Highways, Market Access, and Spatial Sorting

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June 2021

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[§]For helpful comments, discussions, and suggestions, we are grateful to the Editor Nezih Guner, three anonymous referee as well as to Simon Alder, Nate Baum-Snow, Marius Brülhart, Lukas Buchheim, Pierre-Philippe Combes, Gilles Duranton, Ed Glaeser, Hans Koster, Stefan Legge, Florian Mayneris, Isabelle Mejean, Guy Michaels, Francis Ostermeijer, Henry Overman, Giovanni Peri, Diego Puga, Jordan Rappaport, Esteban Rossi-Hansberg, Yasu Sato, Jörg Schläpfer, Kurt Schmidheiny, Uwe Sunde, Jacques Thisse, Jos van Ommeren, John Van Reenen, Elisabet Viladecans-Marsal, as well as to conference participants at CRED Bern, SSES Basel, IIPF Dublin, CURE Basel, UEA Portland, NTA Boston, IEB Barcelona, UEA Copenhagen, SSES Lausanne, CESifo Summer Institute Venice, EEA Lisbon, GATE Lyon, IEE Workshop Geneva, RUES Paris, GSE Summer Forum Barcelona, UEA New York, RIETI Tokyo, and seminar participants at the University of Kentucky, ETH Zurich, Università Cattolica del Sacro Cuore Milan, University of Luxembourg, CEMFI, and at the Tinbergen Institute (Amsterdam). We also thank the Swiss Federal Roads Office for providing the opening dates of the different sections of the Swiss national road network, and the Swiss Federal Statistical Office for their access to individual-level population censuses. We also thank Philip Fröhlich and Kai Axhausen for their data on car-based accessibility. We are particularly indebted to Roger Ammann and Bruno Jeitziner at the Swiss Federal Tax Administration for granting us access to individual-level federal tax data. We acknowledge support from the Swiss National Science Foundation (Sinergia Grants No. 130648 and 147668; Division I Grant No. 182380). Finally, Robert-Nicoud gratefully acknowledges the hospitality and research environments of HEC Lausanne and CEMFI, where part of this paper was written. A previous version of this paper by Fretz and Parchet alone circulated under the title 'Is Highway Access Good for Your Tax Base?'.

Abstract: This paper studies the consequences of the construction of a major transportation infrastructure on the sorting of residents and workers with heterogeneous incomes and skills. We design a parsimonious spatial equilibrium model featuring workers embodied with heterogeneous skills and non-homothetic preferences. In equilibrium, locations with improved commuting access become relatively more attractive to the high-skilled, high-income earners. We then empirically analyze the effects of the construction of the Swiss highway network between 1960 and 2010 on the population size and composition of municipalities. We find that the advent of a new highway access within 10km led to a long-term 24% increase in the share of top-income taxpayers and a 8% decrease in the share of low-income taxpayers, impacting segregation by income in connected municipalities. Highways also contributed to changes in commuting patterns, as well as to job and residential urban sprawl.

JEL classification: D31, O18, H54, R11, R23

Keywords: Transportation; Highways; Market Access; Commuting; Income Sorting.

Introduction

Transportation infrastructure shapes the spatial economy in fundamental ways. Commuting allows people to access labor markets and amenities that are distant from their home, and workers to access housing markets that are remote from their workplace. Therefore, by facilitating commuting, highways make connected municipalities more attractive. Heterogeneous workers may make different working and residential location choices, implying that highways affect the composition of workers and residents in the locations they connect. This paper studies the consequences of the development of a major transportation infrastructure over a long time period – the creation and comprehensive development of the Swiss highway network from 1960 to 2010 – on the sorting of residents and workers with heterogeneous incomes and skills.

The paper starts by presenting some stylized facts that preview the main results of the paper (Section 1). In order to formalize the distributional consequences of highway expansions and guide our empirical work, we then develop a parsimonious spatial equilibrium model featuring costly commuting (Section 2). The model features a labor force consisting of workers embodied with heterogeneous skills, non-homothetic preferences over housing and other goods and services, and idiosyncratic location and commuting-mode preferences. In equilibrium richer workers spend a lower fraction of their income on housing than poorer workers, and they are more likely to commute by car (the more expensive commuting mode). We find that both properties are borne out by the Swiss data.[1]

Connection to the highway network increases the commuting access of a municipality, which leads to two effects in the model. First, an improvement in the commuting access of a municipality attracts residents, which raises demand for housing locally and in-

[1]For evidence that housing is an income inelastic good in the US, France and Germany, see Albouy, Ehrlich and Liu (2016), Combes, Duranton and Gobillon (2018), and Dustmann, Fitzenberger and Zimmermann (2018), respectively. Also, car use increases with income in the US (Glaeser, Kahn and Rappaport, 2008).

creases housing prices. This effect disproportionately hurts low-income earners because, with housing being a necessity, they spend a higher-than-average fraction of earnings on housing. Second, improving commuting access by car disproportionately benefits the well-off because they are more likely to own and commute by car. Both mechanisms yield the same qualitative outcome: a newly connected municipality becomes especially attractive to high-income, high-skilled residents and the latter mechanism also makes such a municipality relatively attractive to high-skilled workers. As a result, its skill and earnings distributions shift to the right.

We then empirically investigate the effect of improved accessibility on income distribution at the local level, exploiting variation in the commuting access of municipalities over time that results from the construction of the Swiss highway network (Section 3). Switzerland provides an ideal setting as the Swiss highway network was defined in 1960 by the federal parliament to connect Switzerland's largest cities, but only gradually constructed over the decades that followed. From the perspective of a non-urban municipality, the opening date of a new highway section in its vicinity is close to random and exogenous to the initial path of its local economic development. Merging several distinct data sets, we exploit this variation over time to identify the effect of the opening of a new highway access point on the total number of taxpayers (resident households), the share of taxpayers in different income categories, as well as employment and commuting by education levels. We also account for the presence of railways, a potential confounding factor, and we include municipality-specific fixed effects and linear time trends, as well as year fixed effects to account for a rich combination of unobserved factors, thereby mitigating important sources of omitted variable bias.

We find that the number of taxpayers and the share of top-income taxpayers both rise in non-urban municipalities located within 10km of newly opened highway access points, resulting in a reduction in segregation by income in connected municipalities (Section 4). Specifically, the total number of taxpayers increases by 14%, the share of low-income taxpayers decreases by 8%, and the share of top-income taxpayers increases by 24%. These causal estimates translate into a 5% and a 42% increase in the *number* of low-income and top-income taxpayers, respectively.

We then submit our baseline specifications to various robustness checks and extensions (Section 5). Our theoretical framework proposes that shifts in the income distribution of municipalities induced by highway access result from the sorting of a heterogeneous population – a composition effect. Other channels are possible, such as effects on wage levels and wage growth that are heterogeneous along the earnings distribution (De La Roca and Puga, 2017; Glaeser, 1999). Our taxpayer data are not suitable to distinguish between sorting and earnings effects because they do not track individuals over time and space. Instead, we provide direct evidence for sorting using census data and an alternative specification based on residence and employment by education level. In contrast to income, the education level of a given population is fixed in the short run. We find that the share of highly educated residents and workers increases in municipalities that get access to the highway network.

Finally, we use the model and our empirical results to estimate relative long-run welfare effects (Section 6). We find that the well-being of residents in non-urban municipalities with a highway connection in 2010 increases over the years 1950-2010 relative to the well-being of residents in non-urban municipalities that were still unconnected by 2010, and that this relative welfare gain increases monotonically with income quantile: the relative gain ranges from only 2% for the below-median income group to 12% for the top-10% income group. Our model relates these differences in welfare changes between income groups to housing being an income-inelastic good and car ownership and car use being a luxury good.

Understanding the spatial and economic consequences of large-scale transportation infrastructures is important for several reasons. First, access to markets and proximity to workers and jobs are prominent criteria in the location decisions of firms and households. As a consequence, transportation infrastructures are an important determinant of individual welfare and of regional disparities. Second, the location of airports and the design of rail, road, and highway networks influence land use patterns as much as 'first nature' geography: highways have been found to increase the size of cities (Duranton and Turner, 2012), to cause suburbanization (Baum-Snow, 2007; Baum-Snow, Brandt, Henderson, Turner and Zhang, 2017; Brinkman and Lin, 2020; Garcia-López, Pasidis and Viladecans-Marsal, 2016), to affect the product mix of cities (Duranton, Morrow and Turner, 2014), and to increase regional disparities (Baum-Snow, Henderson, Turner, Zhang and Brandt, 2020; Faber, 2014). Third, at around five percents of GDP, the financial amounts involved in transportation infrastructure dwarf those of most other investment programs (Redding and Turner, 2015) but they may also bring large-scale economic benefits (Allen and Arkolakis, 2014; Donaldson, 2018; Donaldson and Hornbeck, 2016). Furthermore, as we document below, highway access leads to worker and resident sorting along skills and incomes, which is likely to have meaningful implications for voting, and, in federal countries such as Switzerland that grant large budget autonomy to their municipalities, on tax competition (Eugster and Parchet, 2019; Parchet, 2019).

Relation to extant works

To the best of our knowledge, our paper and the contemporaneous work by Tsivanidis (2019) are the first to examine the effect of transportation infrastructure on the spatial allocation of heterogeneous workers. In doing so, our paper speaks to various, sometimes hitherto separated, strands of the literature.

First, we develop a spatial general equilibrium model featuring mobile agents and heterogeneous locations as in Allen and Arkolakis (2014), Redding (2016), or Redding and Turner (2015); commuting, as in Ahlfeldt, Redding, Sturm and Wolf (2015), Gaigne, Koster, Moizeau and Thisse (2021), Monte, Redding and Rossi-Hansberg (2018), Teulings, Ossokina and de Groot (2018), or Tsivanidis (2019); and non-homothetic preferences, as in Albouy, Ehrlich and Liu (2016), Gaigne, Koster, Moizeau and Thisse (2021), Gaubert and Robert-Nicoud (2021), and Tsivanidis (2019). Much of the quantitative economic geography literature assumes homogeneous agents and homothetic preferences. Relaxing *either* assumption is notoriously difficult but since we are interested in heterogeneous commuting decisions along the income distribution, we need to relax *both*. To achieve our aim, we simplify the economic geography of the Tsivanidis (2019) model by assuming that there is free trade in goods in order to focus on commuting and sorting, as Gaigne, Koster, Moizeau and Thisse (2021) do in a polycentric-city model. We can also perform comparative static exercises and obtain clear qualitative predictions from the model.

Second, existing studies on the heterogeneous impact of transportation infrastructure over space focus on various economic outcomes leaving effects on the local compositions of skill and income aside.[2] Two noticeable exceptions are provided by Heuermann and Schmieder (2019) and Mayer and Trevien (2017), who report some results on the skill composition of municipalities. We complement such studies with micro-evidence on the consequences for the local composition of the workforce and of the population. We find strong evidence of sorting along skills and incomes. We also find that highways contributed to a reduction in segregation by income in non-urban municipalities. By contrast, Mahajan (2020) finds that the construction of the Interstate Highway System contributed to racial segregation in US cities.[3] By linking residential location choices to highway access, we also complement works studying the sorting of workers with

[2]See Ahlfeldt and Feddersen (2018), Audretsch, Dohse and dos Santos (2017), Banerjee, Duflo and Qian (2020), Jedwab and Moradi (2016), Qin (2017), and Storeygard (2016) on regional output; Chandra and Thompson (2000) on regional earnings by industry; Atack, Bateman, Haines and Margo (2010), Baum-Snow *et al.* (2020), Berger and Enflo (2017), Duranton and Turner (2012), and Hornung (2015) on urban development; Donaldson (2018), Donaldson and Hornbeck (2016), Duranton, Morrow and Turner (2014), Faber (2014), and Volpe Martincus and Blyde (2013) on trade; Datta (2012), Ghani, Goswami and Kerr (2015), Gibbons, Lyytikäinen, Overman and Sanchis-Guarner (2019), and Hayakawa, Koster, Tabuchi and Thisse (2021) on firms; or Michaels (2008) and Sanchis-Guarner (2019) on labor market outcomes.

[3]Our heterogeneous results of highway access on urban and rural populations in Sections 1 and 5 are also related to the findings of Brinkman and Lin (2020) for the United States.

heterogeneous skills and incomes across local labor markets and cities.[4]

Third, our empirical identification strategy exploits variation over time within municipalities, as in Donaldson (2018) and Hornung (2015), while much of the literature is cross-sectional in nature, addressing the non-randomness of highway (or railway) location using an instrumental variable approach (Redding and Turner, 2015). Importantly, our long panel data with heterogeneity in the timing of highway construction allow us to restrict our sample to all municipalities close to a highway access that will be eventually treated; to control for municipality-specific time trends and yearly common shocks; and to test for pre-opening dynamics. In contrast, comparing municipalities located close to a highway with municipalities further away as in a classical difference-in-differences specification may distort results if the two groups are heterogeneous along some unobserved dimensions (Gobillon and Magnac, 2016).

1. Results in a Nutshell

Table 1 offers a bird's eye view of the empirical design and results of the paper. Panels A, B, and C provide a partition of Swiss municipalities. Panel A pertains to non-urban municipalities with an access to the highway network as of 2010 (defined as no more than 10km from an access point); this is the main sample of municipalities we are working with, as we explain below. Panel B pertains to non-urban municipalities that did not get access to the highway network during our sample period. Panel C refers to urban municipalities, further broken down into urban centers (Panel D) and suburbs (Panel E). In each panel the first and second rows report the fraction of taxpayers residing in each type of municipalities at the beginning and end of our sample period, respectively. These

[4] See Behrens, Duranton and Robert-Nicoud (2014), Behrens and Robert-Nicoud (2015), Combes, Duranton and Gobillon (2008), Cuberes, Sechel and Roberts (2019), Davis and Dingel (2019), De La Roca (2017), De La Roca and Puga (2017), Diamond (2016), Fajgelbaum and Gaubert (2020), Gyourko, Mayer and Sinai (2013), Handbury (2019), Matano and Naticchioni (2012) or Moretti (2013). Combes, Duranton, Gobillon, Puga and Roux (2012) and Gaubert (2018) deal with the sorting of heterogeneous firms.

fractions across Panels A, B, and C (or, alternatively, across Panels A, B, D, and E) sum to unity. The third row in each panel reports the ratio of the first two. A figure larger than unity means that such municipalities have experienced an increase in the number of residents relative to the country as a whole; a figure below one means that the relative residential population in these municipalities has fallen over the six decades covered by our data. All figures are rounded to 2 decimal places. Finally, columns refer to the number of taxpayers, further broken down by income category. The leftmost column pertains to the total number of taxpayers (regardless of income), while Columns (2) to (5) refer to subcategories of taxpayers according to their position in the countrywide income distribution.[5] The rightmost column presents the Theil entropy index of a municipality.[6] Five stylized facts stand out:

1. *Size effects*. The relative population of non-urban municipalities that get an access to the highway network over the course of the six decades 1950-2010 grew 17% (Panel A).

[5]To illustrate, consider Panels A to C. At the beginning of our sample period, 12% of taxpayers reside in non-urban municipalities that will be connected to the highway network by 2010. The same fraction resides in non-urban municipalities that are still unconnected by 2010; the remaining 76% reside in urban municipalities. The corresponding shares at the end of the sample period are 14%, 12%, and 75%. The ratios reported in the third line (1.17, 0.94, and 0.98, respectively) imply that the relative population of non-urban connected municipalities grew about 17%, and this relative growth was mostly at the expense of non-connected non-urban municipalities (relative growth of −6%) while the population of urban municipalities grew at about the same pace as the Swiss population (relative growth of −2%). The shift of top-10% income earners was more impressive still: the share of such taxpayers residing in non-urban connected municipalities grew 42%, from 7% to 10%. The corresponding shares for non-urban non-connected municipalities fell 22%, from 8% to 7%, while the share in urban municipalities stayed broadly put (they fell 1%).

[6]Throughout the paper we use the Theil entropy index, henceforth entropy index for short. The value of this index ranges from zero when a single income category resides in it – which corresponds to maximum segregation – to the natural logarithm of the number of categories when all categories are equally represented. Equation (10) below provides a formal definition.

2. *Local income distribution*. This relative growth rises monotonically with the position in the income distribution, from 5% for the bottom half to 42% for the top decile (Panel A).

3. *Non-urban to non-urban relocation*. The bulk of this relative growth arose at the expense of non-urban municipalities that were still not connected by 2010 (Panel B): the overall share of such municipalities fell 6%, and the relative decline along the income distribution is the mirror image of the (positive) growth of non-urban connected municipalities in Panel A. The relative size and income distribution of urban municipalities overall was little affected (Panel C).

4. *Urban sprawl.* The absence of overall relative urban flight masks a relocation of households from urban centers (relative growth of −41%) to suburban municipalities (relative growth of +42%). Furthermore, the relative relocation of taxpayers from urban centers to suburbs rises with the position in the income distribution, from +26% for the bottom half to +85% for the top decile (Panels D and E).

5. *Segregation*. Non-urban municipalities are the most segregated among Swiss municipalities at the beginning of the sample period, and this pattern is most pronounced for those that end up accessing the highway network (the entropy index is lowest in Panel A). By 2010, segregation has fallen in non-urban municipalities with a highway access and in suburban municipalities, while it has risen in non-urban, non-connected municipalities as well as in urban centers.

Table 1 also shows that connected and non-connected non-urban municipalities (Panels A and B) were very similar before the construction of the highway network. The subsequent evolution over the next six decades reported in this table is however purely descriptive. The heart of the paper is to establish a causal effect from highway expansion to the size and composition of the non-urban connected municipalities in Panel A (stylized facts 1 and 2). We also document facts 3 to 5 more systematically.

2. Model

We design a spatial equilibrium model featuring commuting and discrete location choices following Ahlfeldt, Redding, Sturm and Wolf (2015) and Monte, Redding and Rossi-Hansberg (2018), workers endowed with non-homothetic preferences as in Gaigne, Koster, Moizeau and Thisse (2021) and Tsivanidis (2019), and heterogeneous units of labor as in Gaubert and Robert-Nicoud (2021), as well as segmented housing markets following Helpman (1998). The purpose of the model is to guide our empirical analysis and the interpretation of our results in a qualitative way. For this reason, we work with a simplified version of Monte, Redding and Rossi-Hansberg (2018) and Tsivanidis (2019) to focus on the mechanisms of interest in our analysis; in particular, production and trade take a back seat in what follows.[7]

Previewing the results of the model, non-homothetic preferences play a central role in two ways. First, in equilibrium, the willingness to pay for residential housing in municipalities with a good commuting access is increasing in income; as a result, the income and skill distributions of the *residential* populations of such municipalities dominate in a first-order stochastic way the income and skill distributions of the residential populations of municipalities with a lesser commuting access. Second, the willingness to commute by car is increasing in income; as a result, the income and skill distributions of the *working* populations of municipalities with a good commuting access dominate in a first-order stochastic way the income and skill distributions of the working populations of municipalities with a lesser access. As Figure 1 shows, both features of our model are consistent with data from the Swiss Household Panel: housing expenditure shares decrease in income while car ownership increases in income.

Below, we sketch the model and the main results that guide our empirical analysis. Appendix A provides the details.

[7] Allowing for heterogeneous productivity across municipalities, for trade costs, and/or for comparative advantage by skill-location pairs would not provide any additional insight that we can bring to the data. Conditions for equilibrium uniqueness can only be derived for special cases anyway (Tsivanidis, 2019).

2.1 *Endowments, Technology, and Preferences*

The economy consists of a set $\mathcal{M} \equiv \{1,...,N\}$ of municipalities (denoted by i,n) and workers of heterogeneous skill or ability groups, $\mathcal{S} \equiv \{1,...,S\}$ (denoted by s,t). The supply of group-s workers in the economy, L_s, is inelastic. Labor is homogeneous and each worker of ability s inelastically supplies w_s units of labor to sector C. This sector produces a freely traded, homogeneous consumption good under constant returns to scale and constant returns to labor. We use this good as the numéraire. All municipalities have access to the same technology and convert one effective unit of labor into one unit of C. Since labor demand is perfectly elastic everywhere, and by the law of one price, the wage of workers with skill s is w_s, independently of their workplace. Without further loss of generality, we rank skills such that $w_1 < ... < w_s < ... < w_S$ so that group t is said to be higher skilled (and to have a higher income) than group s if and only if $s < t$ holds.

Individuals may reside or work in any location. We designate residential locations by subscript n and workplace locations by subscript i. If $i \neq n$ for some worker, this worker commutes between municipalities n and i. They may also choose to commute by car or to use alternative transit modes. Swiss data report a non-homothetic use of cars for commuting purposes, as the use of cars increases with income (see Figure 1). We thus add (endogenous) car use for commuting proposes to the model, following Tsivanidis (2019). Car use is a discrete choice $a \in \{0,1\}$, where $a = 1$ if the modal choice is automobile and $a = 0$ otherwise.

Each location is endowed with a fixed supply of residential land H_n. Workers hold heterogeneous preferences about each pair of locations and about commuting modes, as well as non-homothetic Stone-Geary preferences over (non-tradable) housing and the homogeneous and tradable numéraire. Specifically, the utility of worker ψ endowed with skill s, residing in n and working in i is equal to

$$U_{anis}(\psi) = \left(\frac{C_{anis}}{\alpha}\right)^{\alpha} \left(\frac{H_{anis} - h}{1-\alpha}\right)^{1-\alpha} B_{ani}\beta_{ani}(\psi), \qquad \alpha \in (0,1), \quad h > 0. \tag{1}$$

C_{anis} and H_{anis} respectively denote the consumption of the homogeneous good C and housing services H of worker of skill group s, working in municipality i, residing in municipality n, and commuting using mode a; α and h are preference parameters, with h being the subsistence level of housing; B_{ani} denotes the common component of the joint assessment of locations n and i as residential and working locations and of commuting mode a, and $\beta_{ani}(\psi)$ denotes the iid idiosyncratic component of the joint assessment of the triplet (a,n,i). B_{ani} captures both n- and i-specific amenities, as well as pair-specific amenities such as the (dis)utility of the bilateral commute using mode a. Therefore, a reduction in the bilateral commuting time using cars corresponds to an increase in B_{1ni}.

Let q_n denote the housing price in n and let $p \in (0,w_1)$ denote the unit cost of using a car for commuting purposes (we assume $p < w_1$ for simplicity). Utility maximization yields the following housing expenditure function:

$$q_n H_{nis} = q_n h + (1-\alpha)(w_s - q_n h - pa) \equiv E^H_{ans}, \tag{2}$$

for any i. Housing expenditure is equal to subsistence expenditure plus a constant fraction of disposable income.

The indirect utility associated with (1) is equal to

$$V_{anis}(\psi) = \beta_{ani}(\psi) V_{anis}, \qquad V_{anis} \equiv B_{ani} \frac{w_s}{(q_n)^{1-\alpha}} \left(1 - \frac{q_n h}{w_s} - \frac{pa}{w_s}\right). \tag{3}$$

If $a = h = 0$ then (3) collapses to the Cobb-Douglas case; otherwise, the incidence of the cost of living q decreases with earnings w in the sense that V is log-supermodular in w_s and q_n:

$$h > 0 \iff \frac{\partial^2 \ln V_{nis}}{\partial w_s \partial q_n} > 0, \tag{4}$$

for any i. Attractive residential locations will command higher housing prices in equilibrium, which has a higher incidence on low income earners than on workers at a higher end of the earnings distribution. Then, in equilibrium, high-s workers will disproportionately sort into high-B_{ani} municipalities for residential purposes.

2.2 Worker Residential Location Decision

We assume that the β_{ani}'s are independently and identically drawn from a Fréchet distribution with shape parameter $\kappa > 1$ so that the probability that a worker with skills s chooses to live in n, work in i, and commute using mode a, denoted as λ_{anis}, obeys:

$$\lambda_{anis} = \left(\frac{V_{anis}}{\mathbb{E}V_s}\right)^{\kappa}, \qquad \mathbb{E}V_s \equiv \left[\sum_{a\in\{0,1\}}\sum_{n\in\mathcal{M}}\sum_{i\in\mathcal{M}} (V_{anis})^{\kappa}\right]^{1/\kappa}. \tag{5}$$

$\mathbb{E}V_s$ is proportional to the expected utility of type s before drawing the idiosyncratic preference shocks.

Let us introduce some additional variables that we observe in (or construct from) our data. First, let

$$\lambda_{ns} \equiv \sum_{a\in\{0,1\}}\sum_{i\in\mathcal{M}} \lambda_{anis}, \qquad \lambda_{is} \equiv \sum_{a\in\{0,1\}}\sum_{n\in\mathcal{M}} \lambda_{anis} \tag{6}$$

denote the fraction of skill-s individuals who reside in municipality n or work in municipality i, respectively, with $\sum_n \lambda_{ns} = \sum_i \lambda_{is} = 1$ for all s, and let

$$\phi_{ans} \equiv \frac{\sum_{i\in\mathcal{M}} \lambda_{anis}}{\lambda_{ns}}, \qquad \phi_{ais} \equiv \frac{\sum_{n\in\mathcal{M}} \lambda_{anis}}{\lambda_{is}} \tag{7}$$

denote the fraction of people of skill s who live in n or work in i and use commuting mode a.

Second, the number of residents in municipality n and the number of workers (jobs) in municipality i are respectively equal to

$$R_n = \sum_{a\in\{0,1\}}\sum_{s\in\mathcal{S}} \lambda_{ns} L_s, \qquad J_i = \sum_{a\in\{0,1\}}\sum_{s\in\mathcal{S}} \lambda_{is} L_s, \tag{8}$$

while

$$\sigma_{ns} \equiv \frac{\lambda_{ns} L_s}{R_n} \tag{9}$$

denotes the fraction of the residential population of municipality n that belongs to skill group s, with $\sum_s \sigma_{ns} = 1$ for all n.

Finally, define the entropy index as

$$T_n \equiv -\sum_{s\in\mathcal{S}} \sigma_{ns} \ln\left(\sigma_{ns}\right). \tag{10}$$

This index is monotonically decreasing in segregation: with four income categories, T_n takes value $\ln(4)$ when all income groups are equally represented and value zero when a single income category resides in n.

2.3 *Housing Markets*

Housing markets are segmented. They clear if the following equality holds:

$$q_n H_n = \sum_{a \in \{0,1\}} \sum_{s \in \mathcal{S}} \lambda_{ans} L_s E^H_{ans}. \tag{11}$$

Landlords own the housing stock and are assumed to spend all their income on the numéraire good C.

2.4 *Equilibrium*

Given the preference parameters of the model $\left\{\alpha, \kappa, h, \{B_{ani}\}_{a\in\{0,1\},n,i\in\mathcal{M}}\right\}$ and endowments $\left\{\{H_n\}_{n\in\mathcal{M}}, \{L_s\}_{s\in\mathcal{S}}, \{w_s\}_{s\in\mathcal{S}}\right\}$, an equilibrium is defined as a vector of endogenous variables $\left\{\{\lambda_{anis}\}_{a\in\{0,1\},n,i\in\mathcal{M},s\in\mathcal{S}}, \{q_n\}_{n\in\mathcal{M}}, \{\mathbb{E}V_s\}_{s\in\mathcal{S}}\right\}$ such that (i) housing markets clear, i.e. equation (11) holds; (ii) location decisions are governed by (6). Such an equilibrium exists and is unique.

2.5 *Comparative Statics – Residential Populations*

Consider two municipalities, n and m, that are similar in all aspects except that the former has better residential amenities than the latter, namely $B_{an} > B_{am}$, $H_n = H_m$, $d_{ni} = d_{mi}$ for all $i \neq n,m$ and all $a \in \{0,1\}$, and $d_{nm} = d_{mn}$. We establish the following results formally in Appendix A:

1. Housing prices are higher in the municipality endowed with nicer amenities:

$$\forall a \in \{0,1\}: \qquad (B_{an} - B_{am})(q_n - q_m) > 0. \tag{12}$$

2. The skill composition of the municipality endowed with nicer amenities first-order stochastically dominates the skill composition of the other municipality.

3. Resident population size and the skill composition of municipalities: there exists $\tilde{s} < S$ such that the resident population with skills $s > \tilde{s}$ is higher in the municipality endowed with nicer amenities. Furthermore, if $1 < \tilde{s} < S$, then the nicer municipality attracts *fewer* low-skill workers than municipality M.

2.6 Qualitative Predictions in Triple Differences

In order to simplify the analysis, assume

$$B_{ani} = \frac{B_{an} B_{ai}}{d_{ni}}.$$

That is, we decompose B_{ani} into three components: an origin-commuting mode component B_{an}, a destination-commuting mode component B_{ai}, which are potentially affected by highway access, and an origin-destination component d_{ni}, which is unaffected by highways. Here, we derive a 'triple-difference' qualitative prediction about the composition of a municipality that gets access to the highway network. Consider two municipalities m,n that are initially identical in all respects – in particular $B_{am} = B_{an}$, $q_m = q_n$ – but that receive two different shocks $\hat{B}_{1m}$ and $\hat{B}_{1n}$.[8] If municipality n gets a highway access but m does not, then we assume $\hat{B}_{1n} > 0$ and $\hat{B}_{1m} = \hat{B}_{0m} = \hat{B}_{0n} = 0$, namely, that a shock impacts car owners positively and has a lower effect (here normalized to zero) on non-car commuters and on commuters from non-connected municipalities.

Consider also two skill groups s,t with $w_s < w_t$. We obtain the following 'triple-difference' expression:[9]

$$\frac{1}{\kappa}\left[\left(\hat{\lambda}_{nt} - \hat{\lambda}_{mt}\right) - \left(\hat{\lambda}_{ns} - \hat{\lambda}_{ms}\right)\right] \approx \underbrace{\left(\phi_{nt} - \phi_{ns}\right)\left(\hat{B}_{1n} - \hat{B}_{1m}\right)}_{\text{Direct effect}} \underbrace{- \left(\frac{q_n h}{w_t - q_n h - pa} - \frac{q_n h}{w_s - q_n h - pa}\right)\left(\hat{q}_n - \hat{q}_m\right)}_{\text{Indirect effect}} > 0, \quad (13)$$

[8] Hereinafter, the 'hat' notation denotes log changes, $\hat{x} \equiv \mathrm{d}x/x$, for any variable x.

[9] This approximation works well when residents of municipalities m and n commute to more than a few municipalities.

where the inequality holds by inspection (recall $w_s < w_t$ and $\phi_{ns} < \phi_{nt}$) and by (12). We are thus left with *heterogeneous* direct and indirect effects that arise because of non-homothetic preferences. If commuting access increases in n (relative to m) and if car use for commuting purposes is skill-biased (i.e. $\phi_{ns} < \phi_{nt}$), as it is the case in the data, then the skill composition of the workforce in municipality n shifts to the right (relative to the skill composition of m). In addition, by implication of (12), we know that housing prices increase in n relative to m by $\hat{B}_{1n} > \hat{B}_{1m}$. High-skill workers also spend a lower share of their income on housing and on car use than lower-skill workers. Together, the indirect and direct effects imply the main result that we take to the data: if access increases in n (relative to m) then the skill composition of the residential population in n shifts to the right (relative to the skill composition of the residential population in m).

We make three additional comments. First, the triple-difference for changes in *worker* populations of two initially identical municipalities i and j is given by

$$\frac{1}{\kappa}\left[\left(\hat{\lambda}_{it} - \hat{\lambda}_{jt}\right) - \left(\hat{\lambda}_{is} - \hat{\lambda}_{js}\right)\right] = \left(\phi_{it} - \phi_{is}\right)\left(\hat{B}_{1i} - \hat{B}_{1j}\right). \qquad (14)$$

If commuting access increases in i (relative to j) and if car use for commuting purposes is skill-biased, then the skill composition of the workforce in municipality i shifts to the right (relative to the skill composition of j). Second, in the regressions below, the dependent variable of main interest is the population share of skill or income category s of some municipality n, σ_{nt}. Changes in this share are related to changes in λ_{nt} by (9) so that $\hat{\sigma}_{ts} - \hat{\sigma}_{ns}$ has the same sign as $\hat{\lambda}_{ts} - \hat{\lambda}_{ns}$. Finally, it follows from (6), (8), (9), (10), and from $\sum_s \mathrm{d}\sigma_{ns} = 0$ for all n (since the σ's are shares) that any change in the entropy index is the following weighted sum of changes in municipal population shares:

$$\mathrm{d}\ln T_n = \sum_{s\in\mathcal{S}} \tau_{ns}\mathrm{d}\ln\sigma_{ns}, \qquad \tau_{ns} \equiv \frac{\ln\left(\sigma_{ns}\right)\sigma_{ns}}{\sum_{t\in\mathcal{S}}\ln\left(\sigma_{nt}\right)\sigma_{nt}}, \qquad \sum_{s\in\mathcal{S}}\tau_{ns} = 1. \qquad (15)$$

Hence, segregation increases ($\mathrm{d}\ln T_n < 0$) if the relative population of groups that are initially over-represented increases.

2.7 *Empirically Testable Qualitative Theoretical Predictions*

Summing up the qualitative results of the model that we take to the data, consider a municipality that gets a positive commuting shock. Then, ceteris paribus:

1. The effect on population sizes is ambiguous. The number of high-skilled, high-income residents increases.

2. The skill and earning distributions of the resident and working populations shift to the right by equations (13) and (14), respectively.

3. The positive commuting shock reduces segregation (increases the entropy index) in municipalities that are the most segregated to start with by equation (15).

Note that the algebra above is implicitly assuming that a highway connection also benefits non-commuters, defined as people who live and work in the same municipality. We do that in order to avoid cluttering notation and we can justify this assumption by emphasizing that households use their cars also for purposes other than commuting (Small and Verhoef, 2007). It is actually straightforward to impose $\hat{B}_{nn} = 0$ and see that the qualitative predictions of the model are unchanged. A corollary of this fact is that all the qualitative predictions that pertain to the composition of the resident populations also hold for the out-commuter populations (defined as households living in the municipality but working in another one), and all the qualitative predictions that pertain to the composition of the worker populations also hold for the in-commuter populations (defined as households working in the municipality but living in another one).

3. Empirical Strategy

We assemble several data sets and test the predictions of the model using evidence from the Swiss highway network. As laid out in more detail in Appendix B, the Swiss highway network provides an ideal setting for our analysis. The highway network was to a large extent defined in 1960 by the federal parliament to connect Switzerland's largest cities, but only gradually constructed over the decades that followed. We exploit this variation over time to identify the effect of the opening of a new highway access point on the total number of taxpayers (households), the share of taxpayers in different income categories, as well as employment and commuting by education level.

3.1 Data

We rely on two sets of household data. First, we construct data on the income distribution using the Swiss federal income tax statistics with information at the municipality level from 1947 to 2010. Our main variables of interest are the number of taxpayers and the share of taxpayers with income above some income percentiles (median, 75th and 90th percentiles). As data are available on a two-year basis from 1947 to 2000, we aggregate all data into two-year averages. We complement these statistics with census data on employment by education level for decennial years for the period 1950-2010. We compute residence- and workplace-based numbers of employees as well as the number of out- and in-commuters for three different levels of education: compulsory school ('low education'), maturity and professional vocation ('middle education'), and university-level ('high education'). Appendix C details the construction of our variables. It provides summary statistics for non-urban connected and non-connected municipalities, and for urban municipalities. It also provides a balancing test of the planning phase figures (1947-1955) among four groups of non-urban connected municipalities (where groups are defined by the decade of connection to the highway network).

3.2 Identification

Our identification strategy exploits the spatial variation and the long panel dimension of the data in three ways. First, we rely on a long panel data set in which the timing of the treatment (i.e. opening of the highway access point) differs across sections of the highway network. We restrict our sample to municipalities that get a highway access over our observation period and exploit the heterogeneity in the opening time of the access as in Donaldson (2018) and Hornung (2015). Thus, all municipalities in our sample are eventually treated.

Second, we include municipality fixed effects as well as municipality-specific linear time trends to control for unobservable differences in the growth rate. Note that municipality time trends are in large part identified over a large number of pre-treatment years. We also include year fixed effects, which account for any macroeconomic shock that affects all municipalities in the sample. The highway access effects that we estimate are thus deviations from individual growth trajectories and countrywide shocks.

Third, we exclude urban municipalities from our sample in order to eliminate a major source of selection bias following Chandra and Thompson (2000) for the US and Faber (2014) for China. Indeed, in Switzerland as in these large countries, highways were designed to connect major urban centers. To non-urban municipalities, therefore, getting an access to the highway network is as close to random as it gets. These municipalities are small (see Table Appendix C.1) and our identifying assumption is that they are unlikely to have systematically influenced the opening time of the highway access. The design of the Swiss highway network was to a large extent sealed in 1960 (see Appendix B.1). The network was then only gradually constructed over time. Considerations based on inter-city transportation defined priorities. To the best of our knowledge, the connection of specific non-urban municipalities to the highway network did not feature among such considerations. The opening of certain highway sections was also subject to substantial delays, due to opposition by environmental groups, unexpected geological features, and other similar reasons, creating additional randomness in the timing. Figure 2 displays the distribution of non-urban municipalities receiving a highway connection, by opening year.

Our long panel data enable us to improve on identification strategies that can rely on variation across space only. Indeed, non-urban municipalities that are located along a direct route between two cities may follow different growth and development paths from those located further away, irrespective of the opening of a highway, something that cross-sectional studies cannot account for. We circumvent this challenge by focusing our analysis on non-urban municipalities that are all located within the same distance to the next highway, and by including municipality-specific time trends. Since all municipalities in our sample eventually get treated, but only gradually over time, there are treated and control municipalities at any point in time. Importantly, municipalities that are treated early are similar to municipalities that are treated later on. As detailed in Table Appendix C.2, there is no relevant difference in terms of economic activity or residential composition during the planning phase (1947-1955) among municipalities treated at different points in time. Regarding unobservable differences, we show in Section 4 that there are no relevant pre-opening dynamics among treated municipalities in the years before the construction of the highway. Furthermore, non-urban municipalities that did and did not get access over our sample period are observationally similar (see Table Appendix C.1). As it turns out, our results are largely unaffected if we include non-connected municipalities in the 'control' group (see Appendix D.6).

In this paper we estimate the effects of highways on location decisions. The Swiss railway network is also famously developed and its expansion would be a confounding factor undermining our identification strategy if its developments were systematically correlated in time and space with the opening of highways. There is no evidence that it is the case over our period of observation. The Swiss railway network was to a very large degree constructed in the second half of the 19th century and in the first decade of the 20th century. Switzerland had one of the densest railway networks across the world already back in 1900. By that time, 70% of Switzerland's population lived in a municipality crossed by a railway track (Büchel and Kyburz, 2020). Further expansion of the railway network after the first decade of the 20th century was limited.[10] The main improvement of rail services in the 20th century came from the development of commuter

[10]The next major upgrade of the network took place in 2004 only, with the so-called 'Bahn 2000' (or 'Rail 2000') initiative. The network connecting the main cities expanded with the opening of 51km of lines, which amounts to the cumulative expansions of the ninety preceding years (Wägli, 2010).

lines within major urban areas towards the end of the century.[11] These urban areas are excluded from our sample. Another major improvement in the quality of the public transportation offering was the introduction of the hourly timetable in May 1982, which affected all train connections simultaneously. Its effect is accounted for by interacting in our baseline specification the year fixed effects with a dummy variable indicating municipalities endowed with a railway access. We also show in Appendix D.7.1 that the effects we uncover are not driven by municipalities with a railway access.

3.3 *Specification*

We identify the effect of highway access by exploiting the heterogeneity in the opening times of highway accesses across municipalities using the panel dimension. We use a distributed lag model and focus on the long-term effect of highway access because we expect the effect of highways to materialize gradually. Our baseline specification investigates the full dynamics of the effects of highway access. Specifically, we include 7 two-year forward lags and 11 two-year lags, yielding the following regression equation:

$$n_{it} = \sum_{\tau=-7}^{11} \beta_\tau \, Access_{i,t-\tau} + \alpha_i + \rho_i \, t + \lambda_t \times Rail_i + \varepsilon_{it} \,, \tag{16}$$

where subscripts $i = 1,...,782$ and $t = 1947,...,2010$ denote municipality and a two-year period, respectively; $n_{i,t}$ is the natural logarithm of the number of taxpayers, the natural logarithm of the share of taxpayers in different income percentiles, or the natural logarithm of the entropy index; $Access_{i,t}$ is a dummy variable that takes value 1 for municipalities with access to a highway within a road distance of a certain number of kilometers, and zero otherwise; α_i is a municipality fixed effect, $\rho_i \, t$ is a linear municipality time trend, λ_t is a year fixed effect that we interact with a dummy variable ($Rail_i$) that takes value one if the municipality has a railway station within its boundaries, and

[11]For instance, Zurich's S-Bahn commuter train was launched in 1990, Basel's Regio-S-Bahn in 1997 (see Berger, Güller, Mauch and Oetterli, 2009).

zero otherwise, and $\varepsilon_{i,t}$ is a municipality-year error term, clustered at the district level in order to account for spatial autocorrelation.[12]

This distributed lag model is equivalent to an event study design in which all the periods after (and including) period 11 are lumped together, and similarly for all years prior to and including -8 (Schmidheiny and Siegloch, 2020). We are then interested in the cumulative effect of the highway access compared to a reference period. Thus, for a reference period r, we have:

$$\gamma_j = \begin{cases} -\sum_{\tau=j+1}^{r} \beta_\tau & \text{if } -8 \leq j \leq r-1 \\ 0 & \text{if } j = r \\ \sum_{\tau=r+1}^{j} \beta_\tau & \text{if } r+1 \leq j \leq 11. \end{cases}$$

Coefficient γ_j quantifies the effect on the variable of interest at the municipality level of getting a highway access at time j relative to getting it at a later stage (in more than 8 periods) or to having been connected more than 11 periods ago.

As the opening of a highway access hardly comes as a surprise to economic agents, anticipations effects imply that the treatment effect must precede the opening of the access point. The construction of the highway also implies important work which may temporarily boost local economic activity in the years prior to accessing the highway network. For these reasons, we conservatively choose period -5 (year -10) as the reference.[13]

The coefficient of each cumulative effect is potentially identified by a different set of municipalities. For this reason, we restrict the dynamics to the window between periods -7 (year -14) and $+10$ (year $+20$). Each coefficient is identified by at least 85% of

[12]Districts are an administrative level in-between municipalities and cantons. There are 102 districts in our sample.

[13]We do not have information on the construction time of each highway section. Our choice of this base year is driven by the auxiliary data extracted from the website www.structurae.net. The average construction time of 65 major highway infrastructure such as bridges or tunnels reported by this website is 4 years, with a maximum of 10 years. Our choice of -10 as reference year is thus conservative by this token.

our municipalities (coefficients for periods -7 to $+7$ are identified by at least 95% of municipalities).[14]

In the baseline specification, we only include one specific $Access_{i,t}$ variable, relating to all municipalities that eventually get an access to the highway within 10km.[15] In additional specifications, we include a vector of $Access_{i,t}$ variables (e.g., for 0-5, 5-10, 10-15, and 15-20km) in order to identify the long-term effect for different distance bandwidths simultaneously.

4. Results

We start by estimating the impact of highway access on the number of taxpayers and on the income distribution for our baseline sample of municipalities. Table 2 presents the results. All specifications include municipality and year fixed effects. Columns (2) to (8) also control for municipality-specific linear time trends. In Columns (3) to (8) the year fixed effects are different for municipalities with and without a railway station. The estimating sample is restricted to have the same number of observations in each column.

Table 2 is divided into two parts. Panel A investigates the dynamics of the effect as modeled by equation (16). Panel B reports the long-term cumulative impact of highway

[14] The share of identifying units for all event-study coefficients is reported in Figure Appendix F.1.

[15] The 10km-buffer appears to be a reasonable threshold for our baseline specification for several reasons. First, like Faber (2014) for the Chinese National Trunk Highway System, we find that the effect vanishes quickly beyond 10km (see Appendix D.8). Second, the typical distance between two highway stops in Switzerland equals 5-10km. A distance band of 10km around each access point implies that our sample of municipalities encompasses municipalities located in a corridor of roughly 10km on both sides of the highway. Third, as explained in Appendix B.2, the actual individual travel distances are likely distributed around our proxy by up to a few kilometers, due to the geographical spread of people within municipalities. Therefore, a more narrow definition (e.g., 5km) might exclude municipalities with individuals that are actually in close reach of the highway. Finally, close proximity to a highway also brings negative externalities to residents. For this reason, people are likely to desire living in municipalities close to, but not directly located along, a highway. Allowing for a distance of up to 10km takes such preferences into account.

access, taking anticipation effects into account. The reference year in this case is -6 and, consistently with the results of Panel A, all earlier years are set to zero. In this specification, our distributed lag model includes 2 forward lags and 11 lags and we report the sum of all forward lags and lags as the long-term cumulative effect.[16]

Qualitative Prediction no. 1 (Municipality Size)

The dynamics of the effect of highway access on the number of taxpayers (Columns 1 to 3) are in line with intuition. The positive effect of the highway opening is anticipated by economic agents and gradually increases over time, as relocation and moving are costly and construction of new housing takes time. Note that the positive effect in year -4 and -2 could also be due to the construction of the highway itself, as was the case for other major transportation infrastructures (Chandra and Thompson, 2000; Ahlfeldt and Feddersen, 2018). Importantly, we do not detect any effect prior to 4 years before the opening, indicating that pre-opening dynamics are correctly captured by the set of fixed effects.

The long-term effect of getting a highway access within 10km on the number of taxpayers in the municipality, as reported in Panel B, is positive and statistically significant in all specifications. Relative to the simple specification (with municipality and year fixed effects only), the addition of municipality-specific time trends in Column (2) leaves the results literally unchanged.[17] Using year-rail fixed effects (Column 3) instead of year fixed effects leads to a slightly larger point estimate of the coefficient (the difference

[16] Specifically, equation (16) becomes:

$$n_{it} = \sum_{\tau=-2}^{11} \beta_\tau \, Access_{it} + \alpha_i + \rho_i \, t + \lambda_t \times Rail_i + \varepsilon_{it} \, .$$

Following Davidson and MacKinnon (2004, p. 575), we reset parameters of this equation by adding and subtracting $\sum_{\tau=-2,\tau\neq 0}^{11} \beta_\tau \, Access_{it}$, so that we can estimate $\gamma \equiv \sum_{\tau=-2}^{11} \beta_\tau$ directly:

$$n_{it} = \gamma \, Access_{it} + \sum_{\tau=-2,\tau\neq 0}^{11} \beta_\tau \left(Access_{it-\tau} - Access_{it} \right) + \alpha_i + \rho_i \, t + \lambda_t \times Rail_i + \varepsilon_{it} \, . \tag{17}$$

[17] Observe that 'literally' has become the most abused adverb of our times. Here we use it, well, literally.

between the two being statistically insignificant). The effect of highway access is also economically significant: on average, the number of taxpayers 22 years after the opening of an access point within 10km is approximately 14% higher ($e^{0.132} - 1 = 0.1411$) than what it would be in the absence of such an access and if the taxpayer population in these municipalities had continued to grow along their trend.

Qualitative Prediction no. 2 (Municipality Composition)

Columns (4) to (7) investigate the effects of a highway access on the distribution of taxpayers within municipalities. The dependent variable is the natural logarithm of the share of various groups of taxpayers classified according to the percentiles of the nation-wide income distribution.[18] Results in Panel A show that the change in composition of taxpayers was gradual. Column (4) of Panel B reports that the opening of a nearby highway access within 10km led to a long-term decrease of the share of taxpayers with a below-median income by about 7.6%. Columns (5) to (7) indicate that the shares of taxpayers between the median and the third quartile, between the top quartile and the top decile, and of the top decile increased by 7.8%, 22.5% and 24.1%, respectively. The difference between the effects reported in Columns (5) and (6) is statistically significant, while results from Column (6) and (7) are statistically undistinguishable at conventional levels.

Qualitative Prediction no. 3 (Segregation)

Column (8) estimates the impact of highway access on residential segregation in these municipalities, as measured by the entropy index defined in equation (10). This impact is positive and hence highway access leads to a *reduction* in segregation by income in

[18] Note that the sum of the coefficients of Column (3) and of any of Columns (4) to (7) gives the effect on the *number* of taxpayers in the corresponding income band. For instance, in Panel B, the cumulative increase in the number of below-median income earners is equal to $e^{0.132-0.079} - 1 = 5.4\%$ in municipalities that get access to the highway network. This increase rises to $e^{0.132+0.216} - 1 = 41.6\%$ for the number of top-10% income earners.

our sample of non-urban municipalities. This result was to be expected from equation (15): high-income earners are under-represented in non-urban municipalities (and over-represented in urban municipalities) to start with; hence, the rightward shift in income distribution brought about by access to the highway network leads to a reduction in segregation.

5. Extensions and Robustness Analysis

We run several extensions in a series of online appendices.

First, results on the distribution of income reported in the previous section are consistent with two distinct economic mechanisms: sorting by income and a heterogeneous increase in earnings. In order to better understand the role of each mechanism, we start by complementing the results on the number of taxpayers with the effect of highway access on total income reported by those taxpayers, as well as on income per taxpayer (Appendix D.1). We find that highway access did not affect income per taxpaying household within income groups. We then look at the effects of highway access on employment by education level. Estimated coefficients of these education variables are only consistent with the sorting mechanism under the plausible assumptions that education is a good proxy for income and that highway access in a given municipality is orthogonal to education choices made years or decades earlier (Appendix D.2). Consistent with our baseline results, we find that the shift in the composition of municipalities is led by highly educated residents and workers.

Second, following the discussion in Section 2.7, we also expect the effects of highway access on out-commuters (people who reside in the municipality and work elsewhere) to be similar to those on the resident populations; and the effects of highway access on in-commuters (people who work in the municipality and reside elsewhere) to be similar to those on working populations. We show that it is indeed the case in Appendix D.3.

Third, the stylized facts presented in Table 1 suggest a relocation of households from urban centers to suburban municipalities, an evolution led primarily by top-income households (see Panels D and E). In Appendix D.4, we assess the role of highway access on this manifestation of urban sprawl. We find that highways contributed to the decentralization of jobs and residences, and that this process is especially pronounced for the highest-skilled workers.

Finally, we present several robustness analyses. Specifically, we run a placebo experiment by randomizing the opening access year (Appendix D.5); we include non-connected municipalities in the 'control' group (Appendix D.6); we assess the role of confounding factors such as railway access and the expansion of cities, and we test whether the effect is constant between early and late connection (Appendix D.7). We also report the effect for different distances to the next highway access point (Appendix D.8); test for a potential bias in the case of multiple openings (Appendix D.9), and investigate the role of initial conditions and amenities (Appendix D.10).

Our baseline results are qualitatively and quantitatively robust to these extensions and robustness analyses.

6. Welfare

In this section we use the model to relate our quantitative results to some long-run measure of the distributional effects of the Swiss highway network, while adding as few additional assumptions as possible. In particular, recall that our estimation strategy requires to have a 'treatment' (municipalities with access to the highway network) and a 'control' group (municipalities without such an access) at all times. Thus, the 'control' group needs to include municipalities that are still not connected to the network by 2010 if one wants to measure welfare effects over the course of the whole time period under study (i.e. from 1950 to 2010). For this reason we use the estimates of Table Appendix D.4 that add such municipalities to the sample (recall that they are similar to our baseline estimates of Table 2 that exclude such municipalities from the sample), and ask the following 'difference-in-difference' questions: to what extent does the welfare of residents of municipalities that are connected change relative to the welfare of residents of municipalities that remain unconnected? And how do these changes vary across income groups?

To this end, let us first rewrite equation (5) in the main text as

$$\lambda_{nis} = \left(\frac{V_{nis}}{\mathbb{E}V_s}\right)^{\kappa}, \quad \mathbb{E}V_s = \left[\sum_{n\in\mathcal{M}} (V_{ns})^{\kappa}\right]^{1/\kappa}, \quad V_{ns} = \left[\sum_{i\in\mathcal{M}} (V_{nis})^{\kappa}\right]^{1/\kappa}.$$

Hence, the share of type-s residents in municipality n is equal to

$$\lambda_{ns} \equiv \sum_{i\in\mathcal{M}} \lambda_{nis} = \left(\frac{V_{ns}}{\mathbb{E}V_s}\right)^{\kappa}.$$

Second, pick two arbitrary municipalities n,$h \in \mathcal{M}$, where h has access to the highway network and n does not. We may then write

$$\frac{\lambda_{hs}}{\lambda_{ns}} = \left(\frac{V_{hs}}{V_{ns}}\right)^{\kappa}.$$

Third, consider some prior time period during which neither had access to the highway network (1950 in our context) and some posterior year at which the network was completed (2010 in our context); we denote variables pertaining to this latter period with a prime. Using exact 'hat algebra', we reset notation and define $\hat{x} \equiv x'/x$ for any variable x. We thus obtain

$$\frac{\hat{\lambda}_{hs}}{\hat{\lambda}_{ns}} = \left(\frac{\hat{V}_{hs}}{\hat{V}_{ns}}\right)^{\kappa}. \tag{18}$$

We do not measure the variables of the right-hand side of this expression, which compose the welfare effects we are interested in, but we do measure its left-hand side, and, importantly, we estimate the part that is due to highway connection.

Fourth, let $\mathcal{M}_h$ denote the set of municipalities currently with a highway connection, and let $\mathcal{M}_\emptyset$ denote the complementary set. Assume

$$\forall h \in \mathcal{M}_H : \hat{V}_{hs} = \hat{V}_{Hs}, \qquad \forall n \in \mathcal{M}_\emptyset : \hat{V}_{ns} = \hat{V}_{\emptyset s},$$

for some $\hat{V}_{Hs}$ and some $\hat{V}_{\emptyset s}$. It then follows from (18) that the welfare change of type-s residents in connected municipalities relative to the welfare change of residents in non-connected municipalities is equal to

$$\frac{\hat{V}_{Hs}}{\hat{V}_{\emptyset s}} = \left(\frac{\hat{\lambda}_{Hs}}{\hat{\lambda}_{\emptyset s}}\right)^{1/\kappa}. \tag{19}$$

Three remarks are in order. First, we can readily measure $\hat{\lambda}_{Hs}/\hat{\lambda}_{\emptyset s}$ using raw data – see Table 1. Remarkably, this procedure does not require any data about changes in housing prices, say, or about any auxiliary economic variable such as amenities; it only requires a strong face in the literal interpretation of the model. Second, populations moved over this long time period for a variety of reasons and we use the estimates of Table Appendix D.4 to compute the part of $\hat{\lambda}_{Hs}/\hat{\lambda}_{\emptyset s}$ that is attributed to the development of the highway network.[19] Finally, we need to assign a value to κ in order to map relative changes in population into relative changes in welfare. We estimate this parameter in Appendix E.

Table 3 presents the relative welfare changes across types for our midpoint value $1/\kappa = 0.28$. Three results deserve comments. First, residents in connected municipalities benefit from the highway network relative to residents remaining in non-connected ones. This result pertains to all income groups. Second, this relative gain increases monotonically across income groups, with below-median income earners benefiting the least (by 2%) and top-income earners benefiting the most (by 12%). Our model attributes these sizable differences to housing being an income-inelastic good as well as to car ownership and car use being a luxury good. Finally, this relative welfare change is exact when comparing 'stayers', namely households who would stay in the same municipality even if that municipality switched status between being connected or not. It is an upper bound for households that have idiosyncratic location preferences that are mild enough for highways to affect their location choice in equilibrium.

[19]To illustrate, go back to the example of footnote 5 and consider shifts in the population of top-10% income earners in non-urban municipalities: $\hat{\lambda}_{Hs} = 1.42$ and $\hat{\lambda}_{\emptyset s} = 0.78$ so that $\hat{\lambda}_{Hs}/\hat{\lambda}_{\emptyset s} = 1.82$. That is, the share of top-income earners living in non-urban municipalities that are connected by 2010 relative to the share of top-income earners living in such municipalities that remain unconnected in 2010 has increased by 82% over the time period 1950-2010. Using the estimates that include non-connected municipalities reported in the top row of Panel B of Table Appendix D.4, we find that the part that is attributable to highways is equal to $e^{0.135+0.255} = 1.48$.

Summary and Conclusion

In this paper we analyze the impact of a reduction in commuting costs on employment and the residential location decisions of a heterogeneous population. To this aim, we first develop a multi-region model featuring commuting costs and workers that are endowed with non-homothetic preferences over housing and consumption, heterogeneous location preferences, and heterogeneous labor productivity. In equilibrium, high-skilled, high-income workers, who are less sensitive to housing prices and disproportionately commute by car, benefit more from an improvement in accessibility than lower skilled workers. The model leads to three main predictions: (1) municipalities that get a highway connection attract more workers and more residents at the top of the skill and earnings distributions; (2) the skill and earnings distributions in these municipalities shift to the right as a result; (3) segregation is therefore reduced in connected municipalities that are the most segregated to start with. Our model also implies that the effect on the number of in- and out-commuters is qualitatively similar to the effect on working and resident populations: the effect is strongest for the top of the skill and income distributions. As a corollary, highways contribute to skill-biased urban sprawl.

We provide empirical evidence for these theoretical predictions by analyzing the impact of the Swiss highway network on the number and distribution of taxpayers as well as on employment and commuting at the local level. For identification purposes, we primarily rely on time variation based on a long panel data set covering the period 1947-2010. Our sample consists of non-urban municipalities that eventually get access to a highway access point within 10km. We exploit the fact that various sections of the highway network opened at different points in time over several decades. Using this 'within' variation mitigates potential issues resulting from differences in growth trends across municipalities that are unrelated to the transport infrastructure of interest, but might be systematically correlated with accessibility measures and thus undermine the common trend assumption.

Our results show that access to the highway network leads to an increase both in the total number of taxpayers and in the share of high-income taxpayers in our sample of Swiss municipalities, resulting in a reduction of segregation by income in non-urban connected municipalities. Highway access also has a causal effect on employment and on the number of in-commuters in connected municipalities; the latter effect is driven by a rise in the number of highly educated workers. We also find an effect on the number of out-commuters at the top of the skill distribution. The empirical findings thus provide support for the theoretical predictions of the model. The data are also consistent with the hypothesis that Swiss highways contributed to urban sprawl in the country.

Finally, we use the model and our empirical results to estimate relative long-run welfare effects. We find that the welfare of all residents in connected municipalities increases relative to residents remaining in non-connected ones, and that this relative welfare gain increases monotonically across income groups, with top-income earners benefiting the most. Our model relates these differences in welfare changes between income groups to housing being an income-inelastic good and car ownership and car use being a luxury good.

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Tables

Table 1: Stylized facts

	Total	Taxpayers with income				Entropy index
		below 50%	top 50%-25%	top 25%-10%	top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Non-urban connected municipalities (N=782)						
Before (1947-1955)	0.12	0.14	0.11	0.09	0.07	1.08
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
After (2003-2009)	0.14	0.15	0.14	0.13	0.10	1.14
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.02)
Ratio After/Before	1.17	1.05	1.25	1.40	1.42	1.06
	(0.08)	(0.07)	(0.10)	(0.11)	(0.07)	(0.02)
Panel B: Non-urban non-connected municipalities (N=789)						
Before (1947-1955)	0.12	0.14	0.12	0.10	0.08	1.12
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
After (2003-2009)	0.12	0.14	0.11	0.09	0.07	1.06
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
Ratio After/Before	0.94	0.96	0.92	0.90	0.78	0.95
	(0.06)	(0.07)	(0.07)	(0.07)	(0.04)	(0.02)
Panel C: Urban municipalities (N=908)						
Before (1947-1955)	0.76	0.71	0.77	0.81	0.85	1.26
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
After (2003-2009)	0.75	0.71	0.75	0.78	0.83	1.24
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Ratio After/Before	0.98	1.00	0.98	0.97	0.99	0.98
	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)
Panel D: Urban centers (N=27)						
Before (1947-1955)	0.40	0.34	0.42	0.47	0.51	1.30
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
After (2003-2009)	0.23	0.24	0.23	0.22	0.22	1.19
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
Ratio After/Before	0.59	0.71	0.56	0.48	0.43	0.92
	(0.04)	(0.05)	(0.04)	(0.04)	(0.01)	(0.01)
Panel E: Suburban municipalities (N=881)						
Before (1947-1955)	0.36	0.38	0.36	0.34	0.33	1.20
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
After (2003-2009)	0.51	0.47	0.52	0.56	0.61	1.26
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)
Ratio After/Before	1.42	1.26	1.46	1.64	1.85	1.05
	(0.01)	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)

Notes: This table reports the average fraction of taxpayers living in non-urban connected, non-urban non-connected, and in urban municipalities, before and after the highway connection. (Non-)connected municipalities refer to non-urban municipalities with (without) a highway access within 10km reach by 2010. Standard deviations in parentheses.

Table 2: Impact of highway access on number and composition of taxpayers

	# Taxpayers			Share of taxpayers				Entropy index
				below 50%	top 50%-25%	top 25%-10%	top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Cumulative effect j years before/after access								
<-14	-0.008	0.008	0.004	0.001	-0.006	-0.015	-0.024	-0.006
	(0.034)	(0.014)	(0.014)	(0.012)	(0.015)	(0.035)	(0.065)	(0.012)
-14	0.002	0.002	0.001	-0.003	0.003	0.007	0.003	0.001
	(0.011)	(0.010)	(0.010)	(0.006)	(0.011)	(0.021)	(0.045)	(0.006)
-12	0.004	0.004	0.003	-0.004	0.002	-0.005	0.034	0.003
	(0.009)	(0.009)	(0.009)	(0.005)	(0.009)	(0.025)	(0.043)	(0.005)
-10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
-8	0.007	0.008	0.009	-0.003	-0.007	0.027	0.027	0.007
	(0.008)	(0.008)	(0.007)	(0.005)	(0.009)	(0.017)	(0.035)	(0.005)
-6	-0.003	0.001	0.003	0.008	-0.010	-0.008	-0.014	-0.003
	(0.011)	(0.010)	(0.010)	(0.007)	(0.012)	(0.018)	(0.053)	(0.006)
-4	0.030**	0.030**	0.033***	0.002	-0.007	0.017	-0.011	0.003
	(0.014)	(0.012)	(0.012)	(0.008)	(0.012)	(0.024)	(0.054)	(0.007)
-2	0.041**	0.042**	0.045***	-0.010	0.005	0.020	0.027	0.007
	(0.017)	(0.016)	(0.016)	(0.009)	(0.012)	(0.026)	(0.060)	(0.009)
+0	0.045**	0.045**	0.049***	-0.012	0.019	0.033	0.050	0.013
	(0.018)	(0.017)	(0.017)	(0.010)	(0.013)	(0.029)	(0.054)	(0.010)
+2	0.058***	0.058***	0.063***	-0.020*	0.012	0.075**	0.070	0.020
	(0.020)	(0.020)	(0.019)	(0.012)	(0.016)	(0.030)	(0.058)	(0.012)
+4	0.063***	0.063***	0.067***	-0.024*	0.026	0.081**	0.026	0.023*
	(0.022)	(0.021)	(0.021)	(0.013)	(0.018)	(0.034)	(0.085)	(0.013)
+6	0.077***	0.074***	0.078***	-0.033**	0.046**	0.105***	0.077	0.034**
	(0.025)	(0.025)	(0.024)	(0.014)	(0.018)	(0.036)	(0.065)	(0.014)
+8	0.082***	0.080***	0.085***	-0.038**	0.049**	0.110***	0.114*	0.041***
	(0.027)	(0.028)	(0.027)	(0.015)	(0.021)	(0.037)	(0.061)	(0.015)
+10	0.089***	0.081**	0.086***	-0.038**	0.050**	0.125***	0.097	0.044***
	(0.031)	(0.032)	(0.030)	(0.015)	(0.020)	(0.037)	(0.068)	(0.015)
+12	0.100***	0.091***	0.096***	-0.045***	0.063***	0.136***	0.128*	0.051***
	(0.034)	(0.034)	(0.033)	(0.017)	(0.022)	(0.041)	(0.069)	(0.017)
+14	0.105***	0.096**	0.101***	-0.052***	0.072***	0.144***	0.150**	0.059***
	(0.037)	(0.038)	(0.037)	(0.017)	(0.021)	(0.042)	(0.069)	(0.017)
+16	0.108**	0.105**	0.110***	-0.053***	0.070***	0.156***	0.169**	0.062***
	(0.045)	(0.042)	(0.040)	(0.018)	(0.022)	(0.045)	(0.070)	(0.018)
+18	0.115**	0.112**	0.118***	-0.059***	0.071***	0.170***	0.189***	0.068***
	(0.049)	(0.045)	(0.044)	(0.019)	(0.023)	(0.047)	(0.071)	(0.018)
+20	0.125**	0.120**	0.125***	-0.068***	0.074***	0.183***	0.212***	0.073***
	(0.053)	(0.049)	(0.048)	(0.019)	(0.022)	(0.047)	(0.077)	(0.019)
>+20	0.137**	0.129**	0.135**	-0.078***	0.073***	0.221***	0.247***	0.085***
	(0.068)	(0.054)	(0.053)	(0.021)	(0.024)	(0.049)	(0.084)	(0.020)
Panel B: Long-term cumulative effect								
Long-term effect	0.129*	0.129**	0.132**	-0.079***	0.075***	0.203***	0.216***	0.078***
	(0.072)	(0.053)	(0.052)	(0.016)	(0.019)	(0.042)	(0.068)	(0.016)
# Observations	23274	23274	23274	23274	23274	23274	23274	23274
# Municipalities	780	780	780	780	780	780	780	780
Municipality time trends	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time-rail fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. The dependent variable is the log of the number of taxpayers in Columns (1) to (3), the log of the share of taxpayers in different income percentiles in Columns (4) to (7), and the log Theil entropy index in Column (8). Two-year panel covering the period 1947-2010. All regressions include municipality fixed effects and time fixed effects.

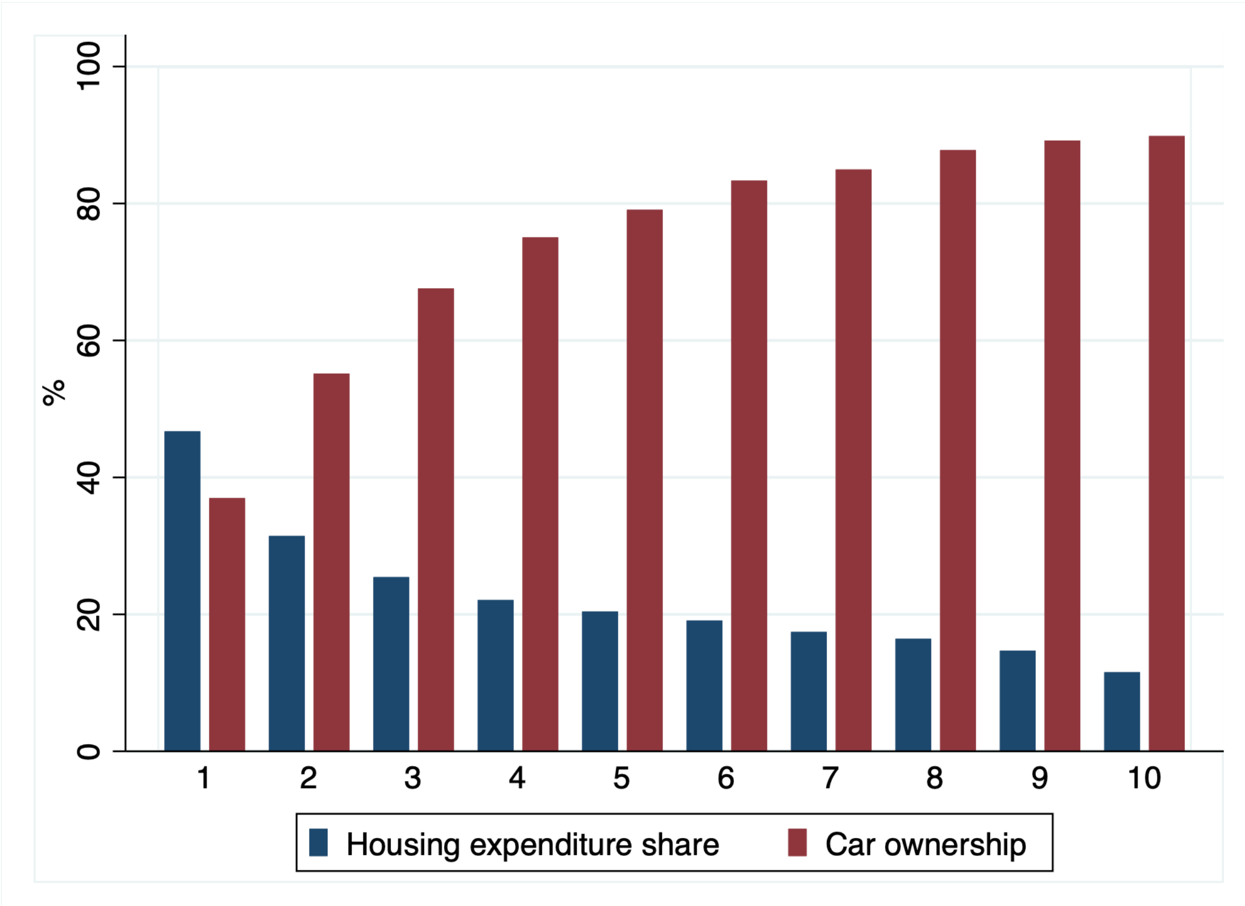
Table 3: Welfare effects

	Taxpayers with income			
	below 50%	top 50%-25%	top 25%-10%	top 10%
$\frac{\hat{\lambda}_{Hs}}{\hat{\lambda}_{\emptyset s}}$	1.06	1.21	1.40	1.48
$\frac{\hat{V}_{Hs}}{\hat{V}_{\emptyset s}}$	1.02	1.05	1.10	1.12

Notes: This table maps the relative changes in population due to highway ($\frac{\hat{\lambda}_{Hs}}{\hat{\lambda}_{\emptyset s}}$) as estimated in top row of Panel B of Table Appendix D.4 into relative changes in welfare $\frac{\hat{V}_{Hs}}{\hat{V}_{\emptyset s}} = \left(\frac{\hat{\lambda}_{Hs}}{\hat{\lambda}_{\emptyset s}}\right)^{\frac{1}{\kappa}}$ with $\frac{1}{\kappa} = 0.28$.

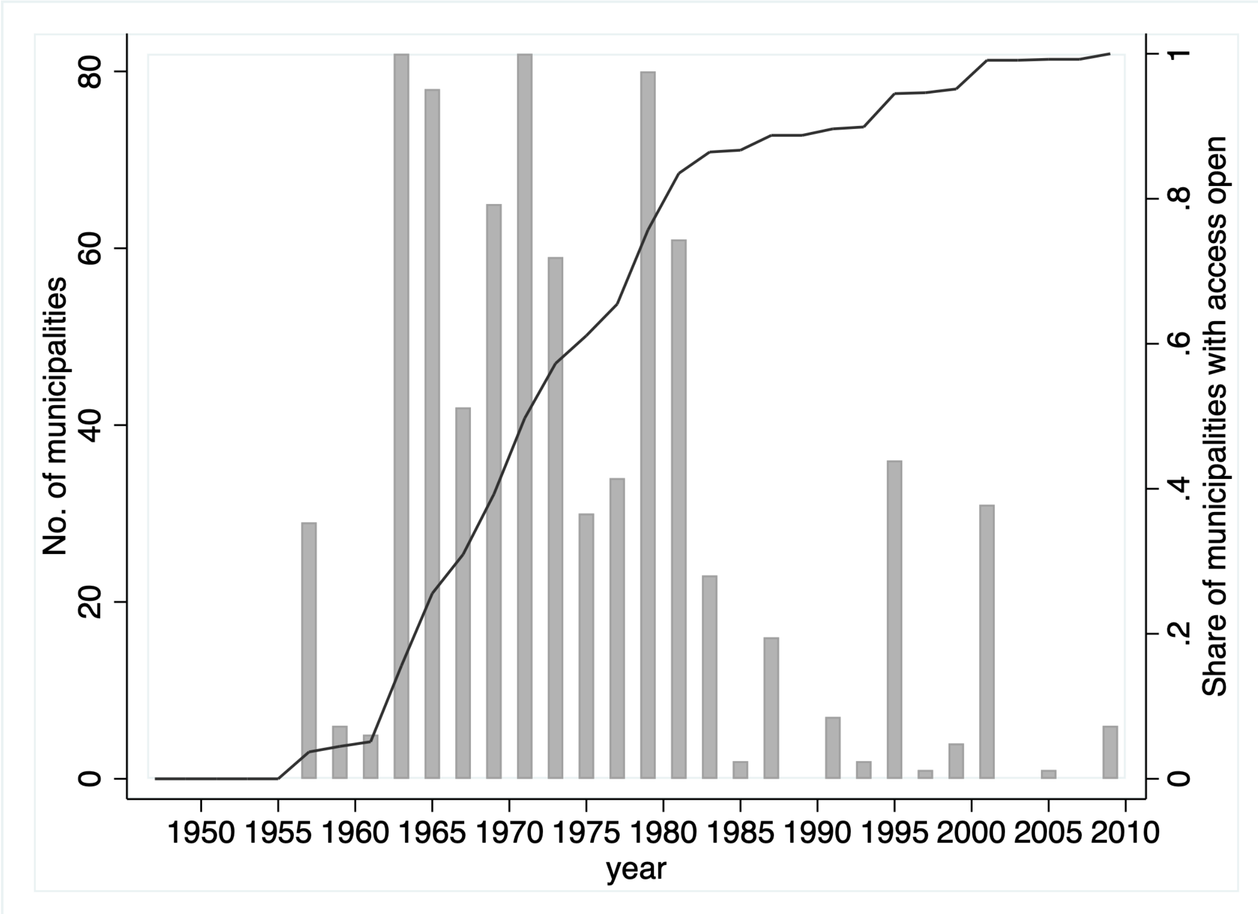
Figures

Figure 1: Housing expenditure shares and car ownership by income decile



Note: The figure shows housing expenditure shares and car ownership by income deciles. Housing expenditure is constructed as total annual rent, including service charges for tenants, over gross annual income. Car ownership is the proportion of respondents with a car for private use. Income deciles are based on gross annual income. Source: Swiss Household Panel, waves 1(1999)-17(2015).

Figure 2: Number of municipalities with a highway access by opening year



Note: The figure shows the number of non-urban municipalities and the corresponding cumulative share receiving a highway access within 10km reach, by opening year (frequency, left axis; and cumulative, right axis).

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Online Appendices

Appendix A. Model Appendix

Appendix A.1 Endowments, Technology, and Preferences

The economy consists of a set $\mathcal{M} \equiv \{1,...,N\}$ of municipalities (denoted by i,n) and workers of heterogeneous skill or ability groups, $\mathcal{S} \equiv \{1,...,S\}$ (denoted by s,t). The supply of group-s workers in the economy, L_s, is inelastic. Labor is homogeneous and each worker of ability s inelastically supplies w_s units of labor to sector C. This sector produces a freely traded, homogeneous consumption good under constant returns to scale and constant returns to labor. We use this good as the numéraire. All municipalities have access to the same technology and convert one effective unit of labor into one unit of C.[1] Since labor demand is perfectly elastic everywhere, and by the law of one price, the wage of workers with skill s is w_s, independently of their workplace. Without further loss of generality, we rank skills such that $w_1 < ... < w_s < ... < w_S$ so that group t is said to be higher skilled (and to have a higher income) than group s if and only if $s < t$ holds.

Individuals may reside or work in any location. We designate residential locations by subscript n and workplace locations by subscript i. If $i \neq n$ for some worker, this worker commutes between municipalities n and i. They also may choose to commute by car or to use alternative transit modes. Swiss data report a non-homothetic use of cars for commuting purposes, as the use of cars increases with income (see Figure 1). We thus add (endogenous) car use for commuting proposes to the model, following Tsivanidis (2019). Car use is a discrete choice $a \in \{0,1\}$, where $a = 1$ if the modal choice is automobile and $a = 0$ otherwise.

Each location is endowed with a fixed supply of residential land H_n. Workers hold

[1] Allowing for heterogeneous productivity across municipalities would clutter notation and complicate expressions for some results; for instance, the housing expenditure of a household would no longer be independent of their job location but the key properties of this share would still obey equation (A3) below. We can bring the qualitative predictions of our current setting to the data in a clear fashion (see Appendix A.6 below); by adding a second-order composition effect, relaxing the assumption of homogeneous productivity would make this link more convoluted without adding much insight.

heterogeneous preferences about each pair of locations and about commuting modes, as well as non-homothetic Stone-Geary preferences over (non-tradable) housing and the homogeneous and tradable numéraire. Specifically, the utility of worker ψ endowed with skill s, residing in n and working in i is equal to

$$U_{anis}(\psi) = \left(\frac{C_{anis}}{\alpha}\right)^{\alpha} \left(\frac{H_{anis} - h}{1-\alpha}\right)^{1-\alpha} B_{ani}\beta_{ani}(\psi), \qquad \alpha \in (0,1), \quad h > 0. \tag{A1}$$

C_{anis} and H_{anis} respectively denote the consumption of the homogeneous good C and housing services H of worker of skill group s, working in municipality i, residing in municipality n, and commuting using mode a; α and h are preference parameters, with h being the subsistence level of housing; B_{ani} denotes the common component of the joint assessment of locations n and i as residential and working locations and of commuting mode a, and $\beta_{ani}(\psi)$ denotes the iid idiosyncratic component of the joint assessment of the triplet (a,n,i). B_{ani} captures both n- and i-specific amenities, as well as pair-specific amenities such as the (dis)utility of the bilateral commute using mode a. Therefore, a reduction in the bilateral commuting time using cars corresponds to an increase in B_{1ni}.

Let q_n denote the housing price in n and let $p \in (0,w_1)$ denote the unit cost of using a car for commuting purposes (we assume $p < w_1$ for simplicity). Utility maximization yields the following housing expenditure function:

$$q_n H_{nis} = q_n h + (1-\alpha)(w_s - q_n h - pa) \equiv E^H_{ans}, \tag{A2}$$

for any i (in our simplified framework, expenditure is independent of the job location). As is standard with such Stone-Geary preferences, housing expenditure is equal to subsistence expenditure plus a constant fraction of disposable income. The fraction of income spent on housing thus varies across skill groups and residential locations. The expenditure shares for housing and for car use,

$$\mu^H_{ans} \equiv \frac{E^H_{ans}}{w_{ns}} = (1-\alpha)\left(1 - \mu^A_{as}\right) + \alpha \frac{q_n h}{w_s}, \qquad \mu^A_{as} \equiv \frac{pa}{w_s},$$

are both non-increasing in w_s: housing (conditional on mode a) and, for households who own one, cars are both necessary goods (though car use increases with income in equilibrium, as we show below). In mathematical symbols:

$$\frac{\partial \mu^H_{ans}}{\partial q_n} > 0, \qquad \left.\frac{\partial \mu^H_{ans}}{\partial w_s}\right|_a < 0, \qquad \frac{\partial \mu^A_{as}}{\partial w_s} \leq 0. \tag{A3}$$

The indirect utility associated with (A1) is equal to

$$V_{anis}(\psi) = \beta_{ani}(\psi) V_{anis}, \qquad V_{anis} \equiv B_{ani} \frac{w_s}{(q_n)^{1-\alpha}} \left(1 - \frac{q_n h}{w_s} - \frac{pa}{w_s}\right). \tag{A4}$$

If $a = h = 0$ then (A4) collapses to the Cobb-Douglas case and $\mu^H_{0ns} = 1 - \alpha$; otherwise, the incidence of the cost of living q decreases with earnings w in the sense that V is log-supermodular in w_s and q_n:

$$h > 0 \iff \frac{\partial^2 \ln V_{nis}}{\partial w_s \partial q_n} > 0, \tag{A5}$$

for any i. Attractive residential locations will command higher housing prices in equilibrium, which has a higher incidence on low income earners than on workers at a higher end of the earnings distribution. Then, in equilibrium, high-s workers will disproportionately sort into high-B_{ani} municipalities for residential purposes.

To see how this mechanism works, assume

$$B_{ani} = \frac{B_{an} B_{ai}}{d_{ni}}.$$

That is, we decompose B_{ani} into three components: an origin-commuting mode component B_{an}, a destination-commuting mode component B_{ai}, which are potentially affected by highway access, and an origin-destination component d_{ni}, which is unaffected by highways. This slight loss of generality greatly simplifies the analysis below. Next, turn to Figure Appendix A.1, which plots indifference curves in the (q,B)-space (logarithmic scale), given mode a. By construction, the common component of utility in (A4) is constant, and hence $\mathrm{d}V_{anis} = 0$ holds along those curves. Consider an arbitrary (residential) municipality M and two arbitrary skill types s and t with $s < t$. The figure plots the indifference curve for these two types going through $M = (q_m, B_{am})$. The indifference curve for the lower type s is steeper than the indifference curve of the higher type t: the marginal willingness to pay a higher housing unit price for better residential amenities increases with type and income because lower type s spends a higher fraction of her income on housing than higher type t. Consider now municipality N, which offers a combination of higher amenities and higher housing prices as shown on the graph. It then follows that the common component of utility of the lower type s is lower in municipality N than in municipality M, while the opposite holds for the higher type t. As we formally establish in Appendix A.2, in equilibrium the skill composition of M will thus dominate the skill composition of N (first-order stochastic dominance). In equilibrium, high amenity locations also command higher housing prices, and hence the case depicted in Figure Appendix A.1 is generic.

Appendix A.2 Worker Residential Location Decision

We assume that the β_{ani}'s are independently and identically drawn from a Fréchet distribution with shape parameter $\kappa > 1$ so that the probability that a worker with skills s chooses to live in n, work in i, and commute using mode a, denoted as λ_{anis}, obeys:

$$\lambda_{anis} = \left(\frac{V_{anis}}{\mathbb{E}V_s}\right)^{\kappa}, \qquad \mathbb{E}V_s \equiv \left[\sum_{a\in\{0,1\}}\sum_{n\in\mathcal{M}}\sum_{i\in\mathcal{M}} (V_{anis})^{\kappa}\right]^{1/\kappa}. \tag{A6}$$

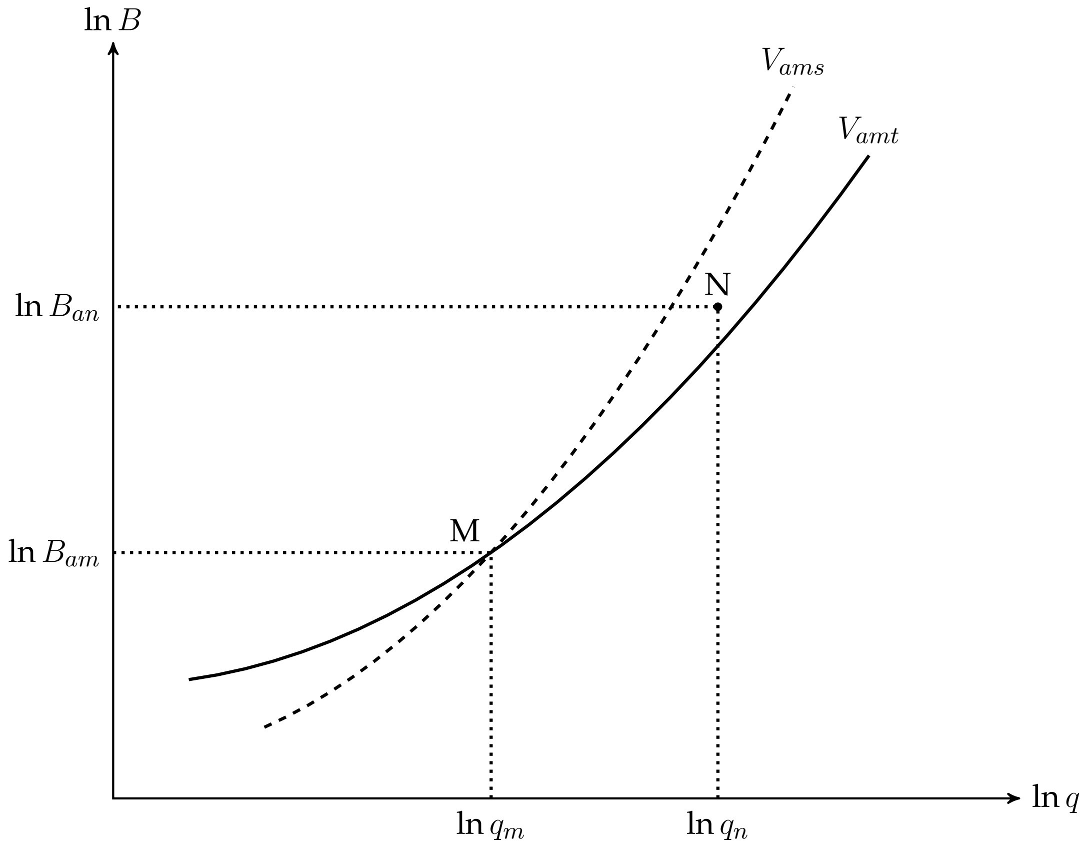
$\mathbb{E}V_s$ is proportional to the expected utility of type s before drawing the idiosyncratic preference shocks (the factor of proportionality is $1/\Gamma\left(\frac{\kappa}{\kappa-1}\right)$, where Γ is the gamma function). Let

$$\lambda_{ns} \equiv \sum_{a\in\{0,1\}}\sum_{i\in\mathcal{M}} \lambda_{anis}, \qquad \lambda_{is} \equiv \sum_{a\in\{0,1\}}\sum_{n\in\mathcal{M}} \lambda_{anis} \tag{A7}$$

denote the fraction of skill-s individuals who reside in municipality n or work in municipality i, respectively, with $\sum_n \lambda_{ns} = \sum_i \lambda_{is} = 1$ for all s.

Observe that V_{anis} is log-supermodular in (pa, w_{ns}) so that automobile use increases with income, namely, the fraction of people of skill s who live in n, work in i, and

Figure Appendix A.1: Indifference curves and sorting



Note: This figure plots (residential) amenities B on the vertical axis and housing prices q on the horizontal one. Indifference curves are type-specific, with V_{ams} and V_{amt} representing the common component of utility respectively enjoyed by skill types s and t in municipality m, with $s < t$. The willingness to pay for better amenities increases with type because of non-homothetic preferences, so that $V_{ans} < V_{ams}$ and $V_{ant} > V_{amt}$ hold: municipality n (which has both better amenities and more expensive housing than municipality m) is more attractive than municipality m for skill type t and less attractive for skill type s.

commute by car relative to the fraction of these people who do not commute by car, is equal to

$$\frac{\lambda_{1nis}}{\lambda_{0nis}} = \frac{B_{1ni}}{B_{0ni}} \left(1 - \frac{p}{w_s - q_n h}\right)^{\kappa}.$$

It is increasing in w_s by inspection.[2] Let

$$\phi_{ans} \equiv \frac{\sum_{i \in \mathcal{M}} \lambda_{anis}}{\lambda_{ns}}, \qquad \phi_{ais} \equiv \frac{\sum_{n \in \mathcal{M}} \lambda_{anis}}{\lambda_{is}} \tag{A8}$$

[2]Note that (A6) is defined for the pairs of skills and locations such that $w_{ns} > q_n h$ (i.e. earnings cover the subsistence level of housing), otherwise $\lambda_{anis} = 0$. We henceforth ignore this possibility in order to avoid cluttering notation.

denote the fraction of people of skill s who live in n or work in i and use commuting mode a; it then follows from the analysis above that the proportions of car commuters ϕ_{1ns} and ϕ_{1is} are also increasing in income.

We introduce some additional notation and definitions for further reference. First, the number of residents in municipality n and the number of workers (jobs) in municipality i are respectively equal to

$$R_n = \sum_{a \in \{0,1\}} \sum_{s \in \mathcal{S}} \lambda_{ns} L_s, \qquad J_i = \sum_{a \in \{0,1\}} \sum_{s \in \mathcal{S}} \lambda_{is} L_s. \tag{A9}$$

Second, let

$$\sigma_{ns} \equiv \frac{\lambda_{ns} L_s}{R_n} \tag{A10}$$

denote the fraction of the residential population of municipality n that belongs to skill group s, with $\sum_s \sigma_{ns} = 1$ for all n. Finally, define the entropy index as

$$T_n \equiv - \sum_{s \in \mathcal{S}} \sigma_{ns} \ln \left(\sigma_{ns} \right). \tag{A11}$$

This index is monotonically decreasing in segregation: with four income categories, T_n takes value $\ln(4)$ when all income groups are equally represented and value zero when a single income category resides in n.

Appendix A.3 Housing Markets

Housing markets are segmented. They clear if the following equality holds:

$$\begin{aligned} q_n H_n = & \sum_{a \in \{0,1\}} \sum_{s \in \mathcal{S}} \lambda_{ans} L_s E^H_{ans} \\ & R_n \left[\alpha q_n h + (1-\alpha) \sum_{s \in \mathcal{S}} \sigma_{ns} w_s \right], \end{aligned} \tag{A12}$$

where the first equality follows from (A2) and (A9) and the second one follows from (A10). That is, housing prices in n depend on both the size and the composition of its residential population: the larger and the wealthier it is, the larger q_n.

Landlords own the housing stock and are assumed to spend all their income on the numéraire good C.

Appendix A.4 Equilibrium

Given the preference parameters of the model $\left\{\alpha,\kappa,h,\{B_{ani}\}_{a\in\{0,1\},n,i\in\mathcal{M}}\right\}$ and endowments $\{\{H_n\}_{n\in\mathcal{M}},\{L_s\}_{s\in\mathcal{S}},\{w_s\}_{s\in\mathcal{S}}\}$, an equilibrium is defined as a vector of endogenous variables $\left\{\{\lambda_{anis}\}_{a\in\{0,1\},n,i\in\mathcal{M},s\in\mathcal{S}},\{q_n\}_{n\in\mathcal{M}},\{\mathbb{E}V_s\}_{s\in\mathcal{S}}\right\}$ such that (i) housing markets clear, i.e. equation (A12) holds; (ii) location decisions are governed by (A7). Such an equilibrium exists and is unique. Labor markets clear in a trivial way (demand for any type of labor is infinitely elastic in all municipalities), and the full employment conditions $L_s = L_s \sum_{a,n,i} \lambda_{anis}$ also hold trivially because the λ_{anis}'s are shares and add up to one as $\sum_{a,n,i} \lambda_{anis} = 1$. The homogeneous good market clears by Walras' law.

Appendix A.5 Comparative Statics – Residential Populations

We establish the following results: consider two municipalities, n and m, that are similar in all aspects except that the former has better residential amenities than the latter, namely $B_{an} > B_{am}$, $H_n = H_m$, $d_{ni} = d_{mi}$ for all $i \neq n,m$ and all $a \in \{0,1\}$, and $d_{nm} = d_{mn}$. Then,

1. Housing prices are higher in the municipality endowed with nicer amenities:

$$\forall a \in \{0,1\}: \qquad (B_{an} - B_{am})(q_n - q_m) > 0. \tag{A13}$$

2. The skill composition of the municipality endowed with nicer amenities first-order stochastically dominates the skill composition of the other municipality:

$$\forall a \in \{0,1\}, \forall s,t \in \mathcal{S}, \quad s < t: \qquad (B_{an} - B_{am})\left(\frac{\lambda_{nt}}{\lambda_{mt}} - \frac{\lambda_{ns}}{\lambda_{ms}}\right) > 0.$$

3. Resident population size and the skill composition of municipalities: there exists $\tilde{s} < S$ such that the resident population with skills $s > \tilde{s}$ is higher in the municipality endowed with nicer amenities, $\forall s > \tilde{s} : \lambda_{ns} > \lambda_{ms}$. Furthermore, if $1 < \tilde{s} < S$, then the nicer municipality attracts *fewer* low-skill workers than municipality M (i.e. $\forall s < \tilde{s} : \lambda_{ns} < \lambda_{ms}$), in which case the difference in equilibrium population sizes $R_n - R_m$ is ambiguous.

To see the first result, assume instead that $B_{an} > B_{am}$ and $q_n \leq q_m$ hold simultaneously. Then, using (A4) and (A6), we obtain that

$$\frac{\lambda_{nis}}{\lambda_{mis}} \geq \left(\frac{B_{an}}{B_{am}}\right)^{\kappa} > 1$$

holds for all i,s, which then implies by (A7) that $\lambda_{ns} > \lambda_{ms}$ for all s, and in turn a higher housing demand in n than in m. Higher housing demand yields higher housing prices, $q_n > q_m$ by (A12), which contradicts our initial working assumption. We thus conclude that

$$(B_{an} - B_{am})(q_n - q_m) \geq 0$$

holds (with strict inequality whenever $B_{an} \neq B_{am}$ for some $a \in \{0,1\}$).

The second and third results follow by (A5). Specifically, the single-crossing property of V_{nis} implies that there exists $\tilde{s} < S$ such that $\lambda_{ni\tilde{s}} = \lambda_{mi\tilde{s}}$ and $\lambda_{nis} > \lambda_{mis}$ for all $s > \tilde{s}$ and all $i \in \mathcal{M}$. That is to say, the more desirable of the two locations attracts a higher number of high-skilled residents and workers at the bottom of the skill distribution with $s < \tilde{s}$ will end up in the less desirable location. This result is a direct consequence of non-homothetic preferences and housing being a necessity by $h > 0$ in (A1).

Appendix A.6 Qualitative Predictions in Triple Differences

Here, we derive a 'triple-difference' qualitative prediction about the composition of a municipality that gets a positive amenity shock such as access to the highway network. If municipality n gets a highway access, then we assume $\hat{B}_{1n} > 0$ but $\hat{B}_{0n} = 0$, namely, that shock impacts car owners positively and has a lower effect (here normalized to zero) on non-car commuters.

1. Consider municipality n that receives a positive shock $\hat{B}_{1n} > 0$ (here the 'hat' notation means log changes, $\hat{x} \equiv \mathrm{d}x/x$). Then, the size of resident population

with skill s changes as per

$$\begin{aligned}\frac{1}{\kappa}\hat{\lambda}_{ns} =& \frac{1}{\kappa}\sum_{a\in\{0,1\}}\sum_{i\in\mathcal{M}}\frac{\lambda_{anis}}{\lambda_{ns}}\hat{\lambda}_{anis}\\ &= \sum_{a\in\{0,1\}}\sum_{i\in\mathcal{M}}\frac{\lambda_{anis}}{\lambda_{ns}}\left\{\left[\underbrace{\hat{B}_{an}}_{\text{Direct}} - \underbrace{\left(1-\alpha+\frac{q_n h}{w_s - q_n h - pa}\right)\hat{q}_n}_{\text{Indirect}}\right](1-\lambda_{anis})\right.\\ &\left. - \underbrace{\sum_{a\in\{0,1\}}\sum_{m\neq n}\sum_{j\neq i}\lambda_{amjs}\hat{V}_{amjs}}_{\text{General Equilibrium}}\right\}. \qquad \text{(A14)}\end{aligned}$$

The size of the resident population of skill s increases as per the *Direct Effect* of improved automobile access to jobs, i.e.

$$\frac{1}{\kappa}\hat{\lambda}^{\text{Direct}}_{ns} = \phi_{ns}\left(1 - \mathcal{H}_{1ns}\lambda_{1ns}\right)\hat{B}_{1n},$$

where

$$\mathcal{H}_{ans} \equiv \sum_{i\in\mathcal{M}}\left(\frac{\lambda_{anis}}{\lambda_{ans}}\right)^2, \qquad \lambda_{ans} \equiv \sum_{i\in\mathcal{M}}\lambda_{anis}$$

are respectively the Herfindahl index and the fraction of the skill-s resident population of municipality n choosing commuting mode a. The size of the resident population of skill s decreases as per the *Indirect Effect* due to the change in housing prices, i.e.

$$\frac{1}{\kappa}\hat{\lambda}^{\text{Indirect}}_{ns} = \sum_{a\in\{0,1\}}\left(\phi_{ans} - \mathcal{H}_{ans}\lambda_{ans}\right)\left(1-\alpha+\frac{q_n h}{w_s - q_n h - pa}\right)\hat{q}_n,$$

where $\hat{q}_n > 0$ by (A13). The sum of the *Direct* and *Indirect Effects* can be positive or negative, depending on the skill level s and commuting mode a. Specifically, this sum is unambiguously negative for all non-car users since the direct effect is nil and the heterogeneous effect is negative (they do not benefit from the highway but are hurt by rising housing prices); among car users, it is positive for all skills s such that

$$\frac{\hat{B}_{1n}}{\hat{q}_n} > 1-\alpha+\frac{q_n h}{w_s - q_n h - p}$$

holds; there exists a unique threshold $\tilde{w}$ such that this inequality holds for all $w_s > \tilde{w}$ and is violated otherwise. Thus, the sum of the *Direct* and *Indirect Effects* is positive for car users at the top of the skill distribution but may be negative for car users at the bottom of the skill distribution. Last, the reallocation of residents brought about by this shock affects other municipalities in a general equilibrium; in particular, housing prices change in all municipalities. These effects are captured by the *General Equilibrium Effect* in the third term of (A14).

2. Consider now another municipality m that is initially identical to n in all respects – in particular $B_{am} = B_{an}$, $q_m = q_n$ – but that it receives a shock $\hat{B}_{1m}$ that is possibly different from $\hat{B}_{1n}$. Using $\lambda_{amis} = \lambda_{anis}$ for all a,i,s, we obtain a somewhat simpler difference-in-difference expression that purges the *General Equilibrium Effect* affecting all municipalities other than m,n:
$$\frac{1}{\kappa}\left(\hat{\lambda}_{ns} - \hat{\lambda}_{ms}\right) = \sum_{a\in\{0,1\}} \sum_{i\in\mathcal{M}} \frac{\lambda_{anis}}{\lambda_{ns}} \left(\hat{V}_{anis} - \hat{V}_{amis}\right)$$
$$= \sum_{a\in\{0,1\}} \left(1 - \mathcal{H}_{ans}\lambda_{ans}\right) \Bigg[\underbrace{\left(\hat{B}_{an} - \hat{B}_{am}\right)}_{\text{Direct}} - \underbrace{\left(1 - \alpha + \frac{q_n h}{w_s - q_n h - pa}\right)\left(\hat{q}_n - \hat{q}_m\right)}_{\text{Indirect}} \Bigg]. \qquad \text{(A15)}$$

3. Finally, consider two skill groups s,t with $w_s < w_t$. We obtain the following 'triple-difference' expression that purges part of the *Direct Effect* when $\mathcal{H}_{ant}\lambda_{ant} \approx \mathcal{H}_{ans}\lambda_{ans}$:[3]
$$\frac{1}{\kappa}\left[\left(\hat{\lambda}_{nt} - \hat{\lambda}_{mt}\right) - \left(\hat{\lambda}_{ns} - \hat{\lambda}_{ms}\right)\right] \approx \left(\phi_{nt} - \phi_{ns}\right)\left(\hat{B}_{1n} - \hat{B}_{1m}\right) - \left(\frac{q_n h}{w_t - q_n h - pa} - \frac{q_n h}{w_s - q_n h - pa}\right)\left(\hat{q}_n - \hat{q}_m\right) > 0, \qquad \text{(A16)}$$

[3]This condition is satisfied when residents of municipalities m and n commute to more than a few municipalities; when that is the case, both $\mathcal{H}_{ant}\lambda_{ant}$ and $\mathcal{H}_{ans}\lambda_{ans}$ are close to zero, and hence their difference is small, too.

where the inequality holds by inspection (recall $w_s < w_t$ and $\phi_{ns} < \phi_{nt}$) and by (A13). We are thus left with *heterogeneous* direct and indirect effects that arise because of non-homothetic preferences. If commuting access increases in n (relative to m) and if car use for commuting purposes is skill-biased (i.e. $\phi_{ns} < \phi_{nt}$), as it is the case in the data, then the skill composition of the workforce in municipality n shifts to the right (relative to the skill composition of m). In addition, by implication of (A13), we know that housing prices increase in n relative to m if and only if $\hat{B}_n > \hat{B}_m$. High-skill workers also spend a lower share of their income on housing and on car use than lower-skill workers. Together, the indirect and direct effects imply the main result that we take to the data: if access increases in n (relative to m) then the skill composition of the residential population in n shifts to the right (relative to the skill composition of the residential population in m).[4]

We make three additional comments. First, the triple-difference for changes in *worker* populations of two initially identical municipalities i and j is given by

$$\frac{1}{\kappa}\left[\left(\hat{\lambda}_{it}-\hat{\lambda}_{jt}\right)-\left(\hat{\lambda}_{is}-\hat{\lambda}_{js}\right)\right]=\left(\phi_{it}-\phi_{is}\right)\left(\hat{B}_{1i}-\hat{B}_{1j}\right). \tag{A17}$$

If commuting access increases in i (relative to j) and if car use for commuting purposes is skill-biased, then the skill composition of the workforce in municipality i shifts to the right (relative to the skill composition of j).

Second, in the regressions, the dependent variable of main interest is the population share of skill or income category s of some municipality n, σ_{nt}. Changes in this share are related to changes in λ_{nt} by (A10) so that $\hat{\sigma}_{ts}-\hat{\sigma}_{ns}$ has the same sign as $\hat{\lambda}_{ts}-\hat{\lambda}_{ns}$.

Finally, it follows from (A7), (A9), (A10), (A11), and $\sum_s \mathrm{d}\sigma_{ns} = 0$ for all n (since the σ's are shares), that any change in the entropy index is the following weighted sum of

[4]In our empirical work, we test this implication of the model qualitatively: we let $\hat{B}_{an} = \hat{B}$ with $\hat{B} > 0$ once municipalities are connected to the highway network, and we let $\hat{B}_{am} = \hat{b} < \hat{B}$ as long as they are not. Without further loss of generality, we normalize $\hat{b} = 0$ and $\hat{B} = 1$, i.e. we use dummy variables.

changes in municipal population shares:

$$\mathrm{d}\ln T_n = \sum_{s\in\mathcal{S}} \frac{\ln(\sigma_{ns})\,\sigma_{ns}}{\sum_{t\in\mathcal{S}}\ln(\sigma_{nt})\,\sigma_{nt}} \mathrm{d}\ln\sigma_{ns}. \tag{A18}$$

Hence, segregation increases ($\mathrm{d}\ln T_n < 0$) if the relative population of groups that are initially over-represented increases (or if the relative population of groups that are initially under-represented falls).[5]

We now turn to the composition of the working populations in municipalities, and how they react to the highway connection.

Appendix A.7 Empirically Testable Qualitative Theoretical Predictions

Summing up the qualitative results of the model that we take to the data, consider a municipality that gets a positive commuting shock. Then, ceteris paribus:

1. The effect on population sizes is ambiguous. The number of high-skilled, high-income residents increases by equation (A15).

2. The skill and earning distributions of the resident and working populations shift to the right by equations (A16) and (A17), respectively.

3. The positive commuting shock reduces segregation (increases the entropy index) in municipalities that are the most segregated to start with by equation (A18).

Two remarks are in order. First, as emphasized by Prediction no. 1 above, the impact of highway access on resident population sizes R_n and on the worker population size J_i are ambiguous. The direct, positive effect dominates the indirect, feedback effect of housing prices for households at the top of the earnings distribution but the latter *may* dominate the former for households at the bottom of the earnings distribution. Though

[5] The point is most easily made with two groups, say the majority group, whose share is equal to $\sigma_n > 1/2$, and the minority group, whose share is equal to $1 - \sigma_n < 1/2$; in this case,

$$\mathrm{d}T_n = -\ln\left(\frac{\sigma_n}{1-\sigma_n}\right)\mathrm{d}\sigma_n$$

and $\mathrm{d}\ln T_n$ are negative if and only if $\mathrm{d}\sigma_n > 0$.

the model is agnostic about the impact of highways on population sizes, it is still a valuable, policy-relevant question that we confront to the data.

Second, note that the algebra above is implicitly assuming that a highway connection also benefits non-commuters, defined as people who live and work in the same municipality. We do that in order to avoid cluttering notation and we can justify this assumption by emphasizing that households use their cars also for purposes other than commuting (Small and Verhoef, 2007). It is actually straightforward to impose $\hat{B}_{nn} = 0$ and see that the qualitative predictions are unchanged. A corollary of this fact is that all the qualitative predictions that pertain to the composition of the resident populations also hold for the out-commuter populations (defined as households living in the municipality but working in another one), and all the qualitative predictions that pertain to the composition of the worker populations also hold for the in-commuter populations (defined as households working in the municipality but living in another one).

Appendix B. The Swiss Highway Network

Appendix B.1 Background

Compared to some of its neighboring countries such as Germany and Italy, Switzerland began relatively late to construct its own national highway network. After World War II, the number of cars in Switzerland experienced a strong increase: from 18,000 personal cars in 1945 to 150,000 in 1950 and 500,000 in 1960 (Grotrian, 2007, p. 44). As a result, motorized traffic rose strongly and in the late 1950s, the federal government created a planning commission for a national road network. Before 1950, several ideas for highway projects in specific regions (e.g., between Bern and Thun) had been put forward, but none had been realized (see Blum, 1951, pp. 137-144).

The commission analyzed different options for the scope of the future road network, based on the guiding principle that the national road network should only serve the most important transport needs, i.e. primarily long-distance travel (Planungskommission, 1959, Band 2, p. 1). The proposal for the national road network not only consisted of highways, but of three different types of roads, including some class III roads that were opened to non-motorized traffic as well. In contrast, class I and class II roads were restricted to motorized travel, with class I roads always requiring a complete separation of the directions of travel and at least four lanes, two in each direction (Planungskommission, 1959, Band 1, pp. 65-66). In 1960, the Swiss parliament passed the national roads law and thus also defined the future location of highways in Switzerland to a large extent.

The subsequent construction of the network spanned over several decades, with cantons being responsible for detailed planning and actual construction work. As one of the first sections, the highway between Geneva and Lausanne was opened to public in 1963/1964, on time for the 1964 national exhibition in Lausanne. A substantial portion of the highway A1 connecting Geneva in the west with St. Gallen in the east was completed in the late 1960s. Other highways constructed during this early phase included a large portion of the A3 linking Zurich with the canton of Grisons, and first highway sections in the canton of Ticino. Other parts of the network, including the construction of the A2 crossing Switzerland from north (Basel) to south (Chiasso), followed a few years later.

Figures Appendix B.1 to A.3 contains a map of Switzerland's municipalities and its national motorway network as of 2012[6]. The map shows, in light grey, municipalities with an access point located within 10km reach that was open in a given year, from 1960 until 2010, the end of our observation period. Note that municipalities close to the A16 'Transjurane' (North/North-West) are not included in our sample as this highway was not part of the original planned network but added in 1984 after the creation of the canton of Jura. Shaded areas are municipalities that are part of an urban agglomeration area, as defined by the Federal Statistical Office in 2000. The five biggest cities (Zurich, Basel, Geneva, Lausanne, Bern), plus the main city at the south of the Alps, Lugano, are also represented.

Besides the cantons, also municipalities and the general public (e.g., land owners) were granted a say in the planning process of the highway network. As a result, the construction of the Swiss highway network was characterized by a 'certain inertia' not present in other countries (Ruckli, 1966, p. 7). Moreover, starting in the 1970s, there was growing opposition against new highway construction by environmental groups, which further slowed down the process (Schärer, 1999). In 1978, the Federal Council established a commission to reevaluate the expected benefits of six highway sections that were planned, but not yet constructed. The recommendation by the commission was to keep all investigated sections in the network, with the exception of one (see Kommission zur Überprüfung von Nationalstrassenstrecken, 1981). In 1986, the national parliament decided differently, removing two other sections from the network (Fischer & Volk, 1999).

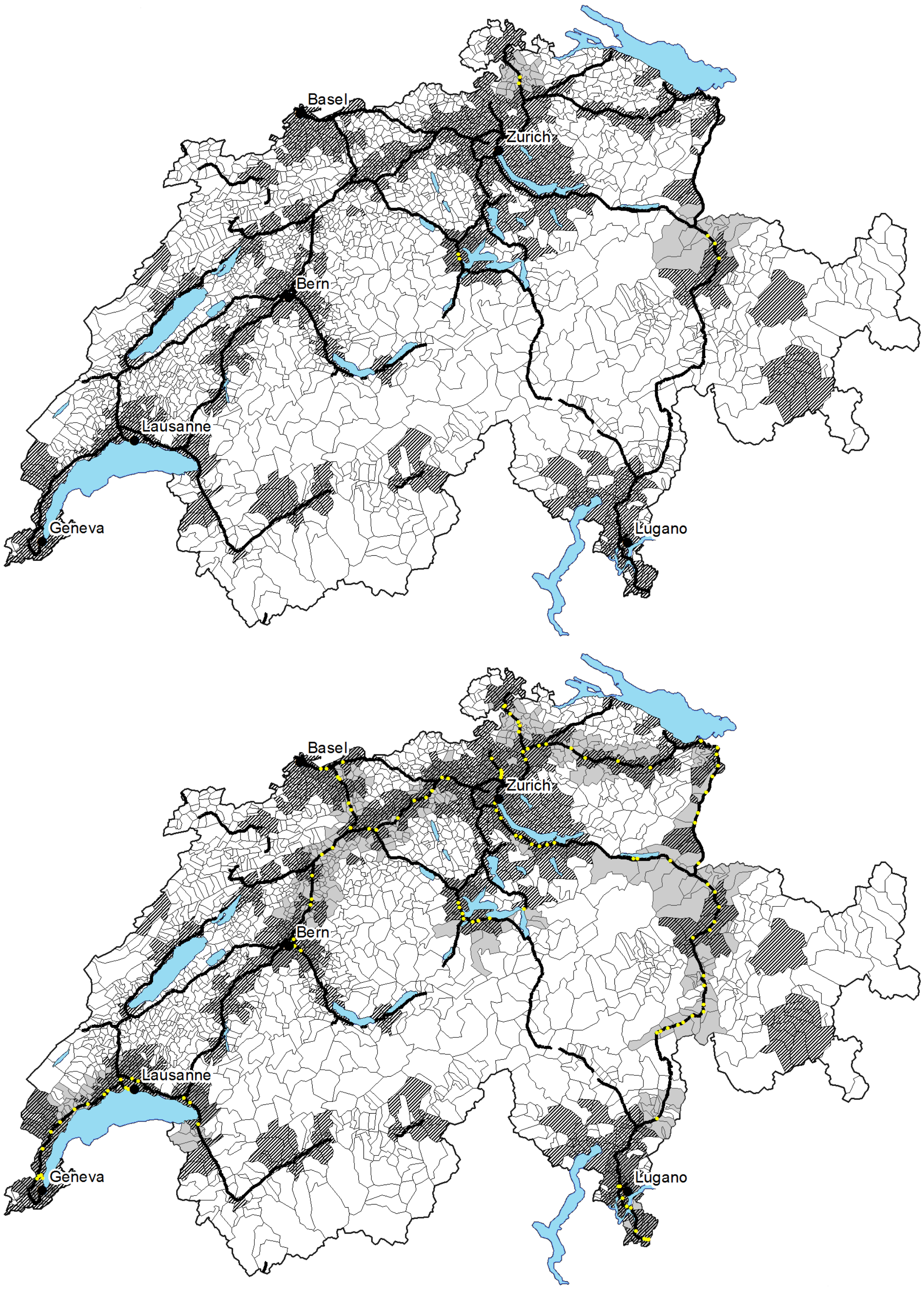
As of 2019, the Swiss national road network had a defined length of 1,892.5km, only slightly more than the originally planned network of 1,840km. Of these national roads, roughly 40km still had to be built (Bundesamt für Strassen, 2019). In addition, some

[6]See Appendix B.2 for a definition of motorways and other types of highways.

cantons have also established cantonal highways that are not part of the national road network. These highways represent only a small fraction of all highways, however.

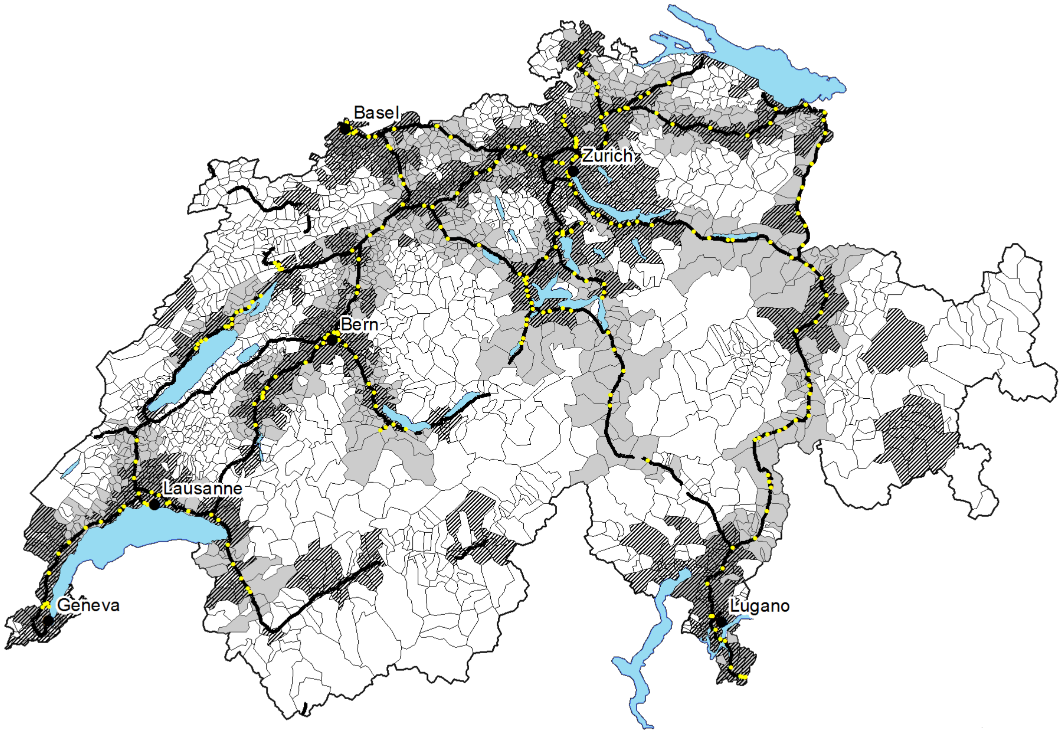
Until 2007, construction and maintenance of the national roads was the responsibility of the cantons, under supervision of the federal government. However, the cantons received substantial financial contributions from the federal government (Ruckli, 1966). These federal funds came from taxes on gasoline, payments from the general budget, and since 1985 from a yearly lump-sum user fee to use the national highways (the so-called 'vignette'). In the initial years between 1959 and 1965, the average funding share of the federal government equaled 86 percent (Ruckli, 1966, p. 9). Cost of highway construction rose substantially over time, soon reaching a multiple of the originally projected cost. By 1996, the estimated cost of the network had increased tenfold (Heller & Volk, 1999). As of January 1, 2008, the national roads and all responsibilities were transfered to the federal government (Galliker, 2009). The national road network plays a crucial role for both traffic within Switzerland and transit across Europe. The national roads account for less than 3 percent of all roads in Switzerland, but carry more than 40 percent of all motorized traffic (Bundesamt für Strassen, 2020).

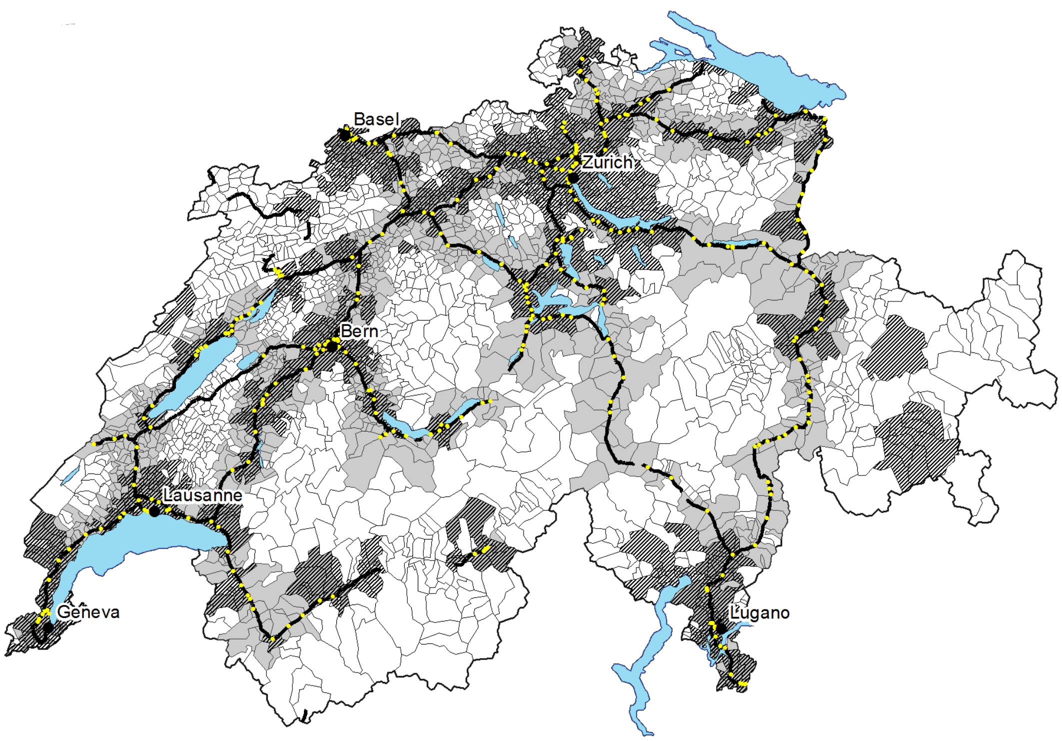
Figure Appendix B.1: Municipalities with highway access in 1960 and 1970



Note: Shaded areas denote municipalities that are part of an urban area as defined by the Federal Statistical Office in 2000. Municipalities with highway access within 10km road distance are in light gray. Access points open at a given year are in yellow. The map on the top (bottom) shows highway access open in 1960 (1970).

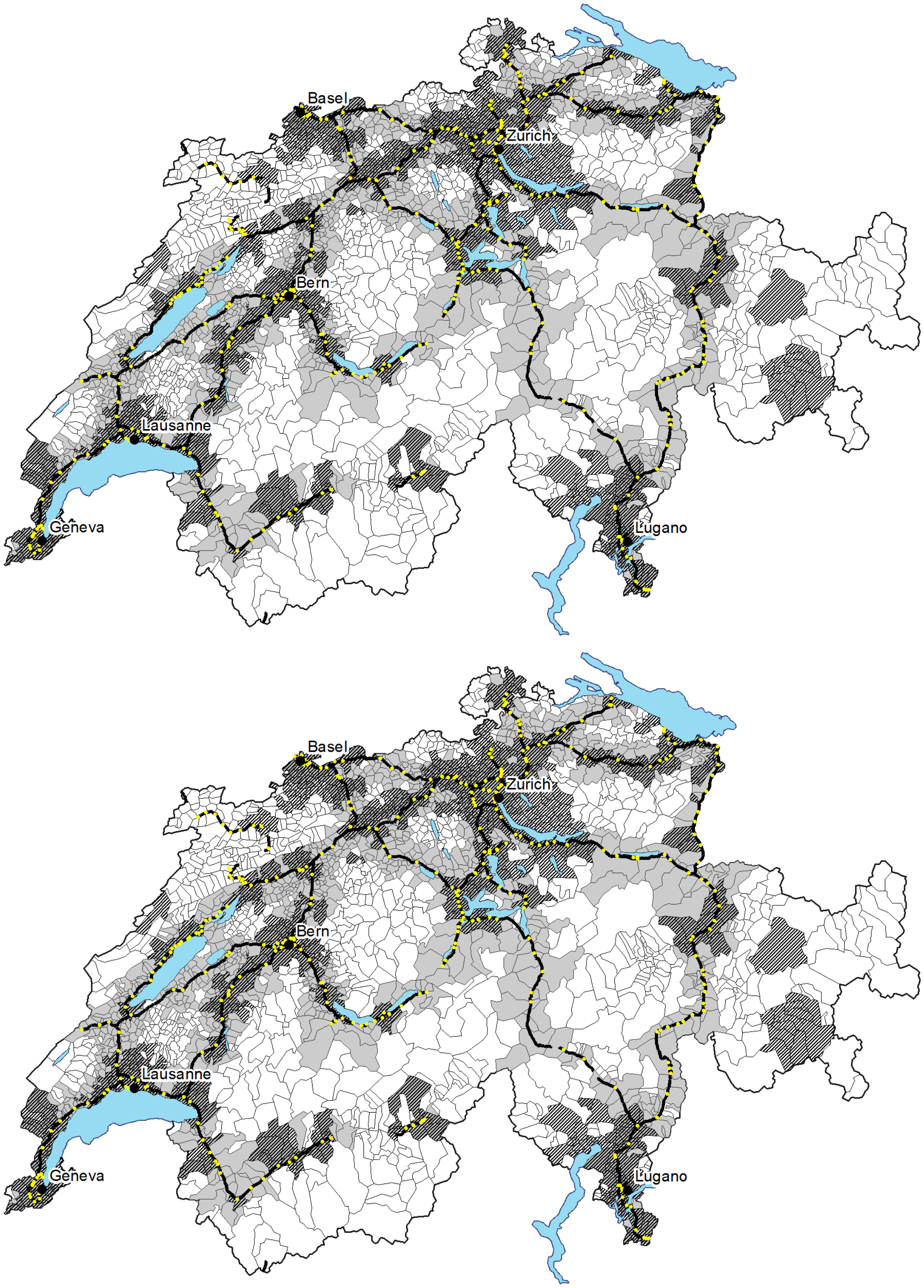
Figure Appendix B.2: Municipalities with highway access in 1980 and 1990





Note: Shaded areas denote municipalities that are part of an urban agglomeration area as defined by the Federal Statistical Office in 2000. Municipalities with highway access within 10km road distance are in light gray. Access points open at a given year are in yellow. The map on the top (bottom) shows highway access open in 1980 (1990).

Figure Appendix B.3: Municipalities with highway access in 2000 and 2010



Note: Shaded areas denote municipalities that are part of an urban agglomeration area as defined by the Federal Statistical Office in 2000. Municipalities with highway access within 10km road distance are in light gray. Access points open at a given year are in yellow. The map on the top (bottom) shows highway access open in 2000 (2010).

Appendix B.2 Data on Highway Access Points

Our database of highway access points is based on all access points contained in the VECTOR200 database from the Swiss Federal Office of Topography, swisstopo (version as of 2013). For each access point, we identified the opening date based on a list with highway section opening dates provided by the Swiss Federal Roads Office (ASTRA). For access points for which the list from ASTRA did not contain an opening date, we relied on information presented in Fischer and Volk (1999), historical maps from swisstopo accessed via their website, and on other public information sources (press releases, newspaper articles, etc.). For access points that were subject to capacity enhancements, we used the year when a new section was originally opened to public, rather than when it was upgraded later. One limitation of this definition is that some important upgrades of the network (such as the Kerenzerberg Tunnel along Walensee) are not captured in our database. We cross-checked our opening date with the work of Fröhlich and Axhausen (2002).

We limit our analysis to highways that have the status of national motorways ('Autobahnen') or dual-carriageways ('Autostrassen'), i.e. we exclude from the analysis cantonal highways. According to the swisstopo classification, national motorways encompass all fast-traffic controlled-access national roads with at least two lanes in each direction and a dividing strip while national dual-carriageways are defined as a national motorways without a dividing strip (with a lower speed limit). Cantonal highways (motorways and dual carriageways) were not necessarily built in order to connect Switzerland's large cities, but to improve accessibility of specific cities or regions[7]. Therefore, their construction is prone to be endogenous to local economic development.

For each town and year, we use the ArcGIS software to calculate the minimum road distance to the next highway access point based on the non-highway road network listed in the VECTOR200 database. These distances serve as proxy for the actual road distance

[7] We distinguish between national and cantonal motorways by the requirement of national motorways to display the national motorway tax vignette on the car.

between the place of residency in a municipality and the next highway access point. The actual road distance may slightly deviate from this measure for two main reasons: First, a municipality may contain more than one town and not all residents live at the town center. Second, certain local roads which are part of our road network database (consisting of all roads opened at the end of 2012) may have only been constructed during the course of the observation period. However, the average area of a municipality only equals approximately 16km^2. Therefore, these deviations should be fairly small and not systematically bias the results, as distances would be overestimated for some residents and underestimated for others. For municipalities consisting of more than one town, we use the minimum distance. The same procedure was used for municipalities that merged over the observation period.

Based on the estimated travel distance to the next highway access point, we clustered municipalities into different distance bands: 1-5km, 5-10km, 10-15km and 15-20km. Distance band 1-5km includes all municipalities with a calculated road distance of up to 5.0km, band 5-10km all municipalities with a distance larger than 5.0km and up to 10.0km, band 10-15km all municipalities with a distance larger than 10.0km and up to 15.0km, and band 15-20km all municipalities with a distance larger that 15.0km and up to 20.0km. We exclude all 908 municipalities that are part of an urban agglomeration area based on the definition by the Swiss Federal Statistical Office in 2000, to further reduce potential endogeneity concerns (see Section 3.2 for details). We also do not look at municipalities located 20km and further away from highway access points as these municipalities are to a large extent concentrated in mountainous regions in the cantons of Valais and Bern.

Appendix C. Data and Summary Statistics

We construct data on the income distribution using the Swiss federal income tax statistics with information at the municipality level from 1947 to 2010. These statistics encompass all regular taxpaying units subject to the federal income tax. These taxpaying units are individuals or households (depending on the marital status) who reside in Switzerland and earn no income in foreign countries. This definition excludes foreign taxpayers, taxpayers with special tax treatment, and taxpayers with annual income below a certain threshold (CHF 16,000 for singles and CHF 27,000 for couples in 2010).[8] In 2010, the share of households not paying any federal income tax was 20% and, among those paying federal income taxes, 90% were regular taxpayers whose earnings accounted for 86% of the taxable income. Data are available on a two-year basis from 1947 to 2000 and on a yearly basis thereafter. We aggregate all data into two-year averages.[9]

Our main variables of interest are the number of taxpayers and the share of taxpayers with income above some income percentiles (median, 75th and 90th percentiles). Percentiles are calculated on the basis of the nation-wide population of taxpayers for each tax period. To fix ideas, in year 2010 these percentiles corresponded to pre-tax incomes of CHF 54,200, CHF 78,300, CHF 115,000 for the 50th, 75th and 90th percentile, respectively. We compute percentiles using individual-level data for the period 1973-2010. For the period 1947-1972, the federal income tax statistics report, at the national level, the number of regular taxpayers paying a federal income tax and their income by income class. We approximate percentiles using a Pareto interpolation. Statistics at the municipality level report only the count of taxpayers for 5 to 8 income classes (depending on the years) with the upper class counting taxpayers with income higher than CHF 100,000 (CHF 50,000 before 1951). We approximate the share of taxpayers using a linear interpolation between the logarithms of taxpayer shares and incomes as implied by a Pareto distribution.

[8] The average exchange rate between 1970 and 2010 equaled 1.80 Swiss francs (CHF) per US dollar.

[9] The tax collection changed from a bi-annual praenumerando system to an annual postnumerando system during the early 2000s (the exact timing varies by canton).

We complement these statistics with census data on employment by education level for decennial years for the period 1950-2010. We compute residence-based and workplace number of employees as well as the number of out- and in-commuters for three different levels of education: compulsory school ('low education'), maturity and professional vocation ('middle education'), university-level ('high education') using individual-level census data available for the years 1970-2010.[10] We complement information on workplace-, residence-based employment and commuting with census data aggregated at the municipality level for 1950 and 1960.

Table Appendix C.1 displays the mean values for different sub-samples. Column (1) pertains to all municipalities, Column (2) to non-urban municipalities that got a highway access within 10km reach during the sample period, and Column (3) to non-urban municipalities that were still not connected by 2010. Columns (4) and (5) present the mean values for the 27 major 'urban centers' and for the remaining 'suburban' municipalities, respectively. We refer to cities of categories 1 and 2 in the nomenclature the municipalities developed by the Swiss Federal Statistical Office (2000) as 'urban centers.' They are the largest Swiss cities and towns, ranging from Zurich (382,623 inhabitants) to Locarno (15,637 inhabitants). 'Urban' and 'non-urban' municipalities refer to municipalities that are part or not of an urban agglomeration area as defined by the Swiss Federal Statistical Office (2000).

Non-urban municipalities have on average fewer inhabitants, taxpayers, and workers than urban municipalities. Importantly, the average non-urban municipality that got a highway access within 10km during the sample period is very similar to the average non-urban municipality that did not get such an access (figures in Columns (2) and (3) are very similar). For instance, municipalities in our sample group are equally likely as other non-urban municipalities to be endowed with a railway station.

Table Appendix C.2 reports summary statistics pertaining to the planning phase (1947-

[10]For year 2010, we use the new census that covers a sample of 300,000 individuals each year over the period 2010-2014. Census data contain only information on the residents in Switzerland. The number of workers does not include cross-border workers living in another country.

1955), namely, before the opening of the first highway section. Column (1) displays the mean values for our sample of non-urban municipalities that eventually get a highway access within 10km. Columns (2) to (5) decompose the sample according to the opening time of the highway access (before 1970, between 1970 and 1980, between 1980 and 1990, and after 1990). The last column reports the p-values of testing the hypothesis that the figures in Columns (2) to (5) are identical. Results display no statistical differences in the mean population, number of taxpayers, income composition of municipalities, workplace- and residence-based employment, nor, to a lesser extent in railway access between municipalities. There is a statistically significant difference in the growth rate of taxpayers, which ranges between -5.6% and -8.5%, but no clear pattern emerges in terms of the timing of access opening.[11] Differences in mean values are also quantitatively small. They are thus unlikely to have affected the highway opening year in a substantial way.

[11] The negative growth rate of the number of taxpayers is due to changes in deductions of the federal income tax for the fiscal periods 1949/50 and 1951/52. These changes are absorbed by the fixed effects in our empirical analysis.

Table Appendix C.1: Summary statistics

	All municipalities	Non-urban connected municipalities	Non-urban non-connected municipalities	Urban centers	Suburban municipalities
	(1)	(2)	(3)	(4)	(5)
Population (in 1,000)	2.57	1.11	1.07	64.67	3.30
	(11.00)	(1.39)	(1.35)	(80.16)	(4.20)
# Taxpayers (in 1,000)	0.83	0.33	0.30	22.70	1.10
	(4.06)	(0.49)	(0.45)	(30.42)	(1.61)
Share in bottom-50% income	0.57	0.59	0.63	0.48	0.50
	(0.12)	(0.10)	(0.11)	(0.06)	(0.11)
Share in 50-25% quartile	0.23	0.23	0.22	0.25	0.25
	(0.05)	(0.05)	(0.06)	(0.03)	(0.04)
Share in top-25-10%	0.12	0.12	0.10	0.16	0.15
	(0.05)	(0.05)	(0.05)	(0.03)	(0.05)
Share in top-10% decile	0.08	0.06	0.05	0.11	0.11
	(0.06)	(0.04)	(0.04)	(0.04)	(0.07)
Entropy index	1.06	1.03	0.95	1.22	1.17
	(0.20)	(0.18)	(0.21)	(0.07)	(0.15)
# Residents (in 1,000)	1.24	0.53	0.50	31.14	1.60
	(5.47)	(0.68)	(0.64)	(40.53)	(2.09)
Share with low education	0.30	0.31	0.36	0.27	0.25
	(0.17)	(0.17)	(0.19)	(0.08)	(0.13)
Share with middle education	0.54	0.54	0.53	0.51	0.54
	(0.11)	(0.11)	(0.13)	(0.07)	(0.08)
Share with high education	0.16	0.15	0.12	0.22	0.20
	(0.11)	(0.10)	(0.09)	(0.12)	(0.12)
Entropy index	0.89	0.88	0.85	0.98	0.93
	(0.10)	(0.10)	(0.11)	(0.05)	(0.07)
# Workers (in 1,000)	1.25	0.43	0.43	45.26	1.33
	(8.15)	(0.71)	(0.66)	(61.91)	(2.21)
Share with low education	0.34	0.35	0.39	0.24	0.30
	(0.17)	(0.17)	(0.19)	(0.09)	(0.13)
Share with middle education	0.53	0.53	0.51	0.54	0.54
	(0.12)	(0.13)	(0.14)	(0.06)	(0.09)
Share with high education	0.13	0.12	0.10	0.22	0.16
	(0.09)	(0.09)	(0.08)	(0.11)	(0.10)
Entropy index	0.88	0.87	0.84	0.97	0.92
	(0.12)	(0.12)	(0.13)	(0.04)	(0.09)
# Out-commuters (in 1,000)	0.56	0.26	0.19	6.27	0.98

Continued on next page

	(1)	(2)	(3)	(4)	(5)
	(1.37)	(0.37)	(0.28)	(7.80)	(1.40)
Share with low education	0.26	0.26	0.30	0.24	0.22
	(0.16)	(0.16)	(0.18)	(0.08)	(0.12)
Share with middle education	0.57	0.57	0.57	0.51	0.56
	(0.12)	(0.12)	(0.14)	(0.08)	(0.09)
Share with high education	0.17	0.16	0.13	0.24	0.22
	(0.12)	(0.11)	(0.10)	(0.12)	(0.13)
Entropy index	0.87	0.86	0.83	0.99	0.92
	(0.13)	(0.13)	(0.16)	(0.05)	(0.07)
# In-commuters (in 1,000)	0.57	0.15	0.12	21.21	0.71
	(4.11)	(0.38)	(0.27)	(32.81)	(1.49)
Share with low education	0.30	0.31	0.31	0.20	0.29
	(0.18)	(0.19)	(0.22)	(0.09)	(0.14)
Share with middle education	0.57	0.58	0.58	0.56	0.56
	(0.17)	(0.19)	(0.21)	(0.07)	(0.12)
Share with high education	0.12	0.11	0.10	0.23	0.15
	(0.12)	(0.12)	(0.12)	(0.11)	(0.11)
Entropy index	0.80	0.76	0.72	0.94	0.88
	(0.25)	(0.26)	(0.29)	(0.05)	(0.16)
Distance to closest urban center	22.80	22.15	32.04	0.00	15.80
	(16.14)	(11.72)	(18.97)	(0.00)	(12.12)
Railway station	0.39	0.33	0.35	1.00	0.46
	(0.49)	(0.47)	(0.48)	(0.00)	(0.50)
# Municipalities	2479	782	789	27	881

Note: Standard deviation in parentheses. Population is based on yearly data for 1981-2010 and decennial census data for 1950-1980. Taxpayer data are based on the federal income tax statistics. Residents (workers) refer the number of employees residing (working) in a municipality. Out-commuters (in-commuters) consist of the number of residents (workers) working (living) in another municipality. Source: Decennial population census data 1950-2010 (1970-2010 for decomposition by education level). 'Urban' and 'non-urban' municipalities refer to municipalities that are part or not of an urban agglomeration area as defined by the Swiss Federal Statistical Office (2000). An 'urban center' is a city of category 1 or 2 according to the nomenclature of the municipalities developed by the Swiss Federal Statistical Office (2000). Distance to the closest urban center is computed using the road network as of 2012 (including highways). Railway station is a dummy variable indicating whether a municipality has a railway station (either for passengers or goods) in 2017. Data from the Swiss Federal Office of Transport.

Table Appendix C.2: Characteristics of connected municipalities by time period

	Mean values for period 1947-1955 for non-urban (to be) connected municipalities					
	All opening years	Access opened before 1970	Access opened 1970-1979	Access opened 1980-1989	Access opened after 1990	Test equality (p-value)
	(1)	(2)	(3)	(4)	(5)	(6)
Population (in 1,000)	0.95	1.00	0.97	0.81	0.83	0.26
	(1.15)	(1.35)	(1.05)	(0.90)	(0.88)	
# Taxpayers (in 1,000)	0.16	0.18	0.16	0.14	0.15	0.41
	(0.25)	(0.30)	(0.21)	(0.20)	(0.20)	
Share in bottom-50% income	0.62	0.62	0.63	0.63	0.62	0.24
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	
Share in 50-25% quartile	0.21	0.21	0.21	0.21	0.21	0.34
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	
Share in top-25-10%	0.11	0.11	0.10	0.11	0.11	0.23
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	
Share in top-10% decile	0.06	0.07	0.06	0.06	0.06	0.26
	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	
Entropy index	0.98	0.99	0.98	0.98	0.99	0.51
	(0.18)	(0.19)	(0.17)	(0.18)	(0.18)	
# Taxpayers growth rate	-7.27	-6.89	-8.54	-5.65	-6.35	0.00
	(30.29)	(29.04)	(29.42)	(36.45)	(29.46)	
# Residents (in 1,000)	0.40	0.43	0.41	0.35	0.35	0.23
	(0.49)	(0.60)	(0.43)	(0.38)	(0.37)	
# Workers (in 1,000)	0.37	0.38	0.38	0.34	0.31	0.46
	(0.51)	(0.63)	(0.44)	(0.40)	(0.37)	
Railway station	0.33	0.30	0.32	0.42	0.39	0.10
	(0.47)	(0.46)	(0.46)	(0.49)	(0.49)	
# Municipalities	782	307	285	102	88	

Note: Standard deviation in parentheses. Taxpayer data are based on the federal income tax statistics for the period 1947-1955. Population, workplace and residence-based employment are from the population census 1950. Test equality performed with standard errors clustered at municipality level.

Appendix D. Extensions and Robustness Analysis

In this Online Appendix, we present several extensions and robustness analysis for our baseline results of Table 2.

Appendix D.1 Income and Income Per Capita

In order to better understand the role of sorting, we complement the results on the number of taxpayers with the effect on total income reported by those taxpayers and on income per taxpayer (our units of observation remain the municipalities). These data are only available since 1973 when half of our sample municipalities are already treated, so we start reproducing results of Panel B, Table 2 in Panel A of Table Appendix D.1. To further ease interpretation of the effect on income per taxpayer, Columns (4) to (7) report the effect on the *number* of taxpayers instead of on *shares* (see footnote 18). The number of observations drops by 40% and results are smaller in magnitude but still comparable to our baseline: highway access leads to an increase of 9.5% of the total number of taxpayers (Column 3), and this effect rises with the position in the income distribution, from +4% for the bottom half (Column 4) to +27% for the top decile (Column 7).

Panels B and C in Table Appendix D.1 present results for total income and for income per taxpayer, respectively (the latter being the difference between Panel B and Panel A). Highway access increased total income by +13.5% (Column 3) with a disproportionate effect for top-10% taxpayers (+26.2%, Column 7) compared to bottom-50% taxpayers (+5.1%, Column 4), confirming the rightward shift of the income distribution uncovered above. The effect on total income is larger than the effect on the number of taxpayers, which establishes that highway access increased the tax base of municipalities. By contrast, highway access did not affect income per taxpaying household within income groups (Panel C, Columns 4-7), suggesting that the rightward shift in the income distribution was driven by income sorting.[12]

[12] The difference between Panel C, Column (3), and Panel C, Columns (4) to (7), is explained by the larger share of top-income taxpayers in the tax base compared to their population shares.

Table Appendix D.1: Impact of highway access on total and per-taxpayer income (1973-2010)

	Total			By income level			
				below 50%	top 50%-25%	top 25%-10%	top 10%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Long-term cumulative effect on number of taxpayers							
Long-term effect	0.098**	0.092***	0.091***	0.043	0.150***	0.131**	0.240***
	(0.047)	(0.030)	(0.030)	(0.028)	(0.045)	(0.060)	(0.087)
# Observations	14220	14220	14220	14220	14220	14220	14220
# Municipalities	779	779	779	779	779	779	779
Panel B: Long-term cumulative effect on total income							
Long-term effect	0.130**	0.129***	0.127***	0.050*	0.147***	0.126**	0.233**
	(0.063)	(0.037)	(0.036)	(0.026)	(0.045)	(0.060)	(0.092)
# Observations	14220	14220	14220	14220	14220	14220	14220
# Municipalities	779	779	779	779	779	779	779
Panel C: Long-term cumulative effect on income per taxpayer							
Long-term effect	0.031	0.037**	0.036**	0.007	-0.003	-0.005	-0.008
	(0.023)	(0.017)	(0.017)	(0.006)	(0.003)	(0.006)	(0.051)
# Observations	14220	14220	14220	14220	14220	14220	14220
# Municipalities	779	779	779	779	779	779	779
Municipality time trends	No	Yes	Yes	Yes	Yes	Yes	Yes
Time-rail fixed effects	No	No	Yes	Yes	Yes	Yes	Yes

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. The dependent variable is the log of the number of taxpayers (Panel A), the log of total income (Panel B) and the log the per-taxpayer income (Panel C). Two-year panel covering the period 1973-2010. All regressions include municipality fixed effects and time fixed effects.

Appendix D.2 Employment Size and Composition

In this section, we look at the effects of highway access on employment by education level. Under the reasonable assumptions that education is a good proxy for income and that highway access in a given municipality is orthogonal to education choices made years or decades earlier, the coefficients of these education variables are consistent with the sorting mechanism only. Table Appendix D.2 presents the results using decennial census data on the working population covering the period 1950 to 2010. Because census data collect information only every ten years, we have far fewer observations than in Section 4. We estimate equation (16) using two lags of our access dummy variable and report the cumulative effect for each decade after the highway access.[13] We present results for

[13] As few observation periods are available for census data, we do not include forward lags in the estimating equation.

residential population of treated municipalities in Panel A and for employees working in the municipality in Panel B. All regressions include municipality fixed effects, rail-year fixed effects and municipality time trends. Thus, the coefficients of Table Appendix D.2, Column (1) should be compared to those of Table 2, Column (3).

Qualitative Prediction no. 1 (Municipality Size)

The coefficient of the long-term effect (after more than two decades) for the number of residents (Table Appendix D.2, Panel A, Column 1) is positive (+7.6%) and statistically significant. The effect builds up over time, starting one decade after opening. The long-term effect for the number of workers (Table Appendix D.2, Panel B, Column 1) is also positive (+4.9%) but not statistically significant at conventional levels.

Qualitative Prediction no. 2 (Municipality Composition)

Columns (2) to (6) of Table Appendix D.2 restrict the sample to years 1970-2010 for which employment by education level is available. The estimating sample is also restricted to have the same number of observations across these columns. The size of the sample drops by almost 50% and coefficients are less precisely estimated as a result. Column (2) replicates the specification of Column (1) and the estimated long-term effect becomes smaller and loses statistical significance. Results on the composition effect show that highway access attracts high-skilled workers (Panel B, Column 5) but has a negative effect on the share of residents and workers with intermediate level of education (Column 4). These results are consistent with the results of Table 2 on the share of top-income taxpayers compared to taxpayers in the bottom-50% of the income distribution.[14]

[14]As our taxpayer data do not include the 20% of low-income taxpayers who do not pay any federal income tax (see Appendix C), our bottom-50% category includes most likely employees with low and intermediate levels of education (which account on average for 86% of the residential population in our connected municipalities, see Table Appendix C.1).

Table Appendix D.2: Impact of highway access on employment size and composition

	# Employees		Share of employees by education level:			Entropy index
			low	middle	high	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Residents						
Effect in 1st decade of opening	0.020	-0.010	0.015	-0.029*	0.049	0.002
	(0.014)	(0.017)	(0.033)	(0.017)	(0.043)	(0.016)
Cumulative effect in 1st and 2nd decades	0.057**	-0.003	0.004	-0.049*	0.085	-0.005
	(0.025)	(0.031)	(0.050)	(0.027)	(0.056)	(0.026)
Cumulative effect after more than 2 decades	0.073**	-0.004	-0.019	-0.078**	0.089	-0.021
	(0.034)	(0.039)	(0.069)	(0.037)	(0.078)	(0.034)
# Observations	5201	3750	3750	3750	3750	3750
# Municipalities	782	781	781	781	781	781
Panel B: Workers						
Effect in 1st decade of opening	0.014	0.008	0.037	-0.029	0.081	0.011
	(0.022)	(0.028)	(0.031)	(0.018)	(0.057)	(0.014)
Cumulative effect in 1st and 2nd decades	0.049	0.031	0.055	-0.060**	0.120*	0.009
	(0.040)	(0.052)	(0.049)	(0.027)	(0.070)	(0.022)
Cumulative effect after more than 2 decades	0.048	0.029	0.077	-0.096**	0.151*	0.004
	(0.047)	(0.071)	(0.070)	(0.037)	(0.087)	(0.028)
# Observations	5114	3568	3568	3568	3568	3568
# Municipalities	782	771	771	771	771	771
Panel C: Out-commuters						
Effect in 1st decade of opening	-0.006	0.013	0.002	-0.022	0.048	0.007
	(0.021)	(0.018)	(0.049)	(0.020)	(0.048)	(0.015)
Cumulative effect in 1st and 2nd decades	-0.003	0.008	0.010	-0.042	0.142**	0.017
	(0.034)	(0.031)	(0.073)	(0.031)	(0.062)	(0.024)
Cumulative effect after more than 2 decades	-0.001	-0.001	-0.010	-0.067	0.186**	0.014
	(0.050)	(0.042)	(0.095)	(0.044)	(0.092)	(0.032)
# Observations	5197	3602	3602	3602	3602	3602
# Municipalities	782	771	771	771	771	771
Panel D: In-commuters						
Effect in 1st decade of opening	0.037	0.014	0.016	-0.007	0.143	0.036**
	(0.039)	(0.043)	(0.052)	(0.035)	(0.095)	(0.017)
Cumulative effect in 1st and 2nd decades	0.107	0.055	0.030	-0.048	0.211	0.034
	(0.070)	(0.068)	(0.081)	(0.054)	(0.132)	(0.025)
Cumulative effect after more than 2 decades	0.154*	0.067	0.080	-0.105	0.307*	0.049
	(0.092)	(0.097)	(0.108)	(0.068)	(0.164)	(0.030)
# Observations	4901	2722	2722	2722	2722	2722
# Municipalities	779	661	661	661	661	661

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. Column (1) presents results using 10-year census data from 1950-2010. Columns (2)-(6) restrict the sample to the period 1970-2010 and use only employees for which information on education level is available. The number of workers (residents) consists of the number of employees working (residing) in a given municipality. The number of out-commuters (in-commuters) consists of the number of residents (workers) working (living) in another municipality. All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific time trends.

Qualitative Prediction no. 3 (Segregation)

The effect on the entropy index defined using education levels is statistically indistinguishable from zero (Column 6). Using two skill groups instead of three (high-skilled vs the rest), we find a positive effect on the entropy index for workers (Table Appendix F.1 reports these results).

Appendix D.3 Commuting

We report the results for in- and out-commuters in Table Appendix D.2, Panels C and D. We find evidence that the number of in-commuters increases by 16.6% as a result of highway access (Panel D, Column 1). The effect is smaller and less precisely estimated for the census sub-sample of years 1970-2010 (Panel D, Column 2). The composition of in-commuters also changes with an increase in the share of in-commuters with high education and a decrease in the share of in-commuters with intermediate level of education (Panel D, Columns 4 and 5), thereby reducing segregation as measured by the entropy index (Panel D, Column 6). In contrast to in-commuters, we find no effect on the number of out-commuters (Panel C, Columns 1 and 2). However, consistent with our theoretical prediction, we do find a positive effect on the share of high-skilled out-commuters (Panel C, Column 5).

It is instructive to cross these results with the 2015 survey results of the Federal Statistical Office's (2017) 'Microcensus Mobility and Transport', which reports an increase in the average commuting distance over time and a less-than proportional increase in the average commuting time, as well as a positive correlation between the daily distance traveled by a household and its income. Together, these results and our findings suggest that highways may ease the dual location choice of households as residents and workers and that this expansion of the choice set is especially beneficial to those at the top of the skill distribution.

Appendix D.4 Urban sprawl

For the analysis of urban sprawl, we include urban municipalities to our sample. Note that we depart from our initial identification strategy by including municipalities for which highway access opening time might not be fully exogenous.

Table Appendix D.3 presents the regression results using the census data. As in Table Appendix D.2, Column (1) contains the results for the full period 1950-2010, and Columns (2) to (6) restrict the sample to the period 1970-2010 and use only employees for which information on education level is available. We find that highways contribute to the spatial decentralization of jobs and residences and that this process is especially pronounced for the high-skilled. Specifically, coefficients in Column (2) imply that highway access leads to substantial long-term reductions in the numbers of residents and jobs in central municipalities: about -29% for the former (Panel A) and about -18% for the latter (Panel B). The reductions in the number of out- and in-commuters (Panels C and D) depict a similar picture.

Columns (3) to (5) reveal an increase in the share of low-skilled residents and workers in central municipalities, especially at the expense of the share of high-skilled residents and workers (Panels A and B). The pattern for out-commuters is similar (Panel C) but reversed for in-commuters (Panel D). This result implies that high-skilled residents fled central municipalities in higher numbers than high-skilled jobs. We also find that highways increased segregation in urban centers. This effect is especially clear using two skill groups (high-skilled vs the rest) instead of three (Table Appendix F.2 reports these results). This outcome is in line with the descriptive results of Table 1, which pertain to taxpayer data. Rossi-Hansberg, Sarte and Owens (2009) report that the suburbanization for both jobs and residences was at work in 1980-90 in the US. Our results suggest that the same pattern is at work in Switzerland, especially at the top of the skill distribution, and that highways are contributing to it.

Table Appendix D.3: Impact of highway access on urban sprawl (27 cities)

	# Employees		Share of employees by education level:			Entropy index
			low	middle	high	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Residents						
Long-term effect						
center	-0.222***	-0.347***	0.857***	-0.175**	-0.896***	0.037
	(0.080)	(0.076)	(0.131)	(0.070)	(0.128)	(0.041)
1-20 km	0.098*	0.036	0.016	-0.101**	0.009	-0.027
	(0.050)	(0.060)	(0.085)	(0.040)	(0.078)	(0.027)
21-40 km	0.221***	0.016	-0.007	-0.066	0.066	0.002
	(0.055)	(0.079)	(0.091)	(0.045)	(0.088)	(0.039)
> 40 km	0.094	-0.039	0.261*	-0.087	-0.092	0.034
	(0.120)	(0.088)	(0.157)	(0.094)	(0.208)	(0.032)
# Observations	10261	7462	7462	7462	7462	7462
# Municipalities	1528	1527	1527	1527	1527	1527
Panel B: Workers						
Long-term effect						
center	-0.126*	-0.201**	0.147	-0.079	-0.394***	-0.051*
	(0.074)	(0.081)	(0.114)	(0.056)	(0.107)	(0.030)
1-20 km	0.130***	0.081	0.063	-0.115***	0.100	-0.002
	(0.042)	(0.055)	(0.065)	(0.042)	(0.087)	(0.023)
21-40 km	0.100	-0.004	0.095	-0.070*	0.186*	0.036
	(0.070)	(0.085)	(0.080)	(0.041)	(0.100)	(0.037)
> 40 km	-0.063	-0.142	0.364**	-0.230*	0.005	0.047
	(0.069)	(0.174)	(0.144)	(0.137)	(0.190)	(0.033)
# Observations	10169	7254	7254	7254	7254	7254
# Municipalities	1528	1516	1516	1516	1516	1516

Continued on next page

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C: Out-commuters						
Long-term effect						
center	-0.220**	-0.241**	1.163***	-0.255***	-0.758***	0.170***
	(0.088)	(0.107)	(0.155)	(0.075)	(0.126)	(0.041)
1-20 km	0.000	-0.009	0.060	-0.086*	0.052	0.004
	(0.062)	(0.065)	(0.097)	(0.044)	(0.075)	(0.023)
21-40 km	0.169*	0.038	-0.006	-0.047	0.092	0.023
	(0.089)	(0.092)	(0.109)	(0.055)	(0.097)	(0.031)
> 40 km	0.247	-0.002	0.128	-0.016	0.148	0.046
	(0.170)	(0.107)	(0.161)	(0.092)	(0.181)	(0.051)
# Observations	10257	7307	7307	7307	7307	7307
# Municipalities	1528	1517	1517	1517	1517	1517
Panel D: In-commuters						
Long-term effect						
center	-0.169**	-0.220**	-0.390***	-0.019	0.105	-0.056*
	(0.082)	(0.102)	(0.136)	(0.063)	(0.141)	(0.029)
1-20 km	0.103	0.102	0.033	-0.071	0.274***	0.048**
	(0.077)	(0.075)	(0.096)	(0.048)	(0.101)	(0.022)
21-40 km	0.205*	0.023	0.103	-0.049	0.314*	0.075**
	(0.120)	(0.112)	(0.117)	(0.060)	(0.170)	(0.032)
> 40 km	0.206	-0.169	0.278	-0.154	0.362	0.143***
	(0.203)	(0.180)	(0.231)	(0.134)	(0.270)	(0.052)
# Observations	9890	6180	6180	6180	6180	6180
# Municipalities	1525	1391	1391	1391	1391	1391

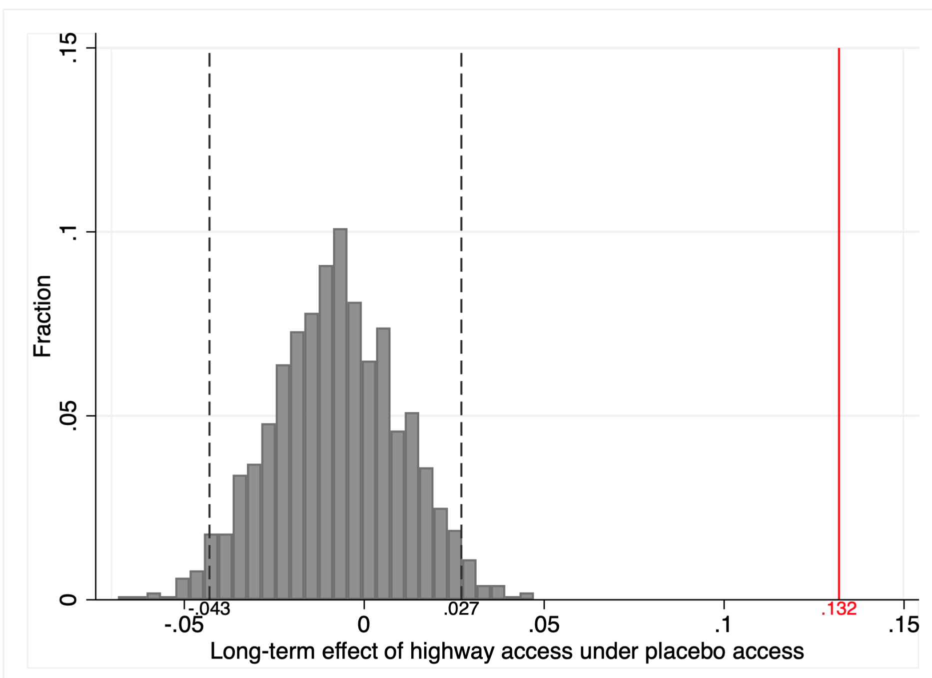
Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all municipalities within 10 km from a highway access (including urban municipalities). An 'urban center' is defined as a city of category 1 or 2 by the Swiss Statistical Office (27 cities). Column (1) presents results using 10-year census data from 1950-2010. Columns (2)-(6) restrict the sample to the period 1970-2010 and use only employees for which information on education level is available. The number of workers (residents) consists of the number of employees working (residing) in a given municipality. The number of out-commuters (in-commuters) consists of the number of residents (workers) working (living) in another municipality. All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific time trends.

Appendix D.5 Placebo Test for Opening Years

To further validate our baseline results, we run a placebo experiment by randomizing 1,000 times the opening access date among the municipalities included in our sample (i.e. non-urban municipalities within 10km of a highway access).

Figure Appendix D.1 plots the distribution of the long-term coefficients obtained by estimating the baseline model for the number of taxpayers (including the full set of municipality fixed effects, linear time trends, and year-rail fixed effects). Dashed lines show the implied estimate for which an effect is statistically significant at a 5% significance level. The red line is the coefficient from the baseline regression of Table 2, Panel B, Column (3). Figure Appendix D.1 reports that our baseline estimate is five times as large as one obtained only by chance. It therefore confirms the positive effect of highway access on the number of taxpayers.

Figure Appendix D.1: Effect on the number of taxpayers - placebo test



Note: Highway access opening date randomized 1,000 times. The sample includes all municipalities within 10km from a highway access that are not part of an urban area. The dependent variable is the log of the number of taxpayers. The regression includes municipality fixed effects, time-rail fixed effects and municipality-specific linear time trends. Two-year panel covering the period 1947-2010. Dashed lines show the implied estimate for which an effect is statistically significant at a 5% significance level. Red line is the coefficient from the baseline regression.

Appendix D.6 Non-connected Municipalities

In our baseline specifications exploiting variation within the sample of connected municipalities, γ quantifies the long-run effect of getting a highway access on the variables of interest at time t relative to getting it at a later time or to have been connected more than two decades ago. In this section, we estimate the same coefficient, but we now include non-connected municipalities to the 'control' group. Including non-connected municipalities may improve the estimation of controls and fixed effects, but also poses the risk of distorting the effect of highway access if highway connection were systematically correlated with other factors affecting our variables of interest.

The number of municipalities in the extended sample almost doubles: about half of non-urban municipalities did not have a highway access within 10km reach by 2010. With the exception of the average distance to the closest urban center, these municipalities are observationally similar to connected municipalities in the sense that the averages and standard deviations of the variables of interest of the two groups are statistically indistinguishable at the usual confidence levels (see Columns 2 and 3 of Table Appendix C.1).[15]

Table Appendix D.4 reports the results. The coefficients of this specification are quantitatively close to those of our central specification reported in Table 2. This result suggests that treated and untreated municipalities are similar, conditional on their time-invariant characteristics and their specific time trend.

[15] The average distance to the closest urban center of the connected municipalities is 26% lower than that of the non-connected ones. This qualitative result is to be expected, since the purpose of the Swiss highway network is to connect its urban centers.

Table Appendix D.4: Impact of highway access on number and composition of taxpayers – Including non-connected municipalities

	# Taxpayers			Share of taxpayers				Entropy index
				below 50%	top 50%-25%	top 25%-10%	top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Cumulative effect j years before/after access								
<-14	0.015	0.029*	0.026	0.002	-0.010	-0.022	-0.023	-0.009
	(0.034)	(0.016)	(0.016)	(0.011)	(0.014)	(0.031)	(0.058)	(0.010)
-14	0.008	0.009	0.008	-0.002	0.003	0.003	-0.007	-0.001
	(0.010)	(0.010)	(0.010)	(0.006)	(0.011)	(0.021)	(0.045)	(0.006)
-12	0.008	0.007	0.007	-0.004	0.002	-0.006	0.027	0.002
	(0.008)	(0.009)	(0.009)	(0.005)	(0.009)	(0.024)	(0.043)	(0.005)
-10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
-8	0.004	0.005	0.006	-0.003	-0.004	0.027	0.021	0.008
	(0.008)	(0.008)	(0.008)	(0.005)	(0.009)	(0.017)	(0.037)	(0.005)
-6	-0.012	-0.006	-0.004	0.007	-0.006	-0.003	-0.017	-0.001
	(0.011)	(0.010)	(0.010)	(0.006)	(0.012)	(0.017)	(0.053)	(0.006)
-4	0.016	0.020	0.023*	0.000	-0.004	0.024	-0.007	0.006
	(0.012)	(0.012)	(0.012)	(0.007)	(0.011)	(0.021)	(0.054)	(0.006)
-2	0.024	0.029*	0.032*	-0.012	0.009	0.030	0.035	0.011
	(0.015)	(0.017)	(0.016)	(0.008)	(0.011)	(0.024)	(0.057)	(0.008)
+0	0.022	0.028	0.031*	-0.014	0.024*	0.045*	0.058	0.018**
	(0.016)	(0.019)	(0.018)	(0.009)	(0.012)	(0.025)	(0.052)	(0.009)
+2	0.031*	0.038*	0.042**	-0.022**	0.017	0.091***	0.082	0.026**
	(0.019)	(0.021)	(0.021)	(0.011)	(0.015)	(0.026)	(0.054)	(0.010)
+4	0.033	0.040*	0.043*	-0.027**	0.031*	0.102***	0.047	0.031***
	(0.021)	(0.024)	(0.023)	(0.011)	(0.016)	(0.029)	(0.082)	(0.011)
+6	0.042*	0.048*	0.051*	-0.035***	0.050***	0.127***	0.101	0.043***
	(0.023)	(0.028)	(0.027)	(0.012)	(0.016)	(0.031)	(0.064)	(0.012)
+8	0.045*	0.053*	0.057*	-0.040***	0.052**	0.136***	0.133**	0.051***
	(0.024)	(0.030)	(0.030)	(0.013)	(0.020)	(0.032)	(0.058)	(0.013)
+10	0.047*	0.050	0.054	-0.041***	0.053***	0.155***	0.122*	0.055***
	(0.028)	(0.035)	(0.034)	(0.014)	(0.019)	(0.033)	(0.065)	(0.013)
+12	0.055*	0.059	0.062*	-0.047***	0.065***	0.165***	0.156**	0.062***
	(0.030)	(0.038)	(0.037)	(0.015)	(0.021)	(0.038)	(0.067)	(0.015)
+14	0.059*	0.064	0.067	-0.054***	0.072***	0.173***	0.175**	0.069***
	(0.032)	(0.041)	(0.041)	(0.016)	(0.020)	(0.039)	(0.068)	(0.015)
+16	0.059*	0.071	0.074*	-0.054***	0.067***	0.186***	0.197***	0.072***
	(0.034)	(0.045)	(0.044)	(0.017)	(0.021)	(0.042)	(0.068)	(0.016)
+18	0.067*	0.080*	0.083*	-0.060***	0.065***	0.198***	0.220***	0.076***
	(0.035)	(0.048)	(0.047)	(0.018)	(0.022)	(0.045)	(0.070)	(0.017)
+20	0.076**	0.089*	0.093*	-0.067***	0.065***	0.207***	0.241***	0.080***
	(0.037)	(0.052)	(0.051)	(0.018)	(0.022)	(0.047)	(0.076)	(0.018)
>+20	0.092**	0.113*	0.118**	-0.075***	0.057**	0.231***	0.281***	0.087***
	(0.045)	(0.057)	(0.056)	(0.021)	(0.024)	(0.052)	(0.087)	(0.020)
Panel B: Long-term cumulative effect								
Long-term effect	0.086*	0.134**	0.135**	-0.074***	0.053***	0.203***	0.255***	0.076***
	(0.044)	(0.055)	(0.054)	(0.016)	(0.018)	(0.047)	(0.070)	(0.017)
# Observations	40662	40662	40662	40662	40662	40662	40662	40662
# Municipalities	1389	1389	1389	1389	1389	1389	1389	1389
Municipality time trends	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time-rail fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. The dependent variable is the log of the number of taxpayers in Columns (1) to (3), the log of the share of taxpayers in different income percentiles in Columns (4) to (7), and the log Theil entropy index in Column (8). Two-year panel covering the period 1947-2010. All regressions include municipality fixed effects and time fixed effects.

Appendix D.7 Confounding Factors

Appendix D.7.1 Railway Access

As noted in Section 3.2, the Swiss railway network was to a very large degree in place before the construction of the highway network. Recent improvements were concentrated in urban areas that are excluded from our sample. Recall also that we interact our year fixed effects with railway access dummies to capture change in the railway network that would differently affect municipalities with and without a rail access. This leaves open the question as to whether the highway effect is different between these two groups of municipalities. Table Appendix D.5, Panel A, provides the answers to this question. We find no difference for the effect on size (Column 1). Interestingly, the effect on the top of the income distribution (Column 5) is driven by municipalities without a railway station. This result suggests that rich households disproportionally pick locations whose accessibility depends on cars. This finding is consistent with our theoretical mechanism and with the patterns of the Federal Statistical Office's Microcensus on car use that we report in Appendix D.3.

Appendix D.7.2 Expansion of Cities

One possible confounding factor for our baseline effect in Table 2 is the expansion of cities over time. If the highway network was built to connect the fastest growing cities first, our effect could be driven by non-urban municipalities in relative proximity to urban centers. In order to rule this possibility out, our baseline sample includes only non-urban municipalities as defined in 2000. In Table Appendix D.5, Panel B, we investigate this issue further as follows. We split our sample of municipalities in two groups of equal size according to the distance between a municipality and the closest urban center. The average size effect is positive for all municipalities, unlike in e.g. China (Faber, 2014). A major difference between Switzerland and large countries is that Swiss urban centers are so close to one another that each one is within at most one hour drive from the next: all Swiss commuting zones overlap as a result.

Table Appendix D.5: Impact of highway access on number and composition of taxpayers - Interactions

	# Taxpayers	Share of taxpayers				Entropy index
		below 50%	top 50%-25%	top 25%-10%	top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Interaction with railway station						
Long-term effect						
without railway station	0.136**	-0.073***	0.074***	0.220***	0.266***	0.089***
	(0.055)	(0.018)	(0.024)	(0.054)	(0.090)	(0.021)
with railway station	0.125**	-0.090***	0.080***	0.169***	0.120	0.058***
	(0.056)	(0.024)	(0.030)	(0.047)	(0.080)	(0.018)
# Observations	23274	23274	23274	23274	23274	23274
# Municipalities	780	780	780	780	780	780
Panel B: Interaction with distance to urban centers						
Long-term effect						
distance $<$ 20 km	0.065*	-0.081***	0.105***	0.209***	0.185	0.082***
	(0.035)	(0.022)	(0.027)	(0.051)	(0.114)	(0.023)
distance $\geq$ 20 km	0.196**	-0.065***	0.047*	0.179***	0.256***	0.075***
	(0.079)	(0.020)	(0.028)	(0.067)	(0.085)	(0.023)
# Observations	23051	23051	23051	23051	23051	23051
# Municipalities	765	765	765	765	765	765
Panel C: Interaction with opening period						
Long-term effect						
opening year before 1973	0.137**	-0.098***	0.227***	0.281***	0.197	0.114***
	(0.067)	(0.037)	(0.082)	(0.109)	(0.192)	(0.041)
opening year after 1973	0.193***	-0.067*	0.126**	0.048	-0.148	0.034
	(0.069)	(0.036)	(0.055)	(0.114)	(0.187)	(0.039)
# Observations	23051	23051	23051	23051	23051	23051
# Municipalities	765	765	765	765	765	765

Notes. *** p<0.01, ** p<0.05, * p<0.10. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. The dependent variable is the log of the number of taxpayers in Column (1), the log of the share of taxpayers in different income percentiles in Columns (2) to (5), and the log Theil entropy index in Column (6). All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific linear time trends. In Panel (B) and (C) time-rail fixed effects are interacted with the highway access $\geq$ 20km dummy (Panel B) and with the highway access opened after 1973 dummy (Panel C). Two-year panel covering the period 1947-2010.

The effect on size (Column 1) is stronger for municipalities distant from urban centers by 20km or more (20km is the median distance). The composition effect does not depend much on the distance to urban centers, as can be seen in Columns (2) to (6).

Appendix D.7.3 Early vs Late Connection

Our identification strategy exploits the timing of connections in a network that has been defined ex-ante. Our effect is identified comparing municipalities connected early vs similar municipalities connected at a later period, assuming that the effect of being connected is constant over time. We test this assumption in Table Appendix D.5, Panel C, by differentiating municipalities connected before and after 1973 (such as our sample is split in two parts of equal size). Results show that the effect on the total number of taxpayers is indeed constant. The effect on composition, which is imprecisely estimated, seems concentrated in the early period. In light of our model, this finding is consistent with the fact that car ownership generalized during the 1960s and 1970s.

Appendix D.8 Distance to Highway Ramp

Results in Table 2 are calculated for a single distance band of 0-10km around the highway access point. In Table Appendix D.6, we differentiate the effect for distance bands of 5km width up to a distance of 20km. Here, the sample is composed of all non-urban municipalities that gained access to the highway network within 20km during our observation period (the number of such municipalities is 1,259, to be compared with 782 municipalities in our baseline sample). Column (1) explores the effect of highway access on the number of taxpayers. Results show that the positive effect is restricted to municipalities within 10km from the highway access, with municipalities located further away experiencing no effect statistically different from zero. Columns (2) to (6) explore the effect on the distribution of taxpayers within municipalities for different distance bands. Changes in income distribution are concentrated mainly among municipalities located between 5 and 15km of the highway ramp. Interestingly, municipalities located between 10 and 15km experienced a shift to the right of their income distribution but no

Table Appendix D.6: Impact of highway access on number and composition of taxpayers - Distance to highway access

	# Taxpayers	Share of taxpayers				Entropy index
		below 50%	top 50%-25%	top 25%-10%	top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)
Long-term effect (0-5 km)	0.103	-0.067***	0.006	0.148*	0.310***	0.058**
	(0.095)	(0.025)	(0.027)	(0.079)	(0.096)	(0.027)
Long-term effect (5-10 km)	0.120*	-0.085***	0.072**	0.291***	0.276***	0.093***
	(0.069)	(0.021)	(0.035)	(0.058)	(0.096)	(0.023)
Long-term effect (10-15 km)	-0.017	-0.042**	0.027	0.158***	0.206**	0.053**
	(0.060)	(0.019)	(0.036)	(0.046)	(0.084)	(0.021)
Long-term effect (15-20 km)	-0.016	-0.011	-0.014	0.062	0.121*	0.012
	(0.053)	(0.018)	(0.037)	(0.049)	(0.072)	(0.020)
# Observations	37139	37139	37139	37139	37139	37139
# Municipalities	1259	1259	1259	1259	1259	1259

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 20km from a highway access. The dependent variable is the log of the number of taxpayers in Column (1), the log of the share of taxpayers in different income percentiles in Columns (2) to (5), and the log Theil entropy index in Column (6). All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific linear time trends. Two-year panel covering the period 1947-2010.

change in the total number of taxpayers. Highway access has no effect on municipalities located beyond 15km, except for the top-10% of income taxpayers.

Appendix D.9 Multiple Openings

Some municipalities get access to more than one highway ramp over time. In our sample of non-urban connected municipalities, 51% of municipalities end up with a single highway access ramp within 10km, 34% of municipalities end up with two, and 15% end up with three or more. We use the first connection as the relevant treatment year for the 49% of municipalities that are treated multiple times. Our current estimates are biased if some municipalities belong to the 'control' group when some subsequent opening happens.

We first re-estimate our baseline long-term effect by excluding municipalities with

Table Appendix D.7: Multiple openings

	# Taxpayers			Share of taxpayers				Entropy index
				below 50%	top 50%-25%	top 25%-10%	top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Excluding municipalities with multiple openings								
Long-term effect of highway access (0/1)	0.124	0.070*	0.071*	-0.063***	0.081**	0.169**	0.162*	0.071***
	(0.078)	(0.041)	(0.041)	(0.023)	(0.031)	(0.065)	(0.093)	(0.025)
# Observations	11822	11822	11822	11822	11822	11822	11822	11822
# Municipalities	399	399	399	399	399	399	399	399
Panel B: Number of accesses opened								
Long-term effect of one additional access	0.018	0.081**	0.084**	-0.044***	0.021*	0.086**	0.124**	0.035***
	(0.028)	(0.036)	(0.036)	(0.011)	(0.011)	(0.033)	(0.050)	(0.011)
# Observations	23274	23274	23274	23274	23274	23274	23274	23274
# Municipalities	780	780	780	780	780	780	780	780
Municipality time trends	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time-rail fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. The dependent variable is the log of the number of taxpayers in Columns (1) to (3), the log of the share of taxpayers in different income percentiles in Columns (4) to (7), and the log Theil entropy index in Column (8). Two-year panel covering the period 1947-2010. All regressions include municipality fixed effects and time fixed effects.

more than one opening. Table Appendix D.7, Panel A reports the results. We then replace our right-hand-side dummy variable (access/no access) by a count variable (number of highway ramps within 10km). Table Appendix D.7, Panel B reports the results. In both cases, the results are weakly smaller but consistent with our baseline results in Table 2, Panel B.

Appendix D.10 Initial Conditions and Amenities

Here, we investigate whether the effects of being connected to a highway network differ according to initial conditions. Specifically, as natural amenities have been found to play an important role in the spatial distribution of income (Lee and Lin, 2018), we are interested in whether municipalities that are initially specialized in residential amenities or in manufacturing activities are affected differently (relative to other municipalities) by highway access. In Panel A and B of Table Appendix D.8 we augment equation (17) with an interaction between the long-term coefficient and a continuous variable defined as the difference between the log of a given ratio and the log of the median of the same ratio ($\ln x_i - \ln \text{med}(x)$ for a variable x to be defined shortly). The main effect denotes therefore the effect of being connected for the municipality with the median initial ratio. In Panel A we investigate differential effects according to the ratio of the number of residents over the number of workers by municipality in 1949. We interpret this ratio as a measure of comparative advantage in residential amenities (relative to production amenities). The result in Column (1) suggests that the effect on the total number of taxpayers decreases with the initial ratio of residents over workers. In contrast, the effect on the composition of taxpayers (Columns 2 to 6) is reinforced with the degree of comparative advantage in residential amenities. This result is in line with rich taxpayers sorting disproportionally more in high-amenity locations. In Panel B we look at the share of employment in the secondary sector by municipality in 1955. Results suggest that the positive effect of highway connection on size (and composition) decreases with the degree of initial specialization in manufacturing activities.[16]

In Panel C we explore further the role of residential amenities and interact the long-term coefficient with two proxies for natural amenities: the straight-line distance to the closest lake shore and the average sunshine exposure in an area, as well as terrain inclination and the geographical orientation of inhabited hectares.[17] We account for the fact that sunlight exposure might vary greatly across Switzerland by using sunlight exposure of a given municipality relative to the median value of all municipalities in the same NUTS-2 region and normalizing this difference by the region-specific inter-quartile range. We find that the sorting effect resulting from highway access is larger in municipalities that are

[16]Results using census data point towards similar conclusions. Table Appendix F.3 reports the results for the interaction with the initial ratio of residents over workers. The interaction term is positive (although not statistically significant) for highly educated residents and out-commuters and negative for workers and in-commuters. Table Appendix F.4 reports the results for the interaction term with the 1955 share of employment in secondary sector. The interaction term for the size effect (Columns 1 and 2) is negative for both residents and workers.

[17]We are grateful to Fahrländer Partner AG, a private consultancy firm, to grant us access to their data on sunlight exposure.

Table Appendix D.8: Impact of highway access on number and composition of taxpayers - Initial conditions

	# Taxpayers	Share of taxpayers				Entropy index
		below 50%	top 50%-25%	top 25%-10%	top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Interaction with 1949 ratio residents/workers						
Long-term effect	0.142***	-0.072***	0.065***	0.177***	0.192***	0.068***
	(0.050)	(0.015)	(0.017)	(0.041)	(0.070)	(0.016)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.175*	-0.077	0.128	0.331**	-0.073	0.063
	(0.101)	(0.058)	(0.085)	(0.149)	(0.265)	(0.049)
# Observations	20434	20434	20434	20434	20434	20434
# Municipalities	655	655	655	655	655	655
Panel B: Interaction with 1955 share of employment in secondary sector						
Long-term effect	0.113**	-0.082***	0.082***	0.199***	0.206***	0.080***
	(0.048)	(0.016)	(0.019)	(0.040)	(0.067)	(0.016)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.063	0.007	-0.040	-0.027	-0.215	-0.020
	(0.041)	(0.034)	(0.057)	(0.077)	(0.185)	(0.031)
# Observations	22259	22259	22259	22259	22259	22259
# Municipalities	723	723	723	723	723	723
Panel C: Interaction with natural amenities						
Long-term effect	0.207***	-0.117***	0.133***	0.250***	0.376***	0.119***
	(0.070)	(0.026)	(0.028)	(0.066)	(0.104)	(0.025)
Long-term effect × sunlight exposure	0.009	-0.007	0.003	0.103**	-0.006	0.022
	(0.039)	(0.021)	(0.037)	(0.046)	(0.086)	(0.018)
Long-term effect × distance to lake	-0.006	0.003***	-0.005***	-0.005*	-0.011*	-0.003***
	(0.004)	(0.001)	(0.001)	(0.003)	(0.005)	(0.001)
# Observations	21980	21980	21980	21980	21980	21980
# Municipalities	733	733	733	733	733	733

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. The dependent variable is the log of the number of taxpayers in Column (1), the log of the share of taxpayers in different income percentiles in Columns (2) to (5), and the log Theil entropy index in Column (6). All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific linear time trends. In Panels A and B time-rail fixed effects are interacted with a dummy indicating municipalities with an initial ratio above the median. Two-year panel covering the period 1947-2010.

closer to a lake shore (Columns 2 to 6). In contrast, we find little evidence of a differential effect of sunlight exposure.

Overall, results of Table Appendix D.8 suggest that residential amenities played an important role. As such, at least part of the composition and size effects are hard to reconcile with an alternative channel that we have switched off by assumption (and for simplicity) in the model: trade.

Appendix E. Gravity Equation

Welfare effects depend on the shape parameter of the Fréchet distribution κ. We exploit the matrix of bilateral commuting flows among all Swiss municipalities contained in the population census of 2000 in order to derive an estimate of this parameter for Switzerland.[18] Recalling that λ_{ni} is the fraction of workers commuting from their residence municipality n to their workplace i, we estimate the following equation:

$$\ln \lambda_{ni} = O_n + D_i + \tau\kappa \ln d_{ni} + \varepsilon_{n,i} \qquad \text{(A19)}$$

where O_n and D_i are origin and destination fixed effects capturing all factors that make a municipality particularly attractive for residential and productive purposes, and where d_{ni} is the driving time as of 2010 between each municipality of a given pair. We assume that commuting carries negative consumption value and that the elasticity of utility with respect to commuting time is constant and equal to τ; we expect τ to be negative. Our estimation strategy does not enable us to estimate the components of $\tau\kappa$ separately. Below, we use estimates of τ from the literature to back out κ.

Table Appendix E.1 presents the results. Column (1) reports the coefficient of equation (A19) estimated by OLS (this regression only includes pairs of municipalities with a strictly positive number of commuters). Similarly to other countries, the commuting matrix in Switzerland is very sparse and omitting pairs of municipalities with zero commuters is a major source of estimation bias (Dingel and Tintelnot, 2020).[19] We therefore estimate the model with a Poisson Pseudo Maximum Likelihood estimator, first on the OLS sample (Column 2), then on the full sample of municipalities (Columns 3 and 4). Estimates using the full matrix of bilateral commutes, reported in Column 3, indicate that a 1% reduction in driving time leads to a 2.7% increase in commuting probability.

[18] The census 2000 is the last census covering the full population.

[19] Table Appendix F.5 presents the transition matrix for pairs of municipalities within 20km of each other by reported number of commuters in 1970 and 2000. In 1970, 73.3% of municipality pairs with a bilateral distance of 20km or less had zero commuters. This share fell to 51.5% in 2000.

Table Appendix E.1: Gravity equation

	OLS	PPML (OLS sample)	PPML	PPML
	(1)	(2)	(3)	(4)
Log of travel time (in min)	-1.335***	-2.219***	-2.697***	-1.230***
	(0.004)	(0.008)	(0.007)	(0.059)
Log of travel distance (in km)				-1.131***
				(0.044)
# Observations	190790	190790	6103298	6103298

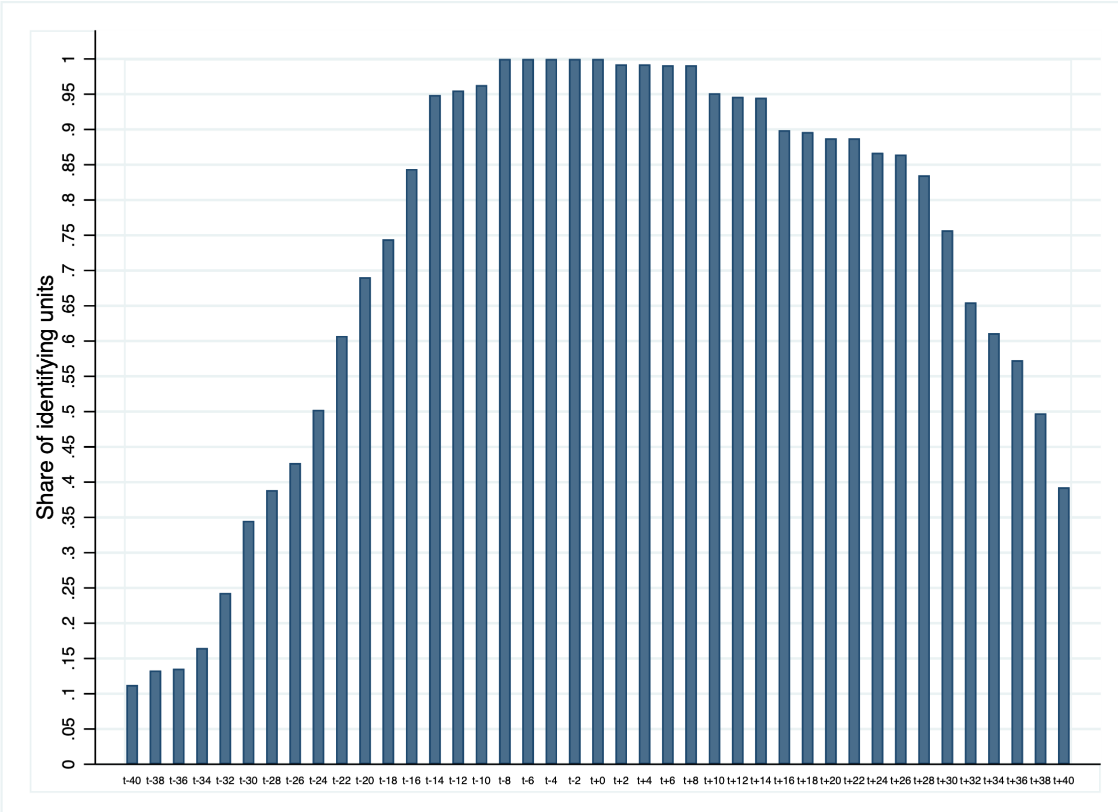
Notes. *** p<0.01, ** p<0.05, * p<0.10. Standard errors (in parentheses) are heteroskedastic-robust. The sample includes all 2479 municipalities. The dependent variable is the log of the share of workers commuting in a pair of municipalities. Travel time (distance) refers to the minimum driving time (distance) between municipalities in a pair based on the road network as of 2010.

Comparing results in Columns (2) and (3) indicates that OLS underestimate the effect of lower travel time on commuting probability. Column 4 includes bilateral driving time and bilateral driving distance separately. Both variables are strongly negatively correlated with the share of commuters. Workers react to both driving time and to driving distance.

To translate our preferred elasticity estimate of $\tau\kappa = -2.7$ into a value for κ, one needs to know the elasticity of commuting costs with respect to driving times, τ. We rely on prior work for this purpose. In their seminal book, Small and Verhoef (2007) estimate that the value of travel time for commuters is about 50% of their hourly wage, while Dingel and Tintelnot (2020) and other urban economists often use a value of 1. Using these bounds and our isoelastic formulation for the utility loss resulting from commuting time together imply $\tau \in \{-1, -0.5\}$ and hence $\kappa \in \{2.7, 5.4\}$. In computing the relative welfare changes in Table 3 using (19), we use the midpoint value of $1/\kappa \in [0.19, 0.37]$, which is 0.28.

Appendix F. Supplementary Figures and Tables

Figure Appendix F.1: Identification of event-study coefficients



Note: The figure shows the share of municipalities contributing to the identification of individual event-study coefficients. The sample includes all municipalities within 10km from a highway access that are not part of an urban area.

Table Appendix F.1: Impact of highway access on employment size and composition

	# Employees		Share of employees by education level:		Entropy index
			low & middle	high	
	(1)	(2)	(3)	(4)	(5)
Panel A: Residents					
Effect in 1st decade of opening	0.020	-0.009	-0.004	0.044	0.031
	(0.014)	(0.016)	(0.006)	(0.043)	(0.030)
Cumulative effect in 1st and 2nd decades	0.057**	-0.004	-0.009	0.078	0.052
	(0.025)	(0.029)	(0.009)	(0.056)	(0.039)
Cumulative effect after more than 2 decades	0.073**	-0.006	-0.017	0.081	0.046
	(0.034)	(0.037)	(0.013)	(0.078)	(0.055)
# Observations	5201	3765	3765	3765	3765
# Municipalities	782	781	781	781	781
Panel B: Workers					
Effect in 1st decade of opening	0.014	0.012	-0.000	0.078	0.062
	(0.022)	(0.027)	(0.007)	(0.057)	(0.041)
Cumulative effect in 1st and 2nd decades	0.049	0.037	-0.005	0.116	0.087*
	(0.040)	(0.051)	(0.010)	(0.071)	(0.050)
Cumulative effect after more than 2 decades	0.048	0.036	-0.006	0.147*	0.109*
	(0.047)	(0.070)	(0.012)	(0.086)	(0.060)
# Observations	5114	3599	3599	3599	3599
# Municipalities	782	773	773	773	773
Panel C: Out-commuters					
Effect in 1st decade of opening	-0.006	0.014	-0.007	0.047	0.041
	(0.021)	(0.019)	(0.007)	(0.047)	(0.034)
Cumulative effect in 1st and 2nd decades	-0.003	0.008	-0.015	0.143**	0.041
	(0.034)	(0.033)	(0.009)	(0.060)	(0.042)
Cumulative effect after more than 2 decades	-0.001	-0.001	-0.026*	0.186**	0.051
	(0.050)	(0.042)	(0.014)	(0.086)	(0.055)
# Observations	5197	3640	3640	3640	3459
# Municipalities	782	774	774	774	761
Panel D: In-commuters					
Effect in 1st decade of opening	0.037	0.005	-0.016	0.149	0.103
	(0.039)	(0.045)	(0.015)	(0.095)	(0.065)
Cumulative effect in 1st and 2nd decades	0.107	0.049	-0.020	0.219	0.155
	(0.070)	(0.070)	(0.022)	(0.138)	(0.094)
Cumulative effect after more than 2 decades	0.154*	0.054	-0.031	0.316*	0.222*
	(0.092)	(0.097)	(0.028)	(0.169)	(0.115)
# Observations	4901	2821	2821	2821	2821
# Municipalities	779	682	682	682	682

Notes. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors (in parentheses) are are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. Column (1) presents results using 10-year census data from 1950-2010. Columns (2)-(5) restrict the sample to the period 1970-2010 and use only employees for which information on education level is available. A low education level refers to all employees without a tertiary (high) education. The number of workers (residents) consists of the number of employees working (residing) in a given municipality. The number of out-commuters (in-commuters) consists of the number of residents (workers) working (living) in another municipality. All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific time trends.

Table Appendix F.2: Impact of highway access on urban sprawl (27 cities)

	# Employees		Share of employees by education level:		Entropy index
			low & middle	high	
	(1)	(2)	(3)	(4)	(5)
Panel A: Residents					
Long-term effect					
center	-0.222***	-0.347***	0.268***	-0.901***	-0.499***
	(0.080)	(0.076)	(0.038)	(0.128)	(0.087)
1-20 km	0.098*	0.035	-0.013	0.002	-0.013
	(0.050)	(0.059)	(0.017)	(0.078)	(0.052)
21-40 km	0.221***	0.012	-0.014	0.064	0.034
	(0.055)	(0.079)	(0.017)	(0.088)	(0.063)
> 40 km	0.094	-0.024	0.012	-0.094	-0.060
	(0.120)	(0.089)	(0.040)	(0.209)	(0.134)
# Observations	10261	7477	7477	7477	7477
# Municipalities	1528	1527	1527	1527	1527
Panel B: Workers					
Long-term effect					
center	-0.126*	-0.201**	0.161***	-0.390***	-0.195***
	(0.074)	(0.080)	(0.029)	(0.107)	(0.067)
1-20 km	0.130***	0.078	-0.011	0.105	0.070
	(0.042)	(0.055)	(0.013)	(0.086)	(0.058)
21-40 km	0.100	0.008	-0.002	0.173*	0.132*
	(0.070)	(0.084)	(0.012)	(0.101)	(0.073)
> 40 km	-0.063	-0.143	-0.024	0.010	-0.007
	(0.069)	(0.173)	(0.016)	(0.189)	(0.139)
# Observations	10169	7288	7288	7288	7288
# Municipalities	1528	1518	1518	1518	1518

Continued on next page

	(1)	(2)	(3)	(4)	(5)
Panel C: Out-commuters					
Long-term effect					
center	-0.220**	-0.246**	0.239***	-0.757***	-0.411***
	(0.088)	(0.107)	(0.038)	(0.125)	(0.082)
1-20 km	0.000	-0.013	-0.017	0.054	0.027
	(0.062)	(0.066)	(0.018)	(0.073)	(0.051)
21-40 km	0.169*	0.034	-0.017	0.100	0.061
	(0.089)	(0.094)	(0.017)	(0.094)	(0.067)
> 40 km	0.247	0.051	0.011	0.107	0.101
	(0.170)	(0.095)	(0.068)	(0.191)	(0.122)
# Observations	10257	7346	7346	7346	7346
# Municipalities	1528	1520	1520	1520	1520
Panel D: In-commuters					
Long-term effect					
center	-0.169**	-0.215**	0.068**	0.105	0.114
	(0.082)	(0.102)	(0.032)	(0.143)	(0.091)
1-20 km	0.103	0.109	-0.021	0.266**	0.189***
	(0.077)	(0.075)	(0.019)	(0.105)	(0.072)
21-40 km	0.205*	-0.001	-0.012	0.303*	0.228*
	(0.120)	(0.117)	(0.024)	(0.174)	(0.120)
> 40 km	0.206	-0.172	-0.081**	0.385	0.234
	(0.203)	(0.180)	(0.041)	(0.266)	(0.183)
# Observations	9890	6292	6292	6292	6292
# Municipalities	1525	1413	1413	1413	1413

Notes. *** p<0.01, ** p<0.05, * p<0.10. Standard errors (in parentheses) are clustered by district. The sample includes all municipalities within 10 km from a highway access (including urban municipalities). An 'urban center' is defined as a city of category 1 or 2 by the Swiss Statistical Office (27 cities). Column (1) presents results using 10-year census data from 1950-2010. Columns (2)-(5) restrict the sample to the period 1970-2010 and use only employees for which information on education level is available. A low education level refers to all employees without a tertiary (high) education. The number of workers (residents) consists of the number of employees working (residing) in a given municipality. The number of out-commuters (in-commuters) consists of the number of residents (workers) working (living) in another municipality. All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific time trends.

Table Appendix F.3: Impact of highway access on employment size and composition - Interaction with 1949 ratio residents/workers

	# Employees		Share of employees by education level:			Entropy index
			low	middle	high	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Residents						
Long-term effect	0.069**	-0.001	-0.011	-0.084**	0.061	-0.022
	(0.034)	(0.039)	(0.071)	(0.038)	(0.080)	(0.034)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.005	-0.054	-0.074	0.118	0.377	0.024
	(0.093)	(0.107)	(0.197)	(0.122)	(0.260)	(0.060)
# Observations	5201	3750	3750	3750	3750	3750
# Municipalities	782	781	781	781	781	781
Panel B: Workers						
Long-term effect	0.029	0.014	0.083	-0.100***	0.135	0.003
	(0.048)	(0.073)	(0.071)	(0.036)	(0.085)	(0.028)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	0.235	0.368**	-0.134	0.117	0.065	-0.004
	(0.157)	(0.182)	(0.215)	(0.115)	(0.337)	(0.080)
# Observations	5114	3568	3568	3568	3568	3568
# Municipalities	782	771	771	771	771	771
Panel C: Out-commuters						
Long-term effect	0.045	0.022	-0.009	-0.075	0.151	0.010
	(0.046)	(0.041)	(0.098)	(0.046)	(0.095)	(0.033)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.075	-0.237	0.082	0.096	0.413	0.054
	(0.163)	(0.154)	(0.247)	(0.121)	(0.306)	(0.069)
# Observations	5197	3602	3602	3602	3602	3602
# Municipalities	782	771	771	771	771	771
Panel D: In-commuters						
Long-term effect	0.098	0.047	0.066	-0.099	0.328**	0.050*
	(0.098)	(0.098)	(0.110)	(0.066)	(0.154)	(0.030)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	0.117	0.871***	0.134	0.009	-0.543	-0.073
	(0.329)	(0.322)	(0.296)	(0.206)	(0.467)	(0.123)
# Observations	4901	2722	2722	2722	2722	2722
# Municipalities	779	661	661	661	661	661

Notes. *** p<0.01, ** p<0.05, * p<0.10. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. Column (1) presents results using 10-year census data from 1950-2010. Columns (2)-(6) restrict the sample to the period 1970-2010 and use only employees for which information on education level is available. All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific time trends. Time-rail fixed effects are interacted with a dummy indicating municipalities with a initial ratio above the median.

Table Appendix F.4: Impact of highway access on employment size and composition - Interaction with 1955 share of employment in secondary sector

	# Employees		Share of employees by education level:			Entropy index
			low	middle	high	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Residents						
Long-term effect	0.061*	-0.023	-0.019	-0.068*	0.094	-0.016
	(0.034)	(0.040)	(0.070)	(0.039)	(0.082)	(0.030)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.076	-0.165**	-0.078	0.083	0.093	0.034
	(0.048)	(0.076)	(0.089)	(0.051)	(0.166)	(0.043)
# Observations	5017	3650	3650	3650	3650	3650
# Municipalities	754	754	754	754	754	754
Panel B: Workers						
Long-term effect	0.048	0.020	0.072	-0.089**	0.158*	0.005
	(0.047)	(0.071)	(0.065)	(0.036)	(0.088)	(0.025)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.071	-0.176	-0.073	0.028	0.083	-0.000
	(0.062)	(0.112)	(0.119)	(0.078)	(0.245)	(0.053)
# Observations	4964	3509	3509	3509	3509	3509
# Municipalities	754	750	750	750	750	750
Panel C: Out-commuters						
Long-term effect	-0.031	-0.021	-0.010	-0.068	0.205**	0.019
	(0.049)	(0.042)	(0.100)	(0.044)	(0.094)	(0.032)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.161**	-0.217**	-0.004	-0.011	0.103	0.020
	(0.079)	(0.089)	(0.121)	(0.067)	(0.156)	(0.036)
# Observations	5017	3526	3526	3526	3526	3526
# Municipalities	754	748	748	748	748	748
Panel D: In-commuters						
Long-term effect	0.118	0.061	0.070	-0.106	0.291*	0.040
	(0.091)	(0.099)	(0.109)	(0.067)	(0.153)	(0.029)
Long-term effect × $[\ln(ratio\_i) - \ln(ratio\_median)]$	-0.313	-0.295	-0.132	-0.129	0.131	-0.100
	(0.201)	(0.275)	(0.216)	(0.153)	(0.352)	(0.096)
# Observations	4790	2704	2704	2704	2704	2704
# Municipalities	753	655	655	655	655	655

Notes. *** p<0.01, ** p<0.05, * p<0.10. Standard errors (in parentheses) are clustered by district. The sample includes all non-urban municipalities within 10km from a highway access. Column (1) presents results using 10-year census data from 1950-2010. Columns (2)-(6) restrict the sample to the period 1970-2010 and use only employees for which information on education level is available. All regressions include municipality fixed effects, time-rail fixed effects, and municipality-specific time trends. Time-rail fixed effects are interacted with a dummy indicating municipalities with initial ratio above the median.

Table Appendix F.5: Transition matrix for count of commuters between pairs of municipalities

		2000						
		0	1	2	3	4	5+	Total
1970	0	49.04	11.17	4.87	2.56	1.64	4.02	73.31
	1	1.92	1.50	1.14	0.82	0.62	2.94	8.94
	2	0.37	0.36	0.36	0.37	0.31	2.03	3.80
	3	0.09	0.13	0.15	0.18	0.15	1.53	2.24
	4	0.05	0.07	0.07	0.08	0.09	1.15	1.50
	5+	0.06	0.09	0.12	0.17	0.17	9.61	10.21
	Total	51.52	13.32	6.71	4.18	2.97	21.29	100.00

Note: This table presents a transition matrix for pairs of municipalities within 20 kilometers of each other by reported number of commuters in 1970 and 2000.