Regional economic effects of transport infrastructure expansions: Evidence from the Swiss highway network

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Abstract

Expansions of transport infrastructure networks may have substantial impacts on the development of regions. Observable regional economic effects do not necessarily reflect efficiency gains, however; they may also stem from redistribution across regions. In this paper, we propose that efficiency gains result from an improvement in the absolute accessibility of regions, whereas redistribution is caused by changes in their relative accessibility. We investigate this hypothesis based on expansions of the Swiss highway network. Using the synthetic control method developed in Abadie, Diamond and Hainmueller (2010), we analyze whether specific highway network expansions led to increases in regional income per capita. We find that effects vary strongly across the different cases. As expected, we observe the largest impact when both absolute and relative accessibility of a region increase.

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Introduction

Transport infrastructure networks have long been recognized as a key ingredient to economic growth and development. Already Adam Smith argued that good roads, canals, and navigable rivers are among "the greatest of all improvements" in that they reduce transportation costs and bring remote regions of a country closer to towns (Smith, 1806, p. 203). At the aggregate level, the establishment of a sound transport infrastructure should lead to efficiency gains, thanks to lower transportation costs, economies of scale, increased competition, and more efficient labor allocation (see e.g., Brueckner, 2011).

That a well functioning transport network is an important determinant of economic growth has also been documented empirically. Fernald (1999), for instance, provides evidence that the construction of the interstate highway system in the U.S. in the late 1950s and early 1960s substantially boosted productivity in industries more dependent on vehicles. Donaldson (2010) shows that the railroad network in India increased welfare by allowing regions to exploit gains from trade.

It is more difficult, however, to assess the economic effects of individual parts of such a network[1]. Often, transport networks are built or expanded in order to accommodate economic growth of a certain region. Identification of a causal impact of expansions on economic outcomes is therefore a difficult endeavor (see Datta, 2012). As a consequence, many of the existing studies focus on highlighting the positive association between a higher degree of accessibility and economic outcomes (see e.g., D'Costa et al., 2013, for a recent example from the United Kingdom). While such findings are informative, they cannot provide guidance for decisions on specific infrastructure investments.

Recently, Ahlfeldt and Feddersen (2010) have made a first step into the direction of causal inference with regard to the regional effects of a major infrastructure expansion in Germany[2]. In their study, they investigate the economic effects of a new high-speed rail track connecting Cologne and Frankfurt. They exploit the fact that both the timing of the construction of this rail link as well as the location of the intermediate stops in the towns of Limburg and Montabaur can be regarded as exogenous to regional economic development. They find that the new high-speed rail promoted economic activity in the regions that enjoyed an increase in accessibility. At the same time, however, they also note that "the transport innovations, if at all, had a rather localized economic impact and did not shift the level of economic wealth for the study area as a whole" (p. 18).

An expansion of an existing transport network may often have a positive impact on those regions that enjoy an increase in their accessibility[3]. At the same time, however, the increased accessibility of one region may come at a cost for another region (Weber, 2011). Crescenzi and Rodríguez-Pose (2012), for instance, review studies on the impact of U.S. highways and conclude that "while the development of highways has raised the level of economic activities

[1]For the case of Switzerland, these challenges become apparent in the study by Bruns et al. (2011) who analyze the regional economic effects of two recent transport infrastructure projects.

[2]Other studies with a similar approach include Banerjee, Duflo and Qian (2012), Datta (2012), and Ghani, Goswami and Kerr (2012).

[3]The impact can also be negative, however, as Krugman (1991) has shown in his seminal paper on "Increasing Returns and Economic Geography".

in those counties through which they pass, they often have detrimental economic effects on adjacent counties" (p. 491). Taking into account the cost of the infrastructure expansion, the net impact for the combined area may be positive or negative. Generally, existing studies do not make a distinction between efficiency gains on the one hand and redistributive gains on the other hand. In the case of the study by Ahlfeldt and Feddersen (2010), for instance, it is possible that the observed positive effects mainly reflect redistributions between regions rather than efficiency gains for the whole larger area affected by the new high-speed rail link.

Disentangling efficiency from redistributive gains empirically is difficult, yet important from a policy perspective. Today, many development assistance programs rely heavily on investments in transportation networks to promote economic development and foster convergence. The World Bank, for instance, has allocated roughly 20% of its lending in recent years to transport infrastructure – a share that is larger than that devoted to health, education, and social services combined (Crescenzi & Rodríguez-Pose, 2012). In the European Union, investments in transport infrastructure are a key element of regional development policies. Understanding the circumstances under which a larger area in fact benefits from transport network expansions is therefore an important issue.

In this paper, we propose a way how to approach the challenge of separating efficiency gains from redistributive gains. To do so, we distinguish between the effect an infrastructure expansion has on a region's absolute versus its relative accessibility. We argue that improvements in absolute accessibility spur efficiency gains, whereas changes in a region's relative accessibility lead to redistribution across regions. Imagine that a network enhancement increases a region's absolute accessibility, but does not change its relative accessibility compared to other regions. This could for instance be the case if speed limits on all highways were increased by a considerable amount thanks to the advent of driverless cars. In this situation, redistribution across regions would likely play a minor role and observable benefits would primarily reflect efficiency gains. The prediction would be different in case speed limits were only increased for one particular highway. In that case, we would expect economic activity to shift towards the new super-highway, at the detriment of the other regions now relatively less accessible. In this situation, the positive effect for the regions located at the new super-highway would consist of both efficiency gains and redistributive gains, with redistributive gains arguably making up for a relatively large share of overall gains.

We investigate these hypotheses based on three case studies from the Swiss highway network. The Swiss highway network provides an attractive setting for studying these effects, for three reasons. First, we are interested in identifying the short- and medium-term effects of transport infrastructure expansions. Given that costs for the transportation of people are considerably higher than for the transportation of goods, we would preferrably want to look at network expansions that primarily reduced transportation costs for people, not goods. People are likely to be relatively quick in responding to changes in travel time, whereas a relocation of companies and adjustments in the industry structure may take time. The Swiss highway network fulfills this condition. The primary benefit of highways accrued to people, who were able to reach their workplace and other parts of the country faster. The transportation cost of goods was reduced as well, but given the small size of Switzerland, it seems unlikely that these reductions had a

fundamental short-term impact on the structure of the economy.

Second, Swiss people are relatively immobile as far as their region of residence is concerned (partly driven by language barriers within the country), but many of them commute to work. Under these conditions, we would expect a reduction in travel time to have a substantial impact on labor market outcomes. In particular, people from more peripheral regions might choose to seek work in nearby cities if commuting time is reduced.

Third, a relatively high number of Swiss cantons are located at the border to other countries. As redistribution is more likely to occur within the same country (e.g., due to immigration laws), border cantons facilitate the distinction of efficiency and redistributive gains.

To analyze the three cases, we rely on the synthetic control method developed in Abadie, Diamond and Hainmueller (2010). This method is well suited to investigate the question at hand as it allows for a quantitative analysis of case studies, i.e. situations where only one unit (canton) is subject to a treatment (accessibility improvement). It explicitly constructs a counterfactual for the treated canton – called synthetic control – based on the donor pool of units (cantons) not affected by the treatment. We approximate income per capita by the average taxable income per taxpaying unit in a canton.

Our results suggest that pure efficiency gains resulting from transport infrastructure expansions might be small, at least when connecting two already well developed regions. Similarly, if neither absolute nor relative accessibility is substantially increased, even large network expansions such as connecting a remote region to the rest of the network may yield no relevant positive economic effects. As expected, we find the largest positive impact for the situation where a region experiences a strong increase in both its absolute and relative accessibility.

The remainder of this paper is structured as follows. Section 1 introduces the conceptual framework based on changes in absolute versus relative accessibility. Section 2 provides background on the Swiss highway network and the case selection. Section 3 describes the methodology and the data underlying our analysis. Section 4 presents the results of the three case studies, including a number of robustness checks. Section 5 concludes and highlights potential avenues for future research.

1 Conceptual Framework

Following Ahlfeldt and Feddersen (2010) and others, we understand "accessibility" in the tradition of Harris (1954), who stated that the market potential of a location is defined as the sum of accessible markets weighted by their distances. D'Costa et al. (2013) refer to this measure as "access to economic mass" (p. 267). We do not specify our measure numerically, but assume that as in Ahlfeldt and Feddersen (2010), cost of distance increases exponentially with travel time. In their case, "spatial interactions diminish by 50% after about 35 min of travel time and are reduced to less than 1% after about 230 min" (p. 15). This definition implies that a travel time reduction is more valuable, the shorter the original travel time between two places.

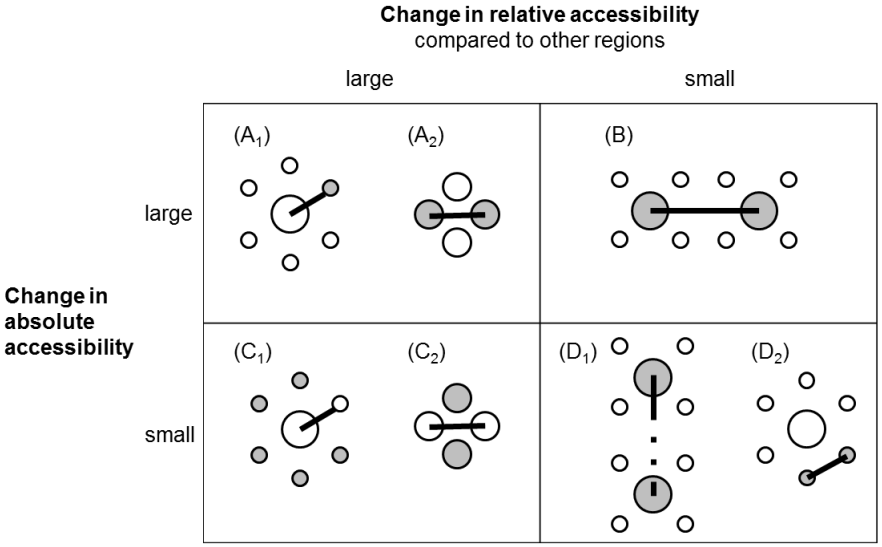
We define a change in absolute accessibility as the change in access to economic mass. In contrast, a change in relative accessibility measures how a region's access to economic mass changes relative to other regions. If region X gets better access to a nearby economic core, and

region Y does not, both the absolute accessibility of region X as well as its relative accessibility compared to region Y increase. Meanwhile, region Y's absolute accessibility remains unchanged, whereas its relative accessibility declines.

Our hypothesis is that efficiency gains related to transport infrastructure expansions stem from changes in a region's absolute accessibility. In contrast, changes in a region's relative accessibility compared to other regions lead to redistributional gains for some regions and to losses for others.

When would we expect which combination of change in absolute and relative accessibility? In the following, we provide a list with the most common examples. Figure 1 provides a conceptual illustration of each case.

Figure 1: Change in absolute vs. relative accessibility: Conceptual illustration



A. Change in absolute and relative accessibility

A substantial change both in a region's absolute and relative accessibility is most likely if an underdeveloped region gets a fast access to a nearby core (A_1). In that situation, access to economic mass in the underdeveloped region increases substantially, both in absolute terms as well as relative to other regions in the neighborhood of the core that do not benefit from a similar transport infrastructure expansion. The effect may also run into the opposite direction if a region that is well connected to a core loses its fast link, e.g., due to the closure of a connecting tunnel.

A change in absolute and relative accessibility may also be observed if two not too distant regions move closer together thanks to a new transport link (A_2). In this situation, these regions may beneft both in absolute terms as well as relative to other regions in the neighborhood.

B. Change in absolute accessibility only

A change in absolute accessibility only implies that while the distance between regions shrinks, the relative accessibility of regions remains unchanged. With regard to transport network

expansions, such a situation might occur if two economic cores are connected (B). In this case, absolute access to economic mass increases for both cores thanks to shorter travel time. Relative to the neighboring peripheral regions, little changes, however. Already before the opening of the new transport link, the two cores had substantially more access to economic mass than the periphery.

C. Change in relative accessibility only

A region's relative accessibility can change even in the absence of an absolute change in its accessibility when other regions experience an increase or decrease in their accessibility. A new fast link from the core to a periphery (C_1) or between two regions (C_2) may come at the detriment of other regions without access to the new transport infrastructure. Similarly, a region may enjoy an increase in its relative accessibility if a fast transport connection between other regions breaks down.

D. Change in neither absolute nor relative accessibility

Under certain circumstances, even major transport network expansions may not have a substantial increase on absolute nor relative accessibility of a region. On the one hand, this may happen if two relatively far apart regions are connected (D_1). In that situation, improvements in both absolute and relative accessibility are limited given that access to economic mass decreases exponentially with distance. On the other hand, changes in absolute and relative accessibility may also be small when two peripheral regions move closer together (D_2).

2 Background and Case Selection

2.1 Background on the Swiss Highway Network

The Swiss highway network was built in the second half of the 20th century, after the Swiss federal parliament had defined the national road network in 1960[4]. The network has been gradually constructed and – with a few notable exceptions (e.g., the Gotthard Road Tunnel) – remained largely unchanged until today. The first section of the network was opened in 1963 between Geneva and 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 and early 1970s. Other highways constructed during this early phase included the connection of Berne with Thun (A6), 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 (Lugano), followed a few years later. Over time, several routes have been enhanced, e.g., in terms of the number of lanes. According to Galliker (2009), by 2009 93% of the defined network were completed.

Until 2007, construction and maintenance of the national roads was the responsibility of the cantons. They received substantial financial contributions from the federal government,

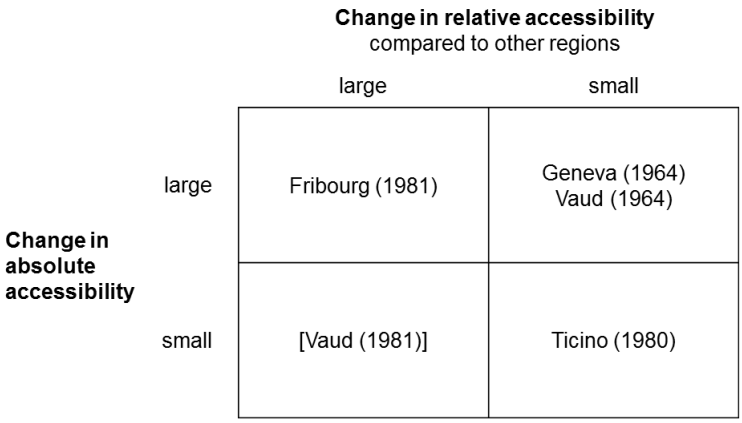
[4]This subsection draws to a large extent on an article by Galliker (2009).

however, from taxes on gasoline and a lump-sum fee to use the national highways (called "Autobahnvignette"). As of January 1, 2008, these responsibilities have been transfered to the federal government.

2.2 Case Selection

Based on our conceptual framework, we select cases where changes in absolute versus relative accessibility differ. Figure 2 shows that our three case studies of highway network expansions in principle cover all possible combinations of changes in absolute versus relative accessibility. We briefly introduce each case study in turn and discuss the expected economic effects.

Figure 2: Conceptual framework and case selection



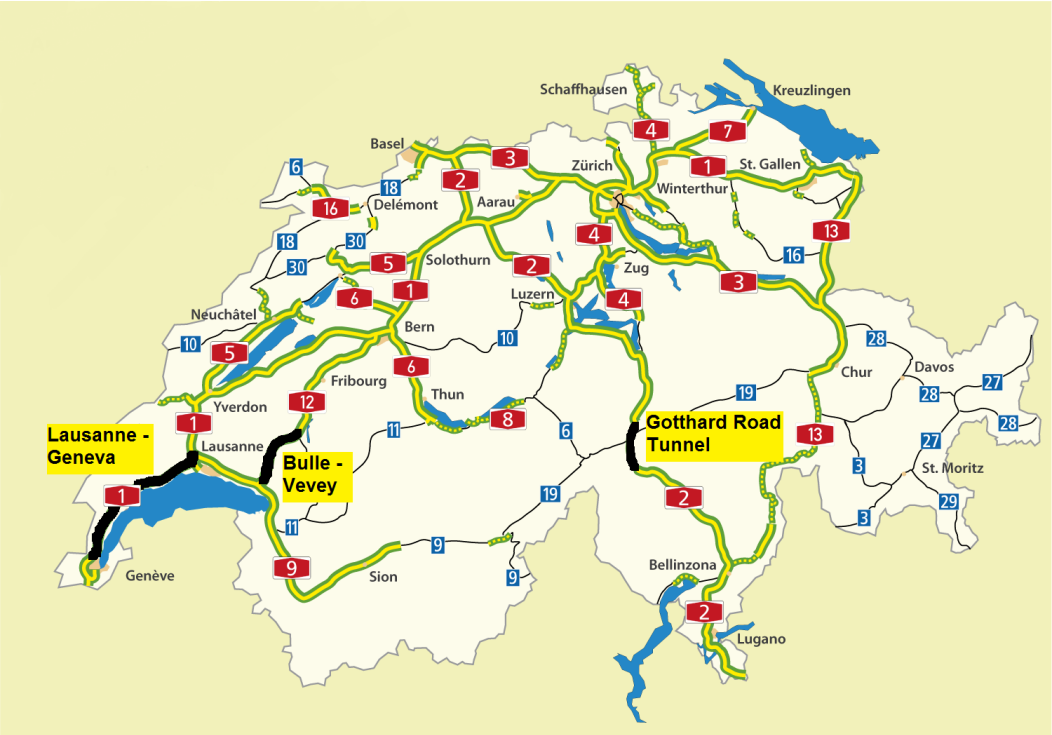
A1: Geneva - Lausanne (Vaud)

In the years 1963 and 1964, the highway between Geneva and Lausanne in the most western part of Switzerland was opened to public. It led to a substantial reduction in commuting time between the two cities of roughly 30 mins, resulting in a travel time of slightly below 1 hour after the opening of the new highway. The absolute increase in accessibility of the two regions was therefore substantial.

In contrast, relative accessibility of the two regions compared to the rest of Switzerland did not change significantly. Vaud is the only neighboring canton of Geneva, and at the time Lausanne was relatively far away from other larger Swiss cities such as Berne. Potentially, the new highway induced some relocation between Geneva and Vaud along Lake Geneva. This effect is likely to have been relatively small, however, given that already before the highway, both regions had an own economic core (Geneva and Lausanne). Moreover, for the combined larger area of the two cantons, such an effect would net out.

As a result, we would only expect increases in the income of the combined area in case the highway led to efficiency gains, e.g., thanks to more efficient labor allocation.

Figure 3: Swiss national road network including case studies



A2: Gotthard Road Tunnel

In September 1980, the Gotthard Road Tunnel was opened to public, establishing an all-year road connection between the canton of Ticino and central Switzerland. Before the opening of the tunnel, cars had to pass over the Gotthard saddle in summer and to use the rail in winter.

While the opening of the tunnel had a fundamental impact on the transportation network in Switzerland and Europe in general, accessibility of the canton of Ticino increased only modestly in terms of access to economic mass as a result. Reason for the relatively low impact on accessibility is that the tunnel connects two regions (the canton Uri in the north and the Leventina (TI) in the south) that have relatively little economic mass. Ticino's economic activity is concentrated in its southern part (Bellinzona, Locarno, Lugano), and the next larger city in central Switzerland is Lucerne. Even today, Bellinzona is 1.5 car hours away from Lucerne; Lugano and Locarno even almost 2 hours. As a result, both absolute and relative accessibility of Ticino did not substantially change from an access to economic mass perspective. We would therefore expect no major regional gains from the tunnel, neither in terms of efficiency nor in terms of redistribution.

A12: Vevey (Vaud) - Bulle (Fribourg)

In late 1981, the southern part of the canton of Fribourg around Bulle was connected to Vevey, which is part of Vaud and located at Lake Geneva. Travel time from Bulle to Vevey decreased by approximately 10 mins from 40 to 30 mins.

Accessibility of the Bulle region also increased relative to other regions, in particular compared to the region around Moudon in Vaud, from which it still today takes roughly 40 mins to

get to Vevey by car.

As a consequence, the canton of Fribourg could have benefited in two ways: On the one hand thanks to efficiency increases (e.g., people living in Bulle seeking work in Vevey), on the other hand thanks to redistributive gains (e.g., people with wages above Fribourg average moving from Vaud to Fribourg). In principle, one would expect that the canton of Vaud would have suffered redistributional losses as a result, while its absolute accessibility remained largely unchanged. Given the large size of the canton, however, it is unlikely that these small losses would have been visible at the cantonal level. To explore these effects, one would have to turn to a more granular level (e.g., districts or municipalities).

From a methodological point of view, it is important that the infrastructure expansions we study happened in isolation. If other cantons experienced similar network expansions at the same time, our counterfactual would be subject to treatment as well. Therefore, we refrain from looking at expansions during the late 1960s and early 1970s when a substantial share of cantons located in the Swiss Plateau were affected by the construction of the new highways, in particular the highway A1.

Clearly, investments in transport networks are affected by regional economic considerations, even if the decision – as in our cases – is taken at the federal level. This situation gives rise to potential endogeneity concerns. Is the new infrastructure indeed the cause of observed growth in later periods? Or has the road network simply been expanded in expectation of future growth? Fortunately, our identification strategy based on the synthetic control method is able to address these concerns. Similarly to Sunde and Strittmatter (2011), we argue that while a transport network expansion might be related to a region's economic outlook, "the particular year in which the implementation [i.e. in our case the opening of the new road] takes place is largely random" (p. 3), given that building a new federal highway or road tunnel involves both a long political decision process and a construction period of several years.

3 Methodology and Data

3.1 Synthetic Control Method

Goal of this paper is to quantitatively assess the impact of improved regional accessibility on the basis of case studies. In each case, only one or a few cantons are affected by a transport infrastructure expansion. The synthetic control method developed in Abadie, Diamond and Hainmueller (2010) is well suited for this purpose. Based on a donor pool of unaffected cantons, the synthetic control method explicitly models a counterfactual that mimics the behavior of the outcome variable – in our case: taxable income per taxpaying unit as proxy for income per capita – as it would have evolved in the absence of the treatment.

More precisely, we construct a synthetic control that consists of non-negative weights of other cantons that sum to 1. To ensure that the counterfactual is indeed relevant, we require that the synthetic control resembles the original canton with respect to a number of important characteristics (such as industry structure and unemployment rate). In the optimization process, the method puts most emphasis on those characteristics that are most powerful in explaining

variation in the dependent variable. The difference between the actual development in the post-treatment period and the evolution of the synthetic control serves as a measure for the effect of the treatment.

The synthetic control method is an elegant way to analyze case studies in a quantitative manner and possesses various strengths. For instance, the conditions under which the synthetic control method is valid are more general than those of traditional linear panel data or difference-in-difference estimators (see Abadie, Diamond & Hainmueller, 2010). The method also has a number of limitations, however. First, the results derived based on the synthetic control are only as good as the donor pool of untreated cantons. In particular, the cantons used to construct the synthetic control should not experience similar canton-specific shocks (e.g., access to a new highway, reform of the cantonal tax system, etc.). Second, it is important that the synthetic control resembles the treated canton in terms of key characteristics. The list of such characteristics is not finite – hence a judgment on the characteristics to be included in the set of predictor variables is required. Third, the method is best suited to analyze cases where the treatment is enacted from one day to another, without any influence on the pre-treatment period (e.g., a change of law). This is only partially true for infrastructure expansions given that they entail a construction period. We will address these limitations in the robustness checks sections of our analysis.

3.2 Data

All data series used in our analysis are at the cantonal level. Obtaining data on income per capita at the cantonal level in Switzerland proves challenging. In particular, there exist no official cantonal GDP (per capita) figures on a yearly basis. Moreover, cantonal GNI measures calculated by the Swiss Federal Statistical Office (Bundesamt für Statistik) are only available starting from 1965 (5-yearly) respectively 1978 (yearly). Therefore we approximate nominal income per capita according to the GNI concept with the average taxable income per taxpaying unit based on an updated version of the data presented in Schaltegger and Gorgas (2011). This data on taxable income is available from 1917 through 2009 from the Swiss Federal Tax Administration (Eidgenössische Steuerverwaltung), generally on a 2-year basis. At the end of the 1990s and in the first years of the new millennium, the figures become available on a yearly basis, following the change to a yearly tax declaration system. The numbers refer to taxable income according to the federal income tax system, i.e. they represent total labor and capital income minus deductions and are comparable across cantons, yet not necessarily across years. For our analysis, we use the data starting after the Second World War in 1945/1946 up to the period 1995/1996 and divide total income tax receipts of a canton in a given year by the number of taxpaying units (households and individuals) to obtain average taxable income per taxpaying unit. This variable serves as proxy for the average nominal income per capita of the residents in the canton.

The sources of the other data series are as follows. Data on the opening dates of the different sections of the Swiss national road network were kindly provided by the Swiss Federal Roads Office. The unemployment rate was published in various volumes of the Swiss periodical *Die Volkswirtschaft*, and the industry structure as well as the percentage of foreigners come from

the Historical Statistics of Switzerland (Historische Statistik der Schweiz) and the Swiss Federal Statistical Office. Where required, we interpolated missing data between existing data points in a linear manner. The number of newly built apartments refers to the number of new apartments completed in a given year and has been obtained from *Die Volkswirtschaft* (various volumes). The data on tourist nights and alpine pastures have been retrieved from the Swiss Federal Statistical Office.

4 Case Studies

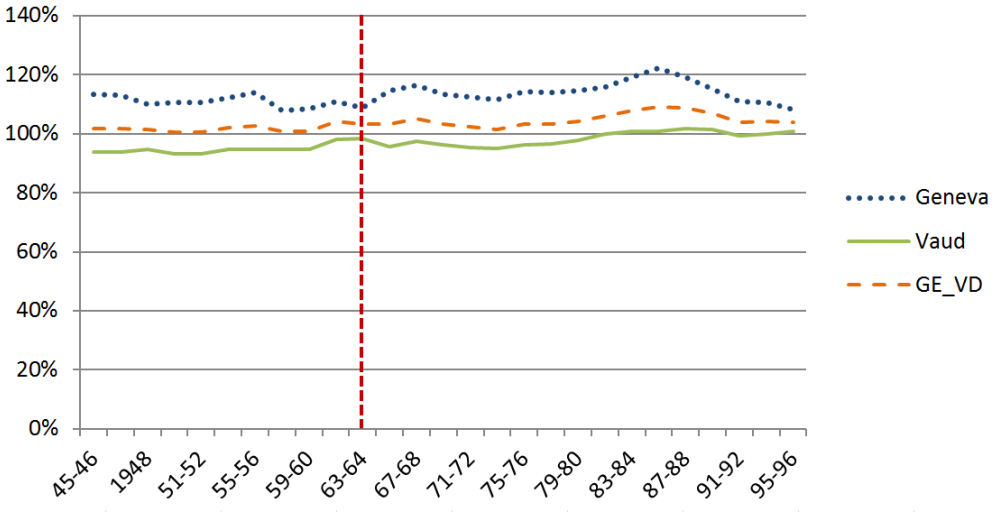
4.1 A1: Geneva - Lausanne (Vaud)

4.1.1 Background

Geneva (GE) and Vaud (VD) are two French speaking cantons in the western part of Switzerland. Figure 4 depicts cantonal income per capita[5] of Geneva and Vaud relative to the Swiss average. In the years 1963/1964, the period the highway between Geneva and Lausanne was opened, income per capita in Geneva stood at 109% of the Swiss average, while Vaud's average income was with 98% very close to the national mean.

For our analysis whether the new highway had a positive impact on overall income per capita of the larger area, we construct a hypothetical combined canton GE_VD. This hypothetical joint canton would have had an income per capita of 103% of the Swiss average at the time the new highway was completed.

Figure 4: Approximated income per capita relative to the Swiss average: Geneva, Vaud and GE_VD



4.1.2 Expected regional economic effects

The highway A1 between Geneva and Lausanne reduced travel time between Geneva and Lausanne substantially and therefore led to an increase in their absolute accessibility. Relative ac-

[5]Cantonal income per capita is approximated with average taxable income per taxpaying unit, see Section 3.2. The Swiss average excludes the canton of Jura in all years.

cessibility of the two cantons compared to the other Swiss cantons remained largely unchanged, however.

Potentially, as a result of the new highway people may have moved across cantonal borders along the Lake Geneva, with Geneva now being more easily reachable also from the south-western areas of Vaud (e.g., Nyon). For the combined hypothetical canton GE_VD, however, we would only expect an impact on income per capita in case the new fast connection between the two cities led to efficiency gains in either or both of the two regions.

4.1.3 Results

Figure 5 displays the evolution of average taxable income per taxpaying unit for the combined canton GE_VD and its synthetic control. We have calculated the synthetic control using the following list of predictor variables: the unemployment rate, the share of foreigners, the shares of economic activity in the primary, secondary and tertiary sectors, the number of newly built apartments per taxable unit, and the values of the taxable income per taxpaying unit in the years 1946, 1954 and 1962[6]. The optimization process covers the full pre-treatment period (1946-1962) and uses averages of the predictor variables over the same period[7]. The donor pool consists of all other Swiss cantons except Geneva, Vaud as well as Jura, which was only founded in 1979.

Figure 5: Average taxable income per taxpaying unit: Evolution of combined GE_VD and its synthetic control

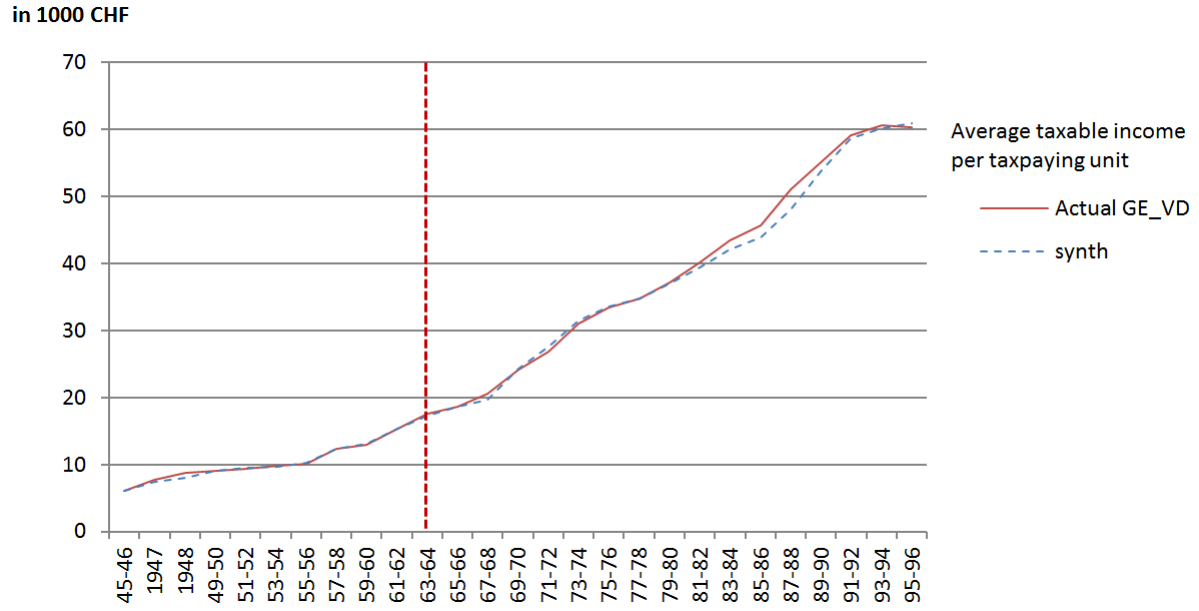


Figure 5 shows that after 1964, income per capita in GE_VD did not increase by substantially more than did its synthetic control. Therefore, the baseline synthetic control specification

[6]For 2-year tax periods, we always refer to the later year in the text. For instance, 1962 denotes the period 1961/1962.

[7]For newly built apartments per taxable unit, the time period for calculating the average pre-treatment value is shorter due to a break in the data series. Missing values are neglected everywhere.

suggests that if the new highway had had short- or medium-term effects on income per capita of the larger region, they would have been relatively small.

Table 1 provides details on the composition of our baseline synthetic control (left-hand side). It also shows the degree of congruence in the pre-treatment characteristics between GE_VD and its synthetic control (right-hand side). The synthetic control method ensures that the variables with the highest predictive power for the dependent variable show the largest degree of congruence (see Abadie, Diamond & Hainmueller, 2010, p. 500). All variables show a relatively high degree of conformance between the actual combined canton GE_VD and the synthetic control.

Table 1: Details on synthetic control for combined GE_VD

A. Composition		**B. Pre-treatment characteristics**		
Canton	Weight	Variable	Actual GE_VD	Synthetic GE_VD
BS	0.388	Unemployment rate (%)	0.179	0.209
TI	0.379	Percentage of foreigners	13.848	12.158
ZG	0.233	Primary sector share (%)	11.215	9.569
		Secondary sector share (%)	39.699	45.960
		Tertiary sector share (%)	48.921	44.253
		Newly built apartments per taxable unit	0.047	0.058
		Dep. variable (1946)	6,053	6,093
		Dep. variable (1954)	9,769	9,675
		Dep. variable (1962)	15,272	15,298

4.1.4 Robustness checks

Figure 5 above suggests that the new highway between Geneva and Lausanne did not have a major impact on overall income per capita in the combined area of the two cantons. There is still the possibility that the highway had a consistent, yet small impact. In the following, we examine this possibility and conduct a number of robustness checks.

Figure 6: Robustness checks, part 1: Relative evolution of average taxable income per taxpaying unit in GE_VD vs. its synthetic counterfactuals

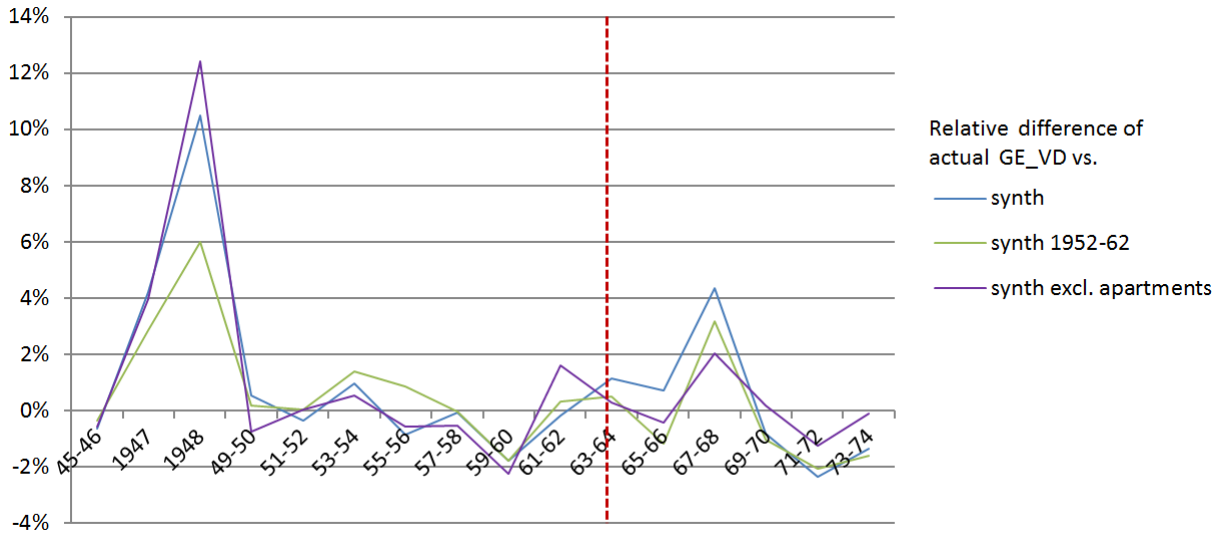
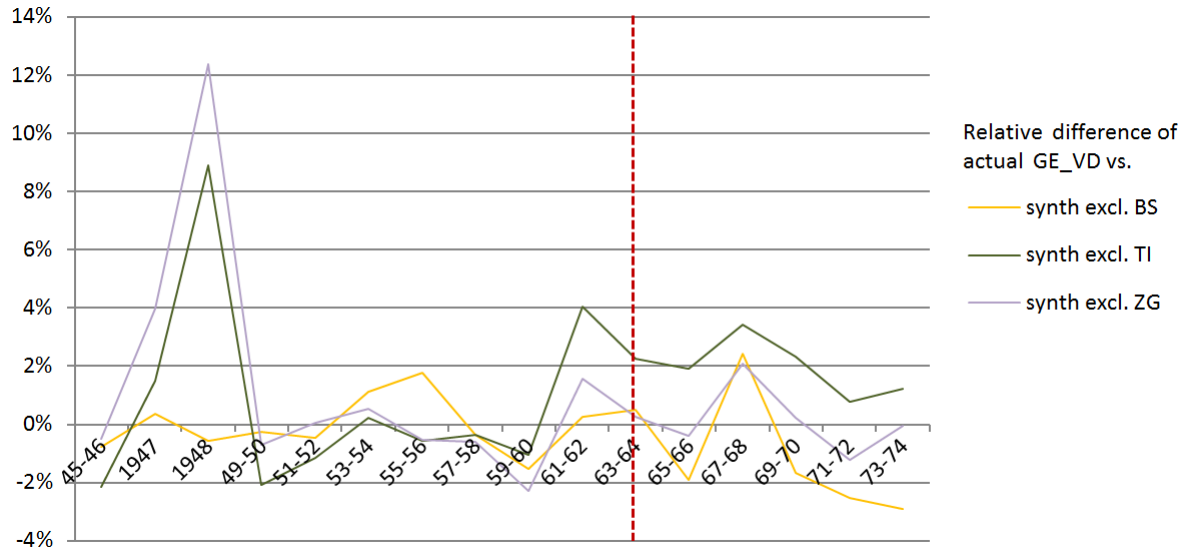


Figure 6 shows the results of the first part of these tests. The lines represent the percentage difference between the actual evolution of income per capita and its counterfactual for different

synthetic control specifications. The blue line (synth) depicts our baseline case presented above. Two observations stand out: First, actual income per capita shows a large deviation from the synthetic control of up to 10% in the years 1947 and 1948, when taxes were levied on a yearly basis. Second, there is no consistent increase in income per capita observable after 1964. If anything, the combined canton GE_VD only outperformed in one 2-year period (1967/1968), before falling behind its synthetic control in the years thereafter. These observations remain materially the same if the synthetic control is calculated over the shorter optimization period 1952-1962 (green line, synth 1952-62), or if the number of newly built apartments is excluded from the list of predictors variables (purple line, synth excl. apartments)[8].

In Figure 7 we check whether these observed deviations are robust to the exclusion of individual cantons from the synthetic control. More precisely, the orange, olive and violet lines represent tests whether our results might be driven by canton-specific developments in Basel-Stadt (BS), Ticino (TI) or Zug (ZG). All three cantons receive a relatively large weight in the synthetic control and thus could potentially bias the results. Therefore, we exclude one canton after the other from the donor pool and check whether the observed positive effects in 1947/1948 and 1967/1968 are due to one of these cantons.

Figure 7: Robustness checks, part 2: Relative evolution of average taxable income per taxpaying unit in GE_VD vs. its synthetic counterfactuals



The orange line (synth excl. BS) suggests that the deviation in 1947/1948 is driven by Basel-Stadt. If Basel-Stadt is excluded from the donor pool, the difference between actual GE_VD and synthetic control shrinks substantially for that period. In contrast, the deviation in period 1967/1968 cannot be explained by an individual canton. It seems unlikely, however, that this increase reflects efficiency gains from the new highway given that the outperformance is only present for one 2-year period. In most specifications, the actual level of income per capita in GE_VD was slightly below its synthetic control counterfactual both in the years before and after 1967/1968.

[8]In an additional robustness check not displayed in Figure 6, we excluded the unemployment rate from the analysis. The result was very similar to the exclusion of the number of newly built apartments.

4.1.5 Discussion

Overall, the results suggest that the highway A1 between Geneva and Lausanne did not have a substantial impact on income per capita in the combined area. Actual income per capita seems to have been higher than the synthetic control in only one out of five 2-year periods after the opening of the highway. It seems unlikely that this outperformance was the result of the new highway, which was of permanent nature. By combining the two cantons for our analysis, we excluded any redistributional effects the highway might have had to a large extent. Therefore, the result suggests that in the case of the highway A1 connecting Geneva and Lausanne, efficiency gains – if existent at all – would have been small.

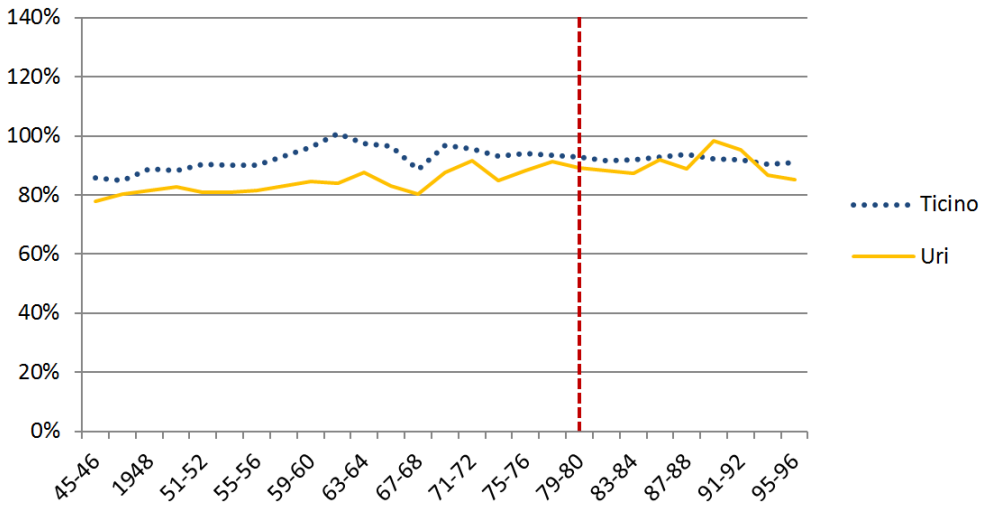
4.2 A2: Gotthard Road Tunnel

4.2.1 Background

Ticino is Switzerland's Italian speaking canton located in the southern part of the country. The canton is separated by the Alps from the central part of Switzerland. Since 1882, there exists a rail tunnel between Airolo and Göschenen. By car, the canton of Ticino was only reachable via the Gotthard saddle for a long time. The saddle is only open in summer, however. In winter, cars had to use the rail to cross the tunnel ("Autoverlad"). The Gotthard Road Tunnel, with a length of 16.9 km, changed this. Opened on September 5, 1980, the tunnel reduced the travel time by approximately 30 mins in summer and more in winter, and it ensured an all-year road connection between Ticino and central Switzerland. Building the tunnel took 10 years. Since its opening, the tunnel has become one of the major routes for people and goods to cross the Alps. In 2010, 943,000 heavy trucks passed through the tunnel, transporting 14.4 million net tons of goods. The tunnel is also used by roughly 5.4 million cars yearly.

Figure 8 shows that at the time the Gotthard Road Tunnel was completed, both cantons located on either side of the tunnel had a below-average income per capita. In the period 1979/1980, Ticino in the south stood at 93% of the Swiss average, and Uri in the north at 89%.

Figure 8: Approximated income per capita relative to the Swiss average: Ticino and Uri



4.2.2 Expected regional economic effects

The opening of the Gotthard Road Tunnel represented a major expansion of the Swiss highway network. It was accompanied by the completion of other sections of the highway A2, such as the Seelisberg Tunnel. While this north-south route through Switzerland had a fundamental impact on transportation in Europe, expected economic effects for the canton Ticino were more limited. Despite the transformational character of the tunnel, Ticino's access to economic mass changed only slightly, both in absolute as well as relative terms, given that the tunnel connects two regions with relatively modest economic output (the canton Uri in the north and the Leventina in the south). The next economic centers – Lucerne as well as Bellinzona, Lugano and Locarno – were 1.5 hours or more apart also after the opening of the A2. Moreover, the different languages (German in the north of the tunnel, Italian in the south) likely represented an additional barrier to market integration. As a result, we would expect no major regional gains for Ticino following the opening of the tunnel.

It could be, however, that the better accessibility of Ticino by car led to an increase in the number of tourists. Ticino's economy has a strong focus on tourism. Roughly a fourth of Ticino's regional GDP is generated in the tourism industry. For tourists, short travel distances might be less important than for companies or workers. Tourists might have valued the convenience of the new tunnel, which allowed a by-passing of the Gotthard saddle in summer and facilitated access to Ticino in winter. A rise in tourist numbers could have spurred productivity enhancements thanks to economies of scale, e.g., through a higher share of tourist nights per hotel bed or more passengers on existing cable cars. Such potential efficiency gains might have translated into higher income per capita.

In that sense, Ticino should serve as a "most likely least likely" case. Based on our concept of absolute versus relative accessibility, we do not expect Ticino to have benefited from the Gotthard Road Tunnel (least likely). Taking into account Ticino's strong focus on tourism, however, positive effects could still have materialized (most likely).

4.2.3 Results

Figure 9 shows the development of average taxable income per taxpaying unit in Ticino compared to its synthetic control. To calculate the baseline synthetic control, taxable income per taxpaying unit in the years 1958, 1968 and 1978 was used in the set of predictor variables. The other predictor variables were averaged over a 20-year pre-treatment period[9]. The same 20-year period was also used in the optimization process to calculate the synthetic control. Figure 9 indicates that for the time after the opening of the tunnel in 1980, actual income per capita in Ticino was not higher than in the synthetic control – if anything, it was lower.

Table 2 provides details on the weights assigned to each canton in the synthetic control (left-hand side) as well as on the predictor variables in the pre-treatment period (right-hand side). Compared to the case of GE_VD presented above, not all variables match equally well. In the robustness checks section below we show that this should not undermine our results, however.

[9] A 20-year optimization period was chosen to ensure that the counterfactual is relevant for our period of interest, which is approximately 10 years following the treatment.

Figure 9: Average taxable income per taxpaying unit: Evolution of Ticino and its synthetic control

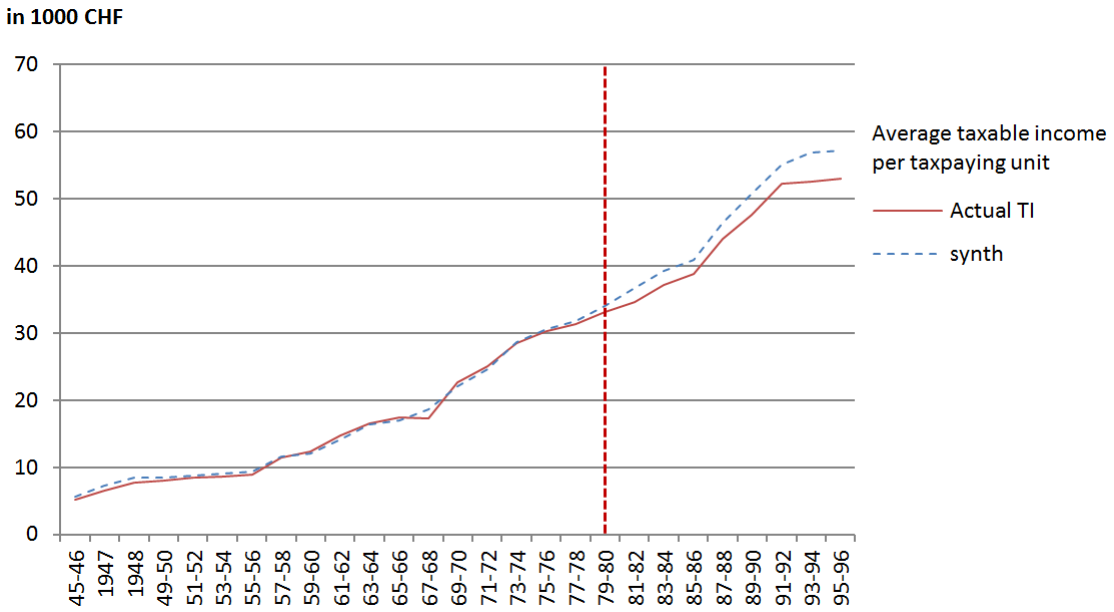


Table 2: Details on synthetic control for Ticino

A. Composition		**B. Pre-treatment characteristics**		
Canton	Weight	Variable	Actual TI	Synthetic TI
GL	0.236	Unemployment rate (%)	0.147	0.090
VD	0.764	Percentage of foreigners	23.611	17.802
		Primary sector share (%)	6.548	9.246
		Secondary sector share (%)	41.946	45.332
		Tertiary sector share (%)	51.003	45.326
		Newly built apartments per taxable unit	0.052	0.029
		Dep. variable (1958)	11,448	11,632
		Dep. variable (1968)	17,318	18,654
		Dep. variable (1978)	31,391	31,800

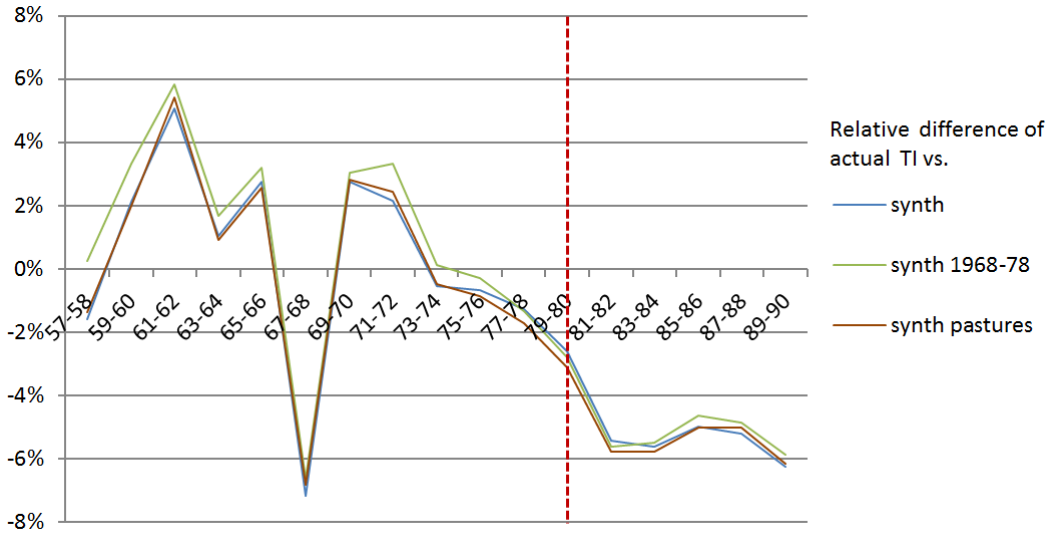
The finding that the tunnel did not substantially boost Ticino's economy is supported by data on tourists from the Swiss Federal Statistical Office. The number of overnight stays in Ticino slightly over-proportionally increased in the inital years after the opening of the tunnel. Between 1979 and 1981, the number of nights rose by 22.1%, compared to 17.8% in total Switzerland. Berner Oberland was the only touristic region in Switzerland that experienced a larger increase during that period (27.3%). However, this rise was not lasting. In the five years after 1981, Ticino lost 9.9% in tourist nights, which was almost double the Swiss average decline of 5.0%. This below-average trend continued in the 1990s.

Ticino also does not seem to be strongly integrated into the Swiss labor market. According to data from 2007, only 2.7% of the people that cross the Gotthard Road Tunnel are commuters between Ticino and central Switzerland (Borner et al., 2011, p. 50).

4.2.4 Robustness checks

We test the robustness of our finding in a number of ways. First, we re-run the analysis for alternative specifications of the synthetic control optimization procedure. The results are displayed in Figure 10.

Figure 10: Robustness checks, part 1: Relative evolution of average taxable income per taxpaying unit in Ticino vs. its synthetic counterfactuals



The blue line (synth) represents our baseline specification. The green line depicts the synthetic control calculated based on a 10-year rather than a 20-year pre-treatment optimization period. The results remain almost unchanged.

We have noted above that the synthetic control does not perfectly match the actual characteristics of Ticino. This might be an important caveat to our analysis. If the synthetic control should not accurately reflect Ticino's characteristics, then the evolution of the synthetic control might not be a relevant counterfactual. In the present case, the highest risk is that the counterfactual does not take Ticino's focus on tourism appropriately into account. To test whether this issue might be a driver of our results, we include an additional predictor variable that is able to explain a large part of the cross-sectional variation in the number of tourist nights per canton: the number of hectares of alpine pastures by taxable unit in 1980[10]. The brown line (synth pastures) shows the corresponding counterfactual. Again, the results are very similar to our baseline specification.

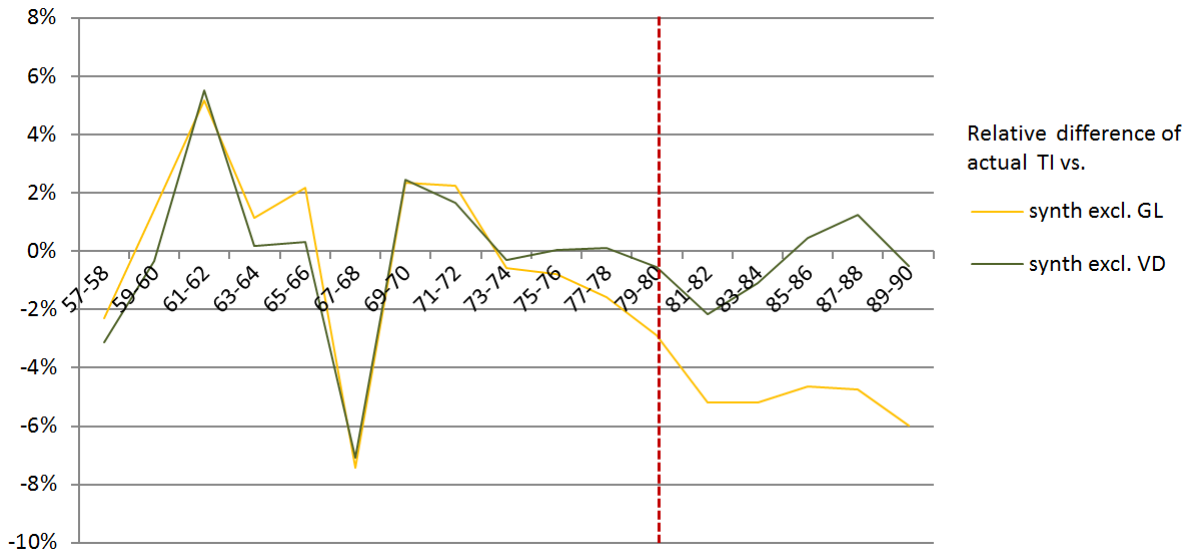
Overall, a consistent picture emerges from Figure 10: Ticino's income per capita did not increase relative to its synthetic counterfactual in the years after the opening of the Gotthard Road Tunnel. Rather, the results suggest that Ticino's income per capita might even have experienced a below-average development after 1980.

As in the case of GE_VD above, we test whether these findings are driven by an individual canton in the synthetic control. Given that the baseline specification only consists of two cantons (Glarus and Vaud), this robustness check is particularly important. Figure 11 presents the corresponding results.

The olive line (synth excl. VD) shows that the composition of the synthetic control indeed seems to matter: If Vaud is excluded from the synthetic control, the relative underperformance of Ticino implied by the other specifications is not visible anymore. Rather, Ticino seems to

[10]We use this proxy since data on tourist nights are not available on a cantonal basis before 2003 (only by touristic region).

Figure 11: Robustness checks, part 2: Relative evolution of average taxable income per taxpaying unit in Ticino vs. its synthetic counterfactuals



have developed more or less in line with its synthetic control after the opening of the Gotthard Road Tunnel. This robustness check therefore suggests that the tunnel had neither a positive nor a negative impact on Ticino's economy.

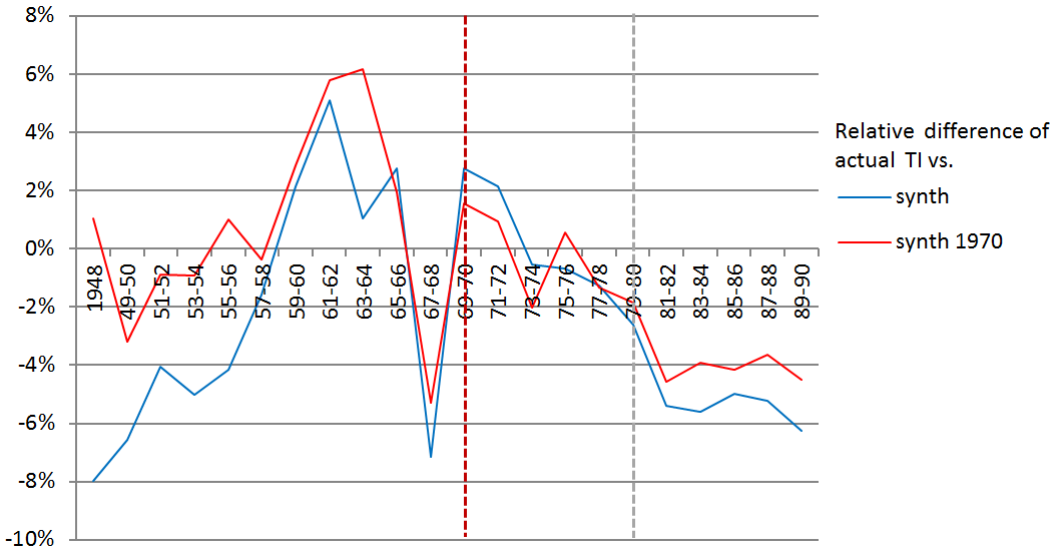
One reason for not finding a positive effect after 1980 could be that tunnel construction might have impacted income per capita in the 1970s. More precisely, the construction of the tunnel between 1970 and 1980 could have generated one-off economic benefits for Ticino. In that case, matching Ticino's income per capita in the years prior to the opening of the tunnel might bias our results. It could lead to a counterfactual that is too high compared to the case without a tunnel construction. To address this concern, we conduct an analysis similar to our baseline analysis, but with 1970 – the starting year of the construction – as treatment. Again, optimization is performed over a 20-year pre-treatment period (1948-1968), and taxable income per taxpaying unit in 1948, 1958 and 1968 is used together with the other predictor variables. The result is depicted as red line (synth 1970) in Figure 12 and provides little support for this hypothesis.

Actual Ticino does not seem to have consistently outperformed its counterfactual during the 1970s in terms of income per capita. The red line with treatment year 1970 shows a development similar to the blue baseline synthetic control with treatment year 1980. This finding implies that the construction period does not seem to have had a major impact on average income in the canton of Ticino.

In consequence, the robustness check with treatment year 1970 not only confirms, but even broadens the scope of our finding: First, the result confirms that the *opening* of the tunnel in 1980 does not seem to have led to an increase in income per capita. Second, it suggests that also the *construction* of the tunnel itself did not result in any substantial gains in income per capita.

Finally, we have also verified that our results are not driven by the inclusion of particular predictor variables. The finding that Ticino's income per capita did not outperform its coun-

Figure 12: Robustness checks, part 3: Relative evolution of average taxable income per taxpaying unit in Ticino vs. its synthetic counterfactual using the start of tunnel construction in 1970 as treatment year



terfactual in the years after the opening of the Gotthard Road Tunnel remains unaffected if we exclude the unemployment rate or the number of newly built apartments per taxpaying unit from the list of pre-treatment characteristics.

4.2.5 Discussion

Overall, our results provide evidence that the Gotthard Road Tunnel does not seem to have played a major role for Ticino's economy, at least not in terms of income per capita. The number of tourists slightly outperformed the Swiss average development immediately after the opening of the tunnel, but declined again after 1981.

If one goes one step further and makes the assumption that the economic fabric in Ticino has not fundamentally changed over the last 30 years, one could argue that closing the Gotthard Road Tunnel for renovation (as it is currently being discussed) would likely not have a disastrous impact on the economy in Ticino. This finding contrasts the predictions by Borner et al. (2011), who write that a temporary closure of the tunnel would have a severe adverse impact on the local economy in Ticino.

Clearly, the macroeconomic effects for the overall economy – both for Switzerland and Europe in general – of the Gotthard Road Tunnel are much larger than for Ticino alone. Hence our analysis should not be taken as an argument against the building of a second Gotthard tunnel. Rather it shows that the decision-making process should be guided by macroeconomic considerations at the national or Europe-wide level, not by regional concerns.

4.3 A12: Vevey (Vaud) - Bulle (Fribourg)

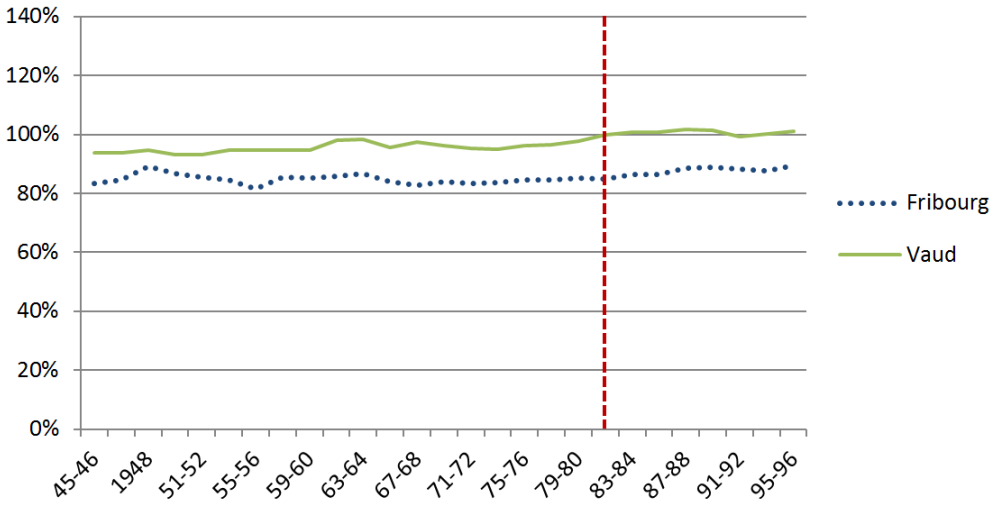
4.3.1 Background

Fribourg is a medium-sized canton at the border of the German and French speaking parts of Switzerland. Both German and French are official languages of the canton. The largest cities are Fribourg in the center and Bulle in the south. Traditionally, the southern part of the canton has been agriculturally oriented.

The construction of the highway A12 through the canton of Fribourg started in the 1970s. Step by step, the highway through the northern parts of Fribourg was established, connecting the canton with the nearby Swiss capital Berne. The link between the cities Fribourg and Berne was completed in 1976/1977. Meanwhile, the connection of the southern parts of Fribourg, particularly the region around Bulle, with Vevey (VD) was established only a few years later, in late 1981.

Figure 13 shows cantonal income per capita of Fribourg and Vaud relative to the Swiss average. In the period 1981/1982, Fribourg's average income stood at only 85% of the Swiss average. In contrast, Vaud's income per capita was equal to the national mean.

Figure 13: Approximated income per capita relative to the Swiss average: Fribourg and Vaud



4.3.2 Expected regional economic effects

The completion of the highway A12 brought the region of Bulle closer to Vevey and Lausanne in the canton of Vaud. As a result, both absolute and relative accessibility of the southern parts of Fribourg increased. The region of Bulle became more attractive both for businesses and residents, potentially at the cost of remote regions in Vaud such as Yverdon or Moudon.

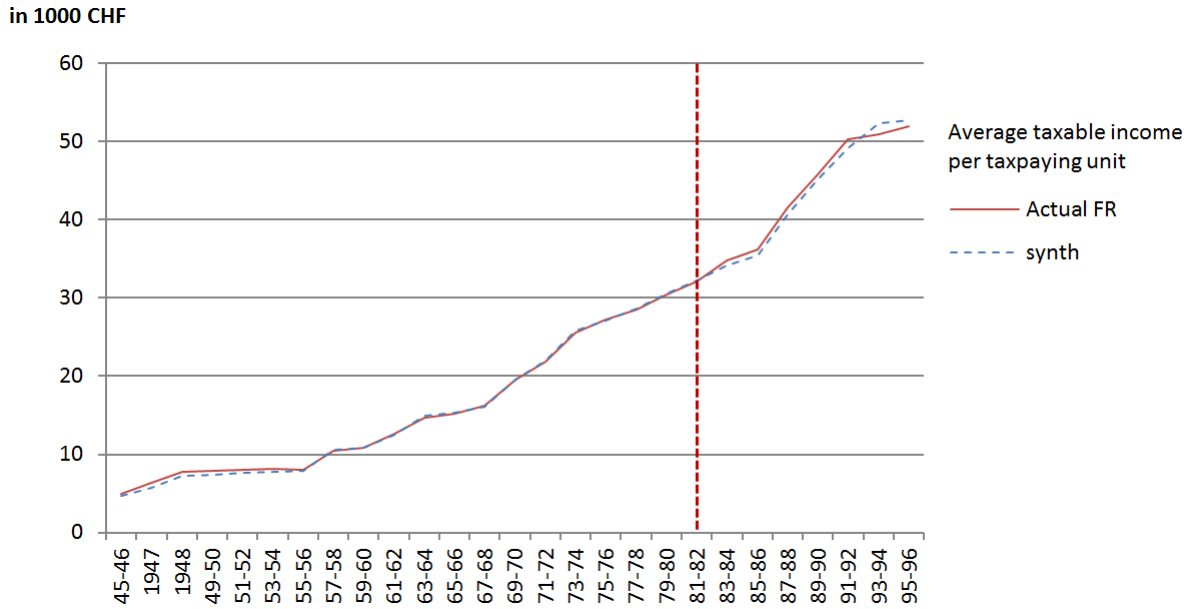
Therefore, we would expect that income per capita in Fribourg increased for two reasons: due to efficiency gains (e.g., people seeking a job in Vevey/Lausanne), and due to redistributional gains (e.g., people working in Vevey/Lausanne with above-average incomes moving to Fribourg). Clearly, the fact that primarily the southern part of Fribourg benefited from this part of the highway A12 attenuates the effect, which we would expect to be larger for the Bulle region

alone. On the other hand, our estimate might potentially also capture medium-term effects resulting from the improved connection to Berne in the north.

4.3.3 Results

Figure 14 shows the evolution of average taxable income per taxpaying unit for the canton of Fribourg and its synthetic control. We have included the same set of predictor variables as in the case of GE_VD presented in Section 4.1, including the lagged dependent variable in years 1960, 1970 and 1980. Optimization was performed over the 20-year period 1960-1980.

Figure 14: Average taxable income per taxpaying unit: Evolution of Fribourg and its synthetic control



According to Figure 14, income per capita in the canton of Fribourg increased by more than did its synthetic control in the years after the opening of the A12 connection between Bulle and Vevey. This finding seems to be backed by the development of the number of newly built apartments: In the five years following the completion of the A12 (1982-1985), the number of newly built apartments increased by 42% relative to the corresponding value during the period 1977-1981.

Table 3 provides details on the composition of the synthetic control and shows that the baseline synthetic control closely matches the pre-treatment characteristics of actual Fribourg.

4.3.4 Robustness checks

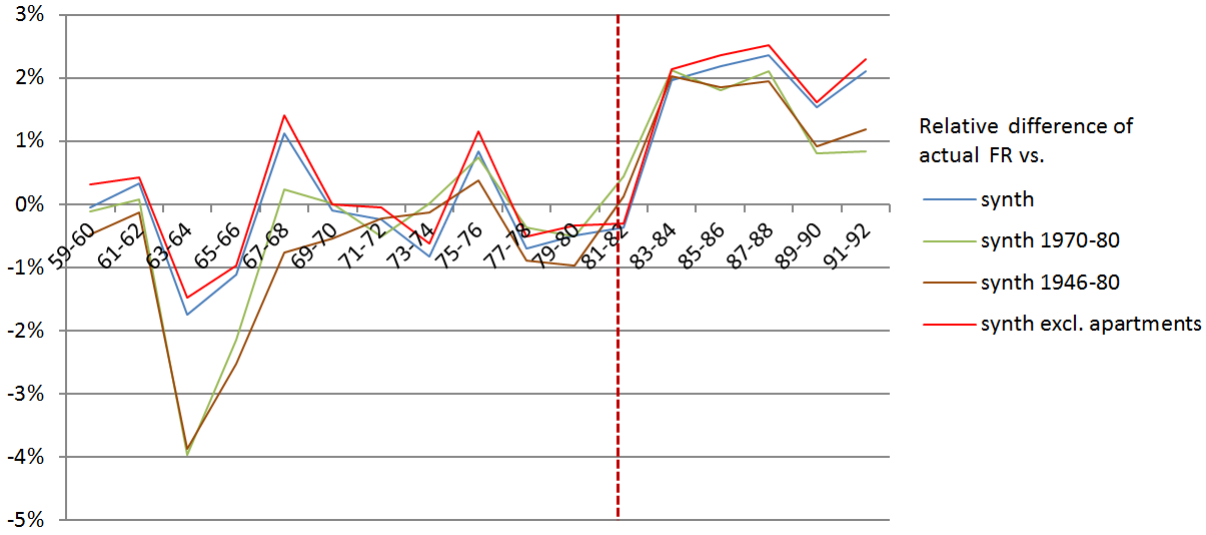
Figure 15 contains the results of a first set of robustness checks. The lines represent the relative difference of income per capita in actual Fribourg compared to its synthetic counterfactuals. The blue line (synth) depicts our baseline specification described above. The green line (synth 1970-80) was calculated using a 10-year instead of a 20-year optimization period. Similarly, the brown line (synth 1946-80) depicts the synthetic control for an optimization over the full pre-treatment period 1946 until 1980. Finally, the red line (synth excl. apartments) refers to a

Table 3: Details on synthetic control for Fribourg

A. Composition		**B. Pre-treatment characteristics**		
Canton	Weight	Variable	Actual FR	Synthetic FR
AI	0.334	Unemployment rate (%)	0.098	0.072
GE	0.077	Percentage of foreigners	7.269	7.946
NW	0.379	Primary sector share (%)	18.942	21.824
VS	0.211	Secondary sector share (%)	42.634	43.627
		Tertiary sector share (%)	38.021	34.392
		Newly built apartments per taxable unit	0.024	0.033
		Dep. variable (1960)	10,864	10,869
		Dep. variable (1970)	19,591	19,610
		Dep. variable (1980)	30,418	30,566

specification similar to our baseline synthetic control, but excluding the number of newly built apartments from the set of predictor variables.

Figure 15: Robustness checks, part 1: Relative evolution of average taxable income per taxpaying unit in Fribourg vs. its synthetic counterfactuals

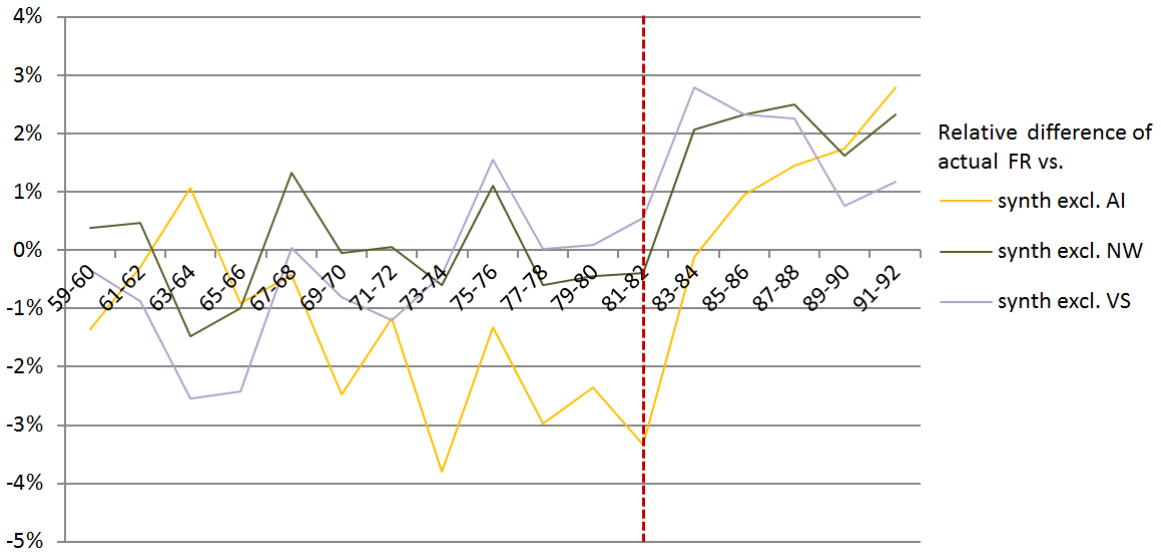


Overall, Figure 15 shows a consistent picture. The development of income per capita in Fribourg in the period after 1981/1982 was more favorable than any of the calculated synthetic counterfactuals. In the first three 2-year periods after the opening of the new highway connection between Bulle and Vevey, taxable income per taxpaying unit in Fribourg was roughly 2% higher than in the synthetic control canton.

To ensure that these results are not driven by a single canton in the synthetic control, we exclude the cantons with the largest weight in the synthetic control one after the other from the donor pool.

Figure 16 presents the corresponding results. The orange line excludes Appenzell-Innerhoden (AI), the olive line Nidwalden (NW), and the violet line Valais (VS). While the exclusion of NW and VS does not seem to have a major impact on the results in the post-treatment period, the quality of the synthetic control strongly decreases when AI is excluded. Even in this case, however, the orange line shows a strong increase after 1982, suggesting that the canton of Fribourg indeed outperformed its synthetic control in the years after the opening of the connection between Bulle and Vevey.

Figure 16: Robustness checks, part 2: Relative evolution of average taxable income per taxpaying unit in Fribourg vs. its synthetic counterfactuals



4.3.5 Discussion

With the completion of the highway A12 in late 1981, the southern part of the canton of Fribourg enjoyed an increase in both its absolute and relative accessibility. The results of our analysis suggest that this improved access translated into an increase in income per capita of about 2% compared to the synthetic control. Interestingly, most of the effect seems to have materialized in the years directly following the opening of the new highway.

5 Conclusion

Transport infrastructure networks are an important enabler of economic growth. Identifying the regional economic impact of specific parts of such networks has proven difficult, however. On the one hand, infrastructure networks are often enhanced in order to accommodate growth and therefore not exogenous to regional economic development. On the other hand, observable effects of improved transportation infrastructure do not necessarily reflect efficiency gains, but may also result from redistribution across regions.

In this paper, we propose a way how to disentangle efficiency gains (e.g., more efficient labor market allocation) from redistributional gains (e.g., people moving from region X to region Y). We argue that efficiency gains result from an increase in a region's absolute accessibility (with accessibility being understood as access to economic mass). Meanwhile, changes in the relative accessibility compared to other regions create redistributional gains for some regions and losses for others. The degree of change in relative and absolute accessibility can therefore be used to predict whether a specific transport infrastructure expansion likely leads to efficiency gains, redistributional gains, both effects, or no impact at all.

We investigate this hypothesis empirically based on three expansions of the Swiss highway network: the highway between Geneva and Lausanne (A1), the Gotthard Road Tunnel (A2), and

the connection between Vevey and Bulle (A12). Using the synthetic control method developed in Abadie, Diamond and Hainmueller (2010), we find that effects vary widely across cases. The highway A1 between Geneva and Lausanne, two economic cores in the western part of Switzerland, did not affect the evolution of income per capita of the combined larger area. Similarly, the Gotthard Road Tunnel connecting Ticino with central Switzerland does not seem to have led to an increase in Ticino's income per capita. In contrast, average income in the canton of Fribourg seems to have underwent an overproportional development in the years following the opening of the highway to Vevey that provided fast access to the region of Bulle.

In the context of our framework based on changes in absolute and relative accessibility, these findings can be interpreted as follows:

- The case study on Geneva and Lausanne suggests that pure efficiency gains resulting from transport infrastructure expansions may be small, at least when two already well developed regions are connected.
- If neither absolute nor relative accessibility of a region is substantially increased, even major network expansions such as connecting a remote region to the rest of the network (as it was the case for the Gotthard Road Tunnel) might have no positive effect on regional income per capita. This finding shows that transport infrastructure investments are no silver bullet to promote economic convergence of peripheral regions, even though they might still yield benefits at a more aggregate macro level (e.g., for Switzerland or Europe in general).
- The largest impact of an infrastructure network expansion can be expected when both absolute and relative accessibility of a region rise, as it was the case when the southern parts of Fribourg were connected to Vevey in the canton of Vaud.

These findings are indicative only in the sense that they are based on three single case studies at the cantonal level. Clearly, more systematic evidence is necessary to derive firm conclusions about the role of efficiency versus redistributional gains in explaining regional economic effects of transport infrastructure investments. It would be beneficial, for instance, to estimate the change in the absolute and relative accessibility of regions quantitatively. The presented case studies show that separating the different effects of infrastructure expansions based on changes in the absolute versus relative accessibility might be a fruitful avenue.

Note that our analysis focuses on tangible benefits (taxable income) only. Transport infrastructure improvements clearly also create intangible benefits (such as reduced commuting time, etc.). Many of these benefits might occur at the regional level.

Our work opens up several areas for future research. First, it would be desirable to further disentangle the redistributive effects of infrastructure expansions from their productivity-enhancing effects in cases where both absolute and relative accessibility increase. To that end, conducting an analysis of incomes at the level of households/individuals might be revealing. For instance, one could compare the evolution of incomes of existing residents with the incomes of new arrivers. One could also look at more disaggregated regional data (e.g., at the district level) and test whether regions whose relative accessibility declines indeed experience adverse economic effects.

Second, our analysis suggests that the integration of labor markets likely plays an important role for infrastructure expansions to generate immediate benefits in terms of income per capita. Understanding the interaction between labor markets and decisions on the place of residence therefore seems to be an issue that deserves special attention.

Third, changes in absolute and relative accessibility are not independent of a region's level of development. Hence, it is important to test our proposed framework in various regional contexts.

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