Spatial Econometrics and Spillover Effects in Panel Data: Evidence from the Swiss Cantons’ Expenditure

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1. Motivation

- Spatial econometrics studies the interdependence between cross-sectional units.
  - The distance between two neighbors can be geographic or more generally economic, social, cultural, demographic.
  - Baltagi (2005): aggregated units such as countries, regions or states exhibit cross-sectional correlation.
  - Bell and Bockstael (2000): ignoring the spatial relationship among the cross-section units is equivalent to ignoring the ordering of time series data.
  - Distinction between spatial dependence and spatial heterogeneity.

- We study whether it exists a spillover effect in the real public spending per capita of Swiss cantons, Case et al. (1993).
  - We use a panel data set for the 26 Swiss cantons over the period 1980-2002.
  - We define two neighboring criteria: contiguity and language.
2. Some Spatial Panel Models

- **Spatial lag model**

\[
y_{it} = \rho \sum_{j=1}^{N} w_{ij} y_{jt} + x_{it}' \beta + \epsilon_{it} \quad i = 1, \ldots, N \quad t = 1, \ldots, T \quad (1)
\]

where

- \( \rho \): spatial autoregressive parameter
- \( w_{ij} \): spatial weight
- \( x_{it} \): a set of \( K \) control variables
- \( \beta \): \( K \) parameters to be estimated along with \( \rho \)
- \( \epsilon_{it} \): error term \( i.i.d. \sim (0, \sigma^2_{\epsilon}) \)

- **Spatial error model**

\[
y_{it} = x_{it} \beta + \epsilon_{it} \quad \text{with} \quad \epsilon_{it} = \lambda \sum_{j=1}^{N} w_{ij} \epsilon_{jt} + u_{it} \quad (2)
\]
2. Spatial Panel Models

- Spatial cross-regressive model

\[ \mathbf{y}_t = \delta \mathbf{W} \mathbf{X}_t + \mathbf{X}_t \beta + \epsilon_t \quad t = 1, \ldots, T \]  

- Spatial models with individual and time effects

\[ \mathbf{y} = \rho (I_T \otimes \mathbf{W}_1) \mathbf{y} + \mathbf{X} \beta + (\nu_T \otimes \mathbf{I}_N) \mu + (I_T \otimes \nu_N) \gamma + \epsilon \]  

and

\[ \epsilon = \lambda (I_T \otimes \mathbf{W}_2) \epsilon + u \]

\( \mu_i \) and \( \gamma_t \) can be either fixed or random and either \( \rho \) or \( \lambda \) can be equal to zero.
Determinants of Spending

- Economic variables
  - Spending of the *neighbors*
  - Spending of the previous period
  - Revenue
  - Income
  - Federal grants
  - Unemployment rate
  - GDP growth rate

- Political variables
  - Budget initiatives
  - Budget referendums
  - Political leaning of the government and parliament
  - Concordance between the government and the parliament

- Demographic variables
  - Share of the population aged less than 20 and more than 65
Neighboring Criteria

- **Contiguity criterion**
  - We assume that there should be a spillover effect among contiguous spatial units: cantons surrounded by neighbors with high spending should tend to spend more and vice-versa.

  \[ w_{ij} = \begin{cases} 
  1 & \text{if } i \text{ and } j \text{ are contiguous} \\
  0 & \text{otherwise} 
  \end{cases} \]

- **Language criterion**
  - It should capture some cultural effect. Feld et al. (2001) and Feld and Matsusaka (2003) outline that Latin cantons have higher preferences for public sector solutions of social problems.

  \[ w_{ij} = \begin{cases} 
  1 & \text{if } i \text{ and } j \text{ are Latin cantons} \\
  0 & \text{otherwise} 
  \end{cases} \]

- Both weight matrices are row-standardized. As a result, the spatial autoregressive parameter \( \rho \in [-1; 1] \).
We have a balanced panel data set with yearly observations for the 26 Swiss cantons over the period 1980-2002. This data set was kindly provided by M.-J. Martin.

All the monetary variables are expressed in real Swiss francs of year 2002 and in per capita unit.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Domain</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure</td>
<td>R^+</td>
<td>6 845</td>
<td>2 773</td>
<td>3 291</td>
<td>20 296</td>
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<tr>
<td>WC-Expenditure</td>
<td>R^+</td>
<td>6 384</td>
<td>1 314</td>
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<td>1 266</td>
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<td>Initiative</td>
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<td>14.64</td>
<td>2.07</td>
<td>10.28</td>
<td>20.10</td>
</tr>
</tbody>
</table>
Data: Average Expenditure and Revenue for all Cantons
Checking for Spatial Dependence

Moran’s scatterplot for $W_{Cy}$ and $W_{Ly}$
Checking for Spatial Dependence

### Moran’s I statistic for spatial autocorrelation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Contiguity</th>
<th></th>
<th>Language</th>
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<td>p-value</td>
<td>Moran’s I</td>
<td>p-value</td>
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<td>6.4950</td>
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</table>

*Notes. $H_0$: No spatial autocorrelation.*

### Pesaran’s CD test on spending

<table>
<thead>
<tr>
<th>Groups</th>
<th>CD Statistics</th>
<th>P-value</th>
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<tbody>
<tr>
<td>All cantons, 2 lags</td>
<td>25.803</td>
<td>0.0000</td>
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<tr>
<td>All cantons, 3 lags</td>
<td>21.879</td>
<td>0.0000</td>
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</tbody>
</table>

*Notes. $H_0$: Cross-section independence.*
Unit Root and Cointegration Tests

- **Panel unit root tests**
  - We perform 5 different unit root tests: two Fisher type tests, LLC, IPS and Pesaran’s test.
  - $H_0$ of nonstationarity of each time series in the panel is not rejected for spending, $W_C$-spending, $W_L$-spending, revenue and income. They are $I(1)$.

- **Panel cointegration tests**
  - Four error correction based cointegration tests, Westerlund (2007).
  - We find that $H_0$ of no cointegration with public spending is rejected for all the variables suspected to be $I(1)$. 
Model and Estimation Method

- Model

\[ y_{it} = \rho y_{i,t-1} + \lambda \sum_{j=1}^{N} w_{ij} y_{jt} + \beta' x_{it} + \mu_i + \epsilon_{it} \] (5)

- Feed-back effect: \( x_{it} \rightarrow y_{it} \rightarrow y_{jt} \rightarrow y_{it} \Rightarrow \partial y_{it} = A_{ii} \beta_k \partial x_{it}^k \)

- Cross effect: \( x_{jt} \rightarrow y_{jt} \rightarrow y_{it} \Rightarrow \partial y_{it} = A_{ij} \beta_k \partial x_{jt}^k \)

where \( A = (I_N - \lambda W)^{-1} \)

- Estimation method

  - We use an IV estimation method.
Endogeneity Issues and Instruments

- **Endogenous variables**
  - Spatial lag of spending
  - Serial lag of spending (dynamic model)
  - Revenue
  - Federal grants
  - Initiative
  - Referendum

- **Instrumental variables**
  - For revenue, federal grants, initiative and referendum, their first serial lag are used as instruments.
  - For the serial and spatial lag of spending we choose among the serial and spatial lag of the exogenous variables.

<table>
<thead>
<tr>
<th>Coefficients of correlation</th>
<th>Expenditure(_t-1)</th>
<th>(W_C)-expenditure</th>
<th>(W_L)-expenditure</th>
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## Estimation Results: Dynamic Model

<table>
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<th>Contiguity (1)</th>
<th>Language (2)</th>
<th>No Wy (3)</th>
<th>No Wy (4)</th>
<th>No Wy (5)</th>
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<td>Expenditure&lt;sub&gt;t−1&lt;/sub&gt;</td>
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<td>0.444***</td>
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<td>Revenue</td>
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<td>94.14***</td>
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<td>(18.53)</td>
<td>(21.67)</td>
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<td>0.0331***</td>
<td>0.0346***</td>
<td>0.0361***</td>
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## Estimation Results: Static Model

<table>
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<tr>
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<th>Language (3)</th>
<th>Language (4)</th>
<th>No Wy (5)</th>
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<td>$W_C$-expenditure</td>
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<td>0.565***</td>
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<td>Population ( &lt; 20)</td>
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<td>-16.21</td>
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<td>(22.53)</td>
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<td>Observations</td>
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<td>$R^2$ Within</td>
<td>0.9395</td>
<td>0.9396</td>
<td>0.9374</td>
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<td>$R^2$ Between</td>
<td>0.8906</td>
<td>0.8965</td>
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<td>$R^2$ Overall</td>
<td>0.8902</td>
<td>0.8947</td>
<td>0.8984</td>
<td>0.9092</td>
<td>0.9335</td>
</tr>
</tbody>
</table>
Estimation Results: Interpretation

- One Swiss franc increase in the public expenditure of its neighbors, increases the spending of a canton by around 24 cents if these cantons are contiguous and by roughly 18 cents for common language. For the static model this effect is stronger and respectively around 27 and 19 cents.

- Feed-back effect: $\hat{A}_{ii}$ varies from 1.0020 to 1.0316.

- Cross effect: the following table shows $\hat{A}_{ij} > 0.05$.

- Control variables
  - The serial lag of spending, revenue, initiative, unemployment rate, income, growth rate and government generally yield significant estimates with the right sign.
  - The estimates in different specifications of the spatial lag model are close to each other than with the estimates of the model without the spatial term.

- $R^2$: are quite high and vary from 89.02% to 96.17%.
## Estimation Results: Cross Effects

Cross effects: elements of the matrix $(I_N - \hat{\lambda}W_C)^{-1}$, greater than 0.05, dynamic

<table>
<thead>
<tr>
<th>Canton $i$</th>
<th>Contiguous neighbor $j$ and value of $A^{ij}$ for $i \neq j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zurich (ZH)</td>
<td>BE (0.0687) LU (0.0653) UR (0.0656) NW (0.0663)</td>
</tr>
<tr>
<td>Bern (BE)</td>
<td>Obwalden (OW) BE (0.0558) LU (0.0546) UR (0.0549) OW (0.0531)</td>
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<tr>
<td>Lucerne (LU)</td>
<td>NW (0.0663)</td>
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<tr>
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<tr>
<td>Schwyz (SZ)</td>
<td>BE (0.0691) NE (0.0869)</td>
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<td>Jura (JU)</td>
<td>BE (0.0677) BS (0.0610) AG (0.0657) JU (0.0655)</td>
</tr>
</tbody>
</table>
4. Conclusion

- One Swiss franc increase in a canton’s neighbors’ expenditure increases its own expenditure by roughly 30 cents. The spillover is stronger among contiguous cantons.

- The definition of the weight matrix is to some extent arbitrary in the sense that it is defined by the researcher, but ignoring the spatial correlation would also be arbitrary.

- The presence of the spatially lagged dependent variable introduces the feed-back and the cross effects.

- An extension of this work should be:
  - The disaggregation of the public expenditure by nature such as education, health, security, infrastructure etc.
  - An alternative functional form for the contiguity weight matrix.
  - Use of other neighboring criteria based on income, political orientation of cantons’ institutions etc.
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THANK YOU