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Accessibility change and its impacts

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Questions

• Why bother with accessibilities?
• What are the trends for Switzerland?
• What are its impacts?
The mistaken logic of public capital

The literature since Aschauer (1989) assumes:

\[ \Delta y(t) = f(\Delta p(t), \Delta x(it)) \]

with

\[ \Delta y(t) : \text{GNP, productivity change} \]
\[ \Delta p(t) : \text{Road or other transport capital change} \]
\[ \Delta x(it) : \text{Change in other relevant variables} \]
Does this work?

Implicit assumption:

\[ \Delta p(t) \sim \Delta \text{Network services}(t) \]

but this implies constant proportionalities for each of the following:

\[ \Delta p(t) \sim \Delta \text{Lane miles}(t) \]
\[ \Delta \text{Lane miles}(t) \sim \Delta \text{Capacity}(t) \]
\[ \Delta \text{Capacity}(t) \sim \Delta \text{Speed}(t) \]
\[ \Delta \text{Speed}(t) \sim \Delta \text{Accessibility}(t) \]
\[ \Delta \text{Accessibility}(t) \sim \Delta \text{Network services}(t) \]
Switzerland: Changing costs of one km motorway
Switzerland: Changing speed gain of capacity expansion

Two-lane motorways

Trunk roads
Size of goods markets and productivity: A hypothesis

Economies of scale
Economies of scope

Activity
Fleet comfort
slots
vtts et al.

GDP

Tours
Energy costs

Market size

Energy costs

+ Elasticity > 0
- Elasticity < 0

Slots: possibilities to move goods or people
For a given infrastructure and commercial and private fleet
Accessibility as the log-sum term of a choice model

In line with the literature we use:

\[ Acc_i = \ln \sum_{\forall j} X_j e^{-\beta c_{ij}} \]

Using:
- Weighting parameter (\(\beta\)) of 0.2
- Travel time as the only generalised cost element (\(c_{ij}\))
- Population as number of opportunities (\(X_j\))
### Description of Elements: Overview

<table>
<thead>
<tr>
<th>Study area:</th>
<th>Switzerland and surrounding jurisdictions in a 350 km band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution:</td>
<td>Municipality equals one zone/Bezirk</td>
</tr>
<tr>
<td></td>
<td>Larger municipalities are subdivided</td>
</tr>
<tr>
<td></td>
<td>Zones outside Switzerland on regional or county level</td>
</tr>
<tr>
<td>Intrazonal travel times:</td>
<td>Dependent on equivalent radius of the size of the built up area</td>
</tr>
</tbody>
</table>
Description of Elements: Road transport

Network resolution: All major road developments inside Switzerland and motorway development outside

Link description: Assumed mean speeds by 51 link types based on a detailed historical review

Centroid connectors: Fixed speeds

Travel time calculation: Shortest-time paths
Description of Elements: Public transport

Timetables: Detailed time tables for all regular interurban trains (without S-Bahn)
Coaches and interurban buses, where relevant

Station connectors: Fixed speeds

Travel time calculation: Shortest-time paths (including transfer times)
Description of Elements: Years

Matching the census the reference areas are:

- 1850, 1888, 1910, 1930 Only Bezirke
- 1950 and then each decade Municipalities and Bezirke
## Road network models

<table>
<thead>
<tr>
<th>Year</th>
<th>mod.</th>
<th>Total CH</th>
<th>mod.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Links CH</td>
<td>Links CH</td>
<td>Links EU</td>
<td>Links EU</td>
</tr>
<tr>
<td>1950</td>
<td>3’527</td>
<td>17’698</td>
<td>136</td>
<td>29’248</td>
</tr>
<tr>
<td>1960</td>
<td>3’589</td>
<td>17’760</td>
<td>195</td>
<td>29’307</td>
</tr>
<tr>
<td>1970</td>
<td>4’147</td>
<td>18’318</td>
<td>422</td>
<td>29’534</td>
</tr>
<tr>
<td>1980</td>
<td>4’810</td>
<td>18’981</td>
<td>747</td>
<td>29’859</td>
</tr>
<tr>
<td>1990</td>
<td>5’215</td>
<td>19’386</td>
<td>896</td>
<td>30’008</td>
</tr>
<tr>
<td>2000</td>
<td>-</td>
<td>19’700</td>
<td>-</td>
<td>30’053</td>
</tr>
</tbody>
</table>
Road travel times from Zürich (1850)
Public transport travel times from Lausanne (1850)
Road travel times from Zürich (2000)
Public transport travel times from Lausanne (2000)
Road travel time-scaled map of Switzerland 1950

Scherer, 2004
Road travel time-scaled map of Switzerland 2000

Scherer, 2004
Rail travel time-scaled map of Switzerland 1950
Rail travel time-scaled map of Switzerland 2000
Accessibilities of the Bezirke since 1850
Road based accessibilities 1950 (without log)
Road based accessibilities 1960 (without log)
Road based accessibilities 1970 (without log)
Road based accessibilities 1980 (without log)
Road based accessibilities 1990 (without log)
Road based accessibilities 2000 (without log)
Growth of the road based accessibilities 1950 to 2000
Ratio of road to public transport accessibilities 2000
First set of conclusions

Tracking the road-based accessibility changes is possible over a long period of time.

It seems advisable to concentrate only on the developments of the motorways and similar high capacity roads.

Public transport requires full timetables.

Public transport accessibilities underestimated due to the omissions of schedule delay effects (headways)
First set: continued

Need to track not only infrastructure, but also regulations and the vehicle fleet.

Policy impetus to the equalisation of speeds

Winners are the suburban municipalities between the major centres

Saturation effects visible
How to model the impacts?

Regression approaches:

- OLS

- Hierarchical multilevel models

- Spatial error and lag models
Starting point

OLS assumes:

\[ y = X\beta + \varepsilon \]
\[ \varepsilon \sim iid N(0, \sigma) \]

\( y \)  Dependent variable
\( \beta \)  Vector of parameters
\( X \)  Matrix of independent variables
\( \varepsilon \)  Error
\( \sigma \)  Variance of the error
What can go wrong?

Heteroscedacity 1

\[ \varepsilon \sim \hat{y} \]

Heteroscedacity 2

\[ \varepsilon \sim x \]

Collinearity

\[
\text{cov}(x_i, x_j) \neq \begin{pmatrix}
1 & 0 & \cdots & 0 \\
0 & 1 & \cdots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
0 & \cdots & 0 & 1
\end{pmatrix}
\]
What else can go wrong?

Spatial or temporal vicinity

$$\text{cov}(\varepsilon_n, \varepsilon_m) \neq \begin{bmatrix} 1 & 0 & \ldots & 0 \\ 0 & 1 & \ldots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & \ldots & 0 & 1 \end{bmatrix}$$
Spatial regression models

Spatial autoregressive model (SAR):

\[ y = \rho W_A y + X\beta + \varepsilon \quad \varepsilon \sim iid \ N(0, \sigma) \]

Spatial error model (SEM)

\[ y = X\beta + u \quad u = \lambda W_E u + \varepsilon \]

Spatial autoregressive and spatial error model combined (SAC):

\[ y = \rho W_A y + X\beta + u \quad u = \lambda W_E u + \varepsilon \]

with \( W \): neighborhood matrix (contiguity matrix) with row sum=1
\( \rho \): influence factor of spatial autoregressive dependence
\( \lambda \): influence factor of spatial dependence of error
Hierarchical regression (Simplest 2-level model)

\[ y_{ij} = \beta_{0ij} x_0 + \beta_{1ij} x_{1ij} \]

with:

- **fixed part**
  - \( \beta_{0ij} = \beta_0 + u_{0j} + \varepsilon_{0ij} \)

- **random part**
  - \( \beta_{1ij} = \beta_1 + u_{1j} + \varepsilon_{1ij} \)

and:

- **fixed part**
  - \( \beta_{0ij} = \beta_0 + u_{0j} + \varepsilon_{0ij} \)

- **random part**
  - \( \beta_{1ij} = \beta_1 + u_{1j} + \varepsilon_{1ij} \)

Example:

- **y** Relative population growth
- **\( \beta_{0,1} \)** Parameter
- **x_0** Constant
- **x_1** Change in accessibility
- **u** Systematic error (departure of the \( j \)-th Cantons intercept (slope) from the overall value)
- **\( \varepsilon \)** Error (departure of the \( i \)-th municipality’s actual score from the predicted score)

\[ \varepsilon \sim iid \ N(0, \sigma) \]

- **i** Level 1 (Municipality)
- **j** Level 2 (Kanton)
Population growth by municipality

![Graph showing relative population growth against accessibility change.](image)
Analysis of the “systematic errors”
Neighbourhoods in Swiss population growth patterns

- Other
- Highest intercepts
- Highest slopes
Above average (> one st dev.) population growth
Growth wave (from Zürich)
Growth wave (from Zürich)
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.383</td>
<td>0.715</td>
<td>0.309</td>
</tr>
<tr>
<td>constant</td>
<td>0.190</td>
<td>0.001</td>
<td>-0.007</td>
</tr>
<tr>
<td>$\Delta$ Employment 2$^{nd}$ sector$_t$</td>
<td>-0.025</td>
<td>0.013</td>
<td>0.014</td>
</tr>
<tr>
<td>$\Delta$ Employment 3$^{nd}$ sector$_t$</td>
<td>0.089</td>
<td>0.068</td>
<td>0.011</td>
</tr>
<tr>
<td>$\Delta$ Road accessibility$_t$</td>
<td>0.246</td>
<td>0.082</td>
<td>0.150</td>
</tr>
<tr>
<td>$\Delta$ Transit accessibility$_t$</td>
<td>0.267</td>
<td>0.777</td>
<td>0.430</td>
</tr>
<tr>
<td>lambda</td>
<td>0.555</td>
<td>0.464</td>
<td>0.412</td>
</tr>
</tbody>
</table>
Conclusions

- Modelling needs to account for spatial correlations
- Starting position makes a difference
- Strength of accessibility impacts change
- Saturation is observable for larger, but still small areas units
Literature: Impacts of accessibility


Literature: Spatial regression

Appendix
### Mean ratios of road to public transport accessibility

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.31</td>
<td>1.33</td>
<td>1.38</td>
<td>1.38</td>
<td>1.37</td>
<td>1.36</td>
</tr>
<tr>
<td>Median</td>
<td>1.28</td>
<td>1.30</td>
<td>1.33</td>
<td>1.33</td>
<td>1.32</td>
<td>1.32</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.19</td>
<td>0.21</td>
<td>0.23</td>
<td>0.24</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>25% percentil</td>
<td>1.16</td>
<td>1.17</td>
<td>1.19</td>
<td>1.19</td>
<td>1.19</td>
<td>1.19</td>
</tr>
<tr>
<td>75% percentil</td>
<td>1.43</td>
<td>1.46</td>
<td>1.53</td>
<td>1.53</td>
<td>1.51</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Based on municipal accessibilities, with their own-accessibility included.