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Causal evidence on quality of life and population size using historical mines

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Quality of life and population size: Causal evidence with historical mines*

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Abstract

In this paper I investigate the causal effect of endogenous population size on quality of life. It has been suggested that the quantity and quality of consumer amenities increase with urban scale. For instance, in cities there would be numerous and diverse restaurants, cultural services, and shopping opportunities. As cities grow they can support even higher levels of consumer amenities. It is an empirical question whether population scale effects are positive; the attractive traits of urban environments might be offset by disamenities like crime, traffic and other congestion effects. To deal with endogeneity, I utilize a quasi-experimental design where I exploit the exogenous spatial distribution of mineral resources by using historical mine locations. The findings suggest a robust positive urban scale effect on quality of life that pass multiple tests of confounding factors. This evidence suggest that the provision of consumer amenities increase in population size, which in general will lead to divergence between countryside and city regions in quality of life.

Keywords: quality of life, urban scale, historical mines. **JEL:**

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1 Introduction

The literature on quality of life focuses on the role of consumer amenities in household migration. It is apparent to everyone that locations differ in quality, that is, some places are more richly endowed with attractive characteristics. When households "shop" for a location they will chose 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 obviously not true. I will distinguish between natural and cultural amenities to elaborate on this point. Natural amenities, like climate, coastline, and desirable scenery, are the more or less fixed features of a location. Cultural amenities are in contrast artificial and a product of human society; for instance, the provision of public services, school quality, infrastructure, cultural services, and shopping opportunities. Consequently, it is reasonable to treat natural amenities as exogenous and unrelated to human behavior while cultural amenities are clearly not.[1]

Whether population scale effects are positive is an empirical question; the positive traits of urban environments might be offset by disamenities like crime, traffic and other congestion effects. Rappaport (2008) argue 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 quality of life measures referred to in Rappaport (2008) might be considered inferior in comparison to the next generation of measures that incorporate the innovations of Albouy (2012). Albouy's quality of life measure 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 get 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, 2013). The association tend to be larger than reported for the US, potentially because of a comprehensive sample of regions and overall smaller cities.

These analyses might potentially be plagued by several sources of endogeneity. First,

[1] Population size might display the social dimension of a location, for example the probability of meeting suitable friends and partner, and might therefore be an amenity in itself.

there might be an issue of two-way causality if households have historically migrated to amenable locations and there are substantial economies of scale in providing goods and services (Mueser and Graves, 1995; Carlino and Saiz, 2008; Jeanty et al., 2010). This would in general overestimate the urban quality of life. Second, there might be omitted variables that affect the result. For example, if there exist consumer amenities that also affect productivity. The direction of such a bias is unclear. Third, the appropriate measure of urban scale is not obvious. In case of classical measurement error the urban quality of life would be underestimated.

To overcome the endogeneity issues inherent in the relationship between local quality of life and population size, I exploit a quasi-natural experiment in Norwegian history. As far as i know this is the first paper to use instrumentation in the quality of life literature.[2] From the 12th till the 19th century Norway had 63 mines operating periodically. This classifies mining as the first industry in Norway. In general, the discovery of workable 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 and abandoned 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] Over 80% of the mines were closed before the 20th century, and 94% had closed before 1970; the last historical mine closed in 1987.

Regions with historical mines tend on average to have significantly more inhabitants, which suggest cumulative population growth in locations with early industrialization. I test for several potential confounding factors with a battery of variables describing the natural environment, industry composition and population traits in the region. To further validate the connection between historical mines and population size I show by regression discontinuity estimation that mineral riches are closely connected to population size in the unique geological area of Oslo. Examining the population development in mining regions, the change in population size between the 19th and 21st century indicate path dependence; i.e., the association between population size and population growth is positive, which

[2]Geological features have been used to instrument the distribution of population by Combes et al. (2010) and Rosenthal and Strange (2008), while historical mines have been exploited in a different context by Glaeser et al. (2012).

[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 mining thorium and uranium ores, quarrying of sand, stone and clay, mining of chemical and fertilizer minerals, and production of salt. Therefore, the relevant figures for comparison are even lower.

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. This suggests that cities have positive amenity returns from increased population, which is interpreted as a positive scale effect in provision of consumer amenities. On average, this effect is not deterred by congestion costs, which indicate that quality of life increase faster than congestion costs with increased urban scale.

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 present additional sensitivity analyses. Section six concludes.

2 Quality of life

2.1 Measuring living quality of local environment

There are several ways to create a meaningful composite measure of local quality of life. It is possible to use subjective measures that describe the attractiveness of the local environment by collecting survey data. A problem is the occurrence of cognitive dissonance, that is, people tend to assess the decision of relocation to be better after it is executed (Festinger, 1957; Aronson, 1994; Beauvois and Joule, 1996). There are multiple other problematic aspects with survey data (See for example Bertrand and Mullainathan (2001)). Objective measures might also be used to create an index of local attractiveness, for example, summer temperature and the number of restaurants. The problem is to choose which traits of the local environment to include, or even discover which local characteristics hold amenity value. Such an index could therefore be easily manipulated or end up misguiding.

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 amenity levels 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).[5] That would make this approach suitable for Norway, which have very high income per capita.[6] 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; It is calibrated by additional micro data and taking into account local taxes. I will follow his approach including the extensions made in Carlsen and Leknes

[5]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).

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

(2013), where an even finer three-sector decomposition of the price index is used, and empirical adjustment for worker heterogeneity.

2.2 The model

Imagine many regions (r) that vary in quantity of endowed local amenities A_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:

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

Following Albouy (2012) and Carlsen and Leknes (2013), I can derive a relative measure of regional quality of life $\tilde{A}_r$ 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:

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

where $\tilde{A}_r$ is specified as quality of life measured as share of post-tax average income and as deviation from the national average. α_H^e, α_{NT}^e, and α_T^e 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. δ_H, δ_L and δ_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

To calibrate the quality of life measure I use much of the same data as in Carlsen and Leknes (2013), 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 of earnings and house prices and county-group[7] data of household spending for each

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

region and year. 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 data base 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 denote a separate local labour market. In general, the literature on urban amenities compare metropolitan areas. I have regional data with national scope. 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.

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 (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 α_r and worker fixed effects γ_i. I also control for time-variant observed worker characteristics X_{irt} - gender, education and age dummies for five year intervals.[8] The estimated region fixed effects $\tilde{\alpha}_r$ is used as wage measure and

[8] I don't have information on work experience. A proxy computed under the assumption that education

is based on the wage for migrating workers. According to Puga and De la Roca (2012) 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 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 is 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 was estimated by hedonic methods for each year. Transaction price was 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. I don't exploit the time variation in the data because of the minuscule occurrence of resales. The estimated fixed effects are used as 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.[9] I divide consumer spending into budget shares for housing, non-tradables and tradables.[10]

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

is completed during normal study time is highly correlated with age and education and therefore omitted.

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

[10]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.

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) "The first documented mining in Norway". The second source is Carstens (2000) "... 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.2 and Table 4.

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 was 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 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

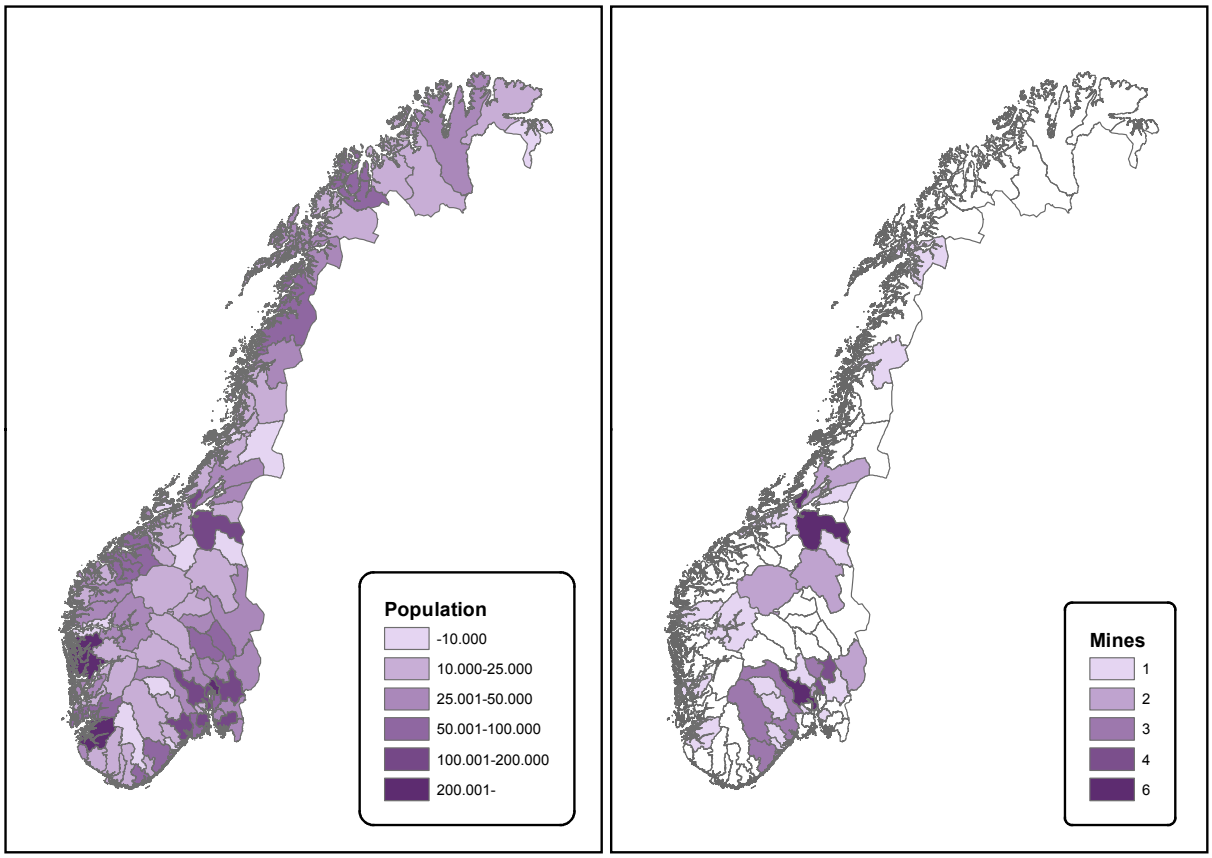
continued operation facilitated learning through experience and the establishment of a professional milieu of iron miners contributed to the success. In addition, technological advancements like the blast furnace separates this period from previous ones.

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

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

Figure 1: Population size and historical mines



The geology in the Oslo graben, a geological area in the south-eastern part of the country,

is unique in a World perspective. Its composition was shaped by earthquakes and volcanos 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 more or less 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. The iron oxide is located in skarn deposits formed in a reaction zone in the gneisses (Masdalen et al., 1990).

3.4 Growth effects of early industrialization and persistence in population patterns

The international history of mining parallels that of civilization, which can be seen from how different cultural eras are named after the minerals of stone, bronze, iron and steel (Hartman and Mutmansky, 2002). From early ages humans have been attracted to locations with valuable minerals and metals. These resources were valuable commodities, which could be made into ornaments, weapons, and tools (Lynch, 2002). Historically, this sorting into mineral rich areas would further contribute to local wealth through agglomeration economies and bring about population growth.

The mining history of Norway indicate what might have driven the regional population growth in mine areas at the time. Mines lead to a surge in employment (at the mine, but also to cover supporting functions), centers of trade were established, and there was technology transfer from abroad. These historical events are clearly not sufficient conditions to explain contemporaneous population size; in addition, there has to be persistence in population patterns.

3.4.1 Employment

The mining industry affected the population size of the location directly through higher demand for workers. In 1770 there was approximately 7000 mine workers in Norway (Carstens, 2000). This might not seem a large number, but it lead to Kongsberg being

one of the largest cities of 18th century Norway. It was comparable to Christiania (Oslo) and Trondheim, two of the largest cities at present. This mining city of Kongsberg was not situated at the coast in comparison to the other large Norwegian cities of the time, which highlights the difference in determinants of growth (Carstens, 2000).

A large proportion of the local employment growth was connected to supporting functions. Local farmers supplied timber, firewood, and charcoal, and assisted with transport[11]. At Røros mines necessary supplies and transport employed twice as many as there were people working in the actual mines (Carstens, 2000). Agricultural resources was scarce and a constraint on population size that were relaxed by the new additional means of livelihood (Carstens, 2000). This is illustrated by splitting of farmland, for example in the typical mining county of Larvik (Rian, 1991).

3.4.2 Trade

Mine regions became strategic locations to conduct business. Mine operations needed deliveries of inputs to the industrial production process, for instance timber and charcoal, in addition to food and other necessities for workers. In general, mines were large and protected markets for supplies of food and gunpowder, and there is evidence indicating that investors profited more from merchant business than from investing directly in the mine operations (Sprauten, 1991). First, because there was very little default on credit since bookkeepers deducted the sums due from the worker's wage. Second, the selling of gunpowder to the mines was very profitable because of the discrepancy between market price and price charged the mine administrators. The mine administrators also contributed to the formation of local markets since they needed to introduce their produce to potential buyers and transport it to an international market. This lead to centers of trade in the region with broader forms of commerce.

3.4.3 Technology transfer

In the 16th Century Norway was an agrarian society with no previous experience with industry. Mining is a knowledge-based industry which made it crucial to import know-how from abroad. King Christian III requested experienced mine workers, capital and machinery from Germany (Saxony) (Berg, 1991). The subsequent ruler, King Christian IV kept to this tradition. He recruited german mining engineers from Sachsen and Harz (Carstens, 2000). The mining communities was industrial enclaves in an agricultural society that demanded large capital investments as well as competent workers overseeing both technical and complex administrative and logistical tasks (Carstens, 2000). A rapid industrial development demanded implementation of a juridical framework and an ad-

[11]Farmers in the "circumference", the immediate surroundings of the mining location, were imposed to supply necessary wood products and transportation for a modest pecuniary compensation.

ministrative structure; It ended up being on the model of German laws and methods. It is not unlikely that this experience with industry had spillover effects.

3.4.4 Persistence in population patterns

Mines provide resources that are non-renewable and will consequently be exhausted after some time. Why would it make sense that these historical economic shocks had a permanent effect on population? 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), an early start in one location would reap advantages in each succeeding stage of location competition.[12]

The notion of path dependence is an important strand within the increasing returns theories (David, 2001; Krugman, 1991). Storper and Scott (2009) theorize on how growth of output leads to further output growth. Increasing return to scale causes the local labor market to expand, which in turn leads to further output growth through the home market effect, and learning and innovation. This is an example of what Myrdal (1957) and Hirschmann (1958) would call respectively circular causation and cumulative growth.

Persistence and path dependence in spatial distribution of population is also demonstrated empirically. Davis and Weinstein (2002) find a striking level of persistence in the 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. Therefore, if returns to scale is high enough it might be able to outweigh a negative shock to the local economy, for example the exhaustion of mining resources. If historical mining activity is a local driver of population growth and there is persistence in the spatial location of population we might find a satisfactory first stage correlation.

4 Empirical strategy and results

4.1 Empirical strategy

The estimation strategy is a standard 2SLS set-up, where (4) illustrate the second stage estimation and (5) the first stage.

[12]It is crucial that industrialization leads to urbanization and not the other way around. This is supported by Williamson (1965). Also Michaels et al. (2012) show how structural transformation, the change from agrarian to industrial production, is a key part of the urbanization process.

$$\hat{A}_r = \delta + \delta_1 population_size_r + \mathbf{X}\boldsymbol{\delta_2} + \nu_r \tag{4}$$

$$population_size_r = \pi + \pi_1 historical_mines_r + \mathbf{X}\boldsymbol{\pi_2} + \omega_r \tag{5}$$

$\hat{A}_r$ is the calibrated measure of local quality of life in each region r. In equation (4) quality of life is regressed on a constant term δ, the predicted number of people in the region $population_size_r$, and a vector $\mathbf{X}$ of natural amenities. The parameter of interest is δ_1, which is the population scale effect on cultural amenities. ν_r is an error term with the standard properties. In equation (5), I instrument population size with the number of historical mines to mitigate several sources of potential endogeneity.

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 $\mathbf{X}$ 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 profitable reservoirs of minerals were exploited. Adjustments in technic and organization made even the harsh environmental conditions at the mines in Årdal achievable.

Mining regions might be on average more mountainous than other regions. Bare rock land, high land elevation and slope makes 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 was chosen as the better measure of harbor and market accessibility.

[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.

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

To investigate how the time dimension of the instrument affect population size I compare how mines opening before the 17th century affect population size compared to the mines opening after this period. Table 1 display the estimation results. An interesting observation is that the older mines have a stronger effect on population size (See column (5)-(8)). 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 this effect might have been particularly strong in determining the spatial distribution of the population.

The instrument used in the subsequent analyses, all historical mines, has a strong relation with population size that meets the threshold suggested by Stock 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, mountainous geological features and coastline.

Table 1: Effect of urban scale on quality of life

	Reduced form		OLS-results		IV-results					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
First stage results. Dependent variable: log(*population*)										
Pre 17th century mines					0.701**	0.709**				
					(2.27)	(2.46)				
17th & 18th century mines							0.303***	0.291***		
							(4.52)	(4.49)		
All historical mines									0.285***	0.285***
									(4.25)	(4.49)
OLS, reduced form, and second stage results. Dependent variable: Quality of life										
Log(population)			0.061***	0.060***	0.072***	0.060**	0.077***	0.065***	0.076***	0.064***
			(7.18)	(7.03)	(2.96)	(2.15)	(4.13)	(3.65)	(4.41)	(3.74)
All historical mines	0.022***	0.018**								
	(2.84)	(2.38)								
Natural amenities	N	Y	N	Y	N	Y	N	Y	N	Y
Adjusted R-Square 1st stage	-	-	-	-	0.09	0.21	0.10	0.20	0.14	0.24
Adjusted R-Square OLS	0.11	0.51	0.21	0.59	-	-	-	-	-	-
Number of mines	63	63	-	-	12	12	51	51	63	63
Number of observations	90	89	90	89	90	89	90	89	90	89

Sample: 90 regions. Dependent variables: Averages for period 1994-2001 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

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 1800 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 shock to the local economy do not fade away, but grows. This would lead to divergence in regional population size over time and is in line with a path dependence hypothesis. Nonetheless, the cross-sectional properties of the data encourage caution when interpreting the results.

Table 2: Persistence. Mines and historical population size

	Population in 1825				Population in 1900	
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: historical log(*population*)						
Pre 17th century mines	0.571***	0.546***				
	(4.98)	(4.28)				
17th & 18th century mines			0.250***	0.261***		
			(4.41)	(4.49)		
All historical mines					0.243***	0.263***
					(4.14)	(4.45)
Natural amenities	N	Y	N	Y	N	Y
Adjusted R-Square	0.09	0.23	0.10	0.22	0.15	0.28
Number of mines	12	12	51	51	63	63
Number of observations	90	89	90	89	90	89

Sample: 90 regions. Dependent variables are averages for period 1994-2001.

Dependent variables are historical log(population); In column (1)-(4) it is year 1825 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 urban 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, 2013). 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 to the result in Albouy (2012), including natural amenities leaves the result practically unchanged. The endogenous relationship between population size and quality of life hinders causal interpretation.

My identification strategy is based on utilizing exogenous distribution of mining resources. The IV results in column (5)-(10) display rather similar results compared to OLS. The coefficients vary between 6-7.7%. The IV-results have as expected larger standard errors than the OLS-results and the results are therefore not significantly different. The inclusion 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. The overall results show a robust positive effect of population size on quality of life, which suggest a positive population scale effect in provision of cultural amenities.

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). 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.[14]

A positive urban scale effect in provision of cultural amenities has a theoretical implication. The model will only reach migration equilibrium when the amenity gain from household relocation is smaller or equal to the decrease in real wage. This implicates a more sluggish transition to equilibrium compared to the traditional Rosen-Roback model with fixed local quality of life. The occurrence of widespread urbanization in the industrialized world (UN, 2006) might be explained by this result if the economy is in transition.[15] However, that is a question of optimal city size, which I will not elaborate on here.

5 Sensitivity analyses

The robustness of the results will be investigated in Table 3 and 4. I will focus on testing the instrument validity and accounting for confounding factors that might explain the first stage result. Additional data details on the covariates introduced in this section can be found in Table B.4. In Table 4 I will use the baseline instrument counting all historical mines.[16]

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

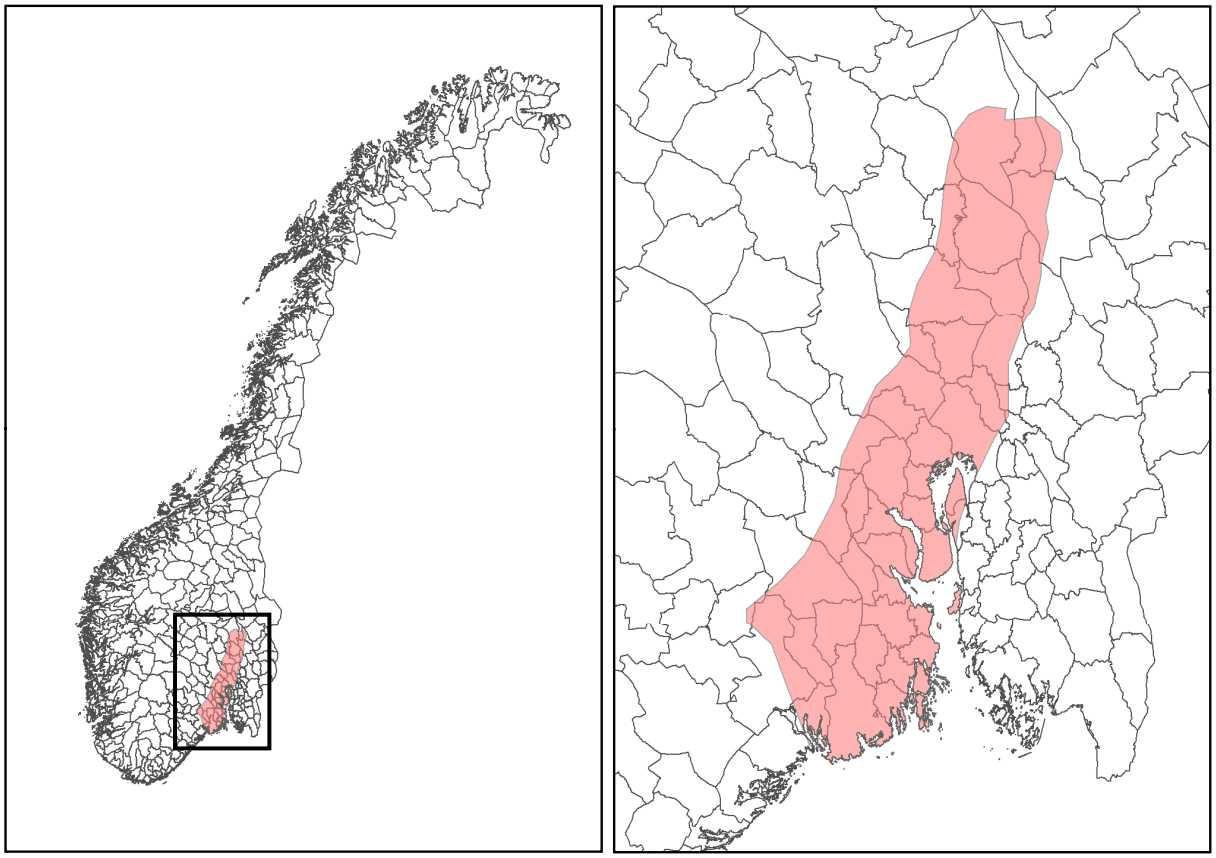
[15] Another candidate explanation for urbanization is changes in household preferences for urban amenities.

[16] An indicator of mine region was used in an unreported sensitivity analysis. The results are qualitatively the same, and the binary instrument is significant at the 5% level in the first stage estimation.

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

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 their spatial distribution cannot be manipulated. The unique geological character of the Oslo graben, which is rich in minerals and clearly defined, can be used to test the first stage correlation in a quasi-experiment.[17] I use a regression discontinuity design where the graben border define the treated and untreated groups. The spatial units that are cut by the threshold is treated, while those adjacent from the outside is defined as non-treated; The close proximity of the units makes it likely that they share many of the same attributes. Economic regions are too large in size to be useful in this comparison, so I will use municipalities which are more spatially disaggregated (See Figure 2).

Figure 2: Oslo graben



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 is counted as treated. The second is created by a buffer of 5 kilometers that shifts the threshold outwards, and the third with a buffer of 10 kilometers. In Table 3

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

column (1), (3) and (5), the highly significant result indicate that municipality population within the graben border is 58-88% larger than outside the border. The result is robust to several variables describing the geographical, political and industry environment.

I test whether the relation is determined by modern factors by using historical population size data from 1825. 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) indicate that there is a strong effect of mineral riches on population for the sharp cutoff and with the 5 kilometer buffer. The effect seem to diffuse for longer distances with an insignificant 10 km buffer cutoff. The results indicate that the Oslo area population pattern is strongly predicted by mineral riches and that the effect is attenuated by distance. Since the location of mines are dependent of mineral endowments, the result supports historical mines as a valid instrument for population size.

Table 3: First stage robustness: Regression discontinuity along Oslo graben

	Sharp cutoff		5 km buffer		10 km buffer	
	log(*pop*1998)	log(*pop*1825)	log(*pop*1998)	log(*pop*1825)	log(*pop*1998)	log(*pop*1825)
	(1)	(2)	(3)	(4)	(5)	(6)
Whitin graben area	0.609***	0.588***	0.882***	0.450***	0.584***	0.112
	(2.78)	(3.75)	(5.27)	(3.05)	(2.77)	(0.78)
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
Adjusted R-Square	0.49	0.31	0.59	0.25	0.36	0.08
Number of observations	59	59	62	62	68	68

Sample: 59-68 municipalities on Oslo graben border. Dependent variables are log(*population*1998) and log(*population*1825).

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

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

Table 4: 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 covariats included
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
First stage results. Dependent variable: Log(population)										
Log(population)	0.277***	0.280***	0.272***	0.272***	0.285***	0.292***	0.242***	0.281***	0.296***	0.230***
	(4.01)	(5.58)	(4.75)	(4.57)	(4.46)	(4.54)	(4.95)	(4.18)	(4.30)	(4.72)
Second stage results. Dependent variable: Quality of life										
All pre 19th mines	0.073***	0.063***	0.063***	0.058***	0.064***	0.063***	0.051***	0.066***	0.065***	0.065***
	(4.56)	(3.91)	(3.57)	(4.12)	(3.77)	(3.68)	(3.44)	(3.60)	(3.63)	(4.25)
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	0.22	0.34	0.36	0.24	0.23	0.24	0.22	0.24	0.27	0.42
Number of mines	63	63	63	63	63	59	59	58	51	63
Number of regions	89	89	89	89	89	87	86	86	82	89

Sample: 90 regions, averages for period 1994-2001. 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.

5.2 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 wood products 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 forrest, woodlands and rivers are perceived as local amenities or disamenities, and they might be correlated with contemporaneous natural production.

Wood was used for timber, firewood and charcoal for the mine trusses, melters and fire setting[18]. However, sometimes gun powder was used instead. This was the case for Årdal mines, where there were considerable challenges with transportation of wood products (Johannessen, 1991).[19] River power was used to pump excess water out of the mines and run the bellows for the melters (Carstens, 2000). I compute the instrument purely on mine location while location of industrial works are disregarded.[20] 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 4 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 forrest growth is fixed and the interval between the deforestation and contemporaneous outcomes would make it likely that the trees have recurred. The second stage result increase somewhat and are more sharply estimated, while it is the opposite for the first stage result. In total, the results are rather unaffected.

5.3 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 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 result are robust to this inclusion.

[18]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.

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

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

5.4 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 hydro-power 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.

5.5 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, population size and might even be disamenities. As seen in column (4), their inclusion don't change the qualitative result.

5.6 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.4. 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. That doesn't seem to be the case since the results are almost unaltered.

5.7 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.

5.8 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.[21] As reported in column (7), this does not affect the robustness of the result.

5.9 Mine closure

A 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 4 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 result remain robust in both cases.

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

[21] Historical excavation of metals in Oslo happened before the hanseatic trade started. That indicates that the exclusion of Oslo might not be relevant.

6 Conclusion

In this paper, I use an improved empirical measure of local quality of life with the innovation of Albouy (2012) and Carlsen and Leknes (2013) 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 was observed. The first stage correlation display persistence 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. The effect is interpreted as economies of scale in providing goods and services that offset disamenities like crime, traffic and other congestion effects. 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 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 cities. A policy implication would be to encourage rural to urban migration as long as the net increase in quality of life is positive. The evidence suggest that place-based policies benefitting country-side areas are contra-productive and should be discontinued.

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A Additional theoretical details

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

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

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

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

I utilize Roy's identity and get:

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

P_A 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:

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

where $\tilde{A}_r$ 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:

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

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

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

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. δ_H, δ_L and δ_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 A_r.

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

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

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:				
$\frac{W_r}{W}$	0.991	0.991	1.001	1.017
$\frac{W_r - t_r(W_r^e)}{W - t(W)}$	0.996	0.996	1.000	1.009
House prices:				
$\frac{P_{H,r}}{P_H}$	0.840	0.865	0.996	1.306
Budget shares:				
α_H	0.196	0.194	0.196	0.199
α_{NT}	0.281	0.284	0.284	0.286
α_T	0.523	0.522	0.519	0.516

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

B.2 Historical mines

Table B.2: Frequency of mine closure by century and descriptive statistics of instruments

Century	16th	17th	18th	19th	20th	Total
Pre 17th century mines *(Mean:0.13, Std. Dev.:0.43)*	1	1	2	6	2	12
17th century mines *(Mean:0.31, Std. Dev.:0.71)*	-	6	5	9	8	28
18th century mines *(Mean:0.26, Std. Dev.:0.63)*	-	-	12	8	3	23
All historical mines *(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.3: 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. One of the regions is omitted from the regressions because of altered administrative structure (municipality fusions). Another of the regions, Haugesund, is somewhat altered from the original region structure. Excluding this region in the sensitivity analyses does not change the conclusions.

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.

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 is collected from Statistics Norway, and is an indicator of coast in the region.

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 is 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.4: 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	1241.1	540.29
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

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, α_{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.5: 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 results. Dependent variable: Quality of life										
Log(population)	0.041***	0.040***	0.045***	0.040***	0.039**	0.035***	0.041***	0.041***	0.027**	0.041**
	(5.36)	(2.60)	(2.94)	(2.69)	(2.43)	(2.66)	(2.61)	(2.61)	(2.15)	(2.47)
First stage results. Dependent variable: Log(population)										
All pre 19th	-	0.285***	0.277***	0.280***	0.272***	0.272***	0.285***	0.292***	0.242***	0.281***
		(4.49)	(4.01)	(5.58)	(4.75)	(4.57)	(4.46)	(4.54)	(4.95)	(4.18)
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	0.46	0.24	0.22	0.34	0.36	0.24	0.23	0.24	0.22	0.24
Number of mines	-	63	63	63	63	63	63	59	59	58
Number of regions	89	89	89	89	89	89	89	87	86	86

Sample: 90 regions, average for period 1994-2001. 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.6: 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 centre)
	(1)	(2)	(3)	(4)	(5)	(6)
OLS results. Dependent variable: Quality of life						
Urban scale	0.060***	0.060***	0.114***	0.053***	0.047***	0.047***
	(7.03)	(7.96)	(6.62)	(9.73)	(7.04)	(7.50)
Second stage results. Dependent variable: Quality of life						
Urban scale	0.064***	0.071***	0.226***	0.074***	0.057***	0.053***
	(3.74)	(4.51)	(2.89)	(4.27)	(3.70)	(4.15)
First stage results. Dependent variable: Urban scale						
All historical mines	0.285***	0.289***	0.078**	0.245**	0.321***	0.339***
	(4.49)	(4.50)	(2.09)	(2.20)	(3.79)	(3.40)
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	0.61	0.72	0.59	0.61
Adjusted R-Square 1st stage	0.24	0.23	0.43	0.34	0.19	0.22
Number of mines	63	63	63	63	63	63
Number of regions	89	89	88	89	89	89

Sample: 90 regions, averages for period 1994-2001. Dependent variable is Quality of life and urban scale.

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

Causal evidence on quality of life and population size using historical mines

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Abstract

I investigate 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 a positive urban scale effect that pass multiple tests of confounding factors. This evidence suggest divergence between countryside and city regions in quality of life.

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

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1 Introduction

The literature on quality of life focuses on the role of consumer amenities in household migration. It is apparent to everyone that locations differ in quality, that is, some places are more richly endowed with attractive characteristics. 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 obviously not true. I will distinguish between natural and cultural amenities to elaborate on this point. Natural amenities, like climate, coastline, and desirable scenery, are the more or less fixed features of a location. In contrast, cultural amenities are artificial and vary with population size; for instance, the provision of public services, school quality, infrastructure, cultural services, and shopping opportunities. Consequently, it is reasonable to treat natural amenities as exogenous and unrelated to human behavior while cultural amenities are clearly not.[1] The role of urban scale in facilitating consumption is important for urban policy and is understudied (Glaeser et al., 2001).

Whether population scale effects on quality of life are positive is an empirical question; the positive traits of urban environments might be offset by disamenities like crime, traffic and other congestion effects. Rappaport (2008) argue 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 tend to be larger than reported for the US, potentially because of a comprehensive sample of regions and overall smaller cities.

These analyses might potentially be plagued by several sources of endogeneity. First,

[1] Population size might display the social dimension of a location, for example the probability of meeting suitable friends and partner, and might therefore be an amenity in itself.

there might be an issue of two-way causality if households have historically migrated to amenable locations and there are substantial economies of scale in providing goods and services (Mueser and Graves, 1995; Carlino and Saiz, 2008; Jeanty et al., 2010). This would in general overestimate the urban quality of life. Second, there might be omitted variables that affect the result. For example, one might imagine all natural amenities are accounted for, but there exist unobserved productive traits of the region. The direction of such a bias is unclear. Third, the appropriate measure of urban scale is not obvious. In case of classical measurement error the urban quality of life would be underestimated.

To overcome the endogeneity issues inherent in the relationship between local quality of life and population size, 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. Although 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. From the 12th till the 19th century Norway had 63 mines operating periodically. This classifies mining as the first industry in Norway. In general, the discovery of workable 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.[2] 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 and abandoned 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.[3] Over 80% of the mines were closed before the 20th century, and 94% had closed before 1970; the last historical mine closed in 1987.

Regions with historical mines tend on average to have significantly more inhabitants, which suggest cumulative population growth in locations with early industrialization. I test for several potential confounding factors with a battery of variables describing the natural environment, industry composition and population traits of the region. To further validate the connection between historical mines and population size I show by regression discontinuity estimation that mineral riches are closely connected to population size in the unique geological area of Oslo. Examining the population development in mining regions,

[2]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.

[3]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 mining thorium and uranium ores, quarrying of sand, stone and clay, mining of chemical and fertilizer minerals, and production of salt. Therefore, the relevant figures for comparison are even lower.

the change in population size between the 19th and 21st century indicate 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. This suggests that cities have positive amenity returns from increased population, which is interpreted as a positive scale effect in provision of consumer 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.

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

There are several ways to create a meaningful composite measure of local quality of life. It is possible to use subjective measures that describe the attractiveness of the local environment by collecting survey data. A problem is the occurrence of cognitive dissonance, that is, people tend to assess the decision of relocation to be better after it is executed (Festinger, 1957; Aronson, 1994; Beauvois and Joule, 1996). There are multiple other problematic aspects with survey data as described in for instance Bertrand and Mullainathan (2001). Objective measures might also be used to create an index of local attractiveness, for example, summer temperature and the number of restaurants. The problem is to choose which traits of the local environment to include, or even discover which local characteristics hold amenity value. Such an index could therefore be easily manipulated or end up misguiding.

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 amenity levels 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).[4] That would make this approach suitable for Norway, which has very high income per capita.[5] 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

[4]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).

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

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 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 amenities A_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:

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

Following Albouy (2012) and Carlsen and Leknes (2014), I can derive a relative measure of regional quality of life $\tilde{A}_r$ 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:

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

where $\tilde{A}_r$ is specified as quality of life measured as share of post-tax average income and as deviation from the national average. α_H, α_{NT}, and α_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. δ_H, δ_L and δ_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

To calibrate the quality of life measure I use 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

of earnings and house prices and county-group[6] data of household spending for each region and year. 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 data base 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 denote a separate local labour market. In general, the literature on urban amenities compare metropolitan areas. I have 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 α_r and worker fixed effects γ_i. I also control for time-variant observed worker characteristics X_{irt} - education and age dummies for five year intervals.[7] The estimated region fixed effects $\tilde{\alpha}_r$ is used as wage measure and is based on the 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

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

[7] 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.

increase in wages. However, I choose to omit dynamic 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. I don't exploit the time variation in the data because of the minuscule occurrence of resales. The estimated fixed effects are used as 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.[8] I divide consumer spending into budget shares for housing, non-tradables and tradables.[9]

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

2.3.4 Quality of life equations and estimation strategy

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

$$\tilde{A}_r = \alpha_{H,r}\frac{P_{H,r}}{P_H} + \alpha_{NT,r}\left(0.23\frac{P_{H,r}}{P_H} + 0.65\frac{W_r(1+s_r)}{W_r(1+s_r)} + 0.12\right) + 1 - \frac{W_r - t_r(W_r)}{W_r - t_r(W_r)}\,, \quad (4)$$

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

[9]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.

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.

$$\hat{A}_r = \delta + \delta_1 population_size_r + \mathbf{X_n}\boldsymbol{\delta_2} + \mathbf{X_o}\boldsymbol{\delta_3} + \nu_r \tag{5}$$

$$population_size_r = \pi + \pi_1 historical_mines_r + \mathbf{X_n}\boldsymbol{\pi_2} + \mathbf{X_o}\boldsymbol{\pi_3} + \omega_r \tag{6}$$

$\hat{A}_r$ 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 δ, the predicted number of people 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 δ_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. ν_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) "The first documented mining in Norway". The second source is Carstens (2000) "... 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 4.

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 was 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).

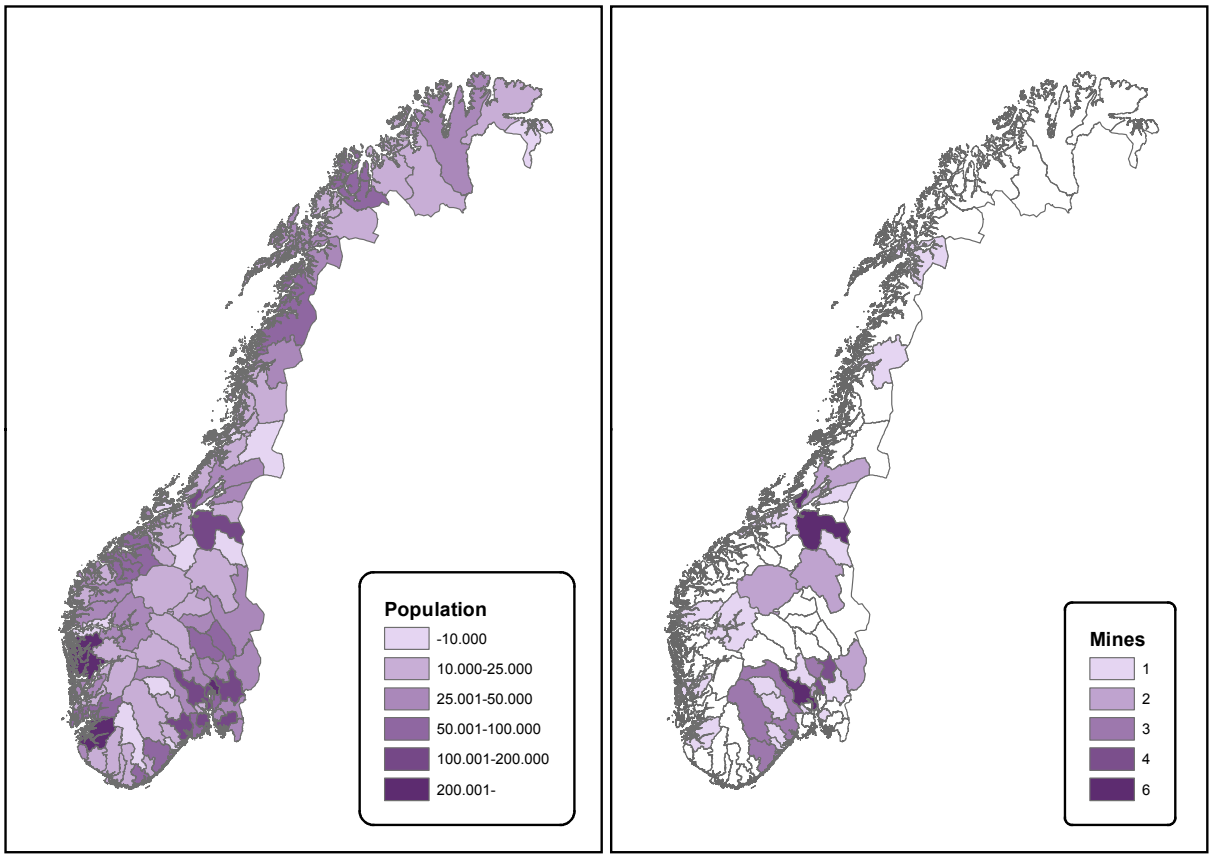
Working of mines became a national industry of importance first after the the discovery of the silver reservoirs in Sandsvær in 1623, which lead to the construction of Kongsberg silver mines (Falck-Muus, 1924). This more or less coincides with the establishment of the iron industry in 1624 (Carstens, 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 the areas of Oslo, Trondheim, and Arendal 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 geology in the Oslo graben, a geological area in the south-eastern part of the country, is unique in a World perspective. Its composition was shaped by earthquakes and volcanos 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 more or less 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. The iron oxide is located in skarn deposits formed in a reaction zone in the gneisses (Masdalen et al., 1990).

3.4 Growth effects of early industrialization and persistence in population patterns

The international history of mining parallels that of civilization, which can be seen from how different cultural eras are named after the minerals of stone, bronze, iron and steel (Hartman and Mutmansky, 2002). From early ages humans have been attracted to locations with valuable minerals and metals. These resources were valuable commodities, which could be made into ornaments, weapons, and tools (Lynch, 2002). Historically, this sorting into mineral rich areas would further contribute to local wealth through agglomeration economies and bring about population growth.

The mining history of Norway indicate what might have driven the regional population growth in mine areas at the time. Mines lead to a surge in employment (at the mine, but also to cover supporting functions), centers of trade were established, and there was technology transfer from abroad. These historical events are clearly not sufficient conditions to explain contemporaneous population size; in addition, there has to be persistence in population patterns.

3.4.1 Employment

The mining industry affected the population size of the location directly through higher demand for workers. In 1770 there was approximately 7000 mine workers in Norway (Carstens, 2000). This might not seem a large number, but it lead to Kongsberg being one of the largest cities of 18th century Norway. It was comparable to Christiania (Oslo) and Trondheim, two of the largest cities at present. This mining city of Kongsberg was not situated at the coast in comparison to the other large Norwegian cities of the time, which highlights the difference in determinants of growth (Carstens, 2000).

A large proportion of the local employment growth was connected to supporting functions. Local farmers supplied timber, firewood, and charcoal, and assisted with transport[10]. At Røros mines necessary supplies and transport employed twice as many as there were people working in the actual mines (Carstens, 2000). Agricultural resources were scarce and a constraint on population size that were relaxed by the new additional means of

[10]Farmers in the "circumference", the immediate surroundings of the mining location, were imposed to supply necessary wood products and transportation for a modest pecuniary compensation.

livelihood (Carstens, 2000). This is illustrated by splitting of farmland, for example in the typical mining county of Larvik (Rian, 1991).

3.4.2 Trade

Mine regions became strategic locations to conduct business. Mine operations needed deliveries of inputs to the industrial production process, for instance timber and charcoal, in addition to food and other necessities for workers. In general, mines were large and protected markets for supplies of food and gunpowder, and there is evidence indicating that investors profited more from merchant business than from investing directly in the mine operations (Sprauten, 1991). First, because there was very little default on credit since bookkeepers deducted the sums due from the worker's wage. Second, the selling of gunpowder to the mines was very profitable because of the discrepancy between market price and price charged the mine administrators. The mine administrators also contributed to the formation of local markets since they needed to introduce their produce to potential buyers and transport it to an international market. This lead to centers of trade in the region with broader forms of commerce.

3.4.3 Technology transfer

In the 16th Century Norway was an agrarian society with no previous experience with industry. Mining is a knowledge-based industry which made it crucial to import know-how from abroad. King Christian III requested experienced mine workers, capital and machinery from Germany (Saxony) (Berg, 1991). The subsequent ruler, King Christian IV kept to this tradition. He recruited german mining engineers from Sachsen and Harz (Carstens, 2000). The mining communities was industrial enclaves in an agricultural society that demanded large capital investments as well as competent workers overseeing both technical and complex administrative and logistical tasks (Carstens, 2000). A rapid industrial development demanded implementation of a juridical framework and an administrative structure; it ended up being on the model of German laws and methods. It is not unlikely that this experience with industry had spillover effects.

3.4.4 Persistence in population patterns

Mines provide resources that are non-renewable and will consequently be exhausted after some time. Why would it make sense that these historical economic shocks had a permanent effect on population? 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), an early start in one location would reap advantages in each

succeeding stage of location competition.[11]

The notion of path dependence is an important strand within the increasing returns theories (David, 2001; Krugman, 1991). Storper and Scott (2009) theorize on how growth of output leads to further output growth. Increasing return to scale causes the local labor market to expand, which in turn leads to further output growth through the home market effect, and learning and innovation. This is an example of what Myrdal (1957) and Hirschmann (1958) would call respectively circular causation and cumulative growth.

Persistence and path dependence in spatial distribution of population is also demonstrated empirically. Davis and Weinstein (2002) find a striking level of persistence in the 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. Therefore, if returns to scale is high enough it might be able to outweigh a negative shock to the local economy, for example the exhaustion of mining resources. If historical mining activity is a local driver of population growth and there is persistence in the spatial location of population we might find a satisfactory first stage correlation.

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[12], 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 profitable reservoirs of minerals were exploited.

[11] It is crucial that industrialization leads to urbanization and not the other way around. This is supported by Williamson (1965). Also Michaels et al. (2012) show how structural transformation, the change from agrarian to industrial production, is a key part of the urbanization process.

[12] 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.

Adjustments in technic and organization made mining at very harsh environmental conditions achievable.

Mining regions might be on average more mountainous than other regions. Bare rock land, high land elevation and slope makes 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 was 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 how the time dimension of the instrument affect population size I compare how mines opening before the 17th century affect population size compared to the mines opening after this period in Table 1. An interesting observation is that the older mines have a stronger effect on population size (See column (5)-(8)). 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.

The instrument used in the subsequent analyses, encompassing all historical mines, has a strong relation with population size that meets the threshold suggested by Stock 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.

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

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 shock effect to the local economy does not fade away, but grows. This is in line with a path dependence hypothesis. Nonetheless, the cross-sectional properties of the data encourage caution when interpreting the results.

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 urban 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. The

coefficients vary between 6-7.7%. The IV-results have as expected larger standard errors than the OLS-results and the results are therefore not significantly different. The inclusion 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. The overall results show a robust positive effect of population size on quality of life, which suggest a positive population scale effect in provision of cultural amenities.

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). 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.[13]

5 Sensitivity analyses

The robustness of the results is investigated in Table 3 and 4. I focus on testing the instrument validity and accounting for confounding factors that might explain the first stage result. Additional data details on the covariates introduced in this section can be found in Table B.5. In Table 4 I use the baseline instrument counting all historical mines.[14]

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

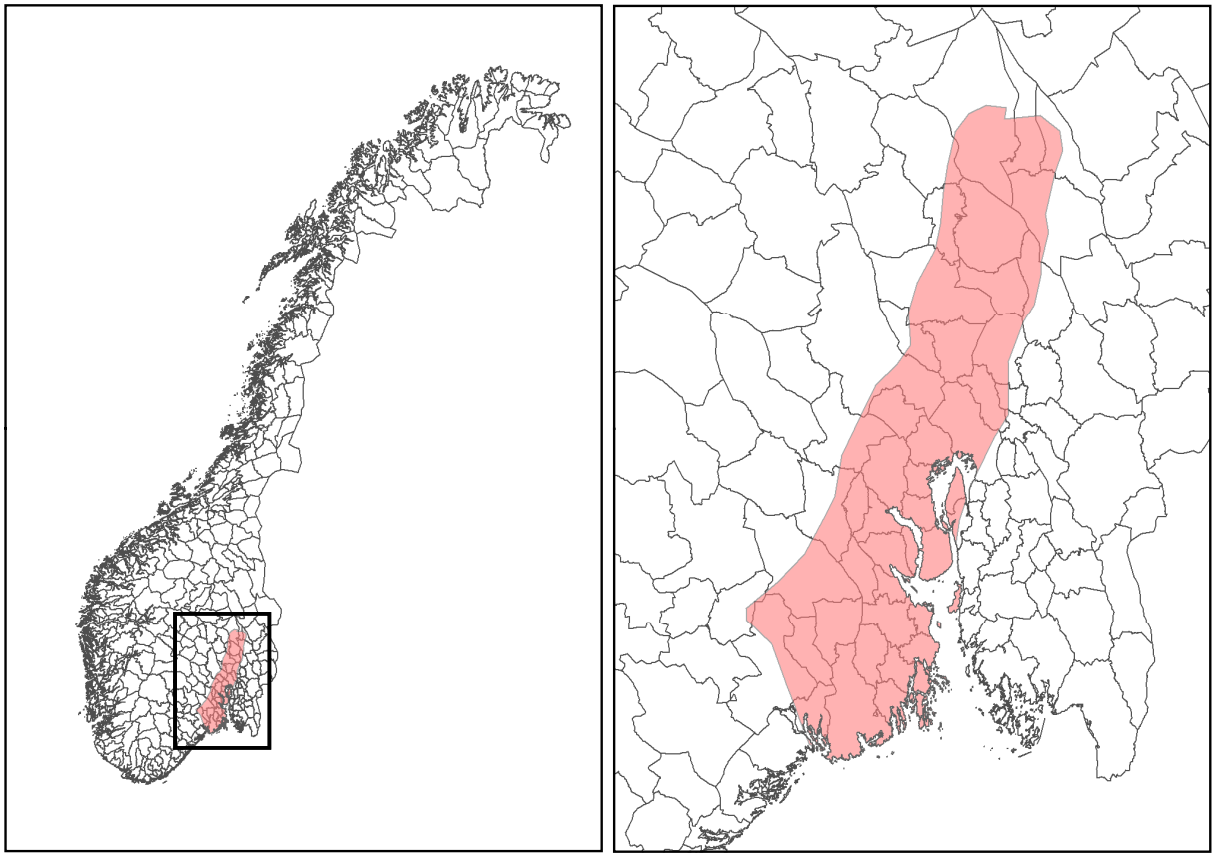
It is in general difficult to determine where mineral resources are located from information on bedrock qualities; gold tend to be where you find it. Nevertheless, bedrock qualities are a tempting source of variation since it's strictly exogenous. The unique geological character of the Oslo graben, which is rich in minerals and clearly defined, can be used to test the first stage correlation in a quasi-experiment.[15] 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 is counted as treated.

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

[14] An indicator of mine region was used in an unreported sensitivity analysis. The results are qualitatively the same, and the binary instrument is significant at the 5% level in the first stage estimation.

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

Figure 2: Oslo graben



The second 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 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.

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

Table 3: 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 graben and its buffers. Dependent variables are log(*population*1998) and log(*population*1801).

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

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

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.[16]

In Table 3 column (1), (3) and (5), the significant result indicate that municipality population 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. 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 seem 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

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

attenuated by distance. Since the location of mines are dependent of mineral endowments, the result supports historical mines as a valid instrument for population size.

5.2 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 wood products 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 forrest, woodlands and rivers are perceived as local amenities or disamenities, and they might be correlated with contemporaneous natural production.

Wood was used for timber, firewood and charcoal for the mine trusses, melters and fire setting[17]. However, sometimes gun powder was used instead. This was the case for Årdal mines, where there were considerable challenges with transportation of wood products (Johannessen, 1991).[18] River power was used to pump excess water out of the mines and run the bellows for the melters (Carstens, 2000). I compute the instrument purely on mine location while location of industrial works are disregarded.[19] 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 4 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 forrest growth is fixed and the interval between the deforestation and contemporaneous outcomes would make it likely that the trees have recurred. The second stage result increase somewhat and are more sharply estimated, while it is the opposite for the first stage result. In total, the results are rather unaffected.

[17]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.

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

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

Table 4: 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.

5.3 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 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 result are robust to this inclusion.

5.4 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 hydro-power 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.

5.5 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, population size and might even be disamenities. As seen in column (4), their inclusion don't change the qualitative result.

5.6 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. That doesn't seem to be the case since the results are almost unaltered.

5.7 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.

5.8 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.[20] As reported in column (7), this does not affect the robustness of the result.

5.9 Mine closure

A 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 4 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 result remain robust in both cases.

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

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

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. The first stage correlation display persistence 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. 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 is interpreted as economies of scale in providing goods and services. That is, a larger local consumer base is able to support higher level and variety of goods and services. 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 cities.

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A Additional theoretical details

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

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

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

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

I utilize Roy's identity and get:

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

P_A 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:

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

where $\tilde{A}_r$ 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:

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

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

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

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. δ_H, δ_L and δ_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 A_r.

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

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

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:				
$\frac{W_r}{W}$	0.991	0.991	1.001	1.017
$\frac{W_r - t_r(W_r^e)}{W - t(W)}$	0.996	0.996	1.000	1.009
House prices:				
$\frac{P_{H,r}}{P_H}$	0.840	0.865	0.996	1.306
Budget shares:				
α_H	0.196	0.194	0.196	0.199
α_{NT}	0.281	0.284	0.284	0.286
α_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 *(Mean:0.13, Std. Dev.:0.43)*	1	1	2	6	2	12
17th century mines *(Mean:0.31, Std. Dev.:0.71)*	-	6	5	9	8	28
18th century mines *(Mean:0.26, Std. Dev.:0.63)*	-	-	12	8	3	23
All historical mines *(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. The final observation is therefore created by aggregating municipality data. 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 are 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 is 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

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, α_{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 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