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# The more the merrier? Evidence on quality of life and population size using historical mines

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# The more the merrier? Evidence on quality of life and population size using historical mines

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**Abstract**

I attempt to find the causal effect of endogenous population size on quality of life. Quantity and quality of consumer amenities would increase with urban scale if not offset by congestion effects. To deal with endogeneity, I utilize a quasi-experimental design where I exploit the exogenous spatial distribution of mineral resources with Norwegian historical mines from the 12th till the 19th century. The findings suggest persistence in population patterns from early industrialization, and a positive urban scale effect on quality of life that pass multiple tests of confounding factors.

**Keywords:** *quality of life, urban scale, path dependence, historical mines.* **JEL:** *J00, R1, R23*

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# 1 Introduction

This paper asks if increased population size cause higher quality of life. A populous area would be able to support more cafés, restaurants, museums, sport arenas and malls, and it might even be the case that high population size is an amenity in itself. The literature on quality of life focuses on the role of consumer amenities in household migration. When households "shop" for a location they choose the most amenable one, everything else equal. It is standard to treat the level of consumer amenities to be an exogenous aggregate both in formal theory and empirical investigations (Roback, 1982; Chen and Rosenthal, 2008; Stewart and Lee, 2009). This simplifying assumption is not necessarily true. I will distinguish between natural and cultural amenities to elaborate on this point. Natural amenities, like climate, coastline, and desirable scenery, are more or less fixed features of a location and unrelated to human influence. In contrast, cultural amenities are artificial and vary with population size; for instance, shopping opportunities, infrastructure, and cultural services. The role of urban scale in facilitating consumption is therefore important for urban policy and is an understudied topic (Glaeser et al., 2001).

Whether the population scale effect on quality of life is positive or not is an empirical question; the positive traits of urban environments might be offset by disamenities like crime, traffic and other congestion effects. Rappaport (2008) argues that quality of life endogenously increase with population scale from low to intermediate level and then decrease as it rises further. He finds mixed result when correlating population density with different quality of life measures, but strongly positive associations with subjective quality criteria. The next generation of quality of life measures, introduced by Albouy (2012), takes into account other costs of living beside housing, and adjustments for local taxes. He finds a positive association between the adjusted quality of life measure and population density, even when controlling for natural amenities. Using population size as the measure of urban scale he gets a positive association without controls, but no significant correlation when natural amenities are included. This might reflect that population density is a better measure of urban scale in the US, or it might be a product of the non-linearity proposed by Rappaport (2008). A related study from Norway that utilize Albouy's approach also display a positive association between population size and quality of life (Carlsen and Leknes, 2014). The association tends to be larger than reported for the US, potentially because of overall smaller cities and a comprehensive sample of regions.

It is difficult to identify how positive spillovers vary with population size since people want to live in places that are nice to start with (Mueser and Graves, 1995; Carlino and Saiz, 2008; Jeanty et al., 2010). To not conflate thick market benefits with natural advantage

I use two strategies; I control for observable natural amenities and use instrumentation.[1] I exploit a quasi-experimental approach using historical mines in Norway as instrument. As far as I know, this is the first paper to use such an approach in the quality of life literature.[2] Geological features have been used in other applications to instrument the distribution of population by Combes et al. (2010) and Rosenthal and Strange (2008), and historical mines have been exploited in Glaeser et al. (2012) to explain degree of innovation.

12th-19th century Norway had 63 mines operating periodically. This classifies mining as the first industry in Norway. In general, the discovery of mining resources would lead to economic activity and population growth. I use the exogenous spatial distribution of mineral resources, the number of historical mines in the region, to predict contemporaneous population size.[3] There are two properties of the instrument that suggest that it is feasible. First, mineral and metal reservoirs are distributed independently of human behavior. Second, all of the registered mines were exhausted before the present amenity outcomes were observed. The mining industry has gone from being one of the largest national industries in the 18th century to be of marginal importance today.[4]

I observe the location of historical mines, but not the potential for mining in the region. Information on mineral resource locations would improve the analysis, but this information is unknown.[5] Nonetheless, I am able to use bedrock quality to separate out a unique resource rich area in eastern Norway, the Oslo graben, to compare population size across the geological threshold. This analysis show the link between mineral resources and population patterns, which is confirmed further by the qualitative fact that the mineral rich areas in the south, east and middle of the country have relatively high population size. Another concern is the possible link between historical population size and the discovery of mineral riches. I include proxies for pre-mining historical population size, iron age graves and noble metal hoards, to give evidence on the contrary. Conditional on past population size the results are actually stronger. To further validate the connection between historical mines and population size I test for several potential confounding factors with a battery of variables describing the natural environment, industry composition and population traits

[1]Another problem concerns the measurement of urban scale. The appropriate measure of urban scale is not obvious; for instance, it might be population density or population size in urban areas. However, regional population size seems most appropriate given the size of Norwegian city and the fact that most regions have large unpopulated areas. The urban scale definition is tested in robustness analyses.

[2]Boualam (2014) investigate how cultural production affect productivity and housing prices. He uses federal grants to instrument for cultural employment.

[3]It would seem more appropriate to weight the mines by employees, production or operation length. This approach is not possible since information on the oldest mines are scarce. An alternative is to weight mines after the century it was opened, but this seems somewhat ad hoc and favors the large cities disproportionally since for instance the capital Oslo had the first mine opening in the 11th Century.

[4]The ratio of present employees in the mining industry to total employment is less than 0.04% on average for the period 1995-2000. For the period 1994-2002 the mining industry accounts for less than 0.3% of GDP. These numbers take into account sectors of mining production not relevant in a historical perspective, like employment and production in mining thorium and uranium ores, quarrying of sand, stone and clay, mining of chemical and fertilizer minerals, and production of salt.

[5]I do have information on bedrock composition, but not at such a detailed level.

of the region.

Regions with historical mines tend on average to have a more diverse industry composition and a higher manufacturing share in the 19th century, but not so in modern times. In combination with the first stage results, this suggests that exogenous historical industry shocks lead to increased local population size that is detectable even today. Examining the population development in mining regions, the change in population size between the 19th and 21st century indicates path dependence; i.e., the association between population size and population growth is positive, which would lead to divergence in regional population size over time. The main finding is the positive causal effect of urban scale on local quality of life. The effect flows through higher quantity and quality of cultural amenities, thick market effects and other benefits from being around people, as independent from a pleasant breeze that comes off the sea or other natural amenities. On average, this effect is not deterred by congestion costs, which indicate that quality of life increases faster than congestion costs with increased urban scale. This is as expected since Norwegian regions are in global comparison on the lower end of the population size spectrum.[6]

The second section presents the measure of quality of life. Section three describes the instrument. The main analyses is conducted in section four, while section five presents additional sensitivity analyses. Section six concludes.

# 2 Quality of life

## 2.1 Measuring living quality of local environment

The revealed preference approach described in Roback (1982) is often used to measure quality of life. It explains household migration as a tradeoff between local quality of life and real wages. Moreover, households are probably more inclined to consider local attributes as their standard of living and wealth increase (Brueckner et al., 1999; Rappaport, 2007).[7] That would make this approach suitable for Norway, which has very high income per capita.[8] In general, the quality of life measures derived from Roback's model have a strong correlation with likability indexes and subjective criteria of local quality, which contribute to the measure's concurrent validity (Rappaport, 2008; Albouy, 2012). Albouy (2012) improved the real wage differential measure by a two-sector decomposition of the price index calibrated by additional micro data, and taking into account local taxes. I follow his approach including the extensions made in Carlsen and Leknes (2014), where a

[6]Using OLS, I can not find a significant non-linearity with quadratic terms in the quality of life-population size relationship. The logarithmic specification of population size gives the best fit and implies a concave relationship.

[7]The importance of jobs and amenities for moving decisions have been explored in several papers. See, for example, studies by Mueser and Graves (1995), Gabriel and Rosenthal (2004), and Chen and Rosenthal (2008).

[8]In 2004 GDP per capita in Norway was 56628 in current US$ according to the World Bank.

three-sector decomposition of the price index is used, in addition to empirical adjustment for worker heterogeneity.

## 2.2 The model

Imagine many regions ($r$) that vary in quantity of endowed local quality of life $QOL_r$, nominal wages $W_r$, post-tax disposable income $Y_r$ and prices. We assume that the relevant prices are those of housing $P_{H,r}$, non-tradables $P_{NT,r}$ and tradables $P_{T,r}$. Households are identical and completely mobile between regions. Hence, there are no costs related to relocation. Households supply one unit of labor in their home region.

Equilibrium requires that there is no migration, which implies that utility is equal across regions. The condition can be stated using an indirect utility function with the usual properties:

$$V(Y_r, P_{H,r}, P_{NT,r}, P_{T,r}, QOL_r) = \overline{V} \tag{1}$$

Following Albouy (2012) and Carlsen and Leknes (2014), I can derive a relative measure of regional quality of life $\widetilde{QOL}_r$ from equation (1). The derivation details can be found in appendix A. I assume that the prices of non-tradables are a weighted sum of its factor prices, and prices of tradables are equal across regions:

$$\widetilde{QOL}_r = \alpha_H \frac{P_{H,r}}{P_H} + \alpha_{NT} \left( \delta_H \frac{P_{H,r}}{P_H} + \delta_L \frac{W_r(1+s_r)}{\overline{W_r(1+s_r)}} + \delta_T \right) + \alpha_T - \frac{W_r - t_r(W_r)}{\overline{W_r - t_r(W_r)}} \ , \tag{2}$$

where $\widetilde{QOL}_r$ is specified as quality of life measured as share of post-tax average income and as deviation from the national average. $\alpha_H$, $\alpha_{NT}$, and $\alpha_T$ are the budget shares of respectively housing, non-tradables and tradables. $t_r(W_r)$ is a wage- and region-specific tax function. $s_r$ is the average pay roll tax rate paid by employers in the region. $\overline{W_r(1+s_r)}$ and $\overline{W_r - t_r(W_r)}$ is the national average cost per unit labour and national average net income respectively. $\delta_H$, $\delta_L$ and $\delta_T$ are the factor shares of housing, labor and a composite of traded goods in the non-tradable sector. (2) equates regional quality of life by how much cost of living exceeds post tax income relative to the national average.

## 2.3 Data and calibration

I calibrate the quality of life measure by much of the same data as in Carlsen and Leknes (2014), where a more detailed account of the data material can be found as well as multiple robustness tests of the calibration method. I calibrate (2) by micro data on earnings and house prices, and county-group[9] data of household spending for each region and year.

[9] Norway is divided into 7 aggregate groups of counties by Statistics Norway.

Region averages are calculated for the period 1994-2002. The period is limited by the Norwegian tax reform of 1992, which makes earlier observations of earnings unavailable. Statistics Norway's house transaction database has comparable data until 2002, which set an upper bound. Descriptives of the components in the quality of life measure can be found in Appendix B.1.

The unit of observation is economic regions, 90 in total, created by Statistic Norway. The bordering is determined by commuting flows across municipalities such that each unit denotes a separate local labor market. In general, the literature on urban amenities compares metropolitan areas. I use regional data with national scope.

### 2.3.1 Regional wage level and post-tax income

The earnings data is computed from Statistic Norway's administrative registers encompassing the entire Norwegian working population. The sample is restricted to full-time workers between the age of 25 and 60 with less than 10% of their total income from self-employment. The procedure left me with 1.05-1.3 million annual observations. Capital income is independent of location and therefore ignored. Local income and wealth taxes and local government tax is subtracted from the earnings to create post tax income.

Wage differences across regions might reflect spatial differences in skills that arise because of worker sorting. To mitigate this potential bias in the regional wage estimates I utilize worker relocations to control for unobserved heterogeneity (Combes et al., 2008, 2010). This approach is supported by theory; migration equilibrium ensures that the marginal mover display the most accurate wage level. A concern is that the sample of movers might not reflect the general working population. In sensitivity analyses I use a wage measure where the entire working population is utilized and add controls for observed heterogeneity (Appendix C). The conclusions are unchanged.

I estimate the following wage equation to quantify the regional net wage:

$$W_{irt} = \alpha_r + \gamma_i + X_{irt}\beta + \epsilon_{irt} \ , \tag{3}$$

where $W_{irt}$ is individual annual income for worker $i$ in region $r$ and year $t$. This specification include both region fixed effects $\alpha_r$ and worker fixed effects $\gamma_i$. I also control for time-variant observed worker characteristics $X_{irt}$ - education and age dummies for five year intervals.[10] The estimated region fixed effects $\tilde{\alpha}_r$ is the component used in the wage measure and is based on the variation in wage for migrating workers. According to De la Roca and Puga (2014) there are arguments for including work experience in urban areas, since it might give a permanent increase in wages. However, I choose to omit dynamic

[10] I don't have information on work experience. A proxy computed under the assumption that education is completed during normal study time is highly correlated with age and education and therefore omitted.

wage effects in line with the static nature of the theoretical model. Dynamic effects on housing prices, wages and quality of life are beyond the scope of this paper and are left to be explored in future research.

### 2.3.2 Regional housing cost

In Norway almost 80% of all places of residence is owner-occupied (Stm 23 (2003-2004)). That is the reason why I consider house prices in stead of rent when calculating housing costs. Register data from Statistics Norway provides me with information of all transactions except those administered by housing co-operatives. There were 285 000 transactions from 1994-2002.

The regional housing cost is estimated by hedonic methods for each year. Transaction price is regressed on a set of regional fixed effects and housing attributes - square meters, square meters squared, age, age squared, the number and type of rooms, and travel distance to municipality center. The time variation in the data is not exploited because of the minuscule occurrence of resale. The estimated fixed effects are used in the regional housing cost measure. They are adjusted to make the mean equal to the national mean price level.

### 2.3.3 Budget and factor shares

Survey data on consumer expenditure is available from Statistical Norway. Average budget shares for categories of goods and services are published for seven county-group regions.[11] I divide consumer spending into budget shares for housing, non-tradables and tradables.[12]

Valentinyi and Herrendorf (2008) provide the factor shares of housing, labor and traded inputs for the non-tradable sector. They are respectively $\delta_H = 0.23$, $\delta_L = 0.65$ and $\delta_T = 0.12$.

[11] The survey data are pooled for two or three years. I compute annual budget shares by linear interpolation.

[12] Housing costs include actual rents for non-owners and imputed interest plus maintenance for owners. Non-tradables include recreation and cultural services, transport and communication, health care, education, personal care and other services.

### 2.3.4 Quality of life equations and estimation strategy

I end up with the following calibrated equation of quality of life:

$$\widetilde{QOL}_r = \alpha_{H,r}\frac{P_{H,r}}{P_H} + \alpha_{NT,r}\left(0.23\frac{P_{H,r}}{P_H} + 0.65\frac{W_r(1+s_r)}{\overline{\overline{W_r(1+s_r)}}} + 0.12\right) + \alpha_{T,r} - \frac{W_r - t_r(W_r)}{\overline{\overline{W_r - t_r(W_r)}}}\ , \tag{4}$$

where the budget shares display spatial variation, factor shares are set to national values, relative price of tradables equates unity, and wages and housing prices are derived from hedonic regressions. A comprehensive list of regional quality of life, housing cost and wage differentials, and population size can be found in appendix B.1. At first glance, quality of life seems to increase in population size. Wage and housing costs are higher in cities, but with much greater variation in housing prices than wages.

To deal with several potential sources of endogeneity, the estimation strategy is a standard 2SLS set-up; equation (5) illustrate the second stage estimation and equation (6) the first stage.

$$\widetilde{QOL}_r = \delta + \delta_1 population\_size_r + \mathbf{X_n}\boldsymbol{\delta_2} + \mathbf{X_o}\boldsymbol{\delta_3} + \nu_r \tag{5}$$

$$population\_size_r = \pi + \pi_1 historical\_mines_r + \mathbf{X_n}\boldsymbol{\pi_2} + \mathbf{X_o}\boldsymbol{\pi_3} + \omega_r \tag{6}$$

$\widetilde{QOL}_r$ is the calibrated measure of local quality of life in each region $r$. In equation (5) quality of life is regressed on a constant term $\delta$, the predicted number of people in log term in the region $population\_size_r$, and vectors $\mathbf{X_n}$ and $\mathbf{X_o}$ of natural and other controls, respectively. I will come back to the relevant controls in the result and sensitivity test sections. The parameter of interest is $\delta_1$, which is the population scale effect on cultural amenities. The variation in urban scale across economic regions is substantial with a mean of 50,267 inhabitants and a standard deviation of 73,499. Population size is the preferred measure of urban scale, since some of the Norwegian regions have sizable unpopulated areas. Alternative urban scale variables are investigated in Appendix D without alteration of the conclusions. $\nu_r$ is an error term with the standard properties. I instrument population size with the number of historical mines as displayed in equation (6).

# 3 Historical mines

## 3.1 Data

The data on number of mines in each region is gathered from several sources. The first source is Thuesen (1979) "Den første dokumenterte bergverksdrift i Norge [The first documented mining in Norway]". The second source is Carstens (2000) "...bygge i berge [mining the mountain]". Third, I received further information on historical mines from the Norwegian Mining Museum. A complete summary of the historical mines can be found in Appendix B.2. Information on the closure of mines is available in Table B.3 and Table 5.

## 3.2 A brief summary of the mining history in Norway

The first written source that mentions mining in Norway is the "Historia Norvegia" from 1170, which describes a silver mine in central Oslo (Thuesen, 1979, 1988). The mine, Akerberg, was also operational in the early 16th century (Carstens, 2000). The second source is a royal letter of enfeoffment signed by King Hans from 1490 giving permission to mine at two locations in the south-eastern part of the country (Benedictow, 1991). It can't be said for certain that these were the first mines, but the existence of written sources indicate that they had some importance. Nonetheless, it is clear that Norwegian mining began on a small scale.

Serious efforts in creating a profitable mining industry were initiated by king Christian III in 1536 after his succession to the throne of Denmark and Norway. The king, who used to be a German prince, was aware of the riches mining created for some principalities in his country of origin. The economic exploitation of mining resources in Norway was made possible by changing the country's status from an independent kingdom to a part of the Danish kingdom (Berg, 1991). The tempting potential revenues lead to investments in mine operations in the areas of Telemark, Kongsberg and Oslo (Falck-Muus, 1924). This early attempt of creating a profitable mining industry failed miserably. The leap from agrarian to industrial production and the difficult process of technology transfer from abroad are proposed as explanations (Berg, 1991; Rian, 1991). In 1549 the operations lead by the crown were terminated (Carstens, 2000).

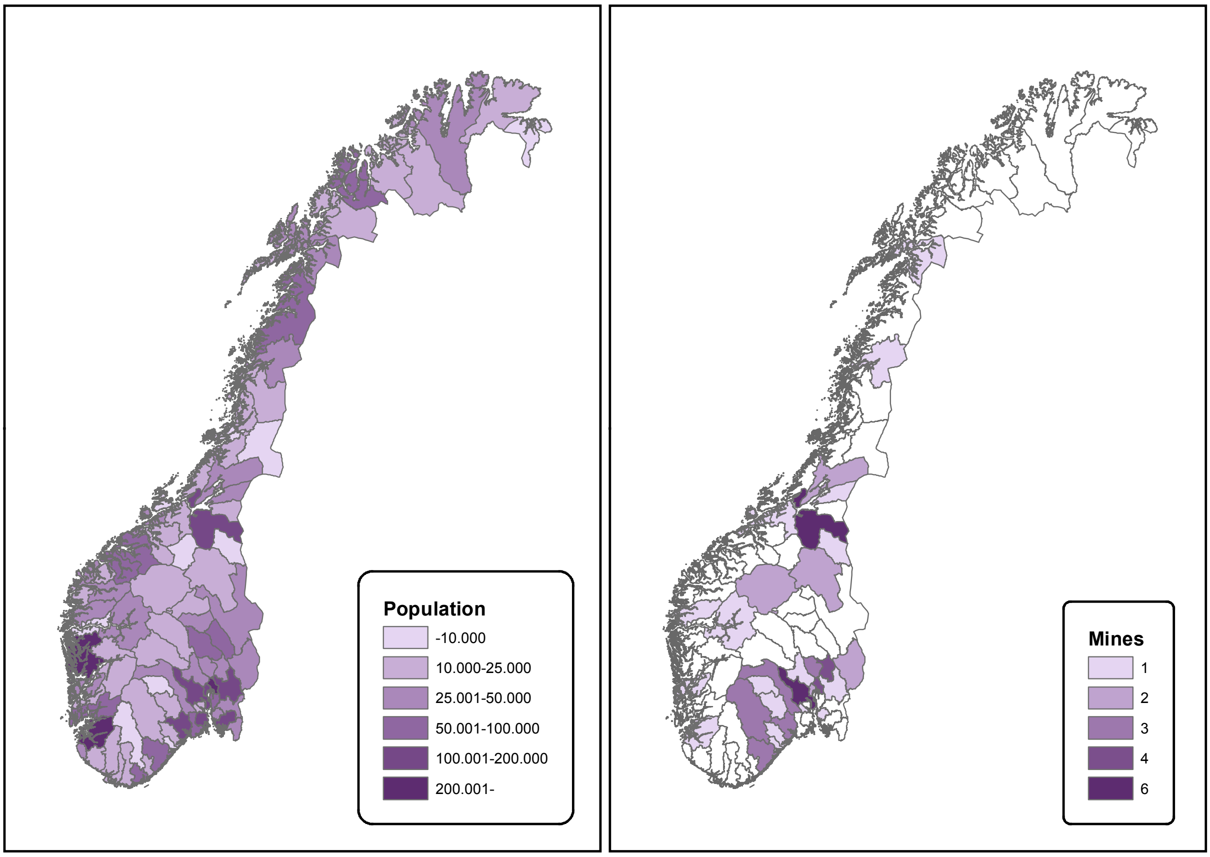
Working of mines became a national industry of importance first after the discovery of the silver reservoirs in Sandsvær in 1623, which lead to the construction of Kongsberg silver mines (Falck-Muus, 1924). This more or less coincides with the establishment of the iron industry in 1624 (Carstens, 2000). The iron industry was at that point no longer an infant industry. Since the middle of the 16th century there had been multiple attempts of making the iron works profitable. For example, the iron works in Skien had been leased by no less than ten different investors in this period (Rian, 1991). It is believed that continued operation facilitated learning through experience and the establishment of a professional milieu of iron miners contributed to the success. In addition, technological advancements like the blast furnace separates this period from previous ones.

In the middle of the 18th century mining was considered one of Norway's most prosperous industries and there were at least 40 mines extracting minerals like gold, silver, copper, iron, and cobalt (Falck-Muus, 1924). In 1770 there was approximately 7000 positions in mining not counting transport and forest work for a substantial amount of farmers (Carstens, 2000). This was a substantial figure for a small agrarian country like Norway that had a total population of about a million in 1825. In the first part of the 19th century the mining industry was again stagnating.

## 3.3 Geology and mineral discoveries

Figure 1 shows the distribution of historical mines across the country with concentrations in the south-eastern, southern and middle part. The special geology in these areas with respective population centers in Oslo, Arendal and Trondheim can explain why these locations are rich in minerals (Carstens, 2000; Ramberg et al., 2006).

Figure 1: Average 1994-2002 population size and historical mines




The Oslo graben geology is unique in a World perspective. Earthquakes and volcanoes shaped the bedrock composition in the Permian period. Metal depositions of lead, zinc, copper, iron pyrite, and silver was formed in the melt and lead to excavations for instance in Hadeland, Oslo and Kongsberg (Skjeseth, 1996).

The bedrock in the Trondheim area belongs to the Caledonian mountain range and was formed between the Cambrian and Silurian period (Skjeseth, 1996). It consists of volcanic, eruptive, and sedimentary rock. The pyrite ores were deposited as metalliferous sulfides containing various degrees of copper (Espelund, 2005). The Trondheim area has some exceptional deposits of volcanic-hosted ores, possibly the largest in the World, at Løkken south-west of Trondheim. Sediment-hosted ores are abundant in the Røros area (Fossen et al., 2008). These deposits of minerals had an historical importance since they were easily accessible from the surface (Carstens, 2000).

The bedrock in the very south encompassing the Arendal field, Bamble, the Fen area close to Skien, and Langøy in Kragerø is known for its many mineral deposits (Nordgulen and Andresen, 2008). The area is especially rich in iron ores with iron oxide located in skarn deposits formed in a reaction zone in the gneisses (Masdalen et al., 1990).

### 3.4 Persistence in population patterns

The mines provide resources that are non-renewable and will eventually be exhausted. Why would it make sense that these historical economic shocks from mining had a persistent effect on population size? If there exist economies of scale in production, which is fairly well documented in the agglomeration literature (Glaeser and Mare, 2001; Wheeler, 2001; Combes et al., 2010; Carlsen et al., 2013), an early start in one location might reap advantages in each succeeding stage of location competition. This process, often called path dependence, would give cumulative growth through home market effects, learning and innovation (Hirschmann, 1958; Krugman, 1991; David, 2001; Storper and Scott, 2009). Persistence and path dependence in the spatial distribution of population has also been demonstrated empirically. Davis and Weinstein (2002) find a striking level of persistence in regional population density throughout Japanese history. Bleakley and Lin (2012) find evidence of path dependence using US data, even after the initial local natural advantage is obsolete.

## 4 Results

### 4.1 Natural controls

Quality of life might be decomposed into natural and cultural amenities. I want to divest the quality of life measure of the natural component to research the population scale effect on cultural amenities. Natural amenities would also be correlated with population size if people historically have migrated to attractive locations. It has been demonstrated empirically in multiple applications that households prefer locations that have a favorable climate, is situated by the coast, and have attractive scenery like mountains (Gyourko et al., 1999; Glaeser, 2005; Combes et al., 2010; Albouy, 2010, 2012). Consequently, the vector $\mathbf{X_n}$ consist of standard amenity variables like January temperature, wind speed, precipitation[13], mountain area share, slope, and coast length.

The natural amenity variables also have a crucial role in the first stage estimation. For example, a concern is that mining was only initiated at locations with feasible climate and weather conditions. I cannot find any examples in the historical transcripts of this being the case, as far as I know, all potentially profitable reservoirs of minerals were exploited. Even though the characteristics determining the profitability of the ores was mostly unobserved it was not a problem to get willing investors (Falck-Muus, 1924), and adjustments in technic and organization made mining at very harsh environmental conditions achievable (Johannessen, 1991).

Mining regions might be on average more mountainous than other regions. Bare rock land, high land elevation and slope make it harder to develop property and might lower the housing supply elasticity of these regions. That would in general attenuate the empirical relationship between quality of life and population size; it might increase housing prices and inflate the measure of quality of life, and reduce population size.

Minerals and metals were part of international trade and dependent of infrastructure for market transport. It is possible that the decision to exploit ores was connected to the cost of bringing mine produce to harbors and established trade centers at the coast. The majority of Norwegian regions are coastal, therefore, kilometers of coastline were chosen as the better measure of harbor and market accessibility.

## 4.2 First stage results: Historical mining activity as a predictor of population size

To investigate the time dimension of the effect of historical mines, I compare how mines opening before the 17th century affect population size compared to the mines opening after this period. As you can see from column (5)-(8) in Table 1, older mines have a stronger effect on population size. One additional 16th century mine suggest about 70% increase in population size, while one more mine after this period gives an average increase of around 30% in population. These are fairly large numbers, which suggest that positive historical economic shocks have a lasting and cumulative effect on population size. Locations that initially establish a certain economic activity can serve a large area and attract broader forms of commerce. Since mining was the first industry in Norway it might have been particularly strong in determining the spatial distribution of the population.

In the subsequent analyses I use all the historical mines in the instrument. The instrument has a strong relation with population size that meets the threshold suggested by Stock

[13] I do not have data on weather conditions at mine openings. This would require detailed data of weather conditions from the last 800 years or so. It is assumed that regional differences in weather and climate condition are fairly stable, so that current weather data can function as a proxy. See more details in appendix B.

et al. (2002) (See column (9) and (10)). The strong first stage result is not surprising given the significant reduced-form results in column (1) and (2). Including natural amenities in the first stage estimations leaves the result close to unaltered. This suggests that the distribution of mining activity is exogenous to climate, geological features and coastline.

In table 2 the first stage relation prevail with historical population size data. In this case the mining instrument will not be completely exogenous from population size, since some mines were still active. An additional mine before the 17th century gives about 55% increase in 1801 population size, while one additional mine after this period leads to approximately 25-26% increase. When using all mines I get a 25% increase in 1900 population size. The results indicate that the relation is not driven by recent events, which strengthens the validity of the instrument. In addition, the greater effect of older mines and stronger results in Table 1 than 2 suggest that the positive impact on population size tend to grow. This is in line with a path dependence hypothesis. Nonetheless, the cross-sectional properties of the data encourage caution when interpreting the results.

Table 1: Effect of urban scale on quality of life

| | Reduced form | | OLS | | IV | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| *First stage results. Dependent variable:* log(*population*) | | | | | | | | | | |
| Pre 17th century mines | | | | | 0.701** | 0.745*** | | | | |
| | | | | | (2.27) | (2.65) | | | | |
| 17th & 18th century mines | | | | | | | 0.303*** | 0.318*** | | |
| | | | | | | | (4.52) | (5.14) | | |
| All historical mines | | | | | | | | | 0.285*** | 0.308*** |
| | | | | | | | | | (4.25) | (5.00) |
| *OLS, reduced form, and second stage results. Dependent variable: Quality of life* | | | | | | | | | | |
| Log(population) | | | 0.061*** | 0.060*** | 0.072*** | 0.061** | 0.077*** | 0.067*** | 0.076*** | 0.065*** |
| | | | (7.18) | (7.05) | (2.96) | (2.33) | (4.13) | (4.10) | (4.41) | (4.18) |
| All historical mines | 0.022*** | 0.020*** | | | | | | | | |
| | (2.84) | (2.69) | | | | | | | | |
| Natural amenities | N | Y | N | Y | N | Y | N | Y | N | Y |
| Adjusted R-Square 1st stage | - | - | - | - | 0.09 | 0.22 | 0.10 | 0.22 | 0.14 | 0.27 |
| Adjusted R-Square OLS | 0.11 | 0.23 | 0.51 | 0.59 | - | - | - | - | - | - |
| Number of mines | 63 | 63 | - | - | 12 | 12 | 51 | 51 | 63 | 63 |
| Number of observations | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |

Sample: 90 regions. Dependent variables: Averages for period 1994-2002 in QOL and logarithm of population size.

Natural amenities are mountain area share, slope, January temperature, wind speed, precipitation, and coast length.

Robust t statistics in parentheses. All regressions control for constant.

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 2: Persistence. Mines and historical population size

| | Population in 1801 | | | | Population in 1900 | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Dependent variable: historical* log(*population*) | | | | | | |
| Pre 17th century mines | 0.551*** | 0.548*** | | | | |
| | (4.44) | (3.98) | | | | |
| 17th & 18th century mines | | | 0.250*** | 0.273*** | | |
| | | | (4.41) | (4.75) | | |
| All historical mines | | | | | 0.243*** | 0.273*** |
| | | | | | (4.14) | (4.64) |
| Natural amenities | N | Y | N | Y | N | Y |
| Adjusted R-Square | 0.09 | 0.20 | 0.10 | 0.23 | 0.15 | 0.29 |
| Number of mines | 12 | 12 | 51 | 51 | 63 | 63 |
| Number of observations | 90 | 90 | 90 | 90 | 90 | 90 |

Sample: 90 regions. Dependent variables are historical log(population); In column (1)-(4) it is year 1801 population, and year 1900 population in column (5)-(6). Historical population data collected from Norwegian Social Science Data Services (NSD).
Natural amenities are mountain area share, slope, January temperature, wind speed, precipitation, and coast length.
Robust t statistics in parentheses. All regressions control for constant.
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

## 4.3 The population scale effect on quality of life

There tend to be a positive correlation between urban scale and quality of life (Albouy, 2012; Carlsen and Leknes, 2014). This is confirmed in this application with positive OLS-results in column (3) and (4) of Table 1. One unit increase in log(population) is associated with about 6% increase in quality of life relative to the national average. In contrast, Albouy (2012) obtain an elasticity of 1.2%, but when he includes natural amenity controls the result turns insignificant. The endogenous relationship between population size and quality of life hinders causal interpretation.

The IV-results in column (5)-(10) is rather similar compared to those with OLS. This might happen if the biases cancel each other out or if endogeneity is not a serious concern. Another possibility is the presence of natural disamenities that are unaccounted for. The IV-results have as expected larger standard errors than the OLS-results and the results are therefore not significantly different. The coefficients vary between 6-7.7%. The inclusions of natural amenity controls reduce the point estimate. This is not surprising since natural amenities are positively correlated with population size, and quality of life by definition partially comprise of natural amenities. Nonetheless, the overall results show a robust positive effect of population size on quality of life, which suggest that thick market benefits and cultural amenities are important for local living quality.

The baseline result in column (10) shows that one unit increase in log(population) is associated with about 6.4% increase in quality of life relative to the national average. It is possible to convert this estimate into pecuniary values since the quality of life measure is composed of real wage differentials. On average a Norwegian post tax income was 188060 NOK a year in 1994-02 ($24810).[14] That means a willingness to pay of 50774 NOK ($6698) for moving from the smallest to the largest population size region. The conclusion is that cities have a clear advantage over country-side regions since their attractiveness increase with population size.[15]

# 5 Sensitivity analyses

## 5.1 Picking up historical population size?

Mines may have been located not everywhere there were mineral resources but where there were resources and people lived. First, mineral resources might have had a higher probability of being discovered at places that were historically densely populated. Second, lower labor cost would have increased the likelihood of production. Unfortunately, there exist no accurate data of local population size before 1801. As an alternative, I use proxies for pre-mining population; the regional number of graves from the early iron age (500 B.C.-500 A.D.) and the regional number of hoards with deposited noble metal artifacts (800-1100 A.D.).

The data on iron age grave sites is published by the Directorate for Cultural Heritage.[16] In the iron age the usual burial custom was to burn the corpses and place them in barrows or mark the graves with cairns or stones placed in circles, which would make these sites easy to spot even today (Alnæs, 1996). Iron age graves would be an appropriate proxy for population size at the time because the entire country was inhabited (Lillehammer, 1994), the population was to a large degree sedentary (Magnus and Myhre, 1995), and there is a tight connection between grave location and place of residence (Magnus and Myhre, 1995; Lillehammer, 1994; Ebbesen, 1982). The exterior size of the gravesites and the number of bodies, ranging from 8 till 200, indicate locations close to towns (Magnus and Myhre, 1995; Lillehammer, 1994). Consequently, the number of grave sites in the region would give information on the spatial distribution of iron age agglomerations.

The source data of hoards from the viking-age is gathered from Bøe (1921), Grieg (1929), Munch (1956), and Skaare (1976), and comprehensive list is republished in Ryste (2005). The placement of noble metal artifacts in nature can be understood both from a ritual and profane perspective. The ritual perspective argue that these valuables were gifts for the gods (Worsaae, 1865) or objects of value that the contributor would bring with him to the next world. There are also historical transcripts from the Icelandic saga

[14] Using data from Central Bank Norway I calculate average exchange rate over the period 1994-02.

[15] A concern is that the result is underestimated since access to cultural amenities charge fees not necessarily reflected in the quality of life measure.

[16] The data is freely available at kulturminnesøk.no

Table 3: Results conditional on historical population size proxies

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *First stage results. Dependent variable:* log(*population*) | | | | |
| All historical mines | 0.308*** | 0.240*** | 0.301*** | 0.247*** |
| | (5.00) | (3.61) | (4.84) | (3.75) |
| Noble metal depots | | 0.174*** | | 0.148*** |
| | | (3.82) | | (3.30) |
| Viking graves | | | 0.012*** | 0.007*** |
| | | | (3.52) | (2.68) |
| *Second stage results. Dependent variable: Quality of Life* | | | | |
| log(*population*) | 0.065*** | 0.074*** | 0.066*** | 0.074*** |
| | (4.18) | (4.00) | (4.09) | (4.02) |
| Noble metal depots control | N | Y | N | Y |
| Viking graves control | N | N | Y | Y |
| Natural amenities | Y | Y | Y | Y |
| Adj. R-Square first stage | 0.27 | 0.39 | 0.33 | 0.41 |
| Number of mines | 63 | 63 | 63 | 63 |
| Number of observations | 90 | 90 | 90 | 90 |

Sample: 90 regions. Estimator: 2SLS with all historical mines as instrument. Dependent variables are log(population) and Quality of Life. In column (1) is the baseline result. (2)-(4) include proxies for historical population size.

Natural amenities are mountain area share, slope, January temperature, wind speed, precipitation, and coast length.

Robust t statistics in parentheses. All regressions control for constant.

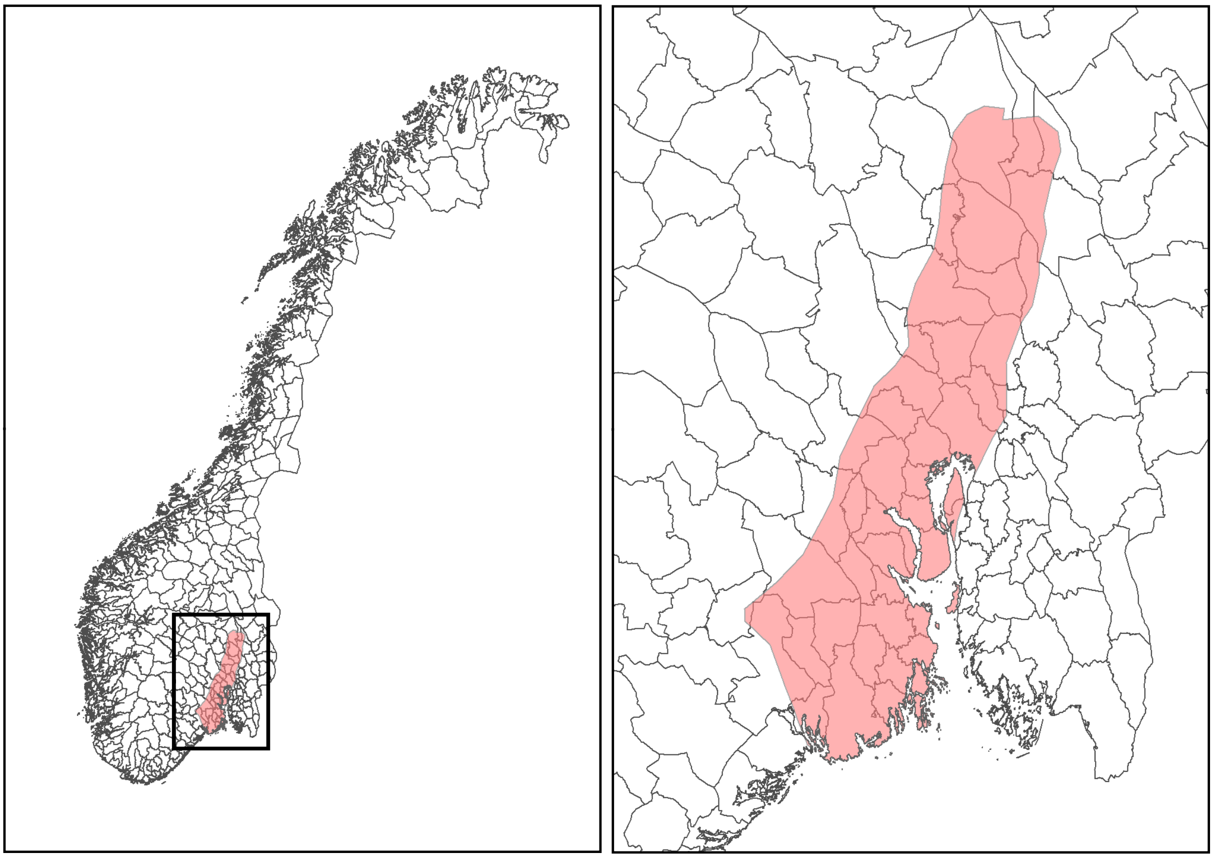
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

literature mentioning the law of Odin, where the god promises that these offering would be retained for the contributor's life in Valhalla (Almgren, 1900). In a profane context the deposits have a different meaning. Silver and gold were used as measures of payment, and placement in nature could be considered safe and temporarily (Montelius, 1919; Grieg, 1929). What is important is the fact that hoards are made of materials that doesn't corrode and disappear over time and they were placed close to where people were living (Fabech, 1991, 1999; Hedeager, 2003). This would make the deposits possible to observe and a suitable proxy for the spatial distribution of pre-mining population.

As can be seen from Table 3 both proxies are significantly predicting contemporaneous population when included separately and together. The relationship between historical mines and population size is not affected much, neither the second stage result. If anything, the population size effect on quality of life gets stronger when it is conditional on proxies for historical population size. This suggests that I draw on a different source of variation, which strengthens the claim that the instrument exogeneity condition is satisfied.

## 5.2 Oslo graben: Regression discontinuity analyses of mineral resources and population size

Figure 2: Oslo graben



It is in general difficult to determine where mineral resources are located from information on bedrock qualities; gold tend to be where you find it. Nevertheless, bedrock qualities are a tempting source of variation since it is strictly independent of human influence. The unique geological character of the Oslo graben, which is rich in minerals and clearly defined in extent, can be used to test the first stage correlation in a quasi-experiment. The Oslo graben is an elongated geological area that is located from Langesundsfjord in the south to the northern end of lake Mjøsa, 220 km long and about 60 km wide.[17] The close connection between geology and population size is shown in section 3.3, but now I will give an empirical test of the relationship. I use a regression discontinuity design where the sample is defined by the graben border. I investigate the spillover effect of mineral resources by having three different thresholds. The first one is a sharp cutoff where all municipalities that are touching the border of the graben are counted as treated. The second one is created by a buffer of 5 kilometers that shifts the threshold outwards, and the third with a buffer of 10 kilometers. Economic regions are too large in size to be useful in this comparison, so I will use municipalities which are more spatially disaggregated (See

[17] I use bedrock data from NGU (Norwegian geological survey) to spatially define the graben.

Figure 2). The econometric specification is as follows:

$$population_{t,m} = \alpha + \gamma Graben_m + \mathbf{X}_m \boldsymbol{\beta} + f(geographic\ location_m) + \upsilon_m \qquad (7)$$

Population in municipality $m$ at time $t$ is the outcome variable. $Graben_m$ is an indicator equal to unity if the municipality is touching the graben border or touching the graben buffer line. That means, the spatial units that are cut by the threshold is treated, while those adjacent from the outside is defined as non-treated. An important identifying assumption is that all relevant factors besides treatment must vary smoothly at the threshold. That would ensure that the adjacent municipalities are appropriate counterfactuals. I investigate this assumption by including a vector $\mathbf{X}_m$ of important municipality characteristics describing the geographical, political and industry environment.

Table 4: First stage robustness: Regression discontinuity along Oslo graben

| | Sharp cutoff | | 5 km buffer | | 10 km buffer | |
|---|---|---|---|---|---|---|
| | log(*pop*1998) | log(*pop*1801) | log(*pop*1998) | log(*pop*1801) | log(*pop*1998) | log(*pop*1801) |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Whitin graben area | 0.618** | 0.668*** | 0.893*** | 0.492*** | 0.480** | 0.041 |
| | (2.57) | (3.43) | (4.91) | (2.93) | (2.24) | (0.29) |
| Coast | Y | Y | Y | Y | Y | Y |
| Area of land | Y | Y | Y | Y | Y | Y |
| Slope | Y | Y | Y | Y | Y | Y |
| Mountain share | Y | Y | Y | Y | Y | Y |
| Capitol | Y | Y | Y | Y | - | - |
| Petroleum share | Y | Y | Y | Y | Y | Y |
| Hydro-power share | Y | Y | Y | Y | Y | Y |
| Quadratic polynomial in latitude and longitude | Y | Y | Y | Y | Y | Y |
| Adjusted R-Square | 0.46 | 0.27 | 0.58 | 0.20 | 0.36 | 0.09 |
| Number of observations | 59 | 59 | 62 | 62 | 68 | 68 |

Sample: 59-68 municipalities on border of Oslo rift and its buffers. Dependent variables are the natural logarithm of 1801 and 1998 population.

Robust t statistics in parentheses. All regressions control for constant.

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

A challenge when working with spatial RD-design is the multidimensional properties of the discontinuity. To handle this complexity, I include a function of longitude and latitude in the regression, $f(geographic\ location_m)$. More specifically, it is a quadratic polynomial of the form $x + y + x^2 + y^2$. The few degrees of freedom do not allow a more flexible function. This approach is in close resemblance with the application in Dell (2010) with different outcome variables.[18]

In Table 4 column (1), (3) and (5), the significant result indicate that municipality popu-

[18] Other examples of spatial RD-designs can be found in Black (1999) and Bayer et al. (2007).

lation within the graben border is approximately 50-90% larger than outside the border. The result is robust to both variables describing the geographical, political and industry environment as well as the quadratic polynomial of latitude and longitude.[19] There seem to be spillover effects to adjacent municipalities both in the 5 and 10 kilometer buffer. Even though the results are positive, concern remains that the relation is determined by modern factors. Therefore, I compare with historical population size data from 1825 as dependent variable. This is especially important since one of the municipalities is the capitol and disproportional public investment in the administrative center might give positive spillovers to adjacent areas over time.

The results in column (2), (4) and (6) with historical population data indicate that there is a strong effect of mineral riches on population size for the sharp cutoff and with the 5 kilometer buffer. The effect seems to diffuse for longer distances with an insignificant 10 km buffer cutoff. There seem to be an amazing persistence in population patterns when comparing population size today with historical records. The results indicate that the Oslo area population pattern is strongly predicted by mineral riches and that the effect is attenuated by distance. This attenuation disappears with 1998 population data, which can be seen as a sign of regional path dependence. Since the locations of mines are dependent on mineral endowments, the overall result supports historical mines as a valid instrument for population size.

## 5.3 Factors of production in mining

It is undoubtedly exogenous where mineral and metal deposits are situated. Nonetheless, it might not be at random where mining operations were initiated. Historically, the mining process was dependent of inputs like timber and sometimes power generated by rivers. A concern is that wood supply and river locations were restrictions on operation and to some extent determined the spatial distribution of the mining industry. It is also unclear whether forest, woodlands and rivers are perceived as local amenities or disamenities, and they might be correlated with contemporaneous natural production.

[19]Other specifications of capitol area was tested. The result is robust to including an indicator of capitol and its adjacent municipalities, instead of the narrower indicator of just the capitol municipality.

Table 5: Sensitivity analyses of IV-results

| | Mine operation inputs | Additional natural amenity | Natural production | Population traits | Current mining production | Mining tourism regions excluded | Hanseatic trade regions excluded | Post 1970 mine regions excluded | Post 1945 mine regions excluded | All covariates included |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| *First stage results. Dependent variable: Log(population)* | | | | | | | | | | |
| All historical mines | 0.296*** | 0.297*** | 0.295*** | 0.289*** | 0.307*** | 0.313*** | 0.261*** | 0.302*** | 0.314*** | 0.239*** |
| | (4.34) | (6.04) | (5.20) | (5.09) | (4.97) | (5.02) | (5.56) | (4.63) | (4.73) | (4.93) |
| *Second stage results. Dependent variable: Quality of life* | | | | | | | | | | |
| Log(population) | 0.074*** | 0.063*** | 0.064*** | 0.059*** | 0.066*** | 0.064*** | 0.054*** | 0.067*** | 0.066*** | 0.065*** |
| | (4.89) | (4.23) | (3.99) | (4.55) | (4.21) | (4.10) | (3.92) | (3.97) | (3.96) | (4.36) |
| Area of woodland | Y | N | N | N | N | N | N | N | N | Y |
| River lenght | Y | N | N | N | N | N | N | N | N | Y |
| Recreation walk share | N | Y | N | N | N | N | N | N | N | Y |
| Hydro-power industry share | N | N | Y | N | N | N | N | N | N | Y |
| Petroleum industry share | N | N | Y | N | N | N | N | N | N | Y |
| Primary education share | N | N | N | Y | N | N | N | N | N | Y |
| Unemployment rate | N | N | N | Y | N | N | N | N | N | Y |
| Miners today | N | N | N | N | Y | N | N | N | N | Y |
| Natural amenities | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Adjusted R-Square 1st stage | 0.26 | 0.36 | 0.36 | 0.29 | 0.26 | 0.27 | 0.24 | 0.27 | 0.29 | 0.44 |
| Number of mines | 63 | 63 | 63 | 63 | 63 | 59 | 59 | 58 | 51 | 63 |
| Number of regions | 90 | 90 | 90 | 90 | 90 | 88 | 87 | 87 | 83 | 90 |

Sample: 90 regions, averages for period 1994-2002. Dependent variable is quality of life and log(population). Robust t statistics in parentheses. All regressions control for constant. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. Natural amenities are mountain area share, slope, January temperature, wind speed, precipitation, and coast length.

Columns (1)-(5) & (10): Additional covariates are included. Further information can be found in Appendix B.3. (6)-(9) is estimated for sub-sample. In column (6) regions engaged in mining tourism are excluded. In column (7) regions related to Hanseatic trade are excluded. In column (8) regions with operational historical mines after 1970 are excluded. In column (9) regions with historical mines operational after WWII (1945) are excluded.

Timber was used for mine trusses, and as firewood and charcoal for smelters and fire setting[20]. However, sometimes gunpowder was used instead. This was the case for Årdal mines, where there were considerable challenges with transportation of timber (Johannessen, 1991).[21] River power was used to pump excess water out of the mines and run the bellows for the smelters (Carstens, 2000). I compute the instrument purely on mine location while location of industrial works are disregarded.[22] This makes it less likely that strategic considerations determined industry location, for instance, by reducing the importance of easily accessible inputs.

I include area of woodland and river length in column (1) of Table 5 to test the importance of factors of production for spatial distribution of mines. Current area of woodland would reflect the historical situation if there is persistence in woodlands over time. This is plausible since the fundamental condition for forest growth is quite fixed and the interval between the deforestation and contemporaneous outcomes would make it likely that the trees have recurred. The second stage result increases somewhat and are more sharply estimated, while it is the opposite for the first stage result. In total, the results are rather unaffected.

## 5.4 Natural amenities

I have already included several of the standard natural amenities variables. In this sensitivity analysis I want to test more thoroughly if the geological features of mining regions might have made them more suited to outdoor activities. Geological features might be correlated with mining locations and accessibility to nature in urban environment is clearly an amenity. In column (2) I control for the share of residents in urban settlements that have access to natural areas. The results are robust to this inclusion.

## 5.5 Natural production

The geological features of mining regions might make them suited for other types of natural production. I have tested extensively for regional fundamentals with variables related to topography, climate and weather, rivers, coast and woodlands. In this section I want to specifically rule out the possibility that industries utilizing natural resource have not affected the results. If these industries are connected to fundamental traits of the local environment they might affect contemporaneous wage, housing prices and population; in addition to being correlated with historical mines. There are especially two industries that are dependent on the geological features of the region - the petroleum industry and

[20] Fire setting is a method to extract the ore from the mountain. It is carried out in two steps: first heat the rock to expand it, and second douse it with cold water to contract and break it.

[21] The mine was located 1500 meters over sea level and in steep cliffs.

[22] Bolvik and Fritzøe ironworks were excluded from the instrument because they didn't depend on supply of metalliferous ores from local mines.

hydropower industry. I control for the regional employment share in both industries in column (3). These variables are very weakly correlated with both quality of life and historical mining locations and the results are rather unchanged.

### 5.6 Regional population characteristics

Traditional historical industries might affect the long-term development of a region through non-random firm selection and worker sorting. Worker heterogeneity is accounted for in the estimation of the regional wage. Nonetheless, regions with "old" or obsolete industries can sometimes fall behind in the competition for firms. An example might be the rust belt in the US. This can to some extent determine worker and population composition, for example, the proportion of low-educated workers and unemployed. These two human capital variables have implications for wage formation, house prices, and population size and might even be disamenities. As seen in column (4), the result is more or less the same.

### 5.7 Contemporaneous mining activity

Mines are opened in areas with rich mineral and metal deposits. That means that even though a historical mine is exhausted there might be locations nearby that still at present are being excavated. In addition, households would probably consider proximity to a mining operation a disamenity. The present metalliferous industry in Norway is marginal as can be seen from the summary statistics in Table B.5. That makes historical mines suitable as instrument for population patterns in this application. I include the number of mine-workers in each region in column (5) to test whether the contemporaneous mining locations are related to historical mining locations. Since the results are almost unaltered that seem not to be the case.

### 5.8 Tourism

A few of the regions use their heritage as historical mining communities to promote the region, and attract tourists. The most relevant regions in that respect are Røros and Kongsberg. These regions have established museums, they organize guided tours to the mines and cultural festivals. Moreover, the mining town of Røros and its circumference are on UNESCO's World Heritage List. The unique status of these regions might affect how households appraise the local environment and increase the number of permanent inhabitants. I exclude these regions from the analysis in column (6). The results are quite unchanged.

## 5.9 Hanseatic trade

Following the example of Falck et al. (2011) I exclude regions that were related to hanseatic trade. I want the to make sure that historic mining activity is the determinant of population growth and not the fact that some of these regions were historical trade centers. This exclusion procedure leaves out the two largest cities of Norway, Oslo and Bergen.[23] As reported in column (7), this does not affect the robustness of the result.

## 5.10 Mine closure

An important property of the instrument is the distance in time between mine closure and amenity outcomes. This will ensure that the historical mines are not likely to affect present regional amenity levels. I want to test this condition by extending the period between mine closure and observation of quality of life.

In column (8) and (9) of Table 5 the estimates are based on a sub-sample of regions. In column (8) all regions with historical mines that are operational after 1970 are excluded. Three regions are excluded and this changes the closure year from 1987 to 1969, extending the intervening period from 7 to 25 years. In column (12) regions with historical mines that are still operational after 1945 are excluded. The results remain robust in both cases.

In the last column (10) I include all covariates. Amazingly, the conclusion is still not affected.

## 5.11 Identifying spillover industry effects of mining

I will investigate the historical sector changes in mining areas to better understand how historical mines affected the local economy and ultimately the population size. In Norway, the discovery and exploitation of historical mining resources can be understood as an industrial shock to an agrarian economy. Mines lead to a surge in employment (at the mine, but also to cover supporting functions), technology transfer from abroad, and establishment of new industries and centers of trade (Berg, 1991; Rian, 1991; Sprauten, 1991; Carstens, 2000). Williamson (1965) and Michaels et al. (2012) describe how industrialization leads to urbanization through a structural transformation process.

Specifically, I will research the impact on the local economy by comparing industry composition in the earliest subsequent period after mine openings with industry outcomes today. First, I create a measure of industry diversity with a Herfindahl index of employment shares in different sectors in 1837, 1891, and 2000. For the two latter years I am able to omit the mining sector. In Table 6 column (1)-(3) I regress these measures of

[23]Historical excavation of metals in Oslo happened before the hanseatic trade started, which indicates that the exclusion of this region might not be relevant.

industry diversity against the number of historical mines in the region, and control for both natural characteristics and area of land. In both 1837 and 1891 mine regions have a more diverse industry composition, which suggests that mining regions attracted broader forms of commerce and spurred industrialization. The diverse industry effect has vanished when we look at contemporaneous outcomes in column (3). This is not surprising when we consider the rapid modernization process in industrial production, globalization and the change to a more service driven economy.

Table 6: Past and present industry in mining regions

| | Industry diversity 1837 | Industry diversity 1891 | Industry diversity 2000 | Manufacturing share 1891 | Manufacturing share 2000 |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| All historical mines | -0.012** | -0.036*** | -0.001 | 0.006*** | -0.002 |
| | (-2.47) | (-3.84) | (-0.29) | (4.61) | (-0.53) |
| Natural characteristics | Y | Y | Y | Y | Y |
| Area of land ($km^2$) | Y | Y | Y | Y | Y |
| Adjusted R-Square | 0.23 | 0.32 | 0.30 | 0.37 | 0.27 |
| Number of mines | 63 | 63 | 63 | 63 | 63 |
| Number of observations | 90 | 90 | 90 | 90 | 90 |

Sample: 90 regions. Dependent variables are in column (1) industry diversity in 1837 measured by Herfindahl Index (HI), same in columns (2) and (3) respectively for year 1891 and 2000. For the two latter years mining industry has been omitted from HI; this is not possible for 1837 because manufacturing and mining comprise one category. In column (4), employment share in traditional manufacturing industry in 1891, same in column (5) but for the year 2000. Historical data collected from Norwegian Social Science Data Services (NSD).

Natural characteristics are mountain area share, slope, January temperature, wind speed, precipitation, and coast length.

Robust t statistics in parentheses. All regressions control for constant.

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

I try to nuance the picture further by looking at another traditional industry - manufacturing - that might have benefitted from spillover effects. The earliest manufacturing employment share data is from year 1891 and I compare it to year 2000 data. There is a positive highly significant effect of historical mines on manufacturing shares in 1891; one additional mine increase the manufacturing share by 0.006 percentage points. This is over a hundred years after the last mine opening and shows a channel of some persistence. When turning to present manufacturing shares there is no significant effect. These results support the theory of location competition, but might also be an effect of industry experience and knowledge spillovers. It might be the case that the mining industry had an especially potent effect on traditional industry location since it was the first industry in Norway. Over time, this effect vanishes as other industry shocks come into play and this favors the exogeneity restriction of the instrument.

# 6 Conclusion

In this paper I use an improved measure of local quality of life with the innovation of Albouy (2012) and Carlsen and Leknes (2014) to study the effect of endogenous population size on regional quality of life. I exploit exogenous variation in the regional distribution of population size determined by the location of historical mining industry. The natural advantages of mining regions was made obsolete by the exhaustion of mineral and metal resources often centuries before quality of life outcomes were observed, which supports for exogeneity restriction of the instrument. The first stage correlations indicate path dependence in population patterns even after the initial advantage had disappeared. This is probably caused by agglomeration economies, which would benefit the location where economic activity first was established in each succeeding stage of competition.

The results show a positive effect of regional population size on quality of life when controlling for natural amenities. Several estimation strategies are employed to test the result robustness, for instance, regression discontinuity using a geological area around Oslo, regressions with pre-mining proxies of population patterns and investigation of the historical mines' impact on industry composition. All sensitivity analyses suggest that the findings can be interpreted as a causal effect and not biased by confounding factors determining both the spatial distribution of historical mining industry and quality of life. The effect flows through cultural amenities, thick market effects, and other benefits from being around people. The results indicate that urban regions have an advantage in the competition for firms and workers, since the cities would tend to get even more amendable over time as the spatial distribution of the population are shifted towards urban areas. It is expected that this relationship will eventually abate with increasing congestion costs.

# References


Albouy, D. (2010). What are cities worth? Land rents, local productivity, and the capitalization of amenity values. *Working Paper*.

Albouy, D. (2012). Are big cities bad places to live? Estimating quality of life across metropolitan areas. *NBER Working Paper 14472*, 1–66.

Almgren, O. (1900). Ur Herjeådalens folktro. En senkvarlefva af en forntida tro. *Svenska fornminnesföreningens tidskrift*, 229–235.

Alnæs, K. (1996). Historien om Norge. In *Det ligger et land*, Volume 1. Oslo: Gyldendal Norsk Forlag.

Bayer, P., F. Ferreira, and R. McMillan (2007, August). A unified framework for measuring preferences for schools and neighborhoods. *Journal of Political Economy 115*(4), 588–638.

Benedictow, O. J. (1991). Om kobbergruva i Sandsvær 1490-1530. In B. I. Berg (Ed.), *Wii Hans 500 års norsk bergverksdrift*, Number 6 in Norsk Bergverksmuseum Skrift, Kongsberg, pp. 9–14. Buskerud trykk.

Berg, B. I. (1991). Fremmedarbeidere i en brytningstid. In B. I. Berg (Ed.), *Wii Hans 500 års norsk bergverksdrift*, Number 6 in Norsk Bergverksmuseum Skrift, Kongsberg, pp. 15–18. Buskerud trykk.

Black, S. (1999). Do better school matter? Parental valuation of elementary education. *Quarterly Journal of Economics 114*, 577–599.

Bleakley, H. and J. Lin (2012). Portage and path dependence. *The Quarterly Journal of Economics*, 1–58.

Bøe, J. (1921). Norske guldfund fra folkevandringstiden. In *Bergens Museums Aarbok 1920-21*, Number 2 in Historisk-antikvarisk række. Bergen.

Boualam, B. (2014). Does culture affect local productivity and urban amenities? *Regional Science and Urban Economics 46*, 12–17.

Brueckner, J. K., J.-F. Thisse, and Y. Zenou (1999). Why is central Paris rich and downtown Detroit poor? An amenity-based theory. *European Economic Review 43*, 91–107.

Carlino, G. A. and A. Saiz (2008). Beautiful city: Leisure amenities and urban growth. *Working Paper*.

Carlsen, F. and S. Leknes (2014, April). Why and for whom are cities good places to live? Working Paper.

Carlsen, F., J. Rattsø, and S. H. E. (2013). Education, experience and dynamic urban wage premium. *Working Paper*, 1–35.

Carstens, H. (2000). *. . . bygger i berge.* Tapir Akademiske Forlag.

Chen, Y. and S. S. Rosenthal (2008). Local amenities and life-cycle migration: Do people move for jobs or fun? *Journal of Urban Economics 64*, 519–537.

Combes, P. P., G. Duranton, and L. Gobillon (2008). Spatial wage disparities: Sorting matters! *Journal of Urban Economics 63*, 723–742.

Combes, P. P., G. Duranton, L. Gobillon, and S. Roux (2010). *Estimating Agglomeration Economies with History, Geology, and Worker Effects*, Chapter 1, pp. 15–66. The University of Chicago Press.

David, P. A. (2001). Path dependence, its critics and the quest for 'historical economics'. In P. Garrouste and S. Ioannides (Eds.), *Evolution and path dependence in economic ideas: Past and present*, Chapter 2, pp. 15–38. Cheltenham, UK: Edward Elgar Publishing Limited.

Davis, D. R. and D. E. Weinstein (2002). Bones, bombs, and break points: The geography of economic activity. *The American Economic Review 92*(5), 1269–1289.

De la Roca, J. and D. Puga (2014). Learning by working in big cities. CEPR discussion paper 9243.

Dell, M. (2010, November). The persistent effects of peru's mining mita. *Econometrica 78*(6), 1863–1903.

Ebbesen, K. (1982). Om yngre steinalders bebyggelseshistorie. Beretninger fra et symposium. Odense 30. april -1. mai 1981. In *Yngre steinalders depotfund som bebyggelseshistorisk kildemateriale*, Number 30 in Skrifter fra Historisk Institutt, Odense Universitet, pp. 60–79.

Espelund, A. (2005). *Fra berggrunn og jordsmonn i Rørostraktom.* Trondheim: Arketype Forlag.

Fabech, C. (1991). Samfundsorganisation, religiøse ceremonier og regional variation. In C. Fabech and J. Ringtvedt (Eds.), *Samfundsorganisation og Regional Variation. Norden i Romersk Jernalder og Folkevandringstid*, Jysk Arkæologisk Selskabs Skrifter XXVII, pp. 283–303. Aarhus: Aarhus Universitetsforlag.

Fabech, C. (1999). Organising the landscape. a matter of production, power, and religion. In T. Dickinson and D. Griffiths (Eds.), *The Making of Kingdoms*, Anglo-Saxon Studies in Archeology and History 10, pp. 37–44. Oxford: Oxford University Committee for Archaeology.

Falck, O., M. Fritsch, and S. Heblich (2011). The phantom of the opera: Cultural amenities, human capital, and regional economic growth. *Labour Economics 18*, 755–766.

Falck-Muus, R. (1924). Bergverksdriften. Dens historiske og tekniske utvikling i Norge samt dens betydning for landet. *Særtrykk av den norske ingeniørforenings festskrift*, 560–590.

Fossen, H., R.-B. Pedersen, S. Bergh, and A. Andresen (2008). *The making of a land. Geology of Norway*, Chapter Creation of a mountain chain, pp. 178–231. Trondheim: Norwegian geological association.

Gabriel, S. A. and S. S. Rosenthal (2004, February). Quality of the business environment versus quality of life: Do firms and households like the same cities? *The Review of Economics and Statistics 86*(1), 438–444.

Glaeser, E. L. (2005). Smarth growth: Education, skilled workers, and the future of cold-weather cities. *Harvard University, Kennedy School, Policy brief PB-2005-1*.

Glaeser, E. L., S. P. Kerr, and W. R. Kerr (2012). Entrepreneurship and Urban Growth: An Empirical Assessment with Historical Mines. *The Review of Economics and Statistics*.

Glaeser, E. L., J. Kolko, and A. Saiz (2001). Consumer city. *Journal of Economic Geography 1*(1), 27–50.

Glaeser, E. L. and D. Mare (2001). Cities and skills. *Journal of Labor Economics 19*(2), 316–342.

Grieg, S. (1929). Vikingetidens skattefund. *Universitetets Oldsaksamlings skrifter* (2), 177–311.

Gyourko, J., M. E. Kahn, and J. Tracy (1999). Quality of life and environmental comparisons. In P. Cheshire and E. Mills (Eds.), *Handbook of Regional and Urban Economics*, Volume 3, Chapter 5, pp. 1413–1454. North-Holland.

Hedeager, L. (2003). Kognitiv topografi: Ædelmetalldepoter i landskapet. In *Universitetets Oldsaksamlings skrifter. Ny rekke*, Number 2. Oslo.

Hirschmann, A. O. (1958). *The strategy of economic development.* New Haven: Yale University Press.

Jeanty, P. W., M. Partridge, and E. Irwin (2010). Estimation of a spatial simultaneous equation model of population migration and housing price dynamics. *Regional Science and Urban Economics 40*, 343–352.

Johannessen, F. E. (1991). Natur og kultur ved Årdal kobberverk tidlig på 1700-tallet. In B. I. Berg (Ed.), *Wii Hans 500 års norsk bergverksdrift*, Number 6 in Norsk Bergverksmuseum Skrift, Kongsberg, pp. 19–23. Buskerud trykk.

Krugman, P. (1991). History versus expectations. *The Quarterly Journal of Economics 106*(2), 651–667.

Lillehammer, A. (1994). Aschehougs norgeshistorie. In K. Helle (Ed.), *Fra jeger til bonde - inntil 800 e.Kr*, Volume 1. Oslo: H. Aschehoug & Co.

Magnus, B. and B. Myhre (1995). Norges Historie. In K. Mykland (Ed.), *Forhistorien - Fra jegergrupper til høvdingsamfunn*, Volume 1. J. W. Cappelens forlag.

Masdalen, K. J., G. Molden, J. H. Simonsen, and A. Vevstad (1990). Jerngruvene i Aust-Agder. Project report, Aust-Agder.

Michaels, G., F. Rauch, and S. J. Redding (2012). Urbanization and structural transformation. *The Quarterly Journal of Economics 127*(2), 535–586.

Montelius, O. (1919). *Vår forntid*. Stockholm: Nordstedt och Sonners Forlag.

Mueser, P. and P. Graves (1995). Examining the role of economic opportunity and amenities in explaining population redistribution. *Journal of Urban Economics 37*, 176–200.

Munch, J. S. (1956). Folkevandringens gullskatter i Norge. *Viking* (XX), 97–126.

Nordgulen, Ø. and A. Andresen (2008). *The making of a land. Geology of Norway*, Chapter The Precambrian, pp. 62–119. Trondheim: Norwegian geological association.

Ramberg, I. B., I. Bryhni, and A. Nøttvedt (2006). *Landet blir til - Norges geologi*. Trondheim: PDC Tangen AS.

Rappaport, J. (2007). Moving to nice weather. *Journal of Urban Economics 37*, 375–398.

Rappaport, J. (2008). Consumption amenities and city population density. *Regional Science and Urban Economics 38*, 533–552.

Rian, Ø. (1991). Tanker om årsakene til gjennombruddet for jernverksdriften på 1600-tallet. In B. I. Berg (Ed.), *Wii Hans 500 års norsk bergverksdrift*, Number 6 in Norsk Bergverksmuseum Skrift, Kongsberg, pp. 29–32. Buskerud trykk.

Roback, J. (1982, December). Wages, rents, and the quality of life. *Journal of Political Economy 90*(6), 1257–1278.

Rosenthal, S. S. and W. C. Strange (2008, February). Agglomeration and hours worked. *The Review of Economics and Statistics 90*(1), 105–118.

Ryste, B. (2005). Edelmetalldepotene fra folkevandringstid og vikingtid i Norge: Gull og sølv i kontekst. Master's thesis, University of Oslo.

Skaare, K. (1976). *Coins and coinage in viking-age Norway*. Oslo: Universitetsforlaget.

Skjeseth, S. (1996). *Norge blir til. Norges geologiske historie*. Oslo: Chr. Schibsteds forlag.

Sprauten, K. (1991). Forsyning av norske kobberverk med matvarer og krutt i første halvdel av 1700-tallet. In B. I. Berg (Ed.), *Wii Hans 500 års norsk bergverksdrift*, Number 6 in Norsk Bergverksmuseum Skrift, Kongsberg, pp. 24–28. Buskerud trykk.

Stewart, G. and J. Lee (2009, May). Implicit amenity prices and the location of retirees in England and Wales. *Applied Economics Letters 17*(11), 1105–1109.

Stock, J. H., J. H. Wright, and M. Yogo (2002, October). A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments. *Journal of Business and Economic Statistics 20*(4), 518–529.

Storper, M. and A. J. Scott (2009). Rethinking human capital, creativity and urban growth. *Journal of Economic Geography 9*, 147–167.

Thuesen, G. (1979). Den første dokumenterte bergverksdrift i Norge. *Volund*, 7–60.

Thuesen, G. (1988). Bergverksdrift i Oslo-området. *Volund*, 56–88.

Valentinyi, A. and B. Herrendorf (2008). Measuring factor income shares at the sectoral level. *Review of Economic Dynamics 11*, 820–835.

Wheeler, C. (2001). Search, sorting and urban agglomeration. *Journal of Labor Economics 19*(4), 879–899.

Williamson, J. (1965). Antebellum urbanization in the american Northeast. *Journal of Economic History*, 592–608.

Worsaae, J. J. A. (1865). *Om Slesvigs eller Sønderjyllands oldtidsminder*. København.

# A Additional theoretical details

From the migration equilibrium condition (A1) I can derive an expression for the compensating differential.

$$V(Y_r, P_{H,r}, P_{NT,r}, P_{T,r}, QOL_r) = \overline{V} \tag{A1}$$

The initial step is to do a first order Taylor series expansion around the national averages. That gives:

$$\begin{aligned}\frac{\delta V}{\delta QOL_r}(QOL_r - QOL) = &-\frac{\delta V}{\delta P_{H,r}}(P_{H,r} - P_H) - \frac{\delta V}{\delta P_{NT,r}}(P_{NT,r} - P_{NT}) - \frac{\delta V}{\delta P_{T,r}}(P_{T,r} - P_T) \\ &-\frac{\delta V}{\delta Y_r}(Y_r - Y)\end{aligned} \tag{A2}$$

I utilize Roy's identity and get:

$$P_{QOL}(QOL_r - QOL) = X_H(P_{H,r} - P_H) + X_{NT}(P_{NT,r} - P_{NT}) + X_T(P_{T,r} - P_T) - (Y_r - Y) \tag{A3}$$

$P_{QOL}$ is the amenity price. $X_H$, $X_{NT}$ and $X_T$ are national averages of quantities of housing, non-tradables and tradables. Divide through the expression by the national average post-tax income $Y$. That gives:

$$\begin{aligned}\widetilde{QOL}_r = \frac{P_{QOL}(QOL_r - QOL)}{Y} = &\frac{X_H P_H}{Y}\frac{(P_{H,r} - P_H)}{P_H} + \frac{X_{NT} P_{NT}}{Y}\frac{(P_{NT,r} - P_{NT})}{P_{NT}} \\ &+\frac{X_T P_T}{Y}\frac{(P_{T,r} - P_T)}{P_T} - \frac{(Y_r - Y)}{Y}\end{aligned} \tag{A4}$$

where $\widetilde{QOL}_r$ is the quality of life measured as share of post-tax average income and as deviation from the national average. The sum of the budget shares equal unity. Therefore, (A4) can be written as:

$$\widetilde{QOL}_r = \alpha_H \frac{P_{H,r}}{P_H} + \alpha_{NT}\frac{P_{NT,r}}{P_{NT}} + \alpha_T \frac{P_{T,r}}{P_T} - \frac{Y_r}{Y} \tag{A5}$$

I decompose the prices of non-tradables as a a weighted sum of its factor prices.

$$\frac{P_{NT,r}}{P_{NT}} = \delta_H \frac{P_{H,r}}{P_H} + \delta_L \frac{W_r(1+s_r)}{\overline{\overline{W_r(1+s_r)}}} + \delta_T \frac{P_{T,r}}{P_T} \tag{A6}$$

where $W_r$ is average regional wage level, $s_r$ is the average pay roll tax rate paid by firms in the region and $\overline{W_r(1+s_r)}$ is the national average cost per unit labour. $\delta_H$, $\delta_L$ and $\delta_T$ are respectively the factor shares of housing, labor and a composite of traded goods.

I assume that the prices of tradable goods are equal across regions,

$$\frac{P_{T,r}}{P_T} = 1 \tag{A7}$$

I set post tax income equal to wages minus taxes $Y_r = W_r - t_r(W_r)$, and $\overline{W_r - t_r(W_r)}$ is the average post tax income. That gives the following expression for the relative post tax income:

$$\frac{Y_r}{Y} = \frac{W_r - t_r(W_r)}{\overline{W_r - t_r(W_r)}} \tag{A8}$$

The tax function, $t_r(W_r)$, vary across regions since inhabitants in some rural areas i Norway benefit from lower federal taxes. Local taxes are included in the tax function. Locally financed government services are therefore included in $QOL_r$.

Substitute (A6)-(A8) into (A5) gives the quality of life for region r. This is equivalent to equation (2) in the main text.

$$\widetilde{QOL}_r = (\alpha_H + \alpha_{NT}\delta_H)\frac{P_{H,r}}{P_H} + \alpha_{NT}\delta_L\frac{W_r(1+s_r)}{\overline{W_r(1+s_r)}} + \alpha_T + \alpha_{NT}\delta_T - \frac{W_r - t_r(W_r)}{\overline{W_r - t_r(W_r)}} \tag{A9}$$

# B Additional data details

## B.1 Descriptives for components in quality of life measure

Table B.1: Descriptive analyses. Averages for 1994-2002

| Population quantiles:* | 1. quartile | 2. quartile | 3. quartile | 4. quartile |
|---|---|---|---|---|
| *Wage measure:* | | | | |
| $\frac{W_r}{\bar{W}}$ | 0.991 | 0.991 | 1.001 | 1.017 |
| $\frac{W_r - t_r(W_r^e)}{\bar{W} - t(\bar{W})}$ | 0.996 | 0.996 | 1.000 | 1.009 |
| *House prices:* | | | | |
| $\frac{P_{H,r}}{\bar{P}_H}$ | 0.840 | 0.865 | 0.996 | 1.306 |
| *Budget shares:* | | | | |
| $\alpha_H$ | 0.196 | 0.194 | 0.196 | 0.199 |
| $\alpha_{NT}$ | 0.281 | 0.284 | 0.284 | 0.286 |
| $\alpha_T$ | 0.523 | 0.522 | 0.519 | 0.516 |

* Quartiles derived from 1994 beginning-of-year population.

Table B.2: Population size, wage and housing cost differentials, and quality of life

| Region | Population size | Wages | Housing costs | Quality of life | QOL rank |
|---|---|---|---|---|---|
| Oslo | 497,331 | 0.050 | 1.22 | 0.321 | 1 |
| Bærum/Asker | 146,030 | 0.060 | 1.16 | 0.294 | 2 |
| Follo | 98,950 | 0.040 | 0.64 | 0.162 | 3 |
| Trondheim | 198,017 | -0.002 | 0.42 | 0.120 | 4 |
| Lillestrøm | 160,445 | 0.041 | 0.48 | 0.117 | 5 |
| Tønsberg/Horten | 102,803 | 0.000 | 0.36 | 0.102 | 6 |
| Tromsø | 71,372 | 0.008 | 0.45 | 0.099 | 7 |
| Bergen | 342,984 | 0.004 | 0.36 | 0.099 | 8 |
| Stavanger/Sandnes | 213,135 | 0.026 | 0.43 | 0.098 | 9 |
| Kristiansand | 96,687 | 0.000 | 0.27 | 0.077 | 10 |
| Lillehammer | 35,516 | -0.014 | 0.23 | 0.076 | 11 |
| Sandefjord/Larvik | 80,511 | -0.009 | 0.23 | 0.075 | 12 |
| Moss | 49,076 | 0.014 | 0.28 | 0.073 | 13 |
| Stjørdalshalsen | 20,609 | -0.01 0 | 0.17 | 0.059 | 14 |
| Ullensaker/Eidsvoll | 47,985 | 0.035 | 0.26 | 0.057 | 15 |
| Drammen | 149,540 | 0.031 | 0.26 | 0.053 | 16 |
| Ålesund | 81,627 | -0.003 | 0.17 | 0.053 | 17 |
| Lillesand | 12,900 | -0.013 | 0.11 | 0.046 | 18 |
| Jæren | 39,908 | 0.006 | 0.15 | 0.042 | 19 |
| Hønefoss | 34,759 | 0.018 | 0.17 | 0.038 | 20 |
| Hamar | 82,874 | -0.008 | 0.08 | 0.036 | 21 |
| Halden | 27,905 | -0.021 | 0.05 | 0.035 | 22 |
| Arendal | 70,577 | -0.014 | 0.07 | 0.035 | 23 |
| Kongsberg | 28,765 | 0.020 | 0.17 | 0.035 | 24 |
| Fredrikstad/Sarpsborg | 124,308 | -0.002 | 0.09 | 0.035 | 25 |
| Førde | 26,677 | -0.006 | 0.08 | 0.028 | 26 |
| Holmestrand | 12,135 | 0.001 | 0.08 | 0.027 | 27 |
| Bodø | 76,134 | 0.006 | 0.15 | 0.025 | 28 |
| Voss | 16,078 | -0.013 | 0.03 | 0.022 | 29 |
| Sande/Svelvik | 13,371 | 0.019 | 0.11 | 0.022 | 30 |
| Mandal | 22,133 | -0.016 | 0.01 | 0.020 | 31 |
| Molde | 60,583 | -0.014 | 0.01 | 0.019 | 32 |
| Florø | 15,235 | -0.001 | 0.05 | 0.013 | 33 |
| Skien/Porsgrunn | 104,404 | -0.006 | 0.00 | 0.013 | 34 |
| Gjøvik | 67,254 | -0.011 | -0.01 | 0.011 | 35 |
| Haugesund | 89,683 | 0.004 | 0.01 | 0.007 | 36 |
| Røros | 7,766 | -0.027 | -0.05 | 0.006 | 37 |
| Levanger/Verdalsøra | 33,534 | -0.025 | -0.08 | 0.004 | 38 |
| Kragerø | 14,939 | -0.017 | -0.07 | 0.001 | 39 |
| Hadeland | 26,906 | 0.011 | 0.00 | -0.001 | 40 |
| Sogndal/Årdal | 26,624 | -0.015 | -0.05 | -0.001 | 41 |
| Flekkefjord | 16,184 | -0.022 | -0.11 | -0.005 | 42 |
| Elverum | 38,249 | -0.010 | -0.07 | -0.006 | 43 |
| Askim/Mysen | 43,277 | 0.018 | -0.01 | -0.009 | 44 |

| | | | | | |
|---|---|---|---|---|---|
| Steinkjer | 37,874 | -0.028 | -0.13 | -0.010 | 45 |
| Ørsta/Volda | 18,570 | -0.023 | -0.12 | -0.010 | 46 |
| Mo i Rana | 31,797 | -0.014 | -0.05 | -0.011 | 47 |
| Kristiansund | 33,985 | -0.008 | -0.09 | -0.012 | 48 |
| Namsos | 19,442 | -0.022 | -0.08 | -0.013 | 49 |
| Ulsteinvik | 26,190 | -0.010 | -0.09 | -0.013 | 50 |
| Nordre Sunnhordaland | 45,412 | -0.003 | -0.08 | -0.015 | 51 |
| Lyngdal/Farsund | 18,004 | -0.015 | -0.14 | -0.016 | 52 |
| Mosjøen | 16,865 | -0.008 | -0.05 | -0.017 | 53 |
| Hallingdal | 20,179 | 0.002 | -0.07 | -0.018 | 54 |
| Egersund | 22,010 | -0.005 | -0.12 | -0.021 | 55 |
| Brønnøysund | 13,414 | -0.026 | -0.13 | -0.023 | 56 |
| Oppdal | 9,062 | -0.022 | -0.15 | -0.023 | 57 |
| Risør | 9,529 | -0.011 | -0.14 | -0.023 | 58 |
| Harstad | 32,018 | -0.001 | -0.07 | -0.026 | 59 |
| Kongsvinger | 49,810 | -0.007 | -0.14 | -0.026 | 60 |
| Nord-Gudbrandsdalen | 20,431 | -0.031 | -0.19 | -0.028 | 61 |
| Narvik | 29,509 | -0.019 | -0.14 | -0.031 | 62 |
| Orkanger | 21,482 | -0.016 | -0.17 | -0.031 | 63 |
| Midt-Gudbrandsdalen | 14,215 | -0.026 | -0.20 | -0.031 | 64 |
| Nordfjord | 29,133 | -0.022 | -0.19 | -0.032 | 65 |
| Notodden/Bø | 23,197 | -0.003 | -0.15 | -0.033 | 66 |
| Rørvik | 9,975 | -0.028 | -0.18 | -0.033 | 67 |
| Vesterålen | 31,488 | -0.019 | -0.15 | -0.033 | 68 |
| Sandnessjøen | 15,925 | -0.006 | -0.11 | -0.033 | 69 |
| Søndre Sunnhordaland | 11,834 | -0.001 | -0.15 | -0.036 | 70 |
| Frøya/Hitra | 8,193 | -0.019 | -0.18 | -0.040 | 71 |
| Brekstad | 15,624 | -0.014 | -0.19 | -0.043 | 72 |
| Rjukan | 6,636 | -0.015 | -0.22 | -0.047 | 73 |
| Valdres | 18,537 | -0.022 | -0.24 | -0.048 | 74 |
| Sunndalsøra | 10,617 | -0.015 | -0.23 | -0.049 | 75 |
| Finnsnes | 19,846 | -0.018 | -0.21 | -0.049 | 76 |
| Odda | 13,749 | 0.005 | -0.18 | -0.050 | 77 |
| Tynset | 15,927 | -0.028 | -0.28 | -0.053 | 78 |
| Lofoten | 24,451 | -0.019 | -0.24 | -0.055 | 79 |
| Vest-Telemark | 15,009 | -0.011 | -0.26 | -0.06 0 | 80 |
| Høyanger | 9,975 | 0.000 | -0.27 | -0.071 | 81 |
| Setesdal | 8,107 | -0.021 | -0.35 | -0.073 | 82 |
| Surnadal | 10,400 | -0.027 | -0.35 | -0.074 | 83 |
| Andselv | 15,788 | 0.005 | -0.31 | -0.094 | 84 |
| Alta | 22,447 | 0.086 | -0.06 | -0.118 | 85 |
| Grong | 5,811 | -0.016 | -0.52 | -0.132 | 86 |
| Kirkenes | 9,752 | 0.109 | -0.11 | -0.148 | 87 |
| Nord-Troms | 11,852 | 0.064 | -0.27 | -0.153 | 88 |
| Hammerfest | 25,887 | 0.087 | -0.28 | -0.173 | 89 |
| Vadsø | 17,018 | 0.105 | -0.32 | -0.200 | 90 |

Population size, wages, housing costs and quality of life are computes as the average over the years 1994-2002.
Wages and housing costs differentials are denoted relative to national average and are here normalized by subtracting 1.

## B.2 Historical mines

Table B.3: Frequency of mine closure by century and descriptive statistics of instruments

| Century | 16th | 17th | 18th | 19th | 20th | Total |
|---|---|---|---|---|---|---|
| Pre 17th century mines<br>*(Mean:0.13, Std. Dev.:0.43)* | 1 | 1 | 2 | 6 | 2 | 12 |
| 17th century mines<br>*(Mean:0.31, Std. Dev.:0.71)* | - | 6 | 5 | 9 | 8 | 28 |
| 18th century mines<br>*(Mean:0.26, Std. Dev.:0.63)* | - | - | 12 | 8 | 3 | 23 |
| All historical mines<br>*(Mean:0.7, Std. Dev.:1.27)* | 1 | 7 | 19 | 23 | 13 | 63 |

Frequency table that summarize mine closure by century.

Mean and standard deviation of the instruments across the 90 regions in parentheses.

Table B.4: Historical mines

| Name | Time period[a] | Municipality | Economic region (No.) |
|---|---|---|---|
| Moss Iron Works | 1704-1876 | Moss | Moss (2) |
| Bærum Works | 1614-1872 | Bærum | Bærum (6) |
| Dikemark Works | 1697-1815 | Asker | Bærum (6) |
| Hakkadal Works | 1514-1865 | Nittedal | Lillestrøm (7) |
| Feiringenberg | before 1539, 1620, 1880 | Eidsvoll | Eidsvoll (8) |
| Eidsvoll Iron Works | 1624-1822 | Eidsvoll | Eidsvoll (8) |
| Eidsvoll Gold Works | 1758-1907 | Eidsvoll | Eidsvoll (8) |
| Lysjø Copper Works | 1790-1811, 1897-1907 | Eidsvoll | Eidsvoll (8) |
| Akerberg | before 1200-1619 | Oslo | Oslo (9) |
| Sogneberg Mines | 1538-1854 | Oslo | Oslo (9) |
| Gothalfske Copper Works | 1704-08, 1717-50, 1880-90 | Oslo | Oslo (9) |
| Alum Shale Works | 1737-1815 | Oslo | Oslo (9) |
| Odal Iron Works | 1708-1877 | Sør-Odal | Kongsvinger (10) |
| Sands Copper Works | 1688. 1723-51 | Nord-Odal | Kongsvinger (10) |
| Kvikne Copper Works | 1620-1814 | Tynset | Tynset (13) |
| Folldal Works | 1745-1969[b] | Folldal | Tynset (13) |
| Lesja Iron Works | 1659-1812 | Lesja | Nord-Gudbrandsdalen (17) |
| Sel Copper Mine | 1642-1789 | Sel | Nord-Gudbrandsdalen (17) |
| Grua Iron Mine | 1540-1800 | Lunner | Hadeland (18) |
| Hadeland Lead Mine | ca 1700-1800 | Lunner | Hadeland (18) |
| Jevnaker Copper Mine | 1668-1800 | Jevnaker | Hadeland (18) |
| Egersberg | 1528, 1602, 1734-60, 1842-64, 1870 | Nedre-Eiker | Drammen (20) |
| Modum Blue Works | 1772-1898 | Modum | Drammen (20) |
| Konnerud Works | 1731-1770 | Drammen | Drammen (20) |
| Bø Mine, Lier Lead Works | 1753 | Lier | Drammen (20) |
| Hassel Iron Works | 1649-1870 | Øvre-Eiker | Drammen (20) |
| Kongs Copper Works, Buttedal | 1751-59 | Lier | Drammen (20) |
| Kongsberg Silver Works | 1623-1958 | Kongsberg | Kongsberg (21) |
| Kongsberg Iron Works | 1690-1850 | Kongsberg | Kongsberg (21) |
| Samsonberg | 1400, 1538-43, 1736 | Kongsberg | Kongsberg (21) |
| Luth's Copper Works | 1680 | Ringerike, Krødsherad | Hønefoss (22) |
| Eidsfoss Iron Works | 1697-1961 | Hof | Holmestrand (25) |
| Trakenberg | 1542-1908 | Skien | Skien/Porsgrunn (28) |
| Gjerpen Iron Works | ca 1540-1868 | Skien | Skien/Porsgrunn (28) |
| Fen Iron Mines | 1657-1927 | Nome | Skien/Porsgrunn (28) |
| Stabbedals/Hitterdals Works | 1753-1761 | Notodden | Notodden/Bø (29) |
| Langøy Iron Mines | 1647-1966 | Kragerø | Kragerø (30) |
| Fossum Copper Works | 1747 | Tinn | Rjukan (31) |
| Sundsberg, Guldnes | 1524, 1539-49, 1780, 1863-88 | Seljord | Vest-Telemark (32) |
| Moisesberg | 1543-49 | Fyresdal | Vest-Telemark (32) |
| Åmdals Copper Works | 1689-1945 | Tokke | Vest-Telemark (32) |
| Egeland Iron Works | 1706-1884 | Gjerstad | Risør (33) |
| Arendal Iron Mines | 1574-1975 | Arendal | Arendal (34) |
| Nes Iron Works | 1665-1959 | Arendal | Arendal (34) |
| Froland Iron Works | 1763-1867 | Froland | Arendal (34) |
| Enigheds Copper Works | 1764-86 | Hjelmeland | Stavanger/Sandnes (42) |
| Lilledal Copper Works | 1642-70, 1689-1759 | Kvinnherad | Nordre Sunnhordaland (47) |
| Årdal Copper Works | 1700-1734 | Årdal | Sogndal/Årdal (52) |
| Grimeliens Copper Works | 1759-85, 1851-83 | Førde | Førde (53) |
| Smølens Copper Works | 1717-23 | Smøla | Kristiansund (56) |
| Selbu Copper Works | 1713-99 | Selbu | Trondheim (62) |
| Mostadmark Iron Works | 1657-1865 | Malvik | Trondheim (62) |
| Skaudalens Copper Works | 1673 (few years) | Rissa | Trondheim (62) |
| Ulriksdal Copper Mine | 1670-75 | Klæbu | Trondheim (62) |
| Sogndal Copper Works | 1665 | Midtre-Gauldal | Trondheim (62) |
| Budals Copper Works | 1673 | Midtre-Gauldal | Trondheim (62) |
| Løkken Copper Works | 1654-1987 | Meldal | Orkanger (66) |
| Røros Copper Works | 1647-1977 | Røros | Røros (67) |
| Gulstad Copper Works | 1770-87 | Steinkjer | Steinkjer (68) |
| Mok Copper Works | 1770-78 | Steinkjer | Steinkjer (68) |
| Ytterøy Copper Works | 1635, 1673, 1750-52, 1840 | Levanger | Levanger/Verdalsøra (71) |
| Bals Copper Mine | 1636-1690 | Ballangen | Narvik (75) |
| Bertelsberget Mine | 1680-1700 | Rana | Mo i Rana (79) |

[a] For some of the mines operation start date is reported only. That means that the closure year is somewhat uncertain, and that the mine was active for just a short period.

[b] The mining company moved it's operation to Hjerkinn after 1969. Hjerkinn is located in another region.

## B.3 Control variables

**Area of woodland** variable is provided by Statistics Norway and denotes square kilometers of woodland in the region in 2011. There is no data for one of the regions, Søndre Sunnhordaland, because of altered municipality structure. I aggregated municipality data to create the last observation. In 2006 Ølen and Vindafjord municipality was merged into one municipality Vindafjord. I assume that woodland is equally distributed between Ølen and old Vindafjord municipality, and calculate area of woodland from area shares.

**River length** is collected from Norwegian Water Resource and Energy Directorate statistic database from 2013. **River length** is the sum of river length for all rivers in the region. The length of rivers is created for Søndre Sunnhordaland in the same manner as for the Area of woodland variable.

**Mountain share** denotes area (square kilometers) of the region covered by bare rock, gravel, block fields, perpetual snow and glaciers. The data is collected from Statistics Norway.

**Slope** is computed as an Herfindahl index of the following form: $HI = \sum_{i=0}^{n} a_r^2$. where $a_r$ denotes the area share of land within each band of 20 meter in a region. This can be understood as spread measure of area across different plateaus, and comprise information similar to a average slope variable. The data is collected from Norwegian Water Resource and Energy Directorate.

**Hydro-power industry** is the regional worker share that is employed in hydro-power production in 2000. The data is collected from Statistics Norway.

**Oil and gas employment share** is the regional worker share that is employed in extraction of crude petroleum and natural gas in 2000. The data is collected from Statistics Norway.

**January temperature**, **Wind speed**, and **Precipitation** are collected from Norwegian Meteorological Institute's climate database (eklima). **January temperature** is the average over the years 1994-2002 of mean January temperature in Celsius. **Wind speed** is average over the years 1994-2002 of mean monthly wind speed (meters per second), and **Precipitation**, is average over the years 1994-2002 of mean monthly precipitation (millimeters per month).

**Coast length** is collected from Statistics Norway, and gives regional data for year 2003 on kilometers of mainland coastline.

**Recreational walk share** is the proportion of residents in urban settlements with access to area for recreational walking. Urban settlement is defined by Statistics Norway as a hub of buildings inhabited by at least 200 people (60-70 dwellings) where the distance between buildings don't normally exceed 50 meters. Recreational areas are defined as large nature areas (larger than 20 hectares) within or bordering urban settlements.

**Primary education share** is the regional share of workers with mandatory education (9 or 10 years) as their highest completed education level. It is the average share over the years 1994-2002. The data is collected from Statistics Norway.

**Unemployment rate** is collected from Statistics Norway, and denotes the average regional unemployment rate in percent for the period 1994-2002.

**Miners today** variable is provided by Statistics Norway and gives information of the average over the years 1994-2002 of number of workers in each region occupied in the sector - mining of metalliferous ores.

Table B.5: Descriptives for region covariates

| | Mean | Std. Dev. |
|---|---|---|
| Area of woodland | 1358.55 | 1173.94 |
| River length | 8823.54 | 9077.9 |
| Mountain share | 0.07 | 0.11 |
| Slope | 0.04 | 0.03 |
| Hydro-power industry share | 0.011 | 0.006 |
| Petroleum industry share | 0.009 | 0.012 |
| January temperature | -1.95 | 3.41 |
| Wind speed | 3.41 | 1.89 |
| Precipitation | 93.28 | 41.46 |
| Coast length | 282.57 | 402.27 |
| Recreation walk share | 63.69 | 16.36 |
| Primary education share | 0.16 | 0.03 |
| Unemployment rate | 5.14 | 1.39 |
| Miners today | 5.76 | 28.29 |
| Iron age grave sites | 8.09 | 21.13 |
| Noble metal hoards | 1.68 | 2.27 |
| Industry diversity 1835 | 0.46 | 0.10 |
| Industry diversity 1891 | 0.44 | 0.15 |
| Industry diversity 2000 | 0.21 | 0.03 |
| Manufacturing employment share 1891 | 0.01 | 0.02 |
| Manufacturing employment share 2000 | 0.15 | 0.06 |
| Area of land ($km^2$) | 3380.55 | 3185.15 |

**Iron age grave sites** is the number of gravesites from the iron age (500 B.C. till 500 A.D.) in each region. The iron age grave sites data is published by the Directorate for Cultural Heritage. The data is freely available at the url: kulturminnesøk.no.

**Noble metal hoards** is the number of noble metal hoards dated 800-1100 A.D. in each region. The source data of hoards from the viking-age is gathered from Bøe (1921); Grieg (1929); Munch (1956); Skaare (1976) and published in Ryste (2005).

**Industry concentration ratio 1835** is a variable that is computed using data from Norwegian Social Science Data Services (NSD). It is computed as a Herfindahl index; the sum of the squared employment share in each profession. The professions registered for 1935 are clergymen, government officials, military officials, merchants, shopkeepers and innkeepers, manufacturers, skippers, sailors and fishermen, farmers (sum of freeholders, tenant farmers and crofters), and servants. The data is registered for cities/towns and countryside areas. I sum the equivalent categories for city and countryside when creating the total employment shares in each profession.

**Industry concentration ratio 1891** is a variable that is computed using data from Norwegian Social Science Data Services (NSD). It is computed as a Herfindahl index; the sum of the squared employment share in each profession. The professions registered for 1891 are farming and husbandry, horticulture, forestry and hunting, fishing, mining, quarrying, factory work, craft industry, trade and banking, inn keeping, land-carriage and railway services, shipping, and log driving. Mining is omitted from the computation. **Manufacturing employment share 1891** is derived from the same data.

**Industry concentration ratio 2000** is a variable that is computed using data from Statistics Norway. It is computed as a Herfindahl index; the sum of the squared employment share in each profession. The professions registered for 2000 are agriculture, hunting, forestry and fishing (1), mining and quarrying (2), manufacturing (3), electricity, gas and water supply (4), construction (5), wholesale, retail trade, hotels and restaurants (6), transport, storage and communication (7), financial intermediation (8), real estate and renting (9), and public services (10). Mining and quarrying are omitted from the computation. **Manufacturing employment share 2000** is derived from the same data.

**Area of land** is denoted in square kilometers and is collected from Statistic Norway.

# C Regional wage estimates without individual fixed effects

I estimate a second measure of the regional wage using the full population of workers. This is the standard approach in the quality of life literature. For each year t, the following hedonic equation are estimated:

$$W_{irt} = \alpha_{rt} + X_{irt}\beta + \epsilon_{irt} \tag{C10}$$

This equation describes individual annual income for worker $i$ in region $r$ and year $t$, $W_{irt}$, as a function of region-year fixed effects, $\alpha_{rt}$, and a vector of worker characteristics, $X_{irt}$. The observable characteristics are age dummies (five year intervals), education and gender. The estimated region-year fixed effects $\tilde{\alpha}_{rt}$ are used as the first measure of regional wage.

Table C.6: Sensitivity analyses with alternative wage measure

| | | | Mine operation inputs | Additional natural amenity | Natural production | Population traits | Current mining production | Mining tourism regions excluded | Hanseatic trade regions excluded | Post 1970 mine regions excluded |
|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | IV | IV | IV | IV | IV | IV | IV | IV | IV |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| *Second stage and OLS results. Dependent variable: Quality of life* | | | | | | | | | | |
| Log(population) | 0.041*** | 0.042*** | 0.046*** | 0.041*** | 0.040*** | 0.036*** | 0.042*** | 0.042*** | 0.029** | 0.043*** |
| | (5.33) | (2.91) | (3.18) | (2.92) | (2.70) | (2.93) | (2.94) | (2.90) | (2.53) | (2.75) |
| *First stage results. Dependent variable: Log(population)* | | | | | | | | | | |
| All historical mines | - | 0.308*** | 0.296*** | 0.297*** | 0.295*** | 0.289*** | 0.307*** | 0.313*** | 0.261*** | 0.302*** |
| | | (5.00) | (4.34) | (6.04) | (5.20) | (5.09) | (4.97) | (5.02) | (5.56) | (4.63) |
| Area of woodland | N | N | Y | N | N | N | N | N | N | N |
| River lenght | N | N | Y | N | N | N | N | N | N | N |
| Recreation walk share | N | N | N | Y | N | N | N | N | N | N |
| Hydro-power industry share | N | N | N | N | Y | N | N | N | N | N |
| Petroleum industry share | N | N | N | N | Y | N | N | N | N | N |
| Primary education share | N | N | N | N | N | Y | N | N | N | N |
| Unemployment rate | N | N | N | N | N | Y | N | N | N | N |
| Miners today | N | N | N | N | N | N | Y | N | N | N |
| Natural amenities | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Adjusted R-Square OLS & 1st stage | 0.47 | 0.27 | 0.26 | 0.36 | 0.36 | 0.29 | 0.26 | 0.27 | 0.24 | 0.27 |
| Number of mines | - | 63 | 63 | 63 | 63 | 63 | 63 | 59 | 59 | 58 |
| Number of regions | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 88 | 87 | 87 |

Sample: 90 regions, average for period 1994-2002. Dependent variable is regional amenity level and log(population).

Robust t statistics in parentheses. All regressions control for constant. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Natural amenities are mountain area share, slope, January temperature, wind speed, precipitation, and coast length.

In column (1) the estimator is OLS. In (2)-(9) are estimated by IV. Further information can be found in Appendix B.3.

# D Sensitivity of urban scale variable

Table D.7: Sensitivity analyses of urban scale variable

| Various measures of urban scale: | Log (pop.) | Log (pop.) | Log (density) | Density | Log(pop. in urban areas) | Log(pop. in region center) |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *OLS results. Dependent variable: Quality of life* | | | | | | |
| Urban scale | 0.060*** | 0.060*** | 0.113*** | 0.056*** | 0.046*** | 0.046*** |
| | (7.05) | (7.96) | (6.50) | (10.21) | (6.94) | (7.46) |
| *Second stage results. Dependent variable: Quality of life* | | | | | | |
| Urban scale | 0.065*** | 0.071*** | 0.208*** | 0.069*** | 0.055*** | 0.053*** |
| | (4.18) | (4.83) | (3.47) | (5.19) | (4.09) | (4.62) |
| *First stage results. Dependent variable: Urban scale* | | | | | | |
| All historical mines | 0.308*** | 0.310*** | 0.094*** | 0.289*** | 0.362*** | 0.376*** |
| | (5.00) | (4.94) | (2.74) | (2.81) | (4.50) | (3.90) |
| Area of land in region | N | Y | N | N | N | N |
| Natural amenities | Y | Y | Y | Y | Y | Y |
| Adjusted R-Square OLS | 0.59 | 0.67 | 0.60 | 0.73 | 0.59 | 0.61 |
| Adjusted R-Square 1st stage | 0.27 | 0.26 | 0.46 | 0.43 | 0.19 | 0.23 |
| Number of mines | 63 | 63 | 63 | 63 | 63 | 63 |
| Number of regions | 90 | 90 | 90 | 90 | 90 | 90 |

Sample: 90 regions, averages for period 1994-2002. Dependent variable is Quality of life and urban scale. Density is computed ad the number of people for each square kilometer. Natural amenities are mountain area share, slope, January temperature, wind speed, precipitation, and coast length.

Robust t statistics in parentheses. All regressions control for constant.

Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$