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# **Urban wage premium increasing with education level: Identification of agglomeration effects for Norway**

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## *Abstract*

Income levels are higher in cities. The evidence for the income gap between urban and rural areas is overwhelming, but the agglomeration effect is hard to identify. Recent advances make use of individual level data to separate out sorting and instrumentation to handle the endogeneity of population density. We offer an analysis based on the whole working population in Norway with complete description of their education level. The data allow for estimation of the agglomeration effect for different education groups and the results show that agglomeration economies are increasing with education level. The elasticity of income with respect to population size and density is significantly lower for individuals with lower education. The result is robust to alternative instruments of urbanization and inclusion of amenity effects.

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

Key words: Agglomeration economies, urban wage premium, sorting, education groups

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## **1. Introduction**

Productivity and incomes are higher in urban areas compared to rural. The differences can be observed in all industrialized countries and with various measures of income and productivity. Agglomeration of economic activity into cities seems to raise productivity and thereby income. The other stylized fact that is broadly accepted is the sorting of highly educated individuals into cities. The urban concentration of highly educated consequently is an important factor in understanding the urban – rural income gap. Agglomeration effects only can explain a part of the gap.

Cities may have high productivity because the inhabitants are productive, not because they are conducive to high productivity. This methodological challenge is recognized in the literature and has stimulated recent studies taking into account the composition of the population. Glaeser and Mare (2001) and Wheeler (2001) innovated the handling of heterogeneity and sorting using individual data for the US. Hedonic regressions clarify how the wages reflect characteristics of the workers and allow for the estimation of a regional fixed wage effect that controls for heterogeneity. Glaeser and Mare estimate the urban wage premium in this way, and Wheeler concludes that larger local markets have higher wages and productivity.

Rauch (1993) turned the attention to the importance of human capital for agglomeration effects and Henderson (2007) summarizes the present understanding. While many studies take into account the heterogeneity of the population, only a few consider the agglomeration effects for different education groups. The main focus of Wheeler (2001) is the complementarity between worker skills and firm capital, but he also presents estimates of the effect of population size for workers of different education groups. He finds that the urban wage premium increases with years of schooling. His analysis does not address the other methodological challenge involved, the endogeneity of population size. Our contribution is to analyze the agglomeration effect for different education groups using instruments for urbanization and with complete data of individual worker incomes.

Most studies separating between education groups conclude that agglomeration gives more benefits the higher the education level. Rosenthal and Strange (2008) find that the effect of agglomeration for workers with college degree is higher than the rest using the GMM method. Glaeser and Resseger (2010) study the link between human capital and agglomeration. Their

main finding is that agglomeration effects are stronger for cities with more human capital. Bacolod et al. (2009) analyze the effects of skills at a very detailed level, but also offer estimates of the urban wage premium depending on worker education. They find that effect of population size increases with education level, but that the effect is equal for workers with college and high school degrees. Some contrarian evidence is published by Lee (2010) involving health care workers. He concludes that the urban wage premium decreases as the skill level rises. The interpretation is that high skilled prefer to live in large cities and smaller cities must pay more to recruit them.

Recent advances use individual panel data estimating an individual fixed effect. Combes et al. (2008) make an important contribution on sorting, but they do not have observation of education level and the individual fixed effect consequently represents a mixed bag of education, skill, experience and ability. They conclude that skill-composition is the major explanatory factor of geographic wage disparities in France. Recent contributions pursue the decomposition of the effects further, notably Baum-Snow and Pavan (2012), Combes et al. (2011a) and Mion and Naticchioni (2009). They look into individual migration and firm data to identify effects of matching between individual and firm characteristics.

The understanding of the sources of agglomeration economies is discussed in a large theoretical literature based on the Rosen-Roback model and with good overviews by Glaeser and Gottlieb (2008) and Moretti (2011). The references go back to Alfred Marshall and his arguments for the role of matching of worker skills and firms in larger labor markets, the specialization and differentiation of intermediate inputs, and the role of knowledge spillovers. Recent research addresses the micro-foundations of agglomeration economies and is discussed by Duranton and Puga (2004). The migration equilibrium model assumes that higher productivity and wages are balanced by higher congestion and housing costs. The model integrates the understanding of migration sorting, agglomeration and local economic factors.

We use data for all workers in Norway to study the urban wage premium effect of population density and population size. The data include observation of education level as well as personal and labor market characteristics. The analysis separates between lower, secondary and tertiary education among individuals in Norway. The main focus is the analysis of differences in population effects for the income level across education groups. The

endogeneity of the population measures is addressed using instrument variables. Our analysis shows that agglomeration effects are significant at all levels of education, but the size of the effect increases with the education level. The elasticity of income with respect to population size and density is significantly lower for individuals with lower education. In our preferred specification, a doubling of the population size increases wages of primary educated workers by 2.1%, while individuals with higher education get a 4% wage increase. The result is robust to alternative instruments of urbanization and inclusion of amenity effects. The longer term aspects of the agglomeration process in Norway are investigated by Rattsø and Stokke (2011a,b).

Section 2 discusses our econometric strategy and data. The estimates of various specifications of the model are presented in section 3. Section 4 summarizes our conclusions and indicates future research.

## **2. Econometric strategy and data**

The analysis deals with the economic importance of urbanization. The measurement of urban scale requires a definition of the agglomeration assumed to influence the income generation. Black and Henderson (1999) discuss the basic understanding of urban evolution. Empirical studies have used measures of size and density of employment and population. We concentrate on population here. Population density is most relevant if the agglomeration forces work over short distances within city areas. Norwegian cities are small by international comparison, and most regions have large unpopulated areas. In this setting population size seems to be the best measure of agglomeration. However, we present results both for regional population size and regional population density, the latter defined as inhabitants per square kilometer. Based on information about commuting flows between municipalities, Statistics Norway has divided Norway into 90 travel-to-work areas, denoted economic regions. The economic regions conform with 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.

### *2.1 Regional wage level and worker heterogeneity*

Our measures of the regional wage level are computed from three administrative registers: the tax, employment and education registers. The tax register gives information about income from employment and self-employment as well as government transfers during the calendar year for the whole population aged 18 and older. The employment register gives yearly information about all employees during a particular week in November. The education register covers the whole population and gives information about the highest completed education level in the beginning of October each year. Due to the tax reform of 1992, income data are comparable only after 1993; we use data for the period 1994-2004.

We are not able to measure hourly wages as the employment register does not have information about work hours. However, the register lists whether an employee worked more or less than 30 hours per week. We use only employees working more than 30 hours – in the following denoted full-time workers – to compute our measures of regional wage level. We also exclude persons above 60, as some workers may choose to reduce work hours in the years before retirement, and persons below 25, since some young workers are part-time students. The standard time norm of the working week is determined by the national labor market organizations and therefore do not vary among regions. The number of workers in our sample varies over time, but lies in the range 1.4 – 1.8 million workers each year during 1994-2004.

We compute regional wage measures for the whole sample of workers, as well as for three subgroups of workers according to the level of education: tertiary (workers that have completed at least one year at college/university), secondary (workers that have completed at least one year of secondary education) and primary (workers with not more than compulsory schooling). The education level is registered the month before registration of employment status and in the same calendar year as income.

Our first measure of the regional wage level is:

$$W_{rt}^R = \log \bar{Y}_{rt} \tag{1}$$

where  $\bar{Y}_r$  is average wage income of workers in region  $r$  and year  $t$ . This variable ignores regional variations in education level, experience and ability. To weed out effects of observable worker characteristics, we estimate the following hedonic equation:

$$Y_{irt} = Y_{rt}^2 + X_{irt}\varphi + \varepsilon_{irt} \quad (2)$$

where  $Y_{irt}$  is annual wage income for worker  $i$  in region  $r$  and year  $t$ ,  $Y_{rt}^2$  is a set of regional  $\times$  year fixed effects and  $X_{irt}$  is a vector of observable worker characteristics.  $X_{irt}$  includes sex-specific dummies for age (5-year intervals) and dummy variables for education level (three levels). When estimates are done for subgroups according to education level, the education dummies are not included in  $X_{irt}$ .

Our second measure of the regional wage level is:

$$W_{rt}^I = \log \hat{Y}_{rt}^2 \quad (3)$$

where  $\hat{Y}_{rt}^2$  is the estimated fixed effect for region  $r$  and year  $t$  from equation (2).

In general, the wage level depends on work experience. We do not have information about jobs prior to 1994. It is common to compute a proxy for work experience by assuming that workers completed education during normal study time and then started to work. We do not include this proxy as it is strongly correlated with our age and education variables.

As noticed in the introduction, the heterogeneity of the population represents an important challenge in the estimation of agglomeration effects. Geographical sorting of workers may create correlations between urban scale/density and observable and unobservable workers characteristics, such as education, experience and ability. Sorting may therefore introduce measurement errors in our estimates of regional wage levels. Our second wage measure,  $W_{rt}^I$ , controls for regional variations in the age and education level of workers. If panel data of workers are available, movements between regions can be used to control also for unobservable worker characteristics (Combes et al., 2008, 2010). We will pursue this approach in future versions of the paper.

Annual wages are a biased measure of hourly wages if there are regional variations in work hours due to variations in the prevalence of overtime work. Annual wage income will tend to underestimate the wage level in regions with relative few overtime hours per worker, and overestimate the wage level in regions with many overtime hours per worker. To gauge the practical importance of this problem, we compute annual wage level for different years and compare the estimated effect of population size on annual wages in different years. Since overtime work is more prevalent during economic expansions compared to periods with low activity, we would expect regional differences in overtime work hours to vary over the business cycle. We therefore check if the estimated effects of size/density on annual wages are robust across the business cycle.<sup>1 2</sup>

## *2.2 Instrumentation and controls*

Population size and density are likely to be determined simultaneously with the wage level. Migration responds to wage level differences. In this case population variables are potentially endogenous due to reverse causality and omitted production and consumer amenities. Migration of workers to regions with high wages will cause a spurious correlation between population size and density and the regional wage level. Omitted production amenities, such as access to natural resources and proximity to markets and ports, will cause an upward bias in the estimated agglomeration effect on productivity if omitted production amenities are disproportionately located in large/dense urban areas. Omitted consumer amenities that make locations more attractive, such as pleasant climate, cultural amenities and local public services, will cause inflow of workers and drive up property rents, causing lower capital intensity and productivity. Omitted consumer amenities positively correlated with urban scale/density will therefore tend to bias estimates of agglomeration effects downward.

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<sup>1</sup> Another source of measurement error is that we know the employment status of a worker in a particular week only. If the worker is unemployed or outside the labor force for part of the year, annual wage income will underestimate the true wage level. We therefore add work-related transfers, such as unemployment benefits, to wage income.

<sup>2</sup> For full-time workers, income from self-employment may accrue from work outside standard work hours, or from periods without low employment. The two cases have different implications: there is an argument for adding income from periods without full-time employment to wage income, whereas income accruing from overtime work should not be added. Since we do not know which of the two cases is more common, we exclude workers that received more than 10% of their income from self-employment. For workers included in our sample, income from self-employment is added to wage income.

Ciccone and Hall (1996) innovated the handling of endogeneity by using lagged population variables as instruments. The instruments used to handle this preferably should predict population and be independent of present wage level and productivity. Long lags of population will work well as instruments when they are important for the early urbanization, the urbanization process is persistent, and the background factors initiating the first urbanization are unimportant now. Glaeser et al. (2011) summarize the persistence for US counties and show that recent population sizes are closely correlated with numbers back to the mid 19<sup>th</sup> century. Eaton and Eckstein (1997) confirm the same pattern for France and Japan. Given the large changes in production structure and production techniques over such long periods of time it seems reasonable to assume that the old population densities are less relevant today. The identification issues are discussed in the overview of Combes et al. (2011b) and Combes et al. (2010) extend the menu of instruments to include geographical and geological variables. Glaeser and Gottlieb (2008) have a migration equilibrium model as point of departure and suggest measures of amenities as instrument to predict population. We use historical censuses to compute regional population size and regional population density in 1825 and 1875. These variables are used as instruments for contemporary regional size and regional density.

To control for omitted consumer amenities, we take advantage of a series of surveys performed by TNS Gallup during 1994-2004 where respondents are asked to rank a set of local amenities on a scale from 1 to 6, where 6 is ‘very satisfied’ and 1 is ‘very unsatisfied’. For each amenity, we use all years to compute average reported satisfaction in the region, while controlling for individual characteristics that may affect the response scale used by respondents (see Carlsen et al, 2009, for details). We present results for satisfaction with general public services. We also include a variable for coastline as covariate; proximity to ocean may affect both productivity and quality of life.

### *2.3 The data*

Table 1 presents summary statistics for our dependent variables (regional wages), the explanatory variables (size, density, coastline and public services) and the instruments (historical size and density). We note that there are large variations in the explanatory variables of main interest, contemporary regional size/density as well as in historical size and density.

Table 1 about here

The top and bottom regions with respect to relative wages are shown in Table 2. The regions with highest wage level are in the south-east of Norway except for the ‘oil capital’ Stavanger/Sandnes region. The regions with the lowest wage level are all much smaller in population size and density and then relating to smaller cities and regional centers and in the northern part of the country. The table illustrates our argument that population size is a better measure of urbanization than population density. The Stavanger/Sandnes and Lillestrøm regions have more population than Bærum/Asker, but their density is much lower because they include a large sparsely populated territory outside the cities. The bottom regions in terms of wages and population size have extremely low population densities because they cover large unpopulated areas. The top regions have higher education level, in particular Oslo and neighbor Bærum/Asker where about 40% of the population have tertiary education. The bottom regions have higher shares of the population with only primary education.

Table 2 about here

### **3. Empirical results**

#### *3.1 Identification of agglomeration effects*

The estimated effect of population size on regional wages is presented in Table 3. We use two different measures of wages:  $W^R$  is the log of mean wages for each of the 90 labor market regions, while  $W^I$  is the log of regional wages after adjusting for observable individual characteristics (including education level and age). Both wages are measured as the average value during 1994-2004. In columns (1) and (2) these wages are regressed on population size using OLS. The raw elasticity of mean wages to population size is given in column (1) and equals 0.076. This is in line with a large literature on agglomeration effects typically finding an elasticity in the range 0.04 – 0.10 (see broad overview by Rosenthal and Strange, 2004). Later studies not accounting for the sorting of individuals mostly find elasticities consistent with this.

The studies correcting for the selection bias of individual heterogeneity have somewhat lower elasticities. Worker sorting represents a potential source of estimation bias since more productive workers often choose to locate in dense areas. Controlling for observed worker effects in column (2) reduces the elasticity to 0.048. The quantitative effects are comparable to the analysis of French workers by Combes et al. (2010). In their dataset, observed individual characteristics include the age of workers, but not the education level, implying that worker sorting cannot be controlled for by observable effects alone. They find that the density elasticity drops from 0.048 with mean wages to 0.033 when individual fixed effects are conditioned out (using OLS estimation). As expected, some of the higher income in larger cities relates to sorting. Recent empirical evidence is summarized by Combes et al. (2011b) and Puga (2010).

Table 3 about here.

A second source of bias is related to the simultaneous determination of population size and wages. More productive regions might attract more workers, or a third variable can be correlated with both population size and productivity. We apply the Wu-Hausman  $F$ -test to check if population is an endogenous explanatory variable. The  $F$ -statistic is around 10, and the null hypothesis of no correlation between the population size and the error term is clearly rejected. As discussed in section 2, we use historical population sizes as instruments to handle this problem. The first stage regressions, where current population measures (average for the period 1994-2004) are regressed on historical population measures (1825 and 1875), are given in Appendix Table 1. All coefficients are highly significant and close to unity, and the models have good explanatory power. We apply the weak instrument test developed by Stock and Yogo (2005) to investigate the relevance of the instruments. The first stage  $F$ -statistic lies between 60 and 340, and compared to the critical values reported by Stock and Yogo, the instruments are very strong.

The regressions in columns (3) and (4) of Table 3 are similar to the first two columns, except we now instrument the current population size with the 1825 population size. When controlling for the endogeneity of population size (but not worker sorting) in column (3), the elasticity equals 0.054. In column (4) we control for both sources of bias by using the wage  $W^I$  adjusted for observable individual characteristics and 2SLS estimation with the 1825 population size as instrument for the current population size. This gives our preferred

elasticity of 0.033, implying that doubling the population size increases wages by 3.3%. As seen from column (5), using the 1875 population size as instrument, does not change the estimated elasticity. Based on our results, the bias from worker sorting is larger than the simultaneity bias. The raw elasticity of 0.076 drops to 0.048 when we control for worker sorting and further to 0.033 with instrument variable estimation.

The results in Table 3 are based on average values for the period 1994 – 2004. To check if the elasticities are robust across the business cycle, we do the same regressions for each year during the period. The raw elasticity of wages with respect to population size lies in the range 0.071 to 0.083. When we control for the two sources of bias, the estimated elasticity varies from a low of 0.029 in 1994 to a peak of 0.036 in 1998 and down to 0.032 in 2004. Running a pooled OLS regression with time dummies also gives a population elasticity of 0.033.

We investigate the effect of population density (defined as inhabitants per square kilometer) as an alternative to population size. When regional wages are regressed on population density, the same pattern of results appears, as illustrated in Table 4. The raw elasticity of mean wages to the population density equals 0.055, and controlling for observable worker characteristics reduces the elasticity to 0.04. Using historical population densities (1825 or 1875) as instruments for the current population density, the elasticity drops to 0.034. Doubling the population density generates 3.4% increase in wages. Using employment density rather than population density does not change the estimated elasticities.

Table 4 about here.

Finally, we check if our estimated elasticity is robust to the introduction of control variables. First-nature geographic characteristics can explain both historical population locations and current productivity. We use coastal location, defined as the share of the regional population living in municipalities with a coastal line, as our measure of first-nature geography. We also control for local amenities, measured by a survey variable of households' satisfaction with local public services. The first stage regressions with control variables are documented in Appendix Table 2. The effects of past population measures on current population measures are highly significant and close to unity, and the strength of the instrument, as measured by the first stage *F*-statistic, has improved. The second stage estimations are given in Table 5,

and show that the estimated elasticities of regional incomes with respect to the population size and density are robust to the inclusion of control variables.

Table 5 about here.

The identification of agglomeration effects follows from the use of individual data to control for worker sorting and instrumentation of the population variables. The estimated elasticity of 0.033 is in line with recent analyses of agglomeration effects. Controlling for the two sources of bias, Combes et al. (2010) find a density elasticity of 0.027 for French employment areas during the period 1976 – 1996.

### *3.2 Agglomeration effects by education groups*

In addition to the average agglomeration effect across regions studied above, we have detailed education data allowing for the analysis of agglomeration effects for different education groups. We separate between primary, secondary and higher education. Regional wages by education level (adjusted for observable individual characteristics) are regressed on regional population size using 2SLS estimation with the 1825 population size as instrument. As seen from Table 6, agglomeration effects are significant at all levels of education, but the size of the effect increases with the education level. The elasticity of wages with respect to population size is almost twice as high for individuals with higher education compared to primary education. A doubling of the population size increases wages of primary educated workers by 2.1%, while individuals with higher education get a 4% wage increase. Using the 1875 population size to instrument for current population does not change the results. The difference between the estimated elasticity for the lower and higher education group is significantly different from zero at the 10% level. An implication of these findings is that wage inequality within regions will tend to be higher in populated areas, which is typically supported by the data (see for instance Baum-Snow and Pavan, 2011).

Existing studies of agglomeration effects for different education groups have shown similar quantitative differences without instrumentation for the endogeneity of population variables. Wheeler (2001) finds that the urban wage premium increases with years of schooling. Glaeser and Resseger (2010) conclude that the agglomeration effect is stronger for cities with more human capital. Bacolod et al. (2009) find similar to us that the effect of population size

increases with education level, but that the effect is equal for workers with college and high school degrees. Both our own results with and without instrumentation and the comparison with other studies without instrumentation indicate that the endogeneity bias is limited. Rosenthal and Strange (2008) find that the effect of agglomeration for workers with college degree is higher than the rest using the GMM method and with similar quantitative difference.

Table 6 about here.

The results above are based on average values for the period 1994 – 2004. To see how the difference between the education groups develops over time, we do the same regressions for each year during the period. The elasticity of wages for primary educated with respect to population size equals 0.02 in 1994, increases to 0.025 in 1997 and then decreases gradually to 0.017 in 2004. For individuals with secondary education the estimated elasticity lies in the range 0.029-0.034. The largest variation is seen for workers with higher education, where the elasticity increases over time from 0.029 in 1994 to 0.044 in 2004. This implies that the difference in the extent of agglomeration effects for individuals with lower and higher education is also increasing over time. During the years 1999-2004, the estimated elasticity for primary educated workers is significantly different from the elasticity of those with higher education, first at 10% significance level and then at 5% in the most recent years.

As a robustness check on our findings, we do the same analysis with population density rather than population size as explanatory variable. The results are similar, as illustrated in Table 7. The density elasticity is 0.022 for individuals with primary education and increases to 0.034 and 0.035 for individuals with secondary and higher education, respectively. All estimates are highly significant, and the elasticity for primary education is significantly different from the two other elasticities at the 5% level. When we consider each of the years during 1994 – 2004, the estimated elasticity for primary educated workers is lowest in 1994 at 0.019, reaches a peak of 0.025 in 1998, and then decreases to 0.02 in 2004. The estimated density elasticity for workers with secondary education lies in the range 0.03-0.038. For individuals with higher education, the elasticity equals 0.026 in 1994, increases gradually the next years and stays around 0.038 from 1998 onwards. Except for the first two years, the difference between the estimated elasticities for the lower and higher education group is significantly different from zero at the 5% level. Similar, the density elasticity for primary educated workers is significantly different from the elasticity of those with secondary education at the 5% level

during all years. There is no significant difference in the density elasticity for individuals with secondary and higher education.

Table 7 about here.

The robustness with respect to control variables of first-nature geography and local amenities also is investigated, as documented in Table 8. We include a variable singling out the coastal regions and a measure of satisfaction with local public services based on survey data. Both amenity variables have independent effect on local wages, but the estimated elasticities of population size and the differences between education groups are not much affected. The effect of population size on wages for individuals with only primary education is significantly different (at the 10% level) from the effect on wages of individuals with higher education. A doubling of population size increases wages by 2.6% for the lowest education group, while workers with secondary and higher education get 3.9% and 4.4% wage increase, respectively.

Table 8 about here.

#### **4. Concluding remarks**

We have used data for all workers in Norway to study the wage effect of population density and population size. The data include observations of education level as well as personal and labor market characteristics. The main focus is the analysis of differences in population effects for the income level across education groups. The endogeneity of the population measures is addressed using instrument variables based on historical population size of regions. We do not know other studies of the agglomeration effect in education groups with this instrumentation of population variables. Our main conclusion is that agglomeration economies are increasing with education level. The elasticity of income with respect to population size and density is significantly lower for individuals with lower education. The result is robust to alternative instruments of urbanization and inclusion of amenity effects.

In future research we will improve this first analysis and look into the background factors of agglomeration economies. The desired improvements include the estimation of individual fixed effects using panel data to account for individual skills and abilities in addition to the measured education achievements and the investigation of possible spillovers between

education groups. There is also work to be done on the measurement of agglomeration. In future analysis of background determinants of agglomeration effects it seems worth looking into the knowledge-accumulation in cities.

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Table 1: Summary statistics (across 90 labor market regions)

|  | Mean    | St dev | Min    | Max     |
|--|---------|--------|--------|---------|
| Regional wage (1994-2004, in 1998 NOK)   | 113 265 | 13 265 | 92 682 | 181 502 |
| $W^l$ (average 1994-2004)                | 8.1     | 0.07   | 8.0    | 8.4     |
| $W^l$ – primary educated workers         | 8.0     | 0.05   | 7.9    | 8.1     |
| $W^l$ – secondary educated workers       | 8.1     | 0.07   | 8.0    | 8.3     |
| $W^l$ – tertiary educated workers        | 8.3     | 0.08   | 8.2    | 8.6     |
| Population size 1994-2004                | 49429   | 71876  | 5 769  | 501 388 |
| Population size 1875                     | 20 149  | 18 173 | 1 628  | 107 833 |
| Population size 1825                     | 11 680  | 9 071  | 528    | 58 101  |
| Population density 1994-2004             | 39.9    | 127.9  | 0.8    | 1 104.4 |
| Population density 1875                  | 12.4    | 25.8   | 0.4    | 237.5   |
| Population density 1825                  | 6.5     | 7.7    | 0.1    | 56.7    |
| Primary education (share of adult pop)   | 17.4    | 3.4    | 7.6    | 26.4    |
| Secondary education (share of adult pop) | 62.1    | 3.8    | 47.1   | 67.6    |
| Tertiary education (share of adult pop)  | 20.5    | 5.0    | 12.8   | 45.2    |
| Coast line                               | 0.47    | 0.43   | 0      | 1       |
| Satisfaction public services             | 0.06    | 0.18   | -0.40  | 0.55    |

Notes: The first row refers to the regional annual wage level (average during 1994-2004), measured in constant 1998 prices. The next four rows give the log of the regional wage level adjusted for observable individual effects ( $W^l$ ), measured both aggregate and for the three main education groups; primary, secondary and tertiary. The population density is defined as inhabitants per square kilometer. Coastline is defined as the share of the regional population living in municipalities with a coastline.

Table 2: Summary statistics, top and bottom regions ranked by the average income level during 1994-2004.

|                         | Relative wage | Population size | Population density | Primary education | Secondary education | Tertiary education |
|-------------------------|---------------|-----------------|--------------------|-------------------|---------------------|--------------------|
| <i>Top 5 regions</i>    |               |                 |                    |                   |                     |                    |
| Bærum/Asker             | 1.60          | 147 369         | 502.9              | 7.7               | 47.1                | 45.2               |
| Oslo                    | 1.48          | 501 388         | 1104.4             | 12.7              | 47.4                | 39.9               |
| Follo                   | 1.26          | 100 207         | 170.8              | 12.1              | 56.1                | 31.8               |
| Stavanger/Sandnes       | 1.23          | 215 547         | 64.3               | 14.3              | 58.5                | 27.2               |
| Lillestrøm              | 1.20          | 162 657         | 60.2               | 18.2              | 59.8                | 22.0               |
| <i>Bottom 5 regions</i> |               |                 |                    |                   |                     |                    |
| Brekstad                | 0.88          | 15 568          | 7.2                | 19.0              | 65.0                | 16.0               |
| Alta                    | 0.88          | 22 516          | 1.5                | 21.0              | 56.6                | 22.4               |
| Rørvik                  | 0.86          | 9 961           | 6.7                | 20.7              | 65.3                | 14.0               |
| Brønnøysund             | 0.85          | 13 404          | 4.2                | 20.0              | 63.7                | 16.3               |
| Nord-Troms              | 0.82          | 11 785          | 1.7                | 23.9              | 59.9                | 16.2               |

Notes: In the first column the regional wage level (before adjusting for observed individual effects) is measured relative to the average wage level across all 90 regions. The last three columns give the share of the adult population with primary, secondary and tertiary education, respectively. All variables are measured as the average during 1994-2004.

Table 3: Local wages as a function of population size (cross section 1994-2004)

|                                  | W <sup>R</sup><br>OLS<br>(1) | W <sup>I</sup><br>OLS<br>(2) | W <sup>R</sup><br>2SLS<br>(3) | W <sup>I</sup><br>2SLS<br>(4) | W <sup>I</sup><br>2SLS<br>(5) |
|----------------------------------|------------------------------|------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Pop size (log)                   | 0.076***<br>(0.012)          | 0.048***<br>(0.007)          | 0.054***<br>(0.012)           | 0.033***<br>(0.007)           | 0.033***<br>(0.008)           |
| Instrument used:                 |                              |                              |                               |                               |                               |
| Pop size 1825 (log)              |                              |                              | Yes                           | Yes                           |                               |
| Pop size 1875 (log)              |                              |                              |                               |                               | Yes                           |
| Observations                     | 90                           | 90                           | 90                            | 90                            | 90                            |
| First stage <i>F</i> -statistics |                              |                              | 59.6                          | 59.6                          | 147.8                         |
| R <sup>2</sup>                   | 0.45                         | 0.44                         | 0.41                          | 0.40                          | 0.40                          |

Notes: In columns (1) and (3), the dependent variable is log of wages for each of 90 regions (average during 1994-2004). In columns (2), (4) and (5), the dependent variable is log of wages adjusted for observable individual effects. Clustered standard errors (at the regional level) are given in parentheses. In columns (3) – (5), the average population size during 1994 – 2004 is instrumented by the population size in 1825 or 1875. The first stage estimations are documented in Appendix Table A1. All regressions include a constant term.

\*\*\* Significant at the 1 percent level.

Table 4: Local wages as a function of population density (cross section 1994-2004)

|                                  | W <sup>R</sup><br>OLS<br>(1) | W <sup>I</sup><br>OLS<br>(2) | W <sup>R</sup><br>2SLS<br>(3) | W <sup>I</sup><br>2SLS<br>(4) | W <sup>I</sup><br>2SLS<br>(5) |
|----------------------------------|------------------------------|------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Pop density (log)                | 0.055***<br>(0.009)          | 0.04***<br>(0.004)           | 0.045***<br>(0.008)           | 0.034***<br>(0.004)           | 0.035***<br>(0.003)           |
| Instrument used:                 |                              |                              |                               |                               |                               |
| Pop density 1825 (log)           |                              |                              | Yes                           | Yes                           |                               |
| Pop density 1875 (log)           |                              |                              |                               |                               | Yes                           |
| Observations                     | 90                           | 90                           | 90                            | 90                            | 90                            |
| First stage <i>F</i> -statistics |                              |                              | 142.8                         | 142.8                         | 338.6                         |
| R <sup>2</sup>                   | 0.51                         | 0.64                         | 0.49                          | 0.63                          | 0.63                          |

Notes: In columns (1) and (3), the dependent variable is log of wages for each of 90 regions (average during 1994-2004). In columns (2), (4) and (5), the dependent variable is log of wages adjusted for observable individual effects. Clustered standard errors (at the regional level) are given in parentheses. In columns (3) – (5), the average population density during 1994 – 2004 is instrumented by the population density in 1825 or 1875. The first stage estimations are documented in Appendix Table A1. All regressions include a constant term.

\*\*\* Significant at the 1 percent level.

Table 5: Local wages as a function of population size or population density (cross section 1994-2004) – with control variables

|                                  | W <sup>I</sup><br>2SLS<br>(1) | W <sup>I</sup><br>2SLS<br>(2) | W <sup>I</sup><br>2SLS<br>(3) | W <sup>I</sup><br>2SLS<br>(4) |
|----------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Pop size (log)                   | 0.038***<br>(0.006)           | 0.039***<br>(0.006)           |                               |                               |
| Pop density (log)                |                               |                               | 0.033***<br>(0.003)           | 0.033***<br>(0.004)           |
| Coastline                        | 0.049***<br>(0.012)           | 0.052***<br>(0.013)           | 0.022**<br>(0.011)            | 0.023*<br>(0.012)             |
| Satisfaction public services     |                               | 0.04<br>(0.031)               |                               | 0.015<br>(0.028)              |
| Instrument used:                 |                               |                               |                               |                               |
| Pop size 1825 (log)              | Yes                           | Yes                           | Yes                           | Yes                           |
| Observations                     | 90                            | 90                            | 90                            | 90                            |
| First stage <i>F</i> -statistics | 83.8                          | 99.3                          | 181.8                         | 219.9                         |
| R <sup>2</sup>                   | 0.52                          | 0.53                          | 0.64                          | 0.64                          |

Notes: The dependent variable is log of wages adjusted for observable individual effects. Clustered standard errors (at the regional level) are given in parentheses. The average population size/density during 1994 – 2004 is instrumented by the population size/density in 1825. The first stage estimations are documented in Appendix Table A2. All regressions include a constant term.

\*\*\* Significant at the 1 percent level.

\*\* Significant at the 5 percent level.

\* Significant at the 10 percent level.

Table 6: Local wages by education groups as a function of population size (cross section 1994-2004)

|                                  | W <sup>I</sup><br>primary<br>2SLS<br>(1) | W <sup>I</sup><br>secondary<br>2SLS<br>(2) | W <sup>I</sup><br>tertiary<br>2SLS<br>(3) |
|----------------------------------|--|--|---|
| Pop size (log)                   | 0.021***<br>(0.005)                      | 0.032***<br>(0.007)                        | 0.04***<br>(0.008)                        |
| Instrument used:                 |  |  |   |
| Pop size 1825 (log)              | Yes                                      | Yes  | Yes                                       |
| Observations                     | 90                                       | 90   | 90  |
| First stage <i>F</i> -statistics | 59.6                                     | 59.6                                       | 59.6                                      |
| R <sup>2</sup>                   | 0.30                                     | 0.36                                       | 0.46                                      |

Notes: The dependent variable is the log of wages by education group adjusted for observable individual effects for each of 90 regions (average during 1994-2004). Clustered standard errors (at the regional level) are given in parentheses. The average population size during 1994-2004 is instrumented by the population size in 1825. The first stage estimations are documented in Appendix Table A1. All regressions include a constant term.

\*\*\* Significant at the 1 percent level.

Table 7: Local wages by education groups as a function of population density (cross section 1994-2004)

|                                  | W <sup>l</sup><br>primary<br>2SLS<br>(1) | W <sup>l</sup><br>secondary<br>2SLS<br>(2) | W <sup>l</sup><br>tertiary<br>2SLS<br>(3) |
|----------------------------------|--|--|---|
| Pop density (log)                | 0.022***<br>(0.003)                      | 0.034***<br>(0.003)                        | 0.035***<br>(0.004)                       |
| Instrument used:                 |  |  |   |
| Pop density 1825 (log)           | Yes                                      | Yes  | Yes                                       |
| Observations                     | 90                                       | 90   | 90  |
| First stage <i>F</i> -statistics | 142.8                                    | 142.8                                      | 142.8                                     |
| R <sup>2</sup>                   | 0.51                                     | 0.62                                       | 0.58                                      |

Notes: The dependent variable is the log of wages by education group adjusted for observable individual effects for each of 90 regions (average during 1994-2004). Clustered standard errors (at the regional level) are given in parentheses. The average population density during 1994-2004 is instrumented by the population density in 1825. The first stage estimations are documented in Appendix Table A1. All regressions include a constant term.  
\*\*\* Significant at the 1 percent level.

Table 8: Local wages by education groups as a function of population size (cross section 1994-2004) – with control variables

|                                  | W <sup>l</sup><br>primary<br>2SLS<br>(1) | W <sup>l</sup><br>secondary<br>2SLS<br>(2) | W <sup>l</sup><br>tertiary<br>2SLS<br>(3) |
|----------------------------------|--|--|---|
| Pop size (log)                   | 0.026***<br>(0.004)                      | 0.039***<br>(0.006)                        | 0.044***<br>(0.007)                       |
| Coastline                        | 0.046***<br>(0.009)                      | 0.056***<br>(0.012)                        | 0.033**<br>(0.015)                        |
| Satisfaction public services     | 0.04**<br>(0.019)                        | 0.049*<br>(0.028)                          | 0.02<br>(0.04)                            |
| Instrument used:                 |  |  |   |
| Pop size 1825 (log)              | Yes                                      | Yes  | Yes                                       |
| Observations                     | 90                                       | 90   | 90  |
| First stage <i>F</i> -statistics | 99.3                                     | 99.3                                       | 99.3                                      |
| R <sup>2</sup>                   | 0.49                                     | 0.51                                       | 0.51                                      |

Notes: The dependent variable is the log of wages by education group adjusted for observable individual effects for each of 90 regions (average during 1994-2004). Clustered standard errors (at the regional level) are given in parentheses. The average population size during 1994-2004 is instrumented by the population size in 1825. The first stage estimations are documented in Appendix Table A2. All regressions include a constant term.

\*\*\* Significant at the 1 percent level.

\*\* Significant at the 5 percent level.

\* Significant at the 10 percent level.

## Appendix Tables: First stage regressions, IV estimation

Table A1: IV, first stage regression

|                                    | (1)                 | (2)                | (3)                 | (4)                 |
|------------------------------------|---------------------|--------------------|---------------------|---------------------|
| Pop size 1825 (log)                | 0.884***<br>(0.114) |                    |                     |                     |
| Pop size 1875 (log)                |                     | 1.08***<br>(0.089) |                     |                     |
| Pop density 1825 (log)             |                     |                    | 1.002***<br>(0.084) |                     |
| Pop density 1875 (log)             |                     |                    |                     | 1.094***<br>(0.059) |
| Observations                       | 90                  | 90                 | 90                  | 90                  |
| R <sup>2</sup>                     | 0.52                | 0.70               | 0.77                | 0.87                |
| F-statistic (weak instrument test) | 59.6                | 147.8              | 142.8               | 338.6               |

Notes: In columns (1) and (2), the dependent variable is log of population size for each of 90 regions (average during 1994-2004). In columns (3) and (4), the dependent variable is log of population density for each of 90 regions (average during 1994-2004). Clustered standard errors (at the regional level) are given in parentheses. All regressions include a constant term.

\*\*\* Significant at the 1 percent level.

Table A2: IV, first stage regression – with control variables

|                                    | (1)                 | (2)                 | (3)                 | (4)                 |
|------------------------------------|---------------------|---------------------|---------------------|---------------------|
| Pop size 1825 (log)                | 0.945***<br>(0.103) | 0.921***<br>(0.092) |                     |                     |
| Pop density 1825 (log)             |                     |                     | 0.953***<br>(0.071) | 0.954***<br>(0.064) |
| Coastline                          | 0.638***<br>(0.152) | 0.533***<br>(0.166) | 0.682***<br>(0.152) | 0.587***<br>(0.158) |
| Satisfaction public services       |                     | -1.081**<br>(0.483) |                     | -1.047**<br>(0.481) |
| Observations                       | 90                  | 90                  | 90                  | 90                  |
| R <sup>2</sup>                     | 0.59                | 0.61                | 0.78                | 0.80                |
| F-statistic (weak instrument test) | 83.8                | 99.3                | 181.8               | 219.9               |

Notes: In columns (1) and (2), the dependent variable is log of population size for each of 90 regions (average during 1994-2004). In columns (3) and (4), the dependent variable is log of population density for each of 90 regions (average during 1994-2004). Clustered standard errors (at the regional level) are given in parentheses. All regressions include a constant term.

\*\*\* Significant at the 1 percent level.

\*\* Significant at the 5 percent level.