000	0.007**	0.000	-0.004***
	(0.0009)	(0.0032)	(0.0014)	(0.0013)
$(\text{Job tenure})^2$ x Oslo	-0.0002**	-0.0004	-0.0002	-0.0001
	(0.0001)	(0.0003)	(0.0001)	(0.0001)
Job tenure x Six other large cities	0.001*	0.004**	0.003***	-0.002*
	(0.0006)	(0.0018)	(0.0008)	(0.0012)
$(\text{Job tenure})^2$ x Six other large cities	-0.0002***	-0.0002	-0.0003***	-0.0001
	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Year fixed effects	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes
Occupation fixed effects	Yes	Yes	Yes	Yes
Age controls	Yes	Yes	Yes	Yes
Worker fixed effects	Yes	Yes	Yes	Yes
Observations	1,792,619	261,695	933,698	597,226
Workers	402,824	67,742	200,440	134,642
R^2	0.77	0.70	0.75	0.78

Notes: Explanatory variables are defined in the notes to Table 4. Robust standard errors (clustered by worker) are given in parenthesis. ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. All regressions include a constant term.

Table A.2

Estimation with regional indicator coefficients

	(1)	(2)	(3)	(4)
Dependent variable	Log hourly wage	Log hourly wage	Log hourly wage	Log hourly wage
Education group	All	Primary	Secondary	College
Experience	0.073***	0.068***	0.069***	0.091***
	(0.0008)	(0.0019)	(0.0011)	(0.0016)
$(\text{Experience})^2$	-0.0006***	-0.0006***	-0.0005***	-0.001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Experience in Oslo	0.02***	0.006***	0.008***	0.013***
	(0.0006)	(0.002)	(0.001)	(0.0009)
$(\text{Experience in Oslo})^2$	-0.0009***	-0.0004***	-0.0005***	-0.0007***
	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Experience six other large cities	0.009***	0.003***	0.004***	0.009***
	(0.0005)	(0.0012)	(0.0006)	(0.0008)
$(\text{Experience six other large cities})^2$	-0.0003***	-0.0000	-0.0001**	-0.0002***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Job tenure	-0.004***	-0.006***	-0.004***	-0.001***
	(0.0002)	(0.0005)	(0.0003)	(0.0004)
$(\text{Job tenure})^2$	0.0001***	0.0002***	0.0001***	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Job tenure x Oslo	0.000	0.004**	0.001	-0.002**
	(0.0005)	(0.0015)	(0.0007)	(0.0007)
$(\text{Job tenure})^2$ x Oslo	0.0000	-0.0001	0.0000	0.0001
	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Job tenure x Six other large cities	0.001***	0.003***	0.001***	-0.001*
	(0.0003)	(0.0008)	(0.0004)	(0.0006)
$(\text{Job tenure})^2$ x Six other large cities	-0.0001**	-0.0001**	-0.0001**	0.0000
	(0.0000)	(0.0001)	(0.0000)	(0.0001)
Regional indicators	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes
Occupation fixed effects	Yes	Yes	Yes	Yes
Age controls	Yes	Yes	Yes	Yes
Worker fixed effects	Yes	Yes	Yes	Yes
Observations	4,131,194	742,262	2,249,737	1,139,195
Workers	850,412	165,741	447,692	236,979
R^2	0.82	0.75	0.80	0.83

Notes: Regional indicators refer to 89 labor market regions at the NUTS-4 level. Other explanatory variables are defined in the notes to Table 4. Robust standard errors (clustered by worker) are given in parenthesis. ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. All regressions include a constant term.