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Abstract

The present article describes how the spatial distribution of income in Switzerland is related to natural amenities. We explore the link between inequalities in Swiss municipalities and the presence of lakes, rivers, mountains, good accessibility and green amenities. By using fiscal data on average income, Gini index and density of taxpayers in different income brackets, we confirm that a larger variety of landscape is associated with larger spatial income differentials. We also show that inequalities are more pronounced within municipalities located in a particularly nice environment.

Keywords Spatial income distribution, natural amenities, income sorting, inequality

JEL Classification D30, J31, J61, R12, R23

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1 Introduction

In the recent past, income inequalities have been increasing in developed countries, generating growing concerns among economists as to the policy impacts of this trend (e.g. Stiglitz (2012) or Bourguignon (2018)). In this context, fully characterising income disparities becomes central. In this paper, we are interested in the spatial dimension of income distribution. Some places are richer than others and these spatial disparities generate a number of key policy questions. The literature on selective migration and income sorting have well established that rich households concentrate in nice places where housing rents are high and where tax rates are low. However, the sorting process is not perfect, since important social inequalities remain within small areas.

In this article, we focus on one particular characteristic of a region: natural amenities. Taxes and housing prices are largely endogenous, whereas the natural environment may be considered as part of the initial conditions. Exploring the relationship between natural amenities and inequality across and within living places is therefore particularly interesting.

Switzerland is well suited to explore this issue. Its federalist structure and its fractioning into small entities makes it an ideal case to study spatial income distribution. While the impact of taxation on income sorting has been widely explored, this is much less the case for the link with natural amenities. Within this small country, moving from one municipality to another is relatively easy, especially if one stays in the same language region. Lower internal migration costs should theoretically lead to a more sorted equilibrium. Moreover, the landscape diversity is remarkable, so that we can exploit the variety of mountains, lakes, rivers, plains and forests.

Because of the income sorting process, we obviously expect a positive correlation between the environmental endowment and the average income. The relationship between natural amenities and inequalities within municipalities is less clear. In section 3, we give an intuition of what their interaction might be. Briefly, commuting costs and the non-mobility of some types of consumption, such as local services, could partly explain why income heterogeneity remains substantial within small geographical areas.

We conduct panel analyses on Swiss data at the municipal level between 2003 and 2015. We estimate a combination of the spatial Durbin and the Mundlak model, with average income and the

Gini index as dependent variables. We also run seemingly unrelated regressions to explore the link between natural amenities and the share of taxpayers in five different income brackets.

We find that income inequalities between and within municipalities are positively related to the disparity of natural endowments. For instance, the shorter the distance to a lake, the higher the average income *and* the Gini index in the municipality. These results are not only driven by the right tail of the income distribution.

The paper is constructed as follows. We first give an overview of the existing literature (section 2), then we present in a stylised way how amenities can theoretically be related to the distribution of income within and between municipalities (section 3). We next turn to the presentation of our data (section 4) and the econometric identification strategy (section 5). We finally discuss the results (section 6) and conclude (section 7).

2 Literature review

Selective migration and income sorting

Why do people live where they live? Economists usually answer with a standard maximisation program in which agents compare their situation in different regions and decide to move if the utility differential overcomes the cost of migration. This utility differential has been soon approximated by the wage differential. In this respect, the first paper to be cited is the one by Sjaastad (1962). The author presents a model in which migration is an investment in human capital: workers move where they get the highest return on their skills, net of migration costs. Spatial income sorting arises essentially because regions reward differently the skills of workers, who self-select themselves into the best location. Borjas (1987) formalises this idea, which is an application of the classical Roy model (Roy, 1951) to migration.

In a federalist framework, income sorting is also explained by the redistribution system. Tiebout (1956) develops a model in which each jurisdiction provides a different combination for financing and providing public goods. When the taxation is progressive and the public goods considered as inferior, the Tiebout model predicts that rich households concentrate in areas where taxes and redistribution are low.

Many other variables can be suspected to drive household location decision at the individual level.[1] None of them seems neither definitely preponderant nor completely exogenous. Maybe the best summary of what microeconomics has to say about spatial income sorting is the model of Roback (1982): households and firms select mutually exclusive areas on the basis of expected local wages, rents and consumption or amenities. If local wages and prices can freely adjust, a general perfect sorting equilibrium arises where nobody wishes to move. However, location choices have undoubtedly a collective dimension. Going beyond the individual level provides important complements.

Spatial distribution of income and the role of amenities

The New Economic Geography (NEG) has developed as a very fertile framework to explore the collective dimension of location choices. According to the seminal paper of Krugman (1991), we should look at households and firms together within a general equilibrium model. If people follow job opportunities, it becomes central to know where firms prefer to settle. The central point of the NEG framework is the hypothesis of agglomeration economies: because of Marshallian externalities, firms move where other firms are already located. The article by Behrens and Robert-Nicoud (2014) is a perfect recent example. The authors present a model which combines natural advantage, agglomeration economies and firm selection to explain why both productivity and inequality increase with the size of a city.

The so-called supply-side approach looks at the exogenous factors behind location decisions of firms and households: amenities. In a central publication, Brueckner et al. (1999) present the amenity-based theory, which aims to explain why Paris is richer than Detroit. The authors distinguish between natural, historical and modern amenities.

About "Natural amenities"[2], Cheshire et al. (2003) highlight the role of water and Marcouiller

[1] For example life-cycle dimensions (Mincer, 1978), housing price (Oates (1969) and Helpman (1998)), travel time to work, population density, school quality, distance to supermarket (Kim et al., 2005), accessibility (Zondag and Pieters, 2005), air quality (Banzhaf and Walsh, 2008), housing attributes and business location (Schirmer et al., 2013).

[2] About historical and modern amenities, see Koster et al. (2014), van Duijn and Rouwendal (2015) and Falck

et al. (2004) explore the relationship between natural amenities and income distribution through the channel of tourism. More recently, Sinha and Cropper (2015) study climate amenities and Schaeffer et al. (2016) distinguish the roles of "blue" and "green" amenities. In general, researchers conclude that natural amenities are a main driver of income sorting and segregation. The water-based amenities have a preponderant impact. However, little is known about the role of natural amenities in influencing income distributions *within* small entities such as municipalities. As far as we know, Lee and Lin (2017) are the only ones to treat this question. They study the spatial distribution of income in the long run and show that variation in natural endowments within American cities is determinant to explain the persistence of disparities between neighbourhoods. The income heterogeneity is therefore more pronounced and the spatial distribution is less fluctuating in Los Angeles (coastal and hilly) than in Dallas (flat and naturally homogeneous).

Switzerland

Switzerland is a federal state with substantial variation in tax rates and very small costs of migration. This country is therefore a natural laboratory to study the effect of tax on income sorting. This is evidenced by the SNF project "The Swiss Confederation: A Natural Laboratory for Research on Fiscal and Political Decentralization".[3] The project led by Marius Brülhart, Monika Bütler, Mario Jametti and Kurt Schmidheiny was funded by the SNF from 2010 to 2016.[4] The impact of taxation on migration and income sorting in Switzerland has also been explored by other authors. Liebig and Sousa-Poza (2006) explore the individual responsiveness of tax variations and Schmidheiny (2006) uses data from the metropolitan area of Basel to estimate the impact of income on residence choice probabilities. Morger (2017) finds that the capitalisation[5] of lower tax rates into higher housing rents is not full. Moreover, the degree of capitalisation varies depending on income level (approximated by the quality of the apartments). Basten et al. (2017) take advantage of the language frontier to

et al. (2015) who explore the role of "Historical amenities" like monuments, conservation areas and historical sites. "Modern amenities" such as arts production, culture and urban facilities are the focus of Throsby (1994), Boualam (2014) and Albouy (2016). The main conclusion is that the income elasticity of demand for historical and modern amenities is larger than one, which is reinforcing the income sorting process.

[3] http://fiscalfederalism.ch for further information.

[4] In the list of publications, we find Eeckhout et al. (2014) on spatial sorting and Brülhart et al. (2015) on tax competition models. See Schmidheiny (2017) for more details.

[5] Capitalisation is the mechanism through which the price increases on the housing market in response to a decrease of the income tax rate. See (Oates, 1969).

implement a boundary discontinuity design and estimate the effect of tax rates on housing rents. More recently, Kübler and Rochat (2017) and Feld et al. (2018) study the role of the Swiss tax system on overall income inequalities. In a nutshell, these articles show that rich people are more likely to choose low tax jurisdictions, that the tax differentials are partly capitalised into land values and that tax decentralisation tends to lower pre-tax income inequality and to increase post-tax inequality.

To the best of our knowledge, amenities have not been the focus of any study on income sorting in Switzerland. Portnov et al. (2011) explore the role of accessibility[6] on population growth, but do not consider income-related questions. The hedonic pricing literature inspects the explanatory power of natural amenities on housing prices. For instance, Baranzini and Schaerer (2011) estimate the value of lake view in the region of Geneva. They find that the rent of dwellings with lake view is 57% higher than those without. Waltert et al. (2011) explore the role of amenities on regional development, in terms of population and employment. None of these does explore the implications of their findings on the spatial distribution of income.

We conclude this literature review by mentioning the contributions of Segessemann and Crevoisier (2013, 2016), who develop the notion of the "residential economy". Economists usually focus on production to explain growth. In this logic, wealth is concentrated in environments that are favourable to the implementation of firms. What is less often included in spatial equilibrium models is the following process: the simple fact that people live where they live calls for additional economic activity. Goods and services such as retails, childcare, housecleaning, gardening or haircuts have to be provided near residents. Therefore, in some regions, economic development is mainly driven by the fact that households - and in particular rich households - live there. Authors call these areas "residential economies". Compared to "productive economies", they tend to be richer in income terms, but also more unequal. In the next section, we translate this intuition into a stylised economic model.

Our paper differs from the ones cited above, first because we study the effect of natural amenities not only on inequalities across areas, but also within them. Second, evidence are based on very small entities that are heterogeneous in terms of natural environment, urbanization, size and wealth.

[6] Accessibility is measured as distances to the closest major city, river, border and road.

Lastly, the present study takes advantage of recently available data derived from tax returns of Swiss individual taxpayers, aggregated at the municipal (communal) level. These data have three advantages. First, they are reliable. Compared to surveys, tax returns do not have problems of non-response and inaccurate self-reporting. The only limitation concerns tax evasion. Second, data are disaggregated down to a small geographical unit, which is central to study spatial issues. Third, they are based on taxable income, which corresponds better to the earnings of residents than gross product.

3 Theoretical insight

This section presents the basic structure of the income-sorting model of Roback (1982), combined with the assumption of Brueckner et al. (1999) - amenities are luxury goods - and the concept of residential economy of Segessemann and Crevoisier (2016), according to which some goods and services have to be consumed on the place of residence, which generates an additional labour demand in dense and rich areas.

The initial idea of Roback (1982) is that households choose to locate in mutually exclusive areas on the basis of three criteria: wage, rent and endowment of consumption amenities. On the other hand, firms maximise profit according to wage, rent and productive amenities. Note that amenities can be part of the decision-making process of both firms and households. For instance, transport facilities and urban infrastructure are productive and consumable. By contrast, non-polluted air is wanted by the households, but unproductive.

At the equilibrium, nobody wishes to move. Therefore, on the household side, a positive wage differential must be compensated either by higher housing prices, or by a poorer endowment in local consumption amenities. Conversely, if firms are ready to pay higher wages, this implies either lower rents or better endowment in productive amenities. From this model, the relationship between amenities and local wage depends on the price sensitivity on housing markets (rents) compared to labour markets (wages) and on whether amenities are productive, consumable, or both. In any case, the model predicts perfect sorting.

In addition, consider that the demand of amenities is highly positively income elastic. This encourages rich households to settle in nice areas, where housing prices will adjust upwards. If these amenities are also productive, wages are pushed even higher.

However in practice, observed income sorting is far from perfect, which calls for further explanations. We introduce here the idea defended by Segessemann and Crevoisier (2016), which points out the role of the imperfect mobility of consumption. When households live somewhere, they consume local goods and services (retails, childcare, housecleaning, gardening, etc). This makes increase the demand for low-skilled workers and results in a local wage premium. If the premium is sufficient to attract some of these people in areas that are usually preferred by rich households (because of high rents), we will find more inequality in these localities.

Let us illustrate the intuition by considering three groups: high-skilled (H), middle-skilled (M) and low-skilled (L) workers. Wage is increasing in skills and constant within groups, such that $w^H \geq w^M \geq w^L$. Each group maximises a utility function which depends on two continuous variables, consumption goods C and natural amenities A:

$$\begin{aligned} \max\ U^i(C, A) \text{ s.t } P(A) \cdot C \leq w^i \\ \text{with: } i = H, M, L\ ;\ w^H \geq w^M \geq w^L \\ \text{and } \frac{\delta P(A)}{\delta A} > 0\ \ \forall\ A \end{aligned} \tag{1}$$

Natural amenities are free, but the price of consumption is higher in “nicer” areas. $P(A)$ reflects the cost of living, including housing rents. By choosing the level of amenities, the agents mechanically select the corresponding place to live. Moreover, groups have heterogeneous preferences. In particular, the higher the wage, the higher the valuation of amenities and hence the lower the marginal rate of substitution between C and A.

If marginal utilities are positive and decreasing, such a framework leads to a sorted equilibrium, as illustrated in figure 1, with $A^H > A^M > A^L$, the level of amenities chosen by the three groups. Indeed, each group aims to attain the higher indifference curve (IC) given the budget constraint

(BC) that depends on wage and prices. The graph relies on two other convenient assumptions: first, the utility function has the form $U^i(C, A) = C^\alpha A^{\beta_i}$ with $\beta_H > \beta_M > \beta_L$. Second, prices have the following positive relationship with amenities: $P(A) = a \cdot [1 - \frac{A}{A_{max}}]^{-1}$ with a and A_{max} strictly positive. Straightforward calculations show that $C^i_{max} = \frac{w^i}{a}$

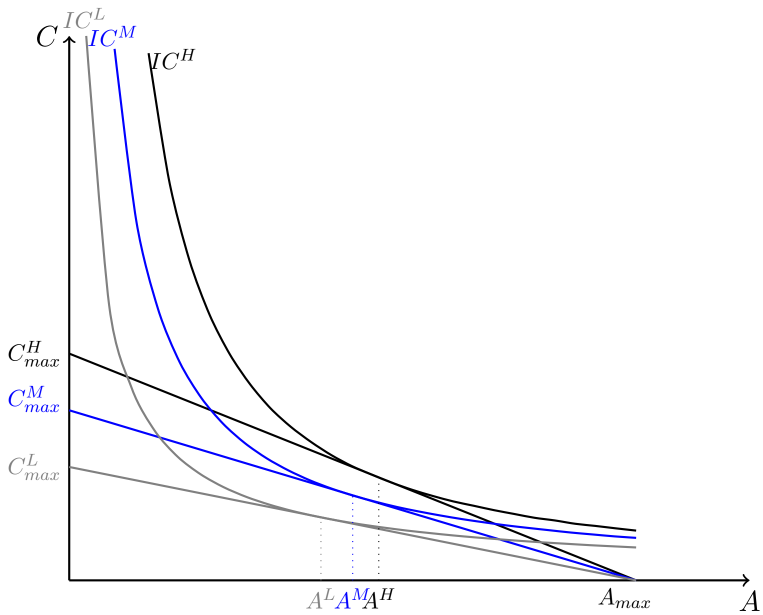


Figure 1: Perfect income sorting case

We now introduce an additional assumption. At places where individuals H live, the wages of L jump at a higher level:

$$w^{L'} = \begin{cases} w^L \text{ if } A < A^H \\ w^L + \Delta \text{ if } A \geq A^H \end{cases} \quad \text{with } \Delta > 0 \tag{2}$$

A^H is the level of amenities selected by skilled workers and Δ is the premium that results from the demand of local services from individuals H. On figure 2, the budget constraint including local premium of the unskilled workers in areas with $A \geq A^H$ is represented by the red solid line (BC^L_Δ). Then, if Δ is large and if commuting costs are just discouraging enough, this may lead group L to choose A^H instead of A^L, since the choice of A^H is on the indifference curve IC^L_Δ, higher than the

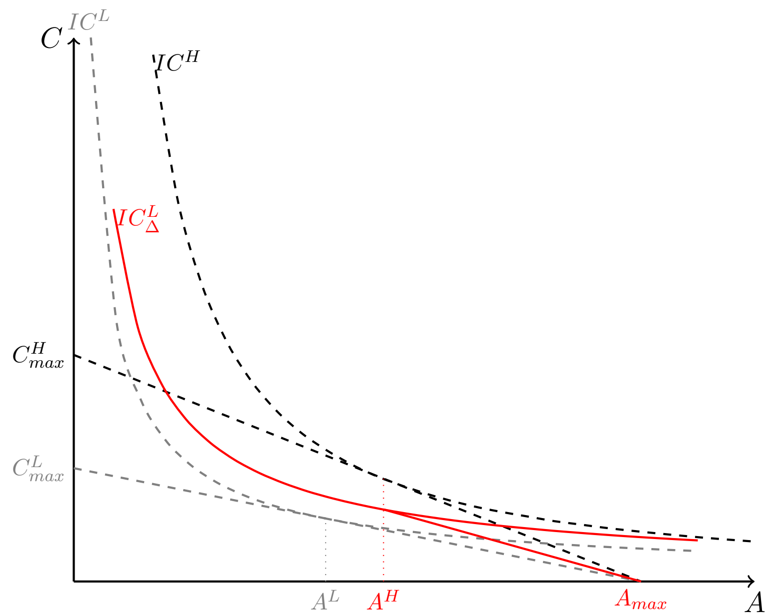


Figure 2: Imperfect income sorting with threshold

previous IC^L .

Obviously, this is a very simplistic view of reality. The endowments in natural amenities are probably not orderable, prices and wages are probably not exogenous to individual location decisions and other factors that are not modelled enter into a resident choice.

Nevertheless, this simple stylised model is consistent with the observed spatial income distribution. When we consider a continuum of skills and a continuum of location possibilities, the low-skilled workers split between places that are particularly well-endowed in amenities and places that are particularly poorly endowed in amenities. Some of the types L will obtain a wage premium just high enough to compensate the fact that prices are higher. If this happens, municipalities with positive valued amenities will be richer and also more unequal.

Note that the threshold effect may work in the other direction. Households located in particularly bad natural environment demand some high-skilled workers for local services anyway (managers, administrators, etc). If there exists such a premium to attract types H, the level of inequality is also higher in municipalities where the quantity (or quality) of A is particularly low.

The imperfection of sorting would therefore be explained by distance-related costs, among which commuting and geographical proximity of consumption. These distance-related costs tend to diminish over time, due to the improvement of the transport infrastructure (see ARE (2013)). A further implication, which is also in line with empirical observations, is the increase of income sorting over time (between-municipalities disparities).

4 Data

The dataset has been constructed from five sources. Fiscal data come from the Federal Tax Administration (see AFC (2013)). They are calculated on the basis of tax returns for the Federal Direct Tax (FDT). The statistics are available from 2003 to 2015.[7] These precious data have been gathered within the SNF project "The Swiss Confederation: A Natural Laboratory for Research on Fiscal and Political Decentralization".[8]

Additional control variables are available on the Federal Statistical Office (FSO) website. They come from four surveys: the Population and Households Statistics (STATPOP), the Buildings and Dwellings statistic (StatBL), the Swiss Film and Cinema Statistics and the Land Use Statistics. Regarding geographical variables, Swisstopo provides the geographical coordinates of the boundaries of the municipalities, lakes and rivers, as well as the altitude at several spot elevations (Geodpoints). Swisstopo uses the LV03 projection system. To capture accessibility, we use the travel time to the closest agglomeration. The Federal office of territorial development (ARE) calculated it in 2011. Finally, the firm Fahrländer Partner AG provides us the rating of the "Exposition", based on the slope and the orientation of each municipality. We have it as is in 2018.

Fiscal data and controls from the FSO are available from 2003 to 2015 and the geographical database contains the municipal boundaries of 2016. One difficulty arises because of the mergers of more than 500 entities between 2003 and 2016. Any drop would induce an important selection bias, because these mergers are non random political choices. To overcome this obstacle, we treat the municipalities as if they had always been like in 2016. In other terms, we artificially put together the composing entities of a new municipality in the years preceding the effective merger. This manipulation relies on the exhaustive list of mutations provided by the Federal Office (OFS, 2018).

[7] Some cantons are missing before 2003 because of the transition from *prae*- to *postnumerando* taxation system. The cantons of Ticino, Valais and Vaud were the last to implement the reform in 2003.

[8] See section 2.

Table 1 summarises the availability, the source and the definition of the variables. Moreover, the summary statistics for 2003, 2008 and 2015 are available in Appendix 8.2.

5 Identification Strategy

The Mundlak model

We work with a typical panel containing N observations over T periods, with N larger than T (2294 municipalities, 13 years). In order to avoid the correlation between the independent variables and the time-invariant part of the error term, we use the Mundlak (1978) specification, which is a mixture of random and fixed effect. Wooldridge (2010)[9] and Baltagi (2013)[10] show how to disentangle within and between effects by multiplying the equation by a time-demeaning matrix. The within effect will be the same as in a fixed effect estimation. Facing the trade-off between unbiasedness and efficiency (Debarsy, 2012), we pragmatically choose unbiasedness relatively important number of observations.

Practically, we write the model following Allison (2009) and Schunck (2013): instead of estimating the effect of X_{it}, we use its deviation from the mean $X_{it} - \bar{X}_i$. We then add $\bar{X}_i$ to obtain the between effect. This specification is called the hybrid model, estimated under the random-effect assumptions:

$$Y_{it} = \beta_0 + \beta_1(X_{it} - \bar{X}_i) + \beta_2 A_i + \beta_3 \bar{X}_i + \alpha_i + \epsilon_{it} \tag{3}$$

where Y_{it} is either the average income or the Gini index in municipality i at time t. The income is expressed in logarithm and the Gini index in logistic transformation. The derivation of this index is detailed in Appendix 8.1. X_{it} is a set of time variant controls, such as tax burden and housing vacation rate, but also indicators of urbanisation (population, share of foreigners) and availability of modern and cultural amenities (number of cinemas). A_i contains time-invariant variables of

[9] In section 10.5.

[10] In chapter 2.

Table 1: List of variables

Variable	Years	N	Source	Description
Income	2003 - 2015	2294[a]	Federal Tax Administration	The dataset contains the median and the mean, net and taxable in equivalent terms (adjusted for the number of people in the household). If not specified, we use the mean net equivalent income.
Gini index	2003 - 2015	2294	Federal Tax Administration	The index is calculated according to formula in Appendix 8.1. If not specified, we use the Gini on net equivalent income.
Share of taxpayers in income class j	2003 - 2015	2294	Federal Tax Administration	The 5 classes of annual taxable income are (in thousands of CHF): $0-30$; $30-40$; $40-50$; $50-75$; more than 75.
Tax burden	2003 - 2007 2008 - 2015	804[b] 2294	Federal Tax Administration	Share of cantonal and communal levies on the labour gross income. We consider the tax burden on married couples with children earning an annual taxable income of 50 000 CHF.
Number of taxpayers	2003 - 2015	2294	Federal Tax Administration	Number of households. Special and normal cases are included.
Population	2003 - 2015	2294	Federal Statistical Office (STATPOP)	Total permanent resident population (mid-August).
Share of foreigners	2003 - 2015	2294	Federal Statistical Office (STATPOP)	Ratio between the number of foreign nationals[c] and the permanent resident population (mid-August).
Housing vacation rate	2003 - 2015	2294	Federal Statistical Office (StatBL)	Percentage of flats to sale or rent (1st June) on the total number of dwellings (1st January).
Number of cinemas	2003 - 2015	2294	Federal Statistical Office (Swiss Film and Cinema Statistics)	Number of cinemas in the municipality.
Share of forest	2007	2294	Federal Statistical Office (Land Use Stat.)	Share of the area of the municipality used as forest.[d]
Share of pasture	2007	2294	Federal Statistical Office (Land Use Stat.)	Share of the area of the municipality used as meadows and farm pastures.[d]
Distance to the closest lake	2016	2294	Swisstopo (VECTOR200)	Distance from the centroid of the municipality to the boundary of the closest lake of more than 100 ha.[e]
Distance to the closest river	2016	2294	Swisstopo (VECTOR200)	Distance from the centroid of the municipality to the axis of the closest river (importance classes 1-3).[e]
Altitude	2016	7427[f]	Swisstopo (VECTOR200)	Altitude in meters at a spot elevation.
Visibility of Alpin peaks	2016	2294	Swisstopo (VECTOR200)	A summit (>3500m) is visible if the vector reaching the centroid of the municipality is not obstructed by any other object.[g]
Accessibility	2011	2294	Federal office for spatial development (ARE)	Travel time (min) by individual motorized transport to the closest agglomeration or isolated town (ARE typology).
Exposition	2018	2222	Fahrländer Partner AG	Rating (1-5) of sunshine exposition, calculated from the slope and orientation of the inhabited parts of the municipality. See Fahrländer and Lehner (2014), p.5.

a: 2294 is the number of municipalities existing in 2016. All the municipalities that have merged since 2003 are treated *as if* they had merged in 2003. To obtain the variables of interest in these "pseudo-municipalities", we calculate either the sum (number of taxpayers, population, surfaces) or the average (weighted by population).
b: Only the municipalities with more than 2000 inhabitants (according to the Census 2000) are in the dataset before 2008.
c: According to the FSO definition, a foreign national is "anyone residing in Switzerland at a given time, but who does not have Swiss nationality. The permanent foreign resident population is the reference population in population statistics. It includes all foreign nationals who hold a residence permit for a minimum duration of 12 months or who have resided in Switzerland for 12 months (Permit B/C/L/F or FDFA permit - international civil servants, diplomats and members of their family)".
d: Standard Nomenclature NOAS04: Basic categories and aggregations.
e: Euclidian distances calculated on the basis of X, Y and Z coordinates of polygons (LV03 projection system) in kilometres.
f: We attribute to each municipality the value measured at the closest spot elevation (from its centroid, Euclidian distance).
g: The vector is calculated from the XY coordinates of the municipality and of the mountain peak. The algorithm looks for a point which is in the neighbourhood (1km) of this segment *and* which has a higher elevation than the linear combination of the two extremities. If it does not find any and if the distance is less than 120 km, we can see the peak from the municipality. See Müri Leupp et al. (2011), p.29.

particular interest, among which the distance to lakes and rivers, altitude and travel time to the closest agglomeration. They are exogenous with respect to the dependent variable. α_i is random and ϵ_{it} are independent and identically distributed. β_1 is the within effect (over time). The estimator would be the same in a fixed-effect estimation.[11] The between-effect β_3 gives the role of X_{it} across observations.

In our empirical setting, housing rents and tax rates are not exogenous with respect to income. We approximate the housing price by the vacation rate and make the assumption that the variation in the excess supply is the cause of the variation in prices, not its consequence, as presented in Rosen and Smith (1983). Moreover, the overall housing vacation rate should not be affected by per capita variables in the short run. Regarding tax burden, we take the five closest entities for which the value is known and calculate the average among them. We then use it as a proxy or as an instrument. If anything, the within coefficients are underestimated compared to the real effect of rental costs and taxes. We can live with it, since we are mainly interested in β_2.

Spatial autocorrelation

Whatever happens in a given municipality is likely to happen also in the neighbouring municipalities. If the event is unobserved, the errors terms α_i and ϵ_{it} are no longer independent. Following Elhorst (2014), we write a model that takes the spatial interaction among the dependent and independent variables into account. In matrix notation, we have:

$$Y_t = \beta_0 + \rho \mathbf{W} Y_t + (\mathbf{X_t} - \bar{\mathbf{X}})\beta_1 + \mathbf{A}\beta_2 + \bar{\mathbf{X}}\beta_3 + (\mathbf{W}\mathbf{X_t} - \mathbf{W}\bar{\mathbf{X}})\beta_4 + \mathbf{W}\mathbf{A}\beta_5 + \mathbf{W}\bar{\mathbf{X}}\beta_6 + \alpha + \epsilon_t \tag{4}$$

where Y_t is a vector of dimension $N \times 1$, N being the number of municipalities. Y_t represents either the logarithm of income or the logistic transformation of the Gini index. $\mathbf{X_t}$ is the matrix of time-dependent variables of dimension $N \times M$, M being the number of variables. β_1 is the vector of coefficients of $M \times 1$ dimension. A is the matrix of amenities ($N \times K$), constant over time. $\bar{\mathbf{X}}$ is the time-average of $\mathbf{X_t}$, of dimension $N \times M$. $\mathbf{W}$ is a matrix $N \times N$ row-standardised contiguity

[11] Except that the FE estimator has a smaller variance.

matrix. The non standardised matrix contains 1 in w_{kl} if municipalities k and l are contiguous[12], zero otherwise. The contiguity matrix is then normalised such that the sum of each row is equal to 1. The scalar ρ represents the endogenous interaction of the dependent variable, whereas β_4 to β_6 are the exogenous interaction effects among the independent variables. α and ϵ_t are the usual error terms, satisfying the random effect assumptions.

In practice, we estimate two models: the spatial autoregressive model (SAR) that forces β_4, β_5 and β_6 to be zero and the spatial Durbin model (SDM) that does not.

Seemingly unrelated Regressions

The mean income and the Gini index are partial indicators of the distribution of income. In particular, it does not indicate to what extent inequality comes from the top of the distribution.[13] Additional information could be obtained by looking at the density of the distribution. We know the number of taxpayers belonging to five mutually exclusive net income categories, namely 0-30; 30-40; 40-50; 50-75 and more than 75 000 CHF per year. Similarly to Feld and Kirchgässner (2001), we are therefore able to estimate the following system of equations:

$$\begin{pmatrix} S_{1it} \\ S_{2it} \\ S_{3it} \\ S_{4it} \\ S_{5it} \end{pmatrix} = \begin{pmatrix} (X_{it} - \bar{X}_i) & ... & 0 \\ ... & ... & ... \\ 0 & ... & (X_{it} - \bar{X}_i) \end{pmatrix} \cdot \begin{pmatrix} \delta_{11} \\ \delta_{12} \\ \delta_{13} \\ \delta_{14} \\ \delta_{15} \end{pmatrix} + \tag{5}$$

$$\begin{pmatrix} A_i & ... & 0 \\ ... & ... & ... \\ 0 & ... & A_i \end{pmatrix} \cdot \begin{pmatrix} \delta_{21} \\ \delta_{22} \\ \delta_{23} \\ \delta_{24} \\ \delta_{25} \end{pmatrix} + \begin{pmatrix} \bar{X}_i & ... & 0 \\ ... & ... & ... \\ 0 & ... & \bar{X}_i \end{pmatrix} \cdot \begin{pmatrix} \delta_{31} \\ \delta_{32} \\ \delta_{33} \\ \delta_{34} \\ \delta_{35} \end{pmatrix} + \begin{pmatrix} \theta_{1i} \\ \theta_{2i} \\ \theta_{3i} \\ \theta_{4i} \\ \theta_{5i} \end{pmatrix} + \begin{pmatrix} \nu_{1it} \\ \nu_{2it} \\ \nu_{3it} \\ \nu_{4it} \\ \nu_{5it} \end{pmatrix}$$

[12] According to the Queen definition, two areas are contiguous if they share a common vertex.

[13] The increase of disparities in developed countries is mainly driven by the elongation of the right tail of the distribution. See for instance Piketty and Saez (2006).

S_{jit} holds for the logistic formulation of the share of taxpayers.[14] We jointly estimate the five equations by the Zellner-Aitken Seemingly unrelated regressions method (Zellner, 1962). The joint estimation allows the error terms $\theta_{ji} + \nu_{jit}$ to be correlated across equations js.

The categories are unfortunately very wide on the right of the distribution. All the households earning more than 75 000 CHF by year are in the same class (which represents one third of the total). Thus, the regression does not tell what happens with the richest people, that are suspected to drive inequalities. Rather, it aims to show whether the relationship with natural amenity is still present in the low and middle income categories.

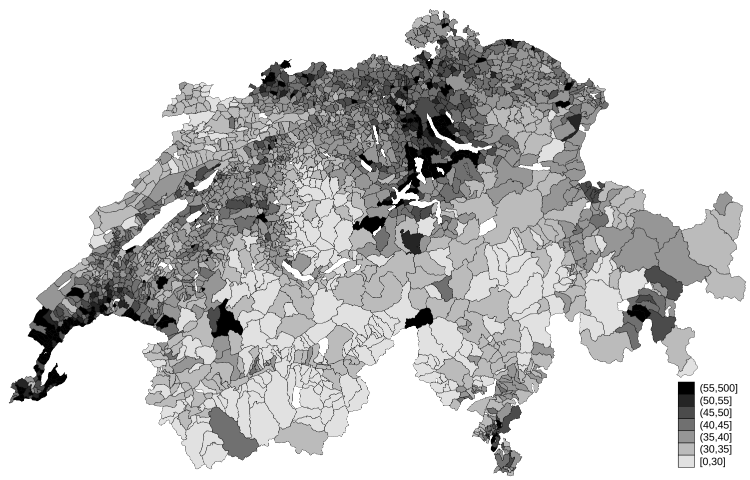
6 Results

Descriptive statistics

We present here some stylised facts about the distribution of income across and within Swiss municipalities. We focus on the last year available in the dataset, namely 2015. The maps show the average income, the Gini index and the share of taxpayers at the beginning and at the end of the distribution.

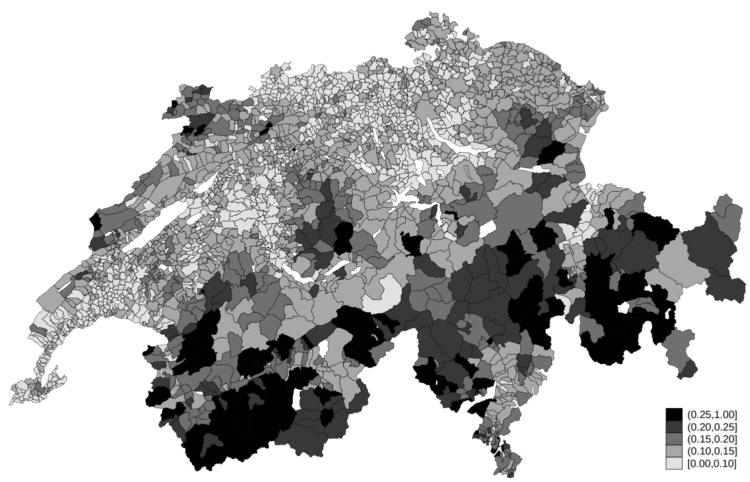
Income distribution has a visible link with mountains and lakes. On the maps showing average income and the share of taxpayers earning more than 75 000 CHF, we clearly see dark spots on the Lemanic Arc, around Lakes Lucerne, Lugano and Zurich. In contrast, the Jura and the Alps are lighter. At first sight, within inequalities are not evenly distributed, neither. The Gini index seems larger the closer the lakes and the higher the altitude.

[14] $S_{jit} = [\frac{Share_{jit}}{1 - Share_{jit}}]^{1/3}$ where $Share_{jit}$ is the fraction of taxpayers in income class j in municipality i at time t.

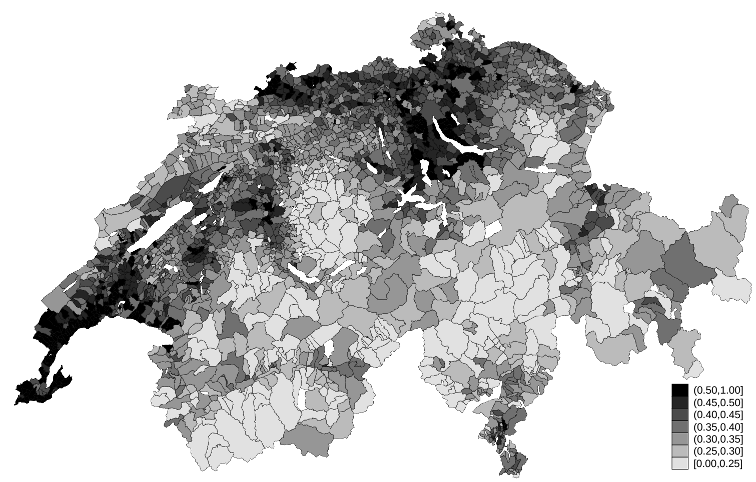


(a) Average annual net income (in thousands of CHF), 2015

(b) Gini Index (on net income), 2015



(c) Share of taxpayers with net income lower than 30 000 CHF, 2015



(d) Share of taxpayers with net income higher than 75 000 CHF, 2015

Figure 3

Turning to summary statistics, Table 2 shows the averages of fiscal variables, weighted by the number of taxpayers. The municipalities were split between lakeside and non-lakeside.[15] In lakeside municipalities, the annual income is 17,77% larger and the Gini index is 13,10% larger than in non-lakeside areas. The share of the richest households is larger in municipalities next to water. Note also that the average number of taxpayers is more than twice larger in lakeside areas, because cities have developed next to blue amenities.

Table 2: Summary statistics 2015, by distance to lake

	Non-lakeside	Lakeside	T-test	P-value
Average net income	40323.049	47489.481	-7.040	0.000
Median net income	32991.427	33907.404	-5.867	0.000
Number of taxpayers	1796.091	4096.163	-5.519	0.000
Gini index (net)	0.435	0.492	-16.466	0.000
Share under 30 000 CHF	0.125	0.123	1.392	0.164
Share 30-40 000 CHF	0.108	0.101	7.816	0.000
Share 40-50 000 CHF	0.138	0.124	8.397	0.000
Share 50-75 000 CHF	0.255	0.243	7.826	0.000
Share over 75 000 CHF	0.375	0.410	-9.041	0.000
Tax burden (married, 50 000 CHF)	20.057	19.348	8.308	0.000
Number of obs.	1882.000	412.000	.	.

The statistics are weighted by the number of taxpayers, except this variable itself

Table 3 shows the information when the sample is divided between low and high altitude. The critical value is set at 610m, the median. The table indicates that average income is lower and Gini index is higher in the second group. The figures on the different shares suggest that the income distribution has more density on the left tail in the mountains. The municipalities at high altitude have a smaller population and charge more taxes than their low-altitude counterparts.

Table 3: Summary statistics 2015, by altitude

	Lower than median	Higher than median	T-test	P-value
Average net income	43582.120	41190.728	7.933	0.000
Median net income	34157.835	31797.235	17.624	0.000
Number of taxpayers	2803.657	1613.669	3.706	0.000
Gini index (net)	0.452	0.457	-3.188	0.001
Share under 30 000 CHF	0.112	0.146	-18.318	0.000
Share 30-40 000 CHF	0.102	0.111	-9.243	0.000
Share 40-50 000 CHF	0.131	0.137	-6.545	0.000
Share 50-75 000 CHF	0.254	0.244	4.035	0.000
Share over 75 000 CHF	0.400	0.363	14.923	0.000
Tax burden (married, 50 000 CHF)	19.730	19.980	7.892	0.000
Number of obs.	1148.000	1146.000	.	.

The statistics are weighted by the number of taxpayers, except this variable itself

[15]"Lakeside" is defined such that the distance between the centroid of the municipality and the closest border of a lake is smaller than 3km.

Regressions

Table 4 presents the models with the logarithm of average annual net income as the dependent variable. Distances to blue amenities are in kilometres and log forms. Altitude is expressed in kilometres to limit the number of digits in the coefficients. The first column shows the fixed effect estimation, the second is the hybrid model with standard errors clustered by municipalities (equation 3), the third and the fourth are hybrid models corrected for spatial autocorrelation (equation 4). In model (3), β_4, β_5 and β_6 are assumed to be zero (spatial autoregressive model).

A battery of tests have been conducted. We do not detect multicollinearity in the variance inflation factor. The robust Lagrange multiplier test confirms the presence of spatial lag dependence in income and Gini index. A Wald test shows that the null hypothesis $\beta_4 = \beta_5 = \beta_6 = 0$ can be rejected. Our preferred specification is therefore the spatial Durbin model (fourth column). The coefficients on spatially lagged explanatory variables are not reported in the table for readability concerns. Interested readers find them in Table 14, Appendix 8.3. Table 5 shows the same models estimated with the logistic transformation of the Gini index as the dependent variable, in which the average income is included as a control.

As expected, income is positively correlated with all the attractive natural amenities (lake, river, proximity to an agglomeration[16]). It has a negative link with altitude and forest. The former may be considered as a natural dis-amenity (because of climate and slope for instance), the latter as an indicator for rurality. The Gini index is higher in lakeside municipalities, in the mountains and in areas with a large share of green amenities. The closer the next urban centre, the lower the indicator of inequality.

In line with Behrens et al. (2014), the most populated municipalities are also the richest one (between coefficient). Regarding the Gini index, the coefficient of population is non significantly positive within and negative between. It indicates that income is more evenly distributed in large municipalities than in small villages. This confirms the observation of Castells-Quintana and Royuela (2015), according to which “In already developed or unequal countries, i.e., countries in which concentration of resources is already high, urbanisation in small and medium-sized cities appears to be

[16]The distance variables (lake, river, travel time) must be reversed in the interpretation.

Table 4: Dependent variable: Log(income)

	(1) OLS	(2) FE	(3) Hybrid model	(4) Spatial AR	(5) Spatial Durbin
Log(distance to the closest lake - km)	-0.0345***	0	-0.0329***	-0.0298***	-0.0466***
	(0.00126)	(.)	(0.00469)	(0.00432)	(0.00536)
Log(distance to the closest river - km)	-0.0578***	0	-0.0587***	-0.0400***	-0.0360***
	(0.00186)	(.)	(0.00701)	(0.00636)	(0.00908)
Altitude - km	-0.122***	0	-0.123***	-0.0875***	-0.0821***
	(0.00246)	(.)	(0.00806)	(0.00750)	(0.00794)
Share of forest	-0.176***	0	-0.173***	-0.110***	-0.0751***
	(0.00816)	(.)	(0.0297)	(0.0277)	(0.0275)
Share of pasture	-0.0673***	0	-0.0731**	-0.0899***	-0.0539
	(0.0108)	(.)	(0.0326)	(0.0315)	(0.0405)
Travel time to the closest agglomeration (min)	-0.00331***	0	-0.00312***	-0.00213***	-0.00291***
	(0.0000912)	(.)	(0.000327)	(0.000287)	(0.000366)
Log(population)	0.0110***				
	(0.00130)				
Share of foreign population	0.370***				
	(0.0184)				
Housing vacation rate (%)	-0.0202***				
	(0.000913)				
Tax burden in the 5 closest municipalities	-0.0279***				
	(0.000554)				
Number of cinemas	-0.0260***				
	(0.00183)				
Log(population) (within)		0.187***	0.187***	0.0971***	0.0285
		(0.00906)	(0.0208)	(0.0176)	(0.0188)
Share of foreign population (within)		0.958***	0.958***	0.562***	0.299***
		(0.0272)	(0.0779)	(0.0718)	(0.0705)
Housing vacation rate (within)		0.00108**	0.00108*	0.000144	-0.000349
		(0.000438)	(0.000650)	(0.000555)	(0.000543)
Tax burden in the 5 closest municipalities (within)		-0.0243***	-0.0243***	-0.0123***	-0.00155
		(0.000530)	(0.00112)	(0.00102)	(0.00175)
Number of cinemas (within)		-0.00846**	-0.00846	-0.00316	0.000321
		(0.00404)	(0.00517)	(0.00429)	(0.00426)
Log(population) (between)			0.0136**	0.0163***	0.0184***
			(0.00529)	(0.00490)	(0.00487)
Share of foreign population (between)			0.326***	0.101	0.0197
			(0.0803)	(0.0714)	(0.0714)
Housing vacation rate (between)			-0.0417***	-0.0277***	-0.0237***
			(0.00422)	(0.00389)	(0.00404)
Tax burden in the 5 closest municipalities (between)			-0.0266***	-0.0188***	-0.0322***
			(0.00230)	(0.00221)	(0.00345)
Number of cinemas (between)			-0.0271***	-0.0210***	-0.0221***
			(0.00681)	(0.00573)	(0.00549)
ρ				0.475***	0.402***
				(0.0161)	(0.0168)
θ				-2.225***	-2.203***
				(0.0575)	(0.0581)
σ_e				0.00423***	0.00417***
				(0.000467)	(0.000463)
Observations	29822	29822	29822	29822	29822
R^2	0.371	0.258	0.388	0.408	0.465

Standard errors in parentheses

* p<.1, ** p<.05, *** p<.01

Table 5: Dependent variable: Gini index[a]

	(1) OLS	(2) FE	(3) Hybrid model	(4) Spatial AR	(5) Spatial Durbin
Log(distance to the closest lake - km)	-0.0426***	0	-0.0430***	-0.0363***	-0.0286***
	(0.00129)	(.)	(0.00437)	(0.00413)	(0.00461)
Log(distance to the closest river - km)	-0.00265	0	-0.00130	0.00683	0.0000887
	(0.00190)	(.)	(0.00698)	(0.00661)	(0.00789)
Altitude - km	0.180***	0	0.182***	0.159***	0.123***
	(0.00258)	(.)	(0.0122)	(0.0115)	(0.00799)
Share of forest	0.0638***	0	0.0654**	0.0872***	0.0811***
	(0.00828)	(.)	(0.0307)	(0.0291)	(0.0252)
Share of pasture	-0.0462***	0	-0.0410	-0.00929	0.0760**
	(0.0109)	(.)	(0.0313)	(0.0295)	(0.0378)
Travel time to the closest agglomeration (min)	0.00184***	0	0.00184***	0.00190***	0.00249***
	(0.0000939)	(.)	(0.000380)	(0.000362)	(0.000367)
Log(population)	-0.0143***				
	(0.00131)				
Share of foreign population	0.445***				
	(0.0187)				
Housing vacation rate (%)	0.00771***				
	(0.000928)				
Tax burden in the 5 closest municipalities	0.0198***				
	(0.000581)				
Number of cinemas	0.0213***				
	(0.00185)				
Log(net income)	0.672***				
	(0.00583)				
Log(population) (within)		0.0834***	0.0834***	0.0191	0.0196*
		(0.0115)	(0.0309)	(0.0297)	(0.0116)
Share of foreign population (within)		-0.106***	-0.106	-0.182**	0.0703**
		(0.0350)	(0.0935)	(0.0910)	(0.0347)
Housing vacation rate (within)		-0.000165	-0.000165	-0.000409	0.000211
		(0.000552)	(0.000872)	(0.000845)	(0.000511)
Tax burden in the 5 closest municipalities (within)		0.0151***	0.0151***	0.0151***	0.000928
		(0.000693)	(0.00178)	(0.00176)	(0.000982)
Number of cinemas (within)		-0.000683	-0.000683	0.000573	-0.00341
		(0.00508)	(0.00575)	(0.00524)	(0.00469)
Log(income)(within)		0.657***	0.657***	0.638***	0.810***
		(0.00759)	(0.0528)	(0.0534)	(0.00795)
Log(population) (between)			-0.0156***	-0.0148***	-0.0213***
			(0.00565)	(0.00544)	(0.00403)
Share of foreign population (between)			0.463***	0.371***	0.505***
			(0.0895)	(0.0859)	(0.0591)
Housing vacation rate (between)			0.0158**	0.0184***	0.0121***
			(0.00621)	(0.00543)	(0.00397)
Tax burden in the 5 closest municipalities (between)			0.0203***	0.0182***	0.00654**
			(0.00219)	(0.00208)	(0.00301)
Number of cinemas (between)			0.0224***	0.0237***	0.0230***
			(0.00591)	(0.00614)	(0.00540)
Log(income)(between)			0.684***	0.653***	0.764***
			(0.0401)	(0.0391)	(0.0201)
ρ				0.288***	0.383***
				(0.0126)	(0.00720)
θ				-1.883***	-1.857***
				(0.0369)	(0.0178)
σ_e				0.00779***	0.00706***
				(0.000289)	(0.0000607)
Observations	29822	29822	29822	29822	29822
R^2	0.445	0.246	0.447	0.433	0.509

Standard errors in parentheses

* p<.1, ** p<.05, *** p<.01

[a]: logistic transformation

associated with decreasing inequality." (p.306). Income and share of foreigners are positively linked across time. The Gini index and the share of foreigners are positively related within and between municipalities.

The coefficient of vacation between municipalities rate is significantly negative on income and positive on the Gini index. Poor and unequal municipalities have high vacation rates (hence probably low housing prices). The mean income is negatively related to the tax burden between municipalities. This result indicates that rich people self-select themselves into areas where taxes are low (Tiebout, 1956). We also find that the tax burden and the Gini index (calculated on pre-taxed incomes) are positively correlated between municipalities. One explanation would be that the tax burden is considered here on married couples with an annual income of 50 000 CHF, which are not rich households. Probably the higher this rate, the less progressive is the taxation, so that taxes fall proportionally more on the middle of income distribution.

The number of cinemas has a negative between-coefficient in the regression on income and Gini. This is quite surprising, since we a priori would have considered this variable as a positive cultural amenity. This result may come from the fact that cinema is not a luxury good. As in Dewenter and Westermann (2005), it would suggest that the income-elasticity of the demand for cinema is smaller than one. In addition, cinemas are usually only located in urban areas and they attract consumers who live in other municipalities, adding some noise to the estimations. Finally, inequality is positively related to the mean income, both across time and space. This reflects the fact that distribution of income is typically more spread on the right than on the left. If there is some sorting, it mechanically implies that richer areas are more unequal.

The seemingly unrelated regression (equation 5) is partially reported in Table 6. For the sake of space, only δ_{2j} coefficients are shown.

The share of households in the two extreme categories is positively related to the proximity of lake or river, contrary to the middle class (30 000 - 75 000 CHF). The proportion of the poorest fringe of the population ($<$ 40 000 CHF) is positively linked to altitude, while the share of households earning over 50 000 CHF is lower in the mountains. The reverse is true concerning accessibility. Forest (and pasture) have a positive coefficient on all the categories but the (two) highest, suggesting

Table 6: Panel Seemingly Unrelated Regression

	(1) SUR
Share < 30 000 CHF[a]	
Log(distance to the closest lake - km)	-0.00467***
	(0.00163)
Log(distance to the closest river - km)	0.00539**
	(0.00238)
Altitude - km	0.0780***
	(0.00313)
Share of forest	0.0644***
	(0.0104)
Share of pasture	0.0366***
	(0.0138)
Travel time to the closest agglomeration (min)	0.00178***
	(0.000117)
Share 30 000 - 40 000 CHF[a]	
Log(distance to the closest lake - km)	0.000377
	(0.000859)
Log(distance to the closest river - km)	0.0119***
	(0.00126)
Altitude - km	0.00826***
	(0.00165)
Share of forest	0.0469***
	(0.00549)
Share of pasture	0.0549***
	(0.00728)
Travel time to the closest agglomeration (min)	0.000527***
	(0.0000618)
Share 40 000 - 50 000 CHF[a]	
Log(distance to the closest lake - km)	0.00372***
	(0.000835)
Log(distance to the closest river - km)	0.0141***
	(0.00122)
Altitude - km	-0.00118
	(0.00161)
Share of forest	0.0350***
	(0.00534)
Share of pasture	0.0552***
	(0.00708)
Travel time to the closest agglomeration (min)	0.000274***
	(0.0000601)

	(1) (continued)
Share 50 00 - 75 000 CHF[a]	
Log(distance to the closest lake - km)	0.00733***
	(0.000858)
Log(distance to the closest river - km)	0.00857***
	(0.00126)
Altitude - km	-0.0114***
	(0.00165)
Share of forest	0.0159***
	(0.00548)
Share of pasture	-0.00684
	(0.00727)
Travel time to the closest agglomeration (min)	-0.000144**
	(0.0000617)
Share > 75 000 CHF[a]	
Log(distance to the closest lake - km)	-0.00767***
	(0.00226)
Log(distance to the closest river - km)	-0.0342***
	(0.00330)
Altitude - km	-0.0631***
	(0.00434)
Share of forest	-0.127***
	(0.0144)
Share of pasture	-0.0941***
	(0.0191)
Travel time to the closest agglomeration (min)	-0.00200***
	(0.000163)
Observations	29822

Standard errors in parentheses
* p<.1, ** p<.05, *** p<.01
[a]: cubic root transformation: $S_{jit} = [\frac{Share_{jit}}{1 - Share_{jit}}]^{1/3}$

again that the share of green amenities is an indicator of rurality, not a positively valued amenity. All in all, these seemingly unrelated regressions show that the link between income distribution and natural amenities is not only driven by the richest households. We find significant and consistent coefficients on the left of the distribution as well.

To conclude, all the regressions in this section show that the valuation of natural amenities is positively related to the mean income. The more the landscape is variate, the larger inequalities between municipalities. The results remain valid when we control for taxes and pressure on the housing market, indicating that natural amenities are factors of income sorting by themselves.

Within inequality is also related to the environmental context. The Gini index is larger next to blue amenities and in the mountains, indicating that disparities are larger in particularly nice (A^H) or particularly bad (A^L) natural environments. This mechanisms is not only driven by the richest households.

Robustness

We first change the definition of variables. That is, we replace the population by the number of taxpayers, we reduce the minimal size of a “lake” at 50 ha and we add the variables “Exposition”[17] and “Visibility of Alpin peaks”. We also use the taxable instead of the net income. Different specifications of the spatial Durbin model are shown in Table 7. The most robust coefficients are lake and altitude, which remain significant in all four specifications. When significant, travel time and distance are of the same sign as in previous section. Share of forest and pasture switch signs in the income regression when exposition is included (the observations numbers vary), which is positively linked to Gini and income. Visibility of Alpin peaks is, if anything, negatively related to income. We suspect multicollinearity between this variable and altitude.

The econometric modelling may also be varied. Instead of using a proxy of tax burden, we use a 2SLS regression. We also introduce time fixed effects, we lag the explanatory factors and estimate the model with first-difference of the time-variant variables. Finally, we run the model only with the 1242 municipalities that have not changed their borders between 2003 and 2016. Note that doing

[17] This inclusion implies the use of the state of municipalities in 2018, hence the reduction of N from 2294 to 2222 observations per year.

Table 7: Robustness: definition of variables - Spatial Durbin model

	(1) Log(taxable income)	(2) Log(taxable income)	(3) Gini index (taxable)	(4) Gini index (taxable)
Distance to the closest lake (50 ha)	-0.0376***	-0.0583***	-0.0683***	-0.0659***
	(0.00485)	(0.0115)	(0.00530)	(0.0137)
Distance to the closest river	-0.0658***	0.0440	-0.0459***	0.0360
	(0.00740)	(0.0317)	(0.00868)	(0.0359)
Altitude	-0.0480***	-0.0216*	0.0917***	0.0462***
	(0.0131)	(0.0128)	(0.0164)	(0.0162)
Number of visible Alpin peaks	-0.00241***	-0.000228	-0.000205	-0.000638
	(0.000660)	(0.000559)	(0.000892)	(0.000771)
Exposition		0.0164***		0.0141***
		(0.00381)		(0.00484)
Share of forest	-0.161***	0.0121**	-0.0473	0.0226***
	(0.0336)	(0.00549)	(0.0382)	(0.00675)
Share of pasture	-0.0982***	0.0115**	-0.0223	0.0167**
	(0.0364)	(0.00515)	(0.0458)	(0.00677)
Travel time to the closest agglomeration	-0.00275***	-0.00117*	-0.000338	0.000618
	(0.000357)	(0.000656)	(0.000415)	(0.000748)
Log(nb of taxpayers) (within)	-0.120***	-0.108***		
	(0.0201)	(0.0269)		
Log(population) (within)			0.162***	0.0800**
			(0.0267)	(0.0318)
Share of foreign population (within)	0.380***	0.0186***	0.392***	0.0209***
	(0.0633)	(0.00432)	(0.0886)	(0.00568)
Housing vacation rate (within)	-0.000188	0.000435	-0.000816	-0.0000154
	(0.000583)	(0.000474)	(0.000867)	(0.000676)
Tax burden in the 5 closest municipalities (within)	-0.00473***	0.104*	0.00400**	0.101
	(0.00115)	(0.0535)	(0.00156)	(0.0680)
Number of cinemas (within)	0.00412	-0.00198	-0.000921	-0.00923**
	(0.00413)	(0.00323)	(0.00570)	(0.00371)
Log(Taxable income)(within)			-0.763***	-0.689***
			(0.0284)	(0.0324)
Log(nb of taxpayers) (between)	0.0368***	0.00598		
	(0.00620)	(0.00523)		
Log(population) (between)			-0.00607	-0.00743
			(0.00767)	(0.00677)
Share of foreign population (between)	0.237***	0.0210***	0.715***	0.0355***
	(0.0872)	(0.00744)	(0.103)	(0.00871)
Housing vacation rate (between)	-0.0442***	-0.0119***	-0.0187***	-0.00794**
	(0.00443)	(0.00324)	(0.00621)	(0.00377)
Tax burden in the 5 closest municipalities (between)	-0.0277***	0.612***	-0.0000751	0.843***
	(0.00242)	(0.193)	(0.00283)	(0.239)
Number of cinemas (between)	-0.0225***	-0.0155***	0.00451	0.00916*
	(0.00601)	(0.00460)	(0.00452)	(0.00533)
Log(Taxable income)(between)			-0.0844	-0.176***
			(0.0601)	(0.0534)
ρ	0.110***	0.379***	0.0638***	0.318***
	(0.0145)	(0.0300)	(0.0106)	(0.0180)
θ	-2.299***	-2.059***	-2.056***	-1.857***
	(0.0534)	(0.0548)	(0.0432)	(0.0495)
σ_e	0.00477***	0.00423***	0.00984***	0.00918***
	(0.000499)	(0.000455)	(0.000750)	(0.000751)
Observations	29822	26664	29822	26664
R^2	0.430	0.528	0.225	0.287

Standard errors in parentheses

* p<.1, ** p<.05, *** p<.01

so, we cannot use the contiguity matrix any more and must settle for the hybrid model specification.

Tables 8 and 9 show a synthesis of these results. The sign of the coefficients on amenities remains similar in the vast majority of cases. One variable is sensitive and looses its significance, namely the share of pasture. In general, the correlations remain in the same order of magnitude.

7 Conclusion

In this paper, we study the link between the Swiss spatial distribution of income and natural amenities. We find that income and inequalities are high in municipalities that are easily accessible, close to water, well exposed to the sunshine and from where we can see the Alps. In addition, the higher the elevation and the larger the forest, the lower the average income. Inequalities are also more pronounced in the mountains.

In general, controlling for other factors, income inequalities both between *and* within municipalities are positively related to the existence of natural amenities. The richer the households, the more they value natural amenities, so that income tends to concentrate next to positive-valued amenities, which explains spatial inequality. Less obviously, nice places are also more unequal, and this fact is not only driven by the richest households. Our proposed explanation is that local services are needed in every area where people live. If rich households are ready to pay a premium in order to consume groceries, gardening, baby sitting, housecleaning and any other local good, low-skilled workers may choose to live near positive-valued amenities, so that the income distribution within the locality becomes more uneven. If that interpretation is correct, then any decrease of distance-related costs (e.g. commuting costs) implies a reinforcement of the income sorting, hence an increase of inequality between municipalities over time.

Our analysis is based on the mean income, the Gini index, and income classes at the municipality level. Other indicators would have been instructive, such as the Theil index (which is additive and decomposable by subgroups) and the share of income hold by the richest households (top 1% or 10%). However, these variables are not available at the municipal level. In the same vein, additional controls could be added in the regressions to refine our understanding of the role of amenities. For instance, the attraction effect of water is not necessarily the same from one lakeside municipality to

Table 8: Robustness: income model

	(1) 2SLS Log(taxable income)	(2) Time FE Log(income)	(3) Lagged Log(income)	(4) 1st diff. Δ Log(income)	(5) Non-merged mun. Log(income)
[1em] Distance to the closest lake (100 ha)	-0.0505***	-0.0313***	-0.0308***	-0.000811***	-0.0265***
	(0.00528)	(0.00475)	(0.00467)	(0.000218)	(0.00648)
Distance to the closest river	-0.0542***	-0.0487***	-0.0596***	0.000436	-0.0326***
	(0.00800)	(0.00698)	(0.00694)	(0.000295)	(0.00884)
Altitude	-0.126***	-0.0826***	-0.0794***	-0.000783*	-0.158***
	(0.00913)	(0.00885)	(0.00881)	(0.000462)	(0.00893)
Share of forest	-0.158***	-0.122***	-0.144***	-0.00589***	-0.207***
	(0.0335)	(0.0304)	(0.0307)	(0.00156)	(0.0396)
Share of pasture	-0.0407	-0.0388	-0.0528	0.00124	0.0242
	(0.0392)	(0.0330)	(0.0325)	(0.00182)	(0.0490)
Travel time to the closest agglomeration	-0.00209***	-0.00200***	-0.00244***	-0.0000497***	-0.00137***
	(0.000344)	(0.000326)	(0.000333)	(0.0000187)	(0.000415)
Log(nb of taxpayers) (within)	0.0882***	-0.167***			0.0819***
	(0.0216)	(0.0193)			(0.0194)
Log(nb of taxpayers) (1st diff)				-0.318***	
				(0.0477)	
Log(nb of taxpayers) (t-1) (within)			-0.0411**		
			(0.0176)		
Share of foreign population (within)	0.740***	0.281***			0.977***
	(0.0738)	(0.0588)			(0.0942)
Share of foreign population (t-1) (within)			0.335***		
			(0.0646)		
Share of foreign population (1st diff)				-0.0448	
				(0.0560)	
Housing vacation rate (within)	0.000402	-0.000284			0.000806
	(0.000573)	(0.000540)			(0.000844)
Housing vacation rate (t-1) (within)			-0.000434		
			(0.000585)		
Housing vacation rate (1st diff)				-0.000454	
				(0.000335)	
Tax burden (within)	-0.0153***				
	(0.00158)				
Tax burden in the 5 closest municipalities (within)		0.000779			-0.0258***
		(0.00112)			(0.00174)
Tax burden in the 5 closest municipalities (t-1) (within)			-0.00380***		
			(0.00101)		
Tax burden in the 5 closest municipalities (1st diff)				-0.000547	
				(0.000810)	
Number of cinemas (within)	-0.00764*	0.00572			-0.0140
	(0.00460)	(0.00353)			(0.00970)
Number of cinemas (t-1) (within)			0.00232		
			(0.00381)		
Number of cinemas (1st diff)				-0.00240	
				(0.00235)	
Log(nb of taxpayers) (between)	0.0165***	0.0373***	0.0315***	-0.00164***	0.0277***
	(0.00599)	(0.00575)	(0.00578)	(0.000298)	(0.00707)
Share of foreign population (between)	0.441***	0.268***	0.201**	0.00161	0.200**
	(0.0901)	(0.0846)	(0.0817)	(0.00341)	(0.0978)
Housing vacation rate (between)	-0.0457***	-0.0411***	-0.0413***	-0.000914***	-0.0496***
	(0.00469)	(0.00423)	(0.00421)	(0.000205)	(0.00494)
Number of cinemas (between)	-0.0277***	-0.0272***	-0.0234***	0.000170	-0.0286***
	(0.00764)	(0.00681)	(0.00607)	(0.000178)	(0.00824)
Tax burden in the 5 closest municipalities (between)		-0.0179***	-0.0260***	-0.000647***	-0.0247***
		(0.00220)	(0.00223)	(0.000104)	(0.00291)
ρ		0.133***	0.186***	0.0635***	
		(0.0194)	(0.0205)	(0.00980)	
θ		-2.339***	-2.263***	20.34***	
		(0.0560)	(0.0574)	(0.0576)	
σ_e		0.00399***	0.00417***	0.00416***	
		(0.000446)	(0.000462)	(0.000599)	
Observations	20861	29822	27528	27528	16634
R^2	0.299	0.406	0.419	0.0274	0.396

Standard errors in parentheses

* p<.1, ** p<.05, *** p<.01

Table 9: Robustness: Gini index model

	(1) 2SLS Gini index (taxable)	(2) Time FE Gini index	(3) Lagged Gini index	(4) 1st diff. Δ Gini index	(5) Non-merged mun. Gini index
Distance to the closest lake (100 ha)	-0.0680***	-0.0441***	-0.0454***	-0.000533*	-0.0588***
	(0.00563)	(0.00436)	(0.00438)	(0.000313)	(0.00623)
Distance to the closest river	-0.0465***	-0.00361	-0.00556	-0.00435***	-0.0274***
	(0.00891)	(0.00704)	(0.00707)	(0.000443)	(0.00924)
Altitude	0.0889***	0.161***	0.165***	0.00210***	0.194***
	(0.0137)	(0.0127)	(0.0128)	(0.000750)	(0.0155)
Share of forest	-0.0703*	0.0651**	0.0663**	0.00848***	0.0309
	(0.0383)	(0.0316)	(0.0316)	(0.00215)	(0.0430)
Share of pasture	-0.0748*	-0.0483	-0.0354	0.00771***	-0.0663
	(0.0432)	(0.0316)	(0.0316)	(0.00240)	(0.0465)
Travel time to the closest agglomeration	-0.000315	0.00143***	0.00131***	-0.0000746***	0.00190***
	(0.000386)	(0.000394)	(0.000396)	(0.0000250)	(0.000536)
Log(Taxable income)(within)	-0.557***				
	(0.0339)				
Log(income)(within)		0.801***			0.677***
		(0.0529)			(0.0621)
Log(income)(t-1) (within)			0.183***		
			(0.0494)		
Log(income)(1st diff)				1.076***	
				(0.0386)	
Log(nb of taxpayers) (within)	0.416***	0.626***			0.510***
	(0.0281)	(0.0311)			(0.0299)
Log(nb of taxpayers) (t-1) (within)			0.367***		
			(0.0280)		
Log(nb of taxpayers) (1st diff)				1.009***	
				(0.0671)	
Share of foreign population (within)	0.503***	-0.168**			-0.668***
	(0.0882)	(0.0819)			(0.111)
Share of foreign population (t-1) (within)			0.0148		
			(0.0736)		
Share of foreign population (1st diff)				-0.0386	
				(0.0747)	
Housing vacation rate (within)	-0.00127	-0.00134			-0.00209*
	(0.000878)	(0.000863)			(0.00107)
Housing vacation rate (1st diff)				0.000360	
				(0.000576)	
Tax burden (within)	-0.000558				
	(0.00207)				
Tax burden in the 5 closest municipalities (within)		0.00757***			0.0233***
		(0.00138)			(0.00236)
Tax burden in the 5 closest municipalities (t-1) (within)			0.00912***		
			(0.00139)		
Tax burden in the 5 closest municipalities (1st diff)				0.00200*	
				(0.00105)	
Number of cinemas (within)	-0.0139**	-0.0102*			-0.000786
	(0.00626)	(0.00536)			(0.00823)
Number of cinemas (t-1) (within)			-0.00231		
			(0.00537)		
Number of cinemas (1st diff)				0.00211	
				(0.00398)	
Log(Taxable income)(between)	-0.117**				
	(0.0580)				
Log(nb of taxpayers) (between)	-0.00577	-0.0144**	-0.0135**	0.00140***	-0.00869
	(0.00676)	(0.00619)	(0.00620)	(0.000444)	(0.00875)
Share of foreign population (between)	0.689***	0.436***	0.446***	0.0159***	0.462***
	(0.101)	(0.0882)	(0.0882)	(0.00499)	(0.131)
Housing vacation rate (between)	-0.0188***	0.0164***	0.0165***	0.00124***	0.0216**
	(0.00652)	(0.00629)	(0.00634)	(0.000337)	(0.00948)
Number of cinemas (between)	0.00115	0.0162***	0.0162***	0.000266	0.0173**
	(0.00466)	(0.00544)	(0.00532)	(0.000256)	(0.00715)
Log(income)(between)		0.703***	0.707***	-0.00814***	0.643***
		(0.0416)	(0.0424)	(0.00188)	(0.0539)
Tax burden in the 5 closest municipalities (between)		0.0212***	0.0213***	0.000402***	0.0185***
		(0.00218)	(0.00220)	(0.000154)	(0.00267)
[1em] Housing vacation rate (t-1) (within)			-0.00190**		
			(0.000935)		
ρ		0.00703	0.0166*	0.103***	
		(0.0123)	(0.00961)	(0.00799)	
[1em] θ		-1.998***	-1.801***	21.22***	
		(0.0380)	(0.0465)	(0.0466)	
σ_e		0.00718***	0.00941***	0.00596***	
		(0.000233)	(0.000685)	(0.000197)	
Observations	20861	29822	27528	27528	16634
R^2	0.208	0.461	0.439	0.467	0.414

Standard errors in parentheses
* p<.1, ** p<.05, *** p<.01

another - it may depend on the characteristics of the lake, on the topography and on the orientation.

Having these several caveats in mind, we can anyway conclude that the link between the studied natural amenities and income distribution exists, that these amenities are permanent and that the income sorting process is self-reinforcing. We thus expect high persistence of inequalities both between and within municipalities in a heterogeneous landscape like Switzerland.

These key features characterising the spatial distribution of income are useful to pursue federal, cantonal and communal policies in terms of regional development, land use, transport, fiscal competition and financial equalisation. Bringing empirical evidence to inform these fundamental debates has been a core objective of this paper.

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8 Appendix

8.1 Derivation of the Gini index

The index is calculated as follows: for a given time t and municipality i, let $Income_n$ be the income of individual $n = 1, 2, ...N$. $Income_n$ is indexed in a non-decreasing order, such that $Income_1 \leq Income_2 \leq ... \leq Income_N$. The Gini coefficient is given by:

$$Gini = \frac{1}{N}[N + 1 - 2\frac{\sum_{n=1}^{N}(N + 1 - n)Income_n}{\sum_{n=1}^{N} Income_n}] = \frac{2\sum_{n=1}^{N} n \cdot Income_n}{N\sum_{n=1}^{N} Income_n} - \frac{N + 1}{N} \tag{6}$$

The Gini index is bounded between 0 and 1, we therefore use its logistic transformation:

$$G_{it} = \log\left(\frac{Gini_{it}}{1 - Gini_{it}}\right) \tag{7}$$

8.2 Descriptive statistics

Table 10: Summary statistics 2003

Variable	Obs	Mean	Std. Dev.	Min	Max
Average net income (CHF/year)	2 294	36 898.69	9 314.55	10 917	193 795
Median net income (CHF/year)	2 294	30 563.66	4 292.385	4 600	53 600
Gini index (net equivalent)	2 294	.427	.058	.258	.858
Tax burden (%)	800	21.436	2.918	5.89	26.9
Tax burden in the 5 closest municipalities (%)	2 294	21.221	2.534	11.044	25.846
Share of taxpayers under 30 000 CHF (net)	2 294	.136	.052	.008	.72
Share of taxpayers 30 - 40 000 CHF (net)	2 294	.126	.025	.036	.368
Share of taxpayers 40 - 50 000 CHF (net)	2 294	.144	.022	0	.296
Share of taxpayers 50 - 75 000 CHF (net)	2 294	.28	.026	0	.507
Share of taxpayers over 75 000 CHF (net)	2 294	.313	.081	0	.685
Number of taxpayers	2 294	1 892.673	6 846.994	17	230 202
Population	2 294	3 188.253	10 596.52	24	342 116
Share of foreign population	2 294	.202	.106	0	.538
Housing vacation rate (%)	2 294	.901	1.134	0	19.108
Number of cinemas	2 294	2.727	5.439	0	18

The statistics are weighted by the population (except for population and number of taxpayers)

Table 11: Summary statistics 2008

Variable	Obs	Mean	Std. Dev.	Min	Max
Average net income (CHF/year)	2 294	41 037.4	13 364.51	13 081	276 359
Median net income (CHF/year)	2 294	32 416.56	48 44.692	4 800	54 700
Gini index (net equivalent)	2 294	.442	.065	.287	.88
Tax burden (%)	804	20.532	2.938	6.843	26.477
Tax burden in the 5 closest municipalities (%)	2 294	20.409	2.569	10.17	25.443
Share of taxpayers under 30 000 CHF (net)	2 294	.123	.05	0	.635
Share of taxpayers 30 - 40 000 CHF (net)	2 294	.109	.022	0	.357
Share of taxpayers 40 - 50 000 CHF (net)	2 294	.135	.024	.03	.458
Share of taxpayers 50 - 75 000 CHF (net)	2 294	.274	.031	.083	.458
Share of taxpayers over 75 000 CHF (net)	2 294	.359	.084	.036	.706
Number of taxpayers	2 294	2 012.986	7 148.246	17	242 480
Population	2 294	3 310.154	10 940.09	19	358 540
Share of foreign population	2 294	.211	.106	0	.568
Housing vacation rate (%)	2 294	.98	1.137	0	14.596
Number of cinemas	2 294	2.422	4.998	0	19

The statistics are weighted by the population (except for population and number of taxpayers)

Table 12: Summary statistics 2015

Variable	Obs	Mean	Std. Dev.	Min	Max
Average net income (CHF/year)	2 294	42 850.58	14 773.31	16 603	478 065
Median net income (CHF/year)	2 294	33 467.16	4 788.394	5 850	55 200
Gini index (net equivalent)	2 294	.452	.069	.264	.936
Tax burden (%)	2 294	19.81	2.933	7.205	25.737
Tax burden in the 5 closest municipalities (%)	2 294	19.731	2.676	10.534	24.823
Share of taxpayers under 30 000 CHF (net)	2 294	.122	.048	.022	.611
Share of taxpayers 30 - 40 000 CHF (net)	2 294	.105	.022	0	.333
Share of taxpayers 40 - 50 000 CHF (net)	2 294	.133	.027	0	.417
Share of taxpayers 50 - 75 000 CHF (net)	2 294	.251	.031	.036	.412
Share of taxpayers over 75 000 CHF (net)	2 294	.389	.087	0	.747
Share of foreign population	2 294	.243	.111	0	.606
Number of taxpayers	2 294	2 209.182	7710.732	18	263 358
Population	2 294	3 590.962	11 856.01	13	391 359
Housing vacation rate	2 294	1.166	1.241	0	11.523
Number of cinemas	2 294	1.821	4.261	0	19

The statistics are weighted by the population (except for population and number of taxpayers)

Table 13: Summary statistics - constant variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Distance to the closest lake (km)	2 294	12.135	10.027	.068	51.19
Distance to the closest river (km)	2 294	28.598	17.533	.541	75.882
Altitude (m)	2 294	823.822	579.883	197	3451
Visibility of Alpin peaks	2 294	5.919	10.869	0	112
Share of forest	2 294	.302	.158	0	.88
Share of pasture	2 294	.16	.129	0	.687
Travel time to the closest agglomeration (min)	2 294	33.093	15.456	0	161
Exposition	2 222	2.274	1.165	1	5

8.3 Regressions

Table 14: Spatial Durbin model: spatial dependence of explanatory variables

		(1) Log(income)	(2) Gini index
β_4	Log(population) (within)	0.0597**	0.267***
		(0.101)	(0.0205)
	Share of foreign population (within)	0.764***	-0.243***
		(0.000776)	(0.0657)
	Housing vacation rate (%) (within)	0.00275**	-0.00234**
		(0.00109)	(0.00108)
	Tax burden in the 5 closest municipalities (within)	-0.0128***	0.00776***
		(0.00196)	(0.00126)
	Number of cinemas (within)	-0.0000906	0.00230
		(0.0149)	(0.0107)
	Log(income)(within)		-0.599***
			(0.0134)
β_5 :	Log(distance to the closest lake - km)	0.0527***	-0.00397
		(0.00739)	(0.00698)
	Log(distance to the closest river - km)	0.0224*	-0.0179*
		(0.0129)	(0.0108)
	Altitude - km	-0.0432***	0.0715***
		(0.0122)	(0.0144)
	Share of forest	-0.165***	-0.114**
		(0.0548)	(0.0465)
	Share of pasture	-0.165***	-0.157***
		(0.0531)	(0.0571)
	Travel time to the closest agglomeration (min)	0.00177***	-0.00266***
		(0.000506)	(0.000518)
β_6 :	Log(population) (between)	-0.0166**	0.0339***
		(0.00813)	(0.00721)
	Share of foreign population (between)	0.700***	-0.353***
		(0.124)	(0.110)
	Housing vacation rate (between)	-0.0224***	0.00423
		(0.00689)	(0.00730))
	Tax burden in the 5 closest municipalities (between)	0.0188***	0.00891**
		(0.00404)	(0.00367)
	Number of cinemas (between)	0.00153	-0.00342
		(0.0133)	(0.0127)
	Log(income)(between)		-0.380***
			(0.0352)
Observations		29822	29822

Complement to column (4) of Tables 4 and 5. It shows the coefficient on spatially lagged explanatory variables in equation (4)

Standard errors in parentheses

* p<.1, ** p<.05, *** p<.01

Table 15: Seemingly unrelated regression

Dep. var:	Share < 30	Share 30-40	Share 40-50	Share 50-75	Share > 75
Log(population) (within)	-0.0209***	-0.00512	-0.0960***	-0.0326***	0.121***
	(0.00421)	(0.00407)	(0.00408)	(0.00391)	(0.00397)
Share of foreign population (within)	0.0440***	-0.0376***	0.0374***	-0.0414***	0.00656
	(0.0133)	(0.0128)	(0.0129)	(0.0123)	(0.0125)
Housing vacation rate (within)	0.000341*	-0.000522***	-0.000785***	0.0000306	0.000283
	(0.000196)	(0.000190)	(0.000190)	(0.000182)	(0.000185)
Tax burden in the 5 closest municipalities (within)	0.000659**	-0.000975***	-0.000915***	-0.00202***	0.00282***
	(0.000278)	(0.000269)	(0.000270)	(0.000258)	(0.000262)
Number of cinemas (within)	-0.000733	0.000128	0.00146	-0.00261	0.00220
	(0.00180)	(0.00174)	(0.00174)	(0.00167)	(0.00170)
Log(population) (between)	-0.0158***	-0.00118	0.00325***	0.00743***	0.0108***
	(0.00168)	(0.000888)	(0.000864)	(0.000887)	(0.00234)
Share of foreign population (between)	0.159***	-0.0552***	-0.0694***	-0.103***	0.0364
	(0.0244)	(0.0129)	(0.0125)	(0.0128)	(0.0338)
Housing vacation rate (between)	0.00957***	0.00891***	0.00765***	0.00537***	-0.0255***
	(0.00164)	(0.000864)	(0.000840)	(0.000863)	(0.00227)
Tax burden in the 5 closest municipalities (between)	0.00478***	0.00461***	0.00315***	-0.000721*	-0.00853***
	(0.000763)	(0.000403)	(0.000392)	(0.000402)	(0.00106)
Number of cinemas (between)	0.0118***	0.00620***	0.00404***	0.00148	-0.0208***
	(0.00236)	(0.00124)	(0.00121)	(0.00124)	(0.00327)
Year FE	yes	yes	yes	yes	yes

Observations: 29 822

Standard errors in parentheses

* p<.1, ** p<.05, *** p<.01