Location relativity in space and time

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Location Relativity in Space and Time: Some Evidence from Swiss Municipalities, 1950-2000

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Abstract

This paper looks into the time dependence of location effects. In particular, it analyzes how location has affected, in the second half of the twentieth century, the population growth of 2889 municipalities in Switzerland. The analysis demonstrates the temporal relativity of location attributes, even for small territorial divisions, such as the Swiss cantons. However, we also show that, both absolute and relative location attributes have weakened over time as population growth predictors, apparently due to improving road infrastructures, as well as to growing motorization. The study has been made possible by a detailed historical population and accessibility database available for Swiss municipalities. To the best of our knowledge, no database of such scope and quality is available for any other European country.

Keywords

Location relativity, Population, Growth, Accessibility, Switzerland, 1950-2000

1 Introduction: absolute or relative location?

The effect of individual location attributes (topography, proximity to international borders, transport networks, etc.) on urban performance, is likely to vary across time and space. Thus, proximity to an international border may become a strong advantage for cities and towns in countries with open economies and low trade barriers (like most European countries today), and a weak advantage elsewhere. By the same token, a cold and rainy place may be a desirable residence in a country with little sunshine overall, but might hold much less attraction in a milder climate. *Location advantage* is thus a relative notion: it may matter regionally and nationally, more than internationally (Portnov and Schwartz, 2008). Furthermore, the development-fostering effect of a location attribute is likely to depend on whether other places in the same region possess similar attributes as well. Thus, the presence of a major university or airport may attract many newcomers and businesses to a town which is the exclusive 'holder' of these functional amenities in the region. However, such establishments may contribute much less to a city's performance, if other cities or towns host similar functions.

The relativity of location preferences may be demonstrated with respect to several specific location attributes – inter-town distances, average winter temperatures, elevation above the sea level, etc. Thus, a distance of 50-100 km is commonly traveled in most European countries, North America and Australia, by people commuting to jobs, schools and entertainment places. However, the same distance may well constitute an insurmountable obstacle in third-world countries with poorly developed road infrastructures. Even within a given country, the *same* distance range may have different implications in different regions, as coastal plains can be more easily crossed than hilly or mountainous areas.

Temperatures are another example of location relativity. Thus, -30--40^{o}C (-22F--40F) is a common winter temperature in the rapidly growing major cities of Russian Siberia, such as Novosibirsk and Krasnoyarsk. There, cities and towns with -20^{o}C (-4F) winter temperatures are perceived as 'warm spots'. However, such temperatures would hardly be considered fit for human habitation in more temperate regions.

Elevation above sea level is a relative location attribute as well. Whereas elevations of 2000m+ above sea level host rapidly growing cities in equatorial or tropical countries, such as Ecuador, Mexico and Ethiopia, high elevations are not *loci* of sustained urban growth in Europe, where comfortable temperatures and fertile soils are more likely to be found on lower grounds (Turok and Mykhnenko, 2007; Portnov and Schwartz, 2009).

Proximity to the closest major city is an important location attribute, considering that big cities are major markets as well as loci of employment and services. Indeed, for small town residents, major city remoteness often implies economic weakness and limited job opportunities. However, what is a 'major city'? The answer may depend on local context. Thus, 500,000 residents (or even 100,000-200,000 residents) constitute a major city threshold in most of Europe. However, the same population size might only 'secure' a 'provincial town' status in, say, India or China.

The relative importance of location attributes may also *change over time*. In the initial stages of economic development, connectivity, and proximity to basic resources (such as fresh water and mineral deposits or train tracks and all-weather roads) are likely to dominate location decision-making. However, as an economy develops, new location-related elements may gain prominence. They may include climate differentials, environmental attractiveness, and proximity to unique urban functions (such as cultural and educational services), which few population centers may provide (Glaeser *et al*, 2001). In addition, average road travel time may dwindle, reflecting infrastructural improvements, construction of new all-weather highways, improved vehicle quality and rising average travel speed and motorization levels, all of which have occurred in Switzerland over the past 50 years (see Fig. 1A).

<<< Figure 1 about here >>>

Summing up, *absolute location attributes* are unlikely to be especially meaningful as growth predictors, as their *weight is likely to be place and time dependent.* In particular, their significance may depend on infrastructure quality, accessibility conditions, motorization levels, and differences in local development and welfare levels. The relative importance of individual location features may also change *over time,* reflecting the diminishing importance of proximity to basic resources (essential in the early phases of industrialization), increased mobility, and the growing importance of cultural and environmental attributes.

The present paper looks into the *context and time dependence of location effects,* showing how they have affected the long-term population growth of individual municipalities in Switzerland's 26 cantons.[1]

The rest of the paper is organized as follows: we start with a brief discussion of population growth and accessibility, for both of which data are available for 2889 municipalities in Switzerland every ten years, between 1950 and 2000. Next, we test our hypothesis that *location attributes matter regionally (that is, at the cantonal level) more than nationally* and that the importance of individual location attributes *changes over time.*

An unexpected finding of our study is that the *difference between the importance of relative (i.e., canton-normalized) and absolute location attributes*, clearly noticeable at the beginning of the study period, in the 1950's and 1970's, appears to decline over time, probably due to improved accessibility and increased mobility nationwide, which may have reduced the importance of cantonal boundaries and geographic obstacles to mobility.

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[1] The Swiss cantons have the authority to tax incomes and set spending priorities, even for social services. In that respect, the cantons are more similar to US states than to German *Länder*.

2 Location as a factor of urban growth

Location is the fundamental concept underlying most early studies in urban geography. Thus, they emphasized the role of transport costs, commuting limits, and geographic barriers to trade (von Thünen, 1826; Christaller, 1933; Lösch, 1938; Isard, 1956; Beckmann, 1968). However, in more recent urban debate, the effect of location on urban performance has not been viewed as either obvious or straightforward. Thus, proponents of a 'non-spatial' approach to urban development deny any 'natural growth advantage.' to individual urban locations According to them, as people of similar backgrounds, incomes and environmental preferences 'flock together,' location differences emerge (Gotlieb 1996). Their view is that societal processes of repulsion and attraction, and individual drives to utility maximization are, rather than physical location *per se*, the real causes of urban place disparities.

That point of view is essentially shared by the proponents of the 'new economic geography', which assumes that concentration and de-concentration forces generate multiple equilibria, which may exist simultaneously in several geographic *loci* (Krugman 1993, 1995; Fujita *et al*. 2001).

Concurrently, the 'neo-cultural' growth approach emphasizes the role of 'second-nature' factors, such as cultural diversity, human capital, innovation, and creativity, as determinants of urban development (Florida 2002). A similar approach is advocated by the 'endogenous growth theory,' which postulates that cities develop because of the production factors they host, and that urban growth (or lack thereof) has little to do with the cities' geographic environment (Jacobs 1969; Henderson 1974; Henderson *et al.* 1995; Glaeser *et al.* 1992).

3 General development patterns in Switzerland

Switzerland has seen a massive transformation since 1950: its population increased by 50%, real incomes rose by 225% and the floor area of housing per capita nearly doubled (Swiss Statistics, 1951-2008). The majority of the country's population lives between the Alps in the south and the Jura mountains to the north-west. This Mittelland region stretches between the Lake Constance in the north-east and the Lake Geneva in the south-west and includes four major conurbations - Zürich, Bern, Lausanne and Geneva; only Basle lies north of the Jura. A large number of middle sized cities complement the Swiss network of major population centers; many of them host highly specialized manufacturing and service industries.

Motorway construction in Switzerland started relatively late in comparison to the neighboring countries and proceeded rather slowly. While the bulk of the originally planed motorways was finished in the 1980’s, the full-scale motorway construction program is still underway.

Suburbanization in Switzerland started at different points in time in different metropolitan areas of the country: first in Zürich and then around Basle and Bern (Tschopp et al, 2003). However, the massive population loss of the core cities appears to have ended in the late 1990's and even reversed in recent years (see **Error! Reference source not found.**). Still, suburbanization continues, albeit at a slower pace, and the commuting catchment areas of the major cities in the Mittelland currently overlap. Suburban sprawl is supported by a dense network of train services, which has been expanding continuously in the past decades, with service frequency and comfort improving substantially. Many of the train lines are small and owned by local governments.

4 Growth and accessibility data

Studying temporal variations in the spatial relativity of location attributes, requires information on changes in population, employment and accessibility, both across individual territorial units (municipalities and cantons) and over a substantial time period. A data base including these variables was collated in an earlier project (Tschopp, Keller and Axhausen, 2003; Tschopp, Sieber, Keller and Axhausen, 2003; Fröhlich and Axhausen, 2004; Fröhlich, Tschopp and Axhausen, 2006), which was focused solely on the impact of accessibility change.

The Swiss census provides the necessary data on population, age structure etc. for each municipality by decade. While some items had to be collated electronically for the first time, the main technical problems to be solved prior to the analysis involved taking into account changes in administrative boundaries: municipality mergers, formation of a new canton (regional government) and shifts of districts between cantons. About 200 changes, which have occurred since 1950, had to be traced. Then, a coherent data set was generated for the 2889 municipalities in the year 2000 (Tschopp and Keller, 2003).

To what extent are residential choices driven by access, and to what extent by accessibility, is an empirical question. To answer it, we calculated a set of access variables and one of accessibility variables, as briefly discussed below.

The central access variable was calculated as the aerial (shortest path) distance between the municipality and the *closest* of Switzerland's five major urban centers – either Zürich, Bern, Geneva, Basel or Lausanne (see Figure 2).

<<< Figure 2 about here >>>

Additional explanatory variables covered by the analysis were the distance from the nearest motorway, aerial distance from the nearest river and finally the (shortest road) distance to the nearest international border crossing. The importance of these variables as potential growth predictors is outlined below in brief.

D*istance to the nearest major urban center* captures access to national *foci* of education, services and employment. *Distance to motorway* implies both the access of local residents to the high-quality road network, facilitating daily and periodical commuting, and the visibility of a municipality for families in search of a suburban residence.

Given Switzerland's alpine and sub-alpine mountainous topography, *distance from a major river or lake* is a rough indicator of the availability of flat land for settlement and of fertile land for agriculture. Moreover, riverside locations (and the enticing views they tend to offer) may be especially attractive to residents, developers, and tourists, enhancing the development potential of a municipality and helping to diversify its employment base.

Distance to *international border crossings* reflects potential benefits which a municipality may achieve by exploiting the economic opportunities of border proximity (such as transshipment, border processing, tourism, cross-border shopping, and the availability of seasonal labor force). Due to development differentials between countries, proximity to an international border crossing may attract labor migrants, as well as enable cross-border shopping for cheaper goods and services in neighboring countries (Soysal, 1994; Timothy, 2005).

Favorable *weather conditions* in localities are likely to reflect their attractiveness to migrants and tourists, thus affecting a municipality's economic performance and population growth. The weather conditions in the municipalities were measured by two climatic indicators: the average hours of *sunshine* and the annual *precipitation* (mm). The values are the latest available estimates provided by Swiss-Meteo, the national metrological office. We assume that their relative positions have not changed in a systematic way over the last 50 years. We expected Swiss municipalities with more sunny days and less precipitation to be more attractive to migrants, all else being equal, and more successful in retaining residents than less favorably located places.

A substantial literature on the measurement of *accessibility* has been reviewed at length (Aschauer, 1989; Vickerman, 1991; Banister and Berechman, 2000). We have chosen the total benefit (consumer surplus) available from a set of spatial alternatives measured through the log-sum term of the minimally specified discrete destination choice model (Williams, 1977; Ben-Akiva and Lerman, 1985):

$$A_i = \ln \sum_{\forall j} X_j \, f(c_{ij})$$

where:

A_i: Accessibility of location *i*;

X_j: Opportunities at location *j*, such as number of residents, work places, customers, purchasing power, etc;[2]

c_{ij}: Generalized cost of travel between locations i and j, here travel time.

$f()$: Weighting function for the generalized costs of travel, here: $e^{-\lambda c_{ij}}$

λ: Parameter set to 0.2 in line with Schilling's 1973 estimate.

The travel time estimates for the five decades were developed for both road and public transport (Axhausen, Dolci, Fröhlich, Scherer and Carosio, 2008; Fröhlich, 2008). Public transport travel times are based on the summer time tables of the Swiss railways in the relevant year, plus calibrated estimates for the scheduled bus travel times for municipalities without a railway station. The road networks were constructed to include new alignments of high capacity roads opened since 1950. As

2 In the present analysis, the number of residents in a locality was chosen as a proxy for opportunities it offers. In the initial phase of the analysis, the *number of jobs* available in the municipality at the beginning of each decade was also used as a growth predictor. It was represented by two separate variables – Employment (II) and Employment (III). While the former measures the number of jobs in the industrial sector, the latter measures it in the *tertiary* (i.e., service) sector. It turned out, however, that 'employment' and 'accessibility' variables showed strong multicollinearity, likely to bias regression estimates. Therefore, in the following discussion, only the models based on accessibility variables, which appeared to provide better fits and (as measured by adjusted R^2) and generality than their 'employment-based' counterparts are reported, for brevity's sake. The 'employment-based' models can be obtained from the authors upon request.

Switzerland has been late in constructing an advanced motorway network and has not yet finished building it as defined in the country's legislation (see the section on general development patterns in Switzerland), change went on during the study period. In the absence of demand matrices for the decades preceding 2000, the speed differences on different road types were captured through a set of average speed assumptions, based on an extensive review of international and Swiss literature (Erath and Fröhlich, 2004).

The results for the year 2000 showed that these averages reproduce the assignment results well enough to generate accurate travel time estimates over longer distances (Fröhlich, Tschopp and Axhausen, 2006). In the analysis, these accessibility measurements were represented by two variables - Access (I) and Access (II), - reflecting access through *public* and *individual* transportation, respectively.

Finally, individual cantons (26) were represented in the analysis by their fixed effects, i.e., dichotomous variables taking on value *one*, if a municipality is in a given canton, and *zero* otherwise (regression estimates for cantonal dummies are not reported in the analysis, for brevity's sake).

Descriptive statistics of research variables and collinearity between them are reported in Tables 1-2.

<<< Tables 1-2 about here >>>

5 Results

The list of variables affecting the population growth rates (ln) of municipalities, and the resulting models, are reported in Tables 3-5, while Table 6 compares goodness of fit statistics. In Table 3 (Models 1-5), the municipalities' location is represented by absolute values (distances to rivers, border crossings, proximity to major cities, etc.) and accessibility variables. Models 6 through 10 in Table 4 preserve the same setting, while location variables are represented by canton-normalized values.

<<< Tables 3-6 about here >>>

Models in Table 5 (Models 11-12) are spatial dependency (SD) models, estimated by two different methods – Spatial Lag (SL) and Spatial Error (SE) regressions. [The models are reported for the 1990-2000 decade only, while regression models for other decades, which are essentially similar to their OLS counterparts, are not reported in the following discussion, for brevity's sake].

Both accessibility variables emerge as statistically significant throughout the study period (P<0.05; Table 3). However, the signs of the regression coefficients for these variables change from positive values in 1950-60 and 1960-70 for Access I [access by public transportation] to negative values later on. The opposite happens with respect to the Access II [private transportation] variable: its regression coefficient changes from negative values in 1950-70 to positive values afterwards (see Table 3). The explanation may be simple: rising motorization levels and improved road networks reduced the dependency of migrants on public transportation, turning municipalities with good access for private car travelers into the main *foci* of in-country migration.

Most location variables in Models 1-5 (D_cities, D_rivers, etc.) emerge as statistically significant and exhibit the expected signs: that is, the rates of population growth of municipalities appear to decline, in line with increasing distances to location 'landmarks' – major cities, main roads, rivers and international border crossings (P>0.05; Table 3), fully in line with our hypothesis about the importance of these variables. Sunshine also appears to foster population growth (t>3.4; P<0.05): municipalities with more sunny days attract (*ceteris paribus*) more new residents and retain a higher proportion of the current ones.

Characteristically, however, the statistical significance of most location variables covered by the analysis appears to *weaken over time*. Thus, the statistical significance of distance to major cities was at its 'zenith' in 1960-70 with t=-6.591 (P<0.001), and gradually dropped to t=-2.647 (P<0.01) in 1990-2000. The same happened with respect to road proximity, for which the value of t-statistic dropped from -9.624 (P<0.001) in 1960-70 to -1.950 (P>0.05) in 1990-2000 (see Table 3). Distances to rivers and border crossings, and sunshine days exhibit a similar pattern, that is, a gradual weakening of statistical significance from 1960 to 2000. The explanation of this interesting trend may be fairly straightforward: as road infrastructures improve and motorization levels rise, the fractional effect of distance, quite naturally, declines.

Although, in line with our initial hypothesis, the substitution of absolute location variables by canton-standardized ones appears to improve the models' fit and generality (see Tables 3-4), the overall pattern remains unchanged: after peaking in 1960-70, the significance levels of all location variables drop in the 1990's.

The investigation of regression residuals from the OLS models indicates relatively strong autocollinearity of errors, especially in the 10-25-km proximity range (see Fig.

3), which required the use of spatial dependency models.[3] Two types of such models – Spatial Lag (SL) and Spatial Error (SE) - are reported in Table 6 (Models 21-24). In general, the use of spatial lag models does not substantially change the outcome of the analysis. In particular, all location variables retain statistical significance at similar significance levels to those observed in corresponding OLS models (see Tables 4&6).

<<< Figure 3 about here >>>

Unexpectedly, differences in the statistical significance levels of absolute and canton-standardized location attributes show a clear tendency to *decline over time*, becoming marginal in 1980-2000, in both employment and accessibility-based models (see Fig. 4). This may be due to increased population mobility, which reduces the importance of cantonal boundaries as geographic obstacles to the flows of goods and commuters.

<<< Figure 4 about here >>>

6 Conclusions

The development-fostering effect of any given location attribute is likely to depend on whether other places possess it as well. Thus, proximity to a main road may attract newcomers and businesses to a municipality in a region in which other municipalities have no good road access. However, the effect of road proximity may be much weaker if other places in the region enjoy similar infrastructure services.

This analysis of factors affecting population growth rates across the 2889 Swiss municipalities between 1950 and 2000, indicates that the substitution of absolute location variables by canton-standardized ones improves the models' fit and generality. However, the differences in the statistical significance levels of location variables, represented by either absolute location attributes or canton-standardized ones, appear to shrink over time, becoming marginal in the 1980-2000 period. This may be due to increased population mobility and improved infrastructures, which have made cantonal boundaries more 'transparent' to cross-border flows of goods, population, and services.

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[3] Characteristically, regression residuals exhibited stronger spatial dependency in 1950-60 than in 1990-2000 (see Fig.3). This may be due to economic specialization and increasing intra-regional disparities across individual municipalities in 1980-2000, which is characteristic for a period of transition from traditional (manufacturing-oriented) to service-oriented economies, especially is small, administratively decentralized countries (see *inter alia,* Felsenstein and Portnov, 2005).

The analysis thus confirms earlier findings that accessibility improvements foster spatial development, adding that their contribution declines as a region develops (Tschopp and Axhausen, 2007). In densely settled and highly accessible urban areas, other variables, such as housing prices and crowding, affect location choice. However, remote areas in Switzerland have solely relied on accessibility gains.

The relative importance of location attributes appears also to vary In particular, as we witnessed, the statistical significance of *most location attributes covered by the analysis appeared to weaken over time*. This was definitely the case for proximity to major cities and roads. Distances to major rivers and international border crossings tend to exhibit a similar pattern, i.e. a gradual weakening of statistical significance from 1960 to 2000. The explanation may be fairly straightforward: If in the initial stages of economic development, connectivity and proximity to basic resources are likely to dominate location decision-making, as an economy develops, new location-related elements may gain importance. Moreover, as roads and railroads improve and motorization levels rise, the fractional effect of distance quite naturally declines.

In urban literature the relativity hypothesis was raised by Felsenstein and Portnov (2005) and tested by Cheshire and Magrini (2006), who investigated how climatic differentials affect population growth in Western Europe. In another recent study, Portnov and Schwartz (2008) demonstrated that the relativity concept is applicable to several location-related indicators, not climate alone, and that location advantages are largely relative to within-country measures.

The main contribution of this study to the location relativity hypothesis is demonstrating the *temporal* relativity of location attributes, even for small regional divisions (not only at the national scale), perhaps due to Switzerland's mountainous terrain, which still hinders intra-country mobility. Even so, the difference between predictive powers of absolute vs. relative location attributes appears to shrink over time. Finally we need to acknowledge that our study was made possible by a detailed historical population database available for Swiss municipalities. To the best of our knowledge, no database of such scope and quality is available for any other European country.

7 Acknowledgements

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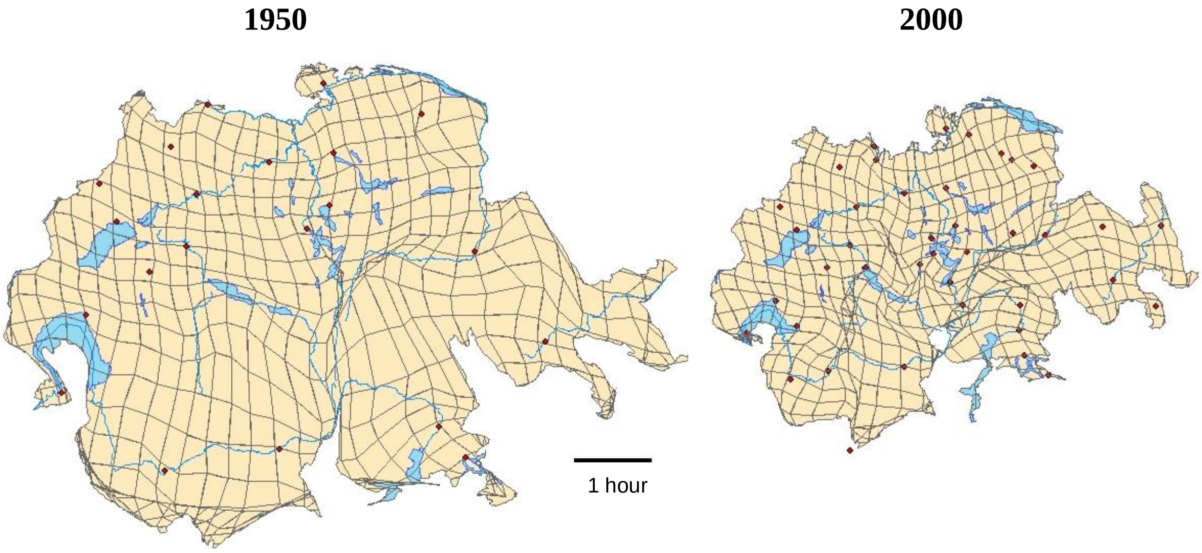
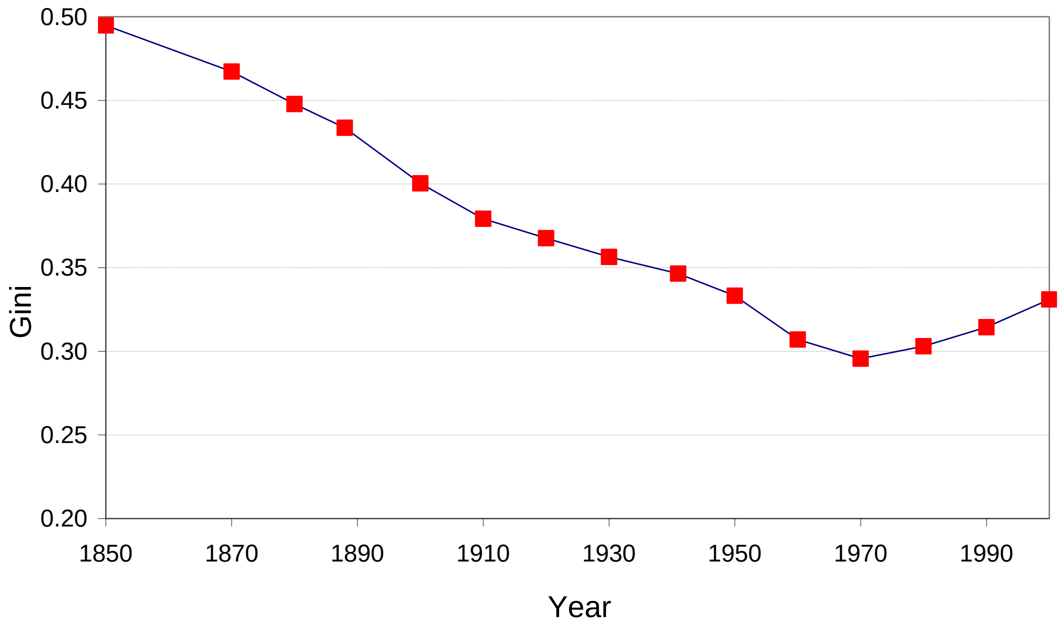
Figure 1 Scaled maps of road travel time (the same scale for both years) (A) and changes in the Swiss population concentration since 1850 (Gini coefficient of municipal population in the 2000 borders) (B)



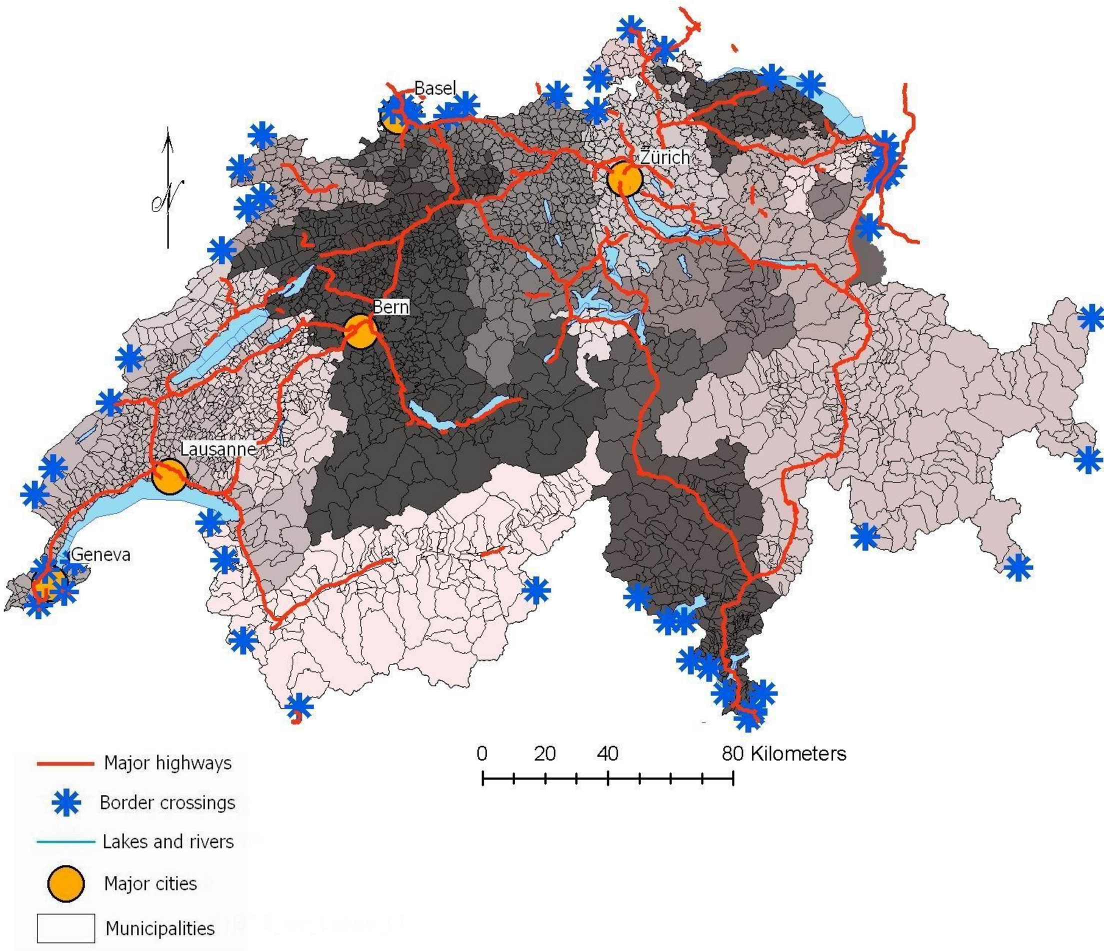
A



B

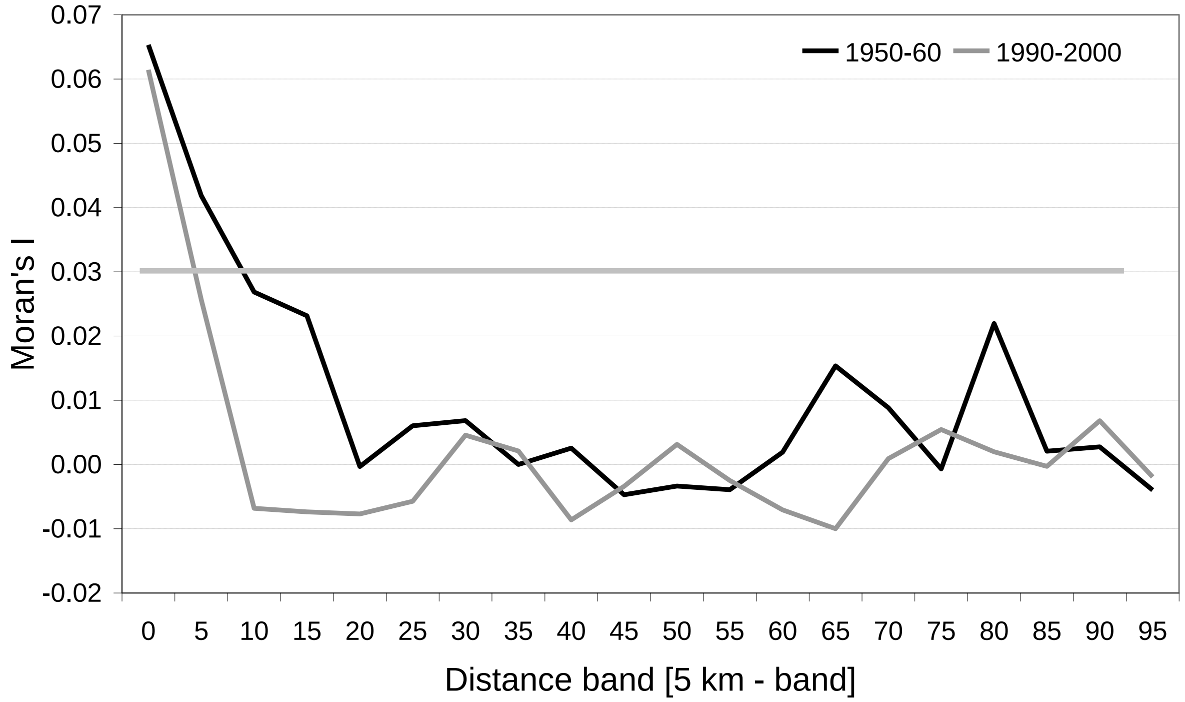
After: Axhausen, Dolci, Fröhlich, Scherer and Carosio (2008)

Figure 2 Relevant geographical elements of Switzerland – municipal, cantonal divisions, major roads, water bodies, population centers and international border crossings



Note: Base maps are obtained from: Axhausen, Dolci, Fröhlich, Scherer and Carosio (2006).

Figure 3 Spatial autocorrelation of OLS regression residuals (global Moran's I index)



The horizontal gray line marks an approximate 1% significance threshold

Figure 4 *t*-statistics before and after normalization (accessibility-based models)

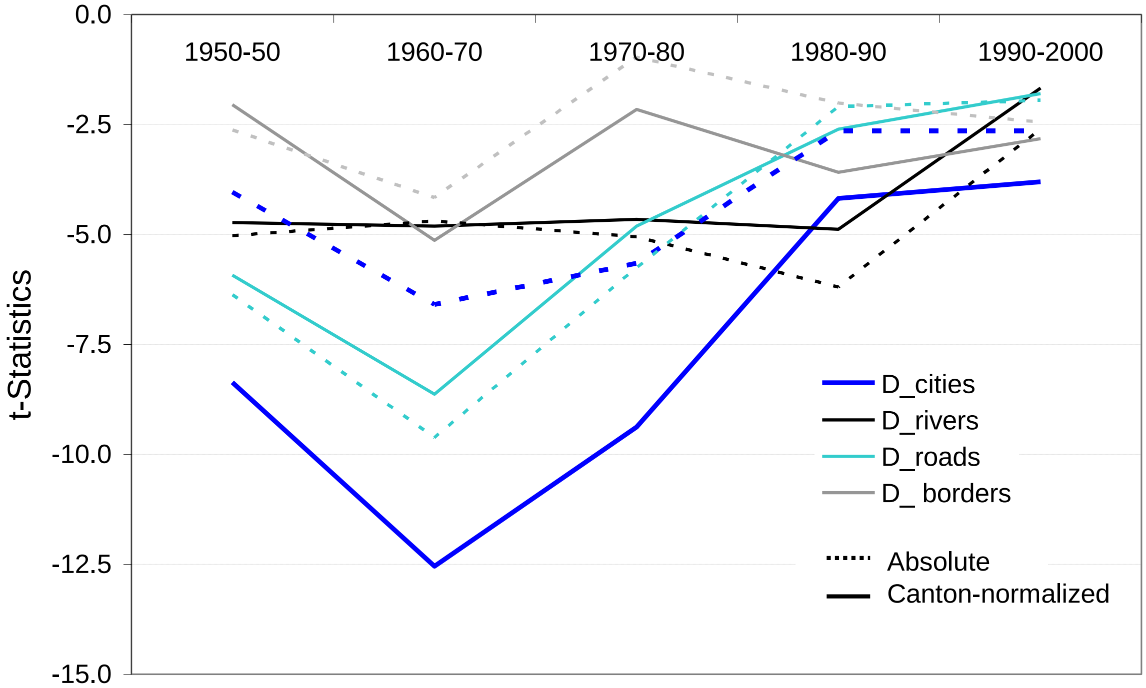


Table 1 Descriptive statistics of the factors tested

Variable		1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
Distance from the major population centers						
	Mean	47113.69	47113.69	47113.69	47113.69	47113.69
	St. Dev.	38748.62	38748.62	38748.62	38748.62	38748.62
	Skewness	1.52	1.52	1.52	1.52	1.52
	Kurtosis	1.49	1.49	1.49	1.49	1.49
Distance to rivers						
	Mean	5885.19	5885.19	5885.19	5885.19	5885.19
	St. Dev.	6089.08	6089.08	6089.08	6089.08	6089.08
	Skewness	1.94	1.94	1.94	1.94	1.94
	Kurtosis	5.45	5.45	5.45	5.45	5.45
Distance to border crossings						
	Mean	28740.85	28740.85	28740.85	28740.85	28740.85
	St. Dev.	19554.01	19554.01	19554.01	19554.01	19554.01
	Skewness	5.49	5.49	5.49	5.49	5.49
	Kurtosis	124.33	124.33	124.33	124.33	124.33
Distance to mayor_roads						
	Mean	4046.06	4046.06	4046.06	4046.06	4046.06
	St. Dev.	4122.34	4122.34	4122.34	4122.34	4122.34
	Skewness	1.72	1.72	1.72	1.72	1.72
	Kurtosis	3.78	3.78	3.78	3.78	3.78
Sunshine						
	Mean	1651.90	1651.90	1651.90	1651.90	1651.90
	St. Dev.	159.66	159.66	159.66	159.66	159.66
	Skewness	1.44	1.44	1.44	1.44	1.44
	Kurtosis	1.59	1.59	1.59	1.59	1.59
Precipitation						
	Mean	1155.83	1155.83	1155.83	1155.83	1155.83
	St. Dev.	417.31	417.31	417.31	417.31	417.31
	Skewness	-0.93	-0.93	-0.93	-0.93	-0.93
	Kurtosis	2.19	2.19	2.19	2.19	2.19
Public transport accessibility (Access I)						
	Mean	1260.91	1480.74	1743.33	1830.92	1971.98
	St. Dev.	5290.24	5989.92	5993.54	5496.90	5609.86
	Skewness	26.49	25.30	22.84	21.02	20.97
	Kurtosis	844.64	781.36	664.10	587.56	589.10
Road transport accessibility (Access II)						
	Mean	5901.20	7337.34	10617.52	11714.84	12576.28
	St. Dev.	22526.03	25311.18	30031.01	27514.76	29257.07
	Skewness	33.04	31.41	29.64	27.56	28.05
	Kurtosis	1279.75	1160.95	1050.88	935.04	970.74

Table 2 Pearson correlations between the research variables over 1990-2000

Variable	Access (II)	D_cities	D_rivers	D_roads	D_borders	Sunshine	Precipitation
Access (I)	0.922	-0.126	-0.123	-0.125	-0.016	-0.047	0.011
	(0.000)	(0.000)	(0.000)	(0.000)	(0.401)	(0.011)	(0.551)
Access (II)		-0.177	-0.113	-0.102	-0.016	-0.054	-0.036
		(0.000)	(0.000)	(0.000)	(0.386)	(0.004)	(0.051)
Distance to major cities			-0.021	-0.033	-0.135	0.539	0.198
			(0.262)	(0.079)	(0.000)	(0.000)	(0.000)
Distance to rivers				0.403	-0.079	-0.048	-0.001
				(0.000)	(0.000)	(0.010)	(0.943)
Distance to major roads					0.138	-0.133	0.052
					(0.000)	(0.000)	(0.005)
Distance to border crossing						-0.286	0.039
						(0.000)	(0.036)
Sunshine							0.085
							(0.000)

Note: Pearson correlation coefficients; significance levels (2-tailed) are in parentheses

Table 3 Factors affecting the population growth (ln) of municipalities in 1950-2000 (Method – OLS; accessibility variables with absolute (unstandardized) location attributes)

Variable	1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
(Constant)	-9.20E-02	-7.30E-01	-4.42E-01	-1.17E-01	-1.08E-01
	(-1.189)	(-7.781**)	(-5.779**)	(-1.918)	(-2.098*)
Access I	1.99E-05	6.56E-06	-1.14E-05	-1.56E-05	-1.19E-05
	(8.396**)	(2.733**)	(-6.991**)	(-12.602**)	(-11.649**)
Access II	-4.39E-06	-1.72E-06	1.78E-06	2.72E-06	1.90E-06
	(-7.918**)	(-3.042**)	(5.483**)	(10.901**)	(9.719**)
D_cities	-1.12E-06	-2.21E-06	-1.55E-06	-5.77E-07	-4.88E-07
	(-4.042**)	(-6.591**)	(-5.657**)	(-2.648**)	(-2.647**)
D_rivers	-3.83E-06	-4.35E-06	-3.82E-06	-3.72E-06	-1.32E-06
	(-5.024**)	(-4.697**)	(-5.054**)	(-6.192**)	(-2.608**)
D_roads	-5.92E-06	-1.08E-05	-5.29E-06	-1.54E-06	-1.21E-06
	(-6.380**)	(-9.624**)	(-5.755**)	(-2.099**)	(-1.950)
D_ borders	-8.01E-07	-1.54E-06	-2.93E-07	-4.83E-07	-4.96E-07
	(-2.628**)	(-4.168**)	(-0.970)	(-2.014*)	(-2.447*)
Sunshine	1.61E-04	5.87E-04	3.55E-04	1.78E-04	1.26E-04
	(3.498**)	(10.501**)	(7.775**)	(4.910**)	(4.100**)
Precipitation	-3.44E-06	1.65E-05	7.47E-06	-6.30E-06	3.90E-06
	(-0.398)	(1.576)	(0.875)	(-0.928)	(0.680)
Canton fixed effects (25)	Yes	Yes	Yes	Yes	Yes
No of cases	2889	2889	2889	2889	2889
R^2	0.261	0.249	0.175	0.192	0.153
R^2 adjusted	0.252	0.241	0.165	0.183	0.143
SEE[a]	0.171	0.207	0.169	0.134	0.114
F	30.534**	28.748**	18.310**	20.590**	15.633**

t-values are in parentheses; * Indicates a 0.05 significance level; ** indicates a 0.01 significance level. [a] standard error of estimate [b] public transportation; [c] individual transportation

Table 4 Factors affecting the population growth (ln) of municipalities in 1950-2000 (Method – OLS; accessibility variables with canton-normalized location attributes)

Variable	1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
	Model 6	**Model 7**	**Model 8**	**Model 9**	**Model 10**
(Constant)	1.12E-02	-4.69E-01	-3.21E-01	-5.94E-02	-6.51E-02
	(0.132)	(-4.583**)	(-3.808**)	(-0.881)	(-1.142)
Access I	1.98E-05	6.39E-06	-1.15E-05	-1.58E-05	-1.18E-05
	(8.396**)	(2.704**)	(-7.104**)	(-12.709**)	(-11.571**)
Access II	-4.50E-06	-1.92E-06	1.68E-06	2.70E-06	1.86E-06
	(-8.168**)	(-3.437**)	(5.189**)	(10.772**)	(9.441**)
D_cities	-8.62E-02	-1.56E-01	-9.62E-02	-3.45E-02	-2.66E-02
	(-8.364**)	(-12.543**)	(-9.375**)	(-4.182**)	(-3.805**)
D_rivers	-1.95E-02	-2.38E-02	-1.90E-02	-1.59E-02	-4.62E-03
	(-4.729**)	(-4.813**)	(-4.656**)	(-4.882**)	(-1.674)
D_roads	-2.20E-02	-3.86E-02	-1.77E-02	-7.70E-03	-4.48E-03
	(-5.922**)	(-8.634**)	(-4.809*)	(-2.611**)	(-1.796)
D_ borders	-1.47E-02	-4.42E-02	-1.53E-02	-2.04E-02	-1.35E-02
	(-2.049*)	(-5.139**)	(-2.160*)	(-3.590**)	(-2.823**)
Sunshine	9.65E-02	6.54E-01	3.92E-01	1.63E-01	1.43E-01
	(1.211)	(6.823**)	(4.961**)	(2.575**)	(2.675**)
Precipitation	9.85E-03	2.76E-02	1.89E-02	1.44E-03	3.03E-03
	(1.058)	(2.463*)	(2.047*)	(0.196)	(0.486)
Canton fixed effects (25)	Yes	Yes	Yes	Yes	Yes
No of cases	2889	2889	2889	2889	2889
R^2	0.272	0.274	0.184	0.192	0.153
R^2 adjusted	0.264	0.265	0.175	0.182	0.143
SEE[a]	0.169	0.204	0.168	0.134	0.114
F	32.322**)	32.607**)	19.510**)	20.521**)	15.609**)

t-values are in parentheses; * Indicates a 0.05 significance level; ** indicates a 0.01 significance level. [a] standard error of estimate; [b] public transportation; [c] individual transportation

Table 5 Factors affecting the population growth (ln) of municipalities in 1990-2000 (Method – Spatial Error (SE) and Lag regressions (SL); employment and accessibility variables with canton-normalized location attributes)

Variable	Spatial Lag	Spatial Error
	Model 11	**Model 12**
(Constant)	-0.033	0.017
	(-0.884)	(0.411)
Access I	-1.15E-05	-1.17E-05
	(-11.336**)	(-11.490**)
Access II	1.79E-06	1.82E-06
	(9.136**)	(9.279**)
D_cities	-0.021	-0.026
	(-3.069**)	(-3.063**)
D_rivers	-0.003	-0.002
	(-0.943)	(-0.663)
D_roads	-0.005	-0.005
	(-1.894)	(-1.835)
D_ borders	-0.012	-0.012
	(-3.159**)	(-2.964**)
Sunshine	0.091	0.068
	(2.480*)	(1.670)
Precipitation	0.003	-0.001
	(0.426)	(-0.142)
Canton fixed effects (25)	Yes	Yes
Rho	0.319	-
	4.130**	
Lamda	-	0.476
	-	6.395**
No of cases	2889	2889
R^2	0.161	0.164
SEE	0.112	0.112
Log likelihood	2218.160	2219.925

t-values are in parentheses; * Indicates a 0.05 significance level; ** indicates a 0.01 significance level. [a] standard error of estimate [b] public transportation; [c] individual transportation

Table 3 Comparison of the goodness of fit statistics

Variable	1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
No of cases	2889	2889	2889	2889	2889
Accessibility variables with absolute location attributes					
R^2	0.261	0.249	0.175	0.192	0.153
R^2 adjusted	0.252	0.241	0.165	0.183	0.143
SEE [a]	0.171	0.207	0.169	0.134	0.114
F	30.534**	28.748**	18.310**	20.590**	15.633**
Accessibility variables with canton-normalized location attributes					
R^2	0.272	0.274	0.184	0.192	0.153
R^2 adjusted	0.264	0.265	0.175	0.182	0.143
SEE [a]	0.169	0.204	0.168	0.134	0.114
F	32.322**	32.607**	19.510**	20.521**	15.609**

* Indicates a 0.05 significance level; ** indicates a 0.01 significance level. [a] standard error of estimate