# Intra-Urban Migration Analysis: Data from Berlin After Unification

***by***

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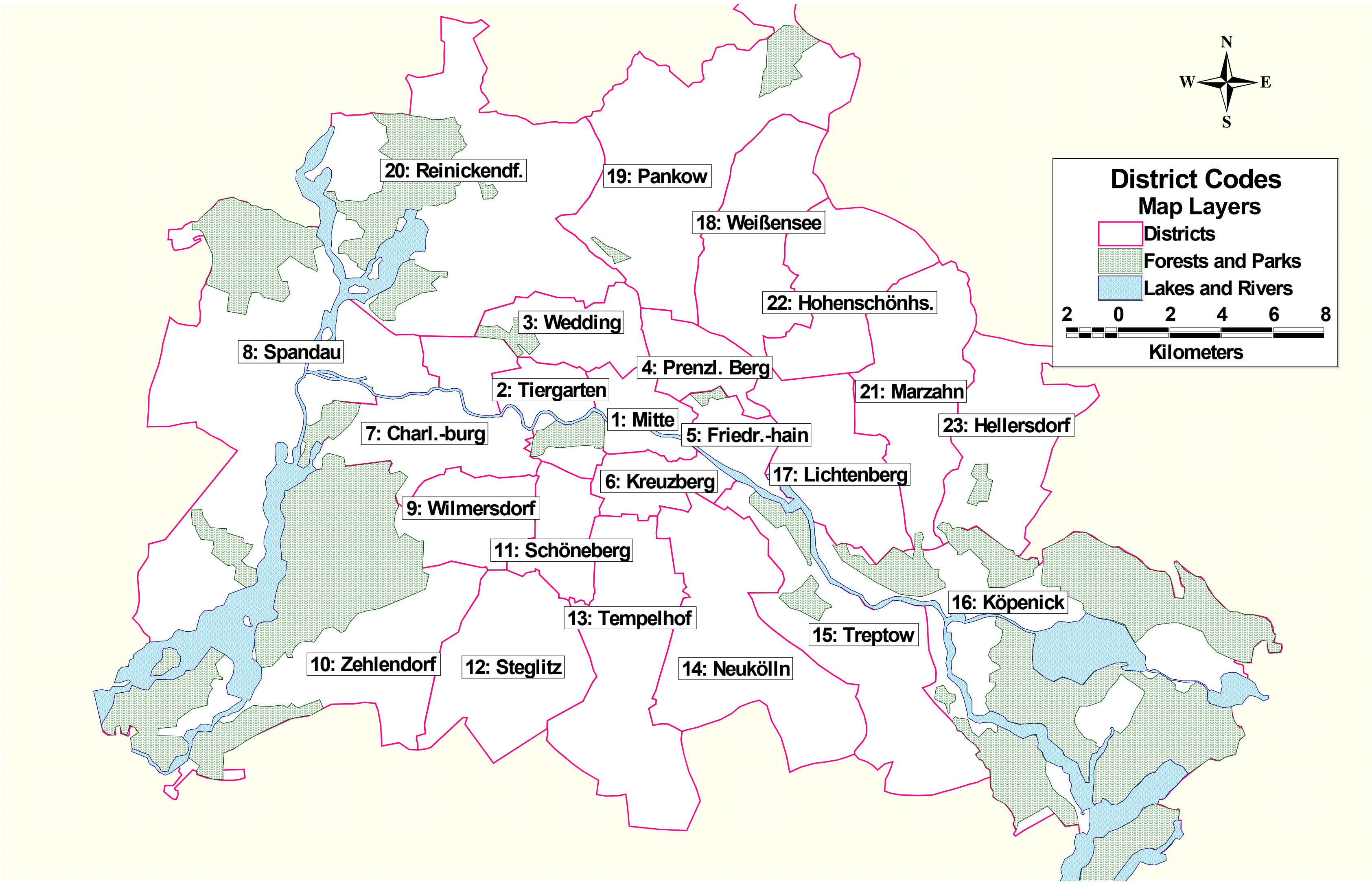
Earlier work on this project was conducted in cooperation with Gerhard Braun, Free University of Berlin, and the support by the Statistical Bureau of the City of Berlin

# Introduction



# Introduction

## Background:

- Physical layout: Sectors, Transportation infra-structure
- History:
  - Blockade 1948-1949
  - Wall erected August 13, 1961 - Wall fallen November 9, 1989
  - German Unification October 3, 1990

## Key Research Questions:

- Are the two migratory sub-systems in the Eastern and Western parts of unified Berlin converging towards a joint equilibrium?
- Is the underlying urban structure reflected in the internal urban migration pattern?

## Data:

- Internal annual migration among the 23 districts of Berlin for the accounting years 1991 to 1997

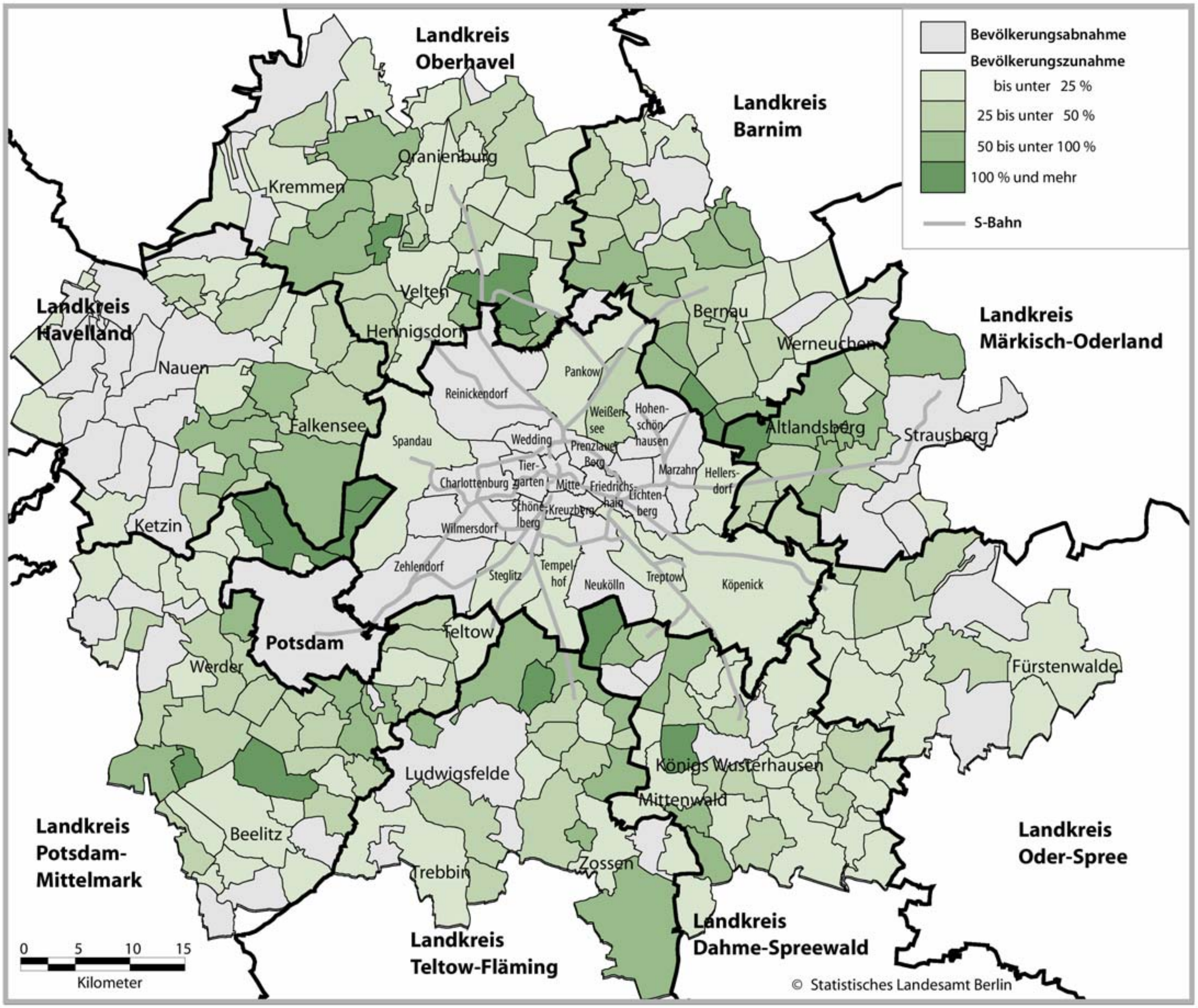
## Method:

- Modeling by Poisson regression within the doubly constrained gravity framework accounting for time, distance and migratory subsystems
- Residual analysis with respect to the underlying urban structure

# Introduction

## Methodological Background

- Closed system perspective, i.e., neglecting of external migration patterns



# Definition of the Migratory Subsystems

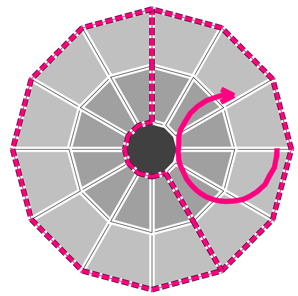
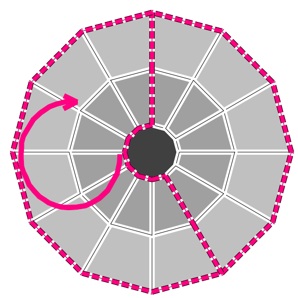
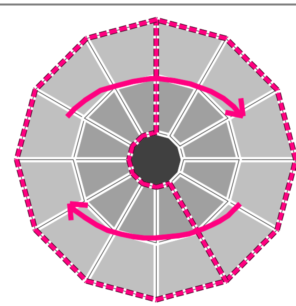
- The annual migration tables

$$\begin{pmatrix} 0 & m_{E\to E} & m_{E\to W} \\ m_{E\to E} & 0 & m_{W\to W} \\ m_{W\to E} & m_{W\to W} & 0 \end{pmatrix}$$

among the 23 districts of Berlin can be logical been broken up into four sub-tables, each reflecting a distinct spatial interaction subsystem.

- Analyzing these four subsystems simultaneously allows investigating whether both parts of Berlin are converging towards a joint equilibrium after the unification.

# Definition of the Migratory Subsystems

| Subsystems | Spatial Partitions | Table Partitions |
|---|---|---|
| **East $\rightleftarrows$ East:**<br>• $\bar{d}_{E \rightleftarrows E} = 9.9$ km<br>• 11 districts |  | $\begin{pmatrix} 0 & m_{E->E} & 0 \\ m_{E->E} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$ |
| **West $\rightleftarrows$ West:**<br>• $\bar{d}_{W \rightleftarrows W} = 9.8$ km<br>• 12 districts |  | $\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & m_{W->W} \\ 0 & m_{W->W} & 0 \end{pmatrix}$ |
| **East $\rightleftarrows$ West:**<br>• $\bar{d}_{E \rightleftarrows W} = 14.8$ km |  | $\begin{pmatrix} 0 & 0 & m_{E->W} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$<br>$\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ m_{W->E} & 0 & 0 \end{pmatrix}$ |

# Specification of the Migration Model

- The internal migration within each district are excluded by *structural zeros*
- *Origin* and *destination constraints* have been imposed so that the estimate in-migration and out-migration figures match the empirical observed ones.
- The effect-coding scheme has been employ to allow comparison of the estimated parameters with respect to the grand-mean.
- The indices of the four-way interaction table are
  - $i$ for the origin,
  - $j$ for the destination,
  - $s$ for the spatial subsystem, and
  - $t$ for the accounting period.
- The specification of Poisson regression migration model is:

$$\ln\left(\hat{\mu}_{ijst}\right) = \hat{\lambda} + \hat{\lambda}_i + \hat{\lambda}_j + \hat{\lambda}_s + \hat{\lambda}_t + \hat{\lambda}_{st} + \hat{\lambda}_d \cdot d_{ij} + \hat{\lambda}_{d|i} \cdot d_{j|i}$$

# Specification of the Migration Model

The specification of the log-linear migration model is:

$$\ln\left(\hat{\mu}_{ijst}\right) = \hat{\lambda} + \hat{\lambda}_i + \hat{\lambda}_j + \hat{\lambda}_s + \hat{\lambda}_t + \hat{\lambda}_{st} + \hat{\lambda}_d \cdot d_{ij} + \hat{\lambda}_{d|i} \cdot d_{j|i} \text{ with}$$

| | |
|---|---|
| $\hat{\mu}_{ijst}$ | Dependent variable *estimated interaction* in the four-way table |
| $\hat{\lambda}$ | *Grand-mean* against which all variations are measured |
| $\hat{\lambda}_i$ | *Origin specific factor* (ensures the destination constraint $\hat{\mu}_{i+} = m_{i+}$) |
| $\hat{\lambda}_j$ | *Destination specific factor* (ensures the destination constraint $\hat{\mu}_{+j} = m_{+j}$) |
| $\hat{\lambda}_s$ | *Subsystem specific factor* captures the variation of each spatial subsystem around the grand-mean (ensures constraint $\hat{\mu}_{+s} = m_{+s}$) |
| $\hat{\lambda}_t$ | *Time specific factor* captures the variation of each accounting period around the grand-mean (ensures constraint $\hat{\mu}_{+t} = m_{+t}$) |
| $\hat{\lambda}_{st}$ | *Time-subsystem specific statistical interaction* captures the specific variation around an accounting period *t* and spatial subsystem *s* |
| $\hat{\lambda}_d \cdot d_{ij}$ | *Overall distance term* with a distance co-variable |
| $\hat{\lambda}_{d\|i} \cdot d_{j\|i}$ | *Origin specific distance term* with $d_{j\|i} = d_{ij}$ |

# Specification of the Migration Model

## Migration and Distance Matrices:

$$
\mathbf{M}_{4\times 4} = \begin{array}{c|cccc} \text{From/To} & D_1 & D_2 & D_3 & D_4 \\ \hline O_1 & m_{11} & m_{12} & m_{13} & m_{14} \\ O_2 & m_{21} & m_{22} & m_{23} & m_{24} \\ O_3 & m_{31} & m_{32} & m_{33} & m_{34} \\ O_4 & m_{41} & m_{42} & m_{43} & m_{44} \end{array}
$$

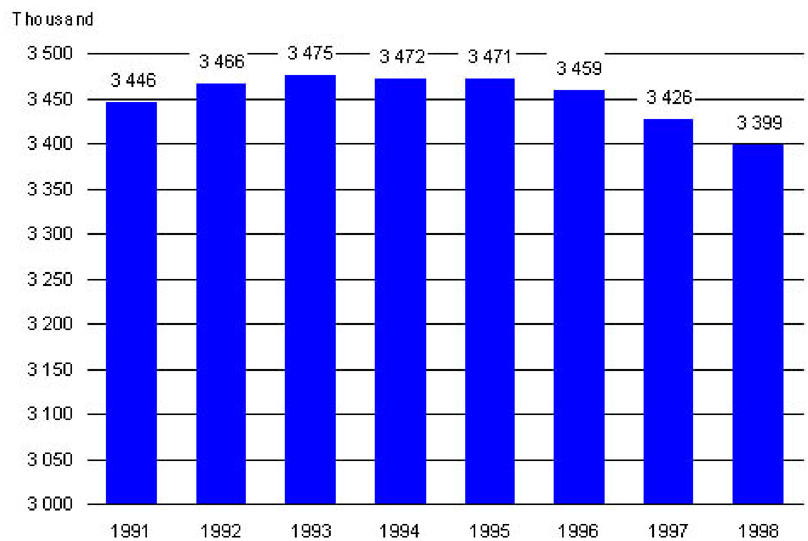
$$
\mathbf{D}_{4\times 4} = \begin{array}{c|cccc} & D_1 & D_2 & D_3 & D_4 \\ \hline O_1 & 0 & d_{12} & d_{13} & d_{14} \\ O_2 & d_{21} & 0 & d_{23} & d_{24} \\ O_3 & d_{31} & d_{32} & 0 & d_{34} \\ O_4 & d_{41} & d_{42} & d_{43} & 0 \end{array}
$$

## Vectorizing the Migration and Distance Matrices:

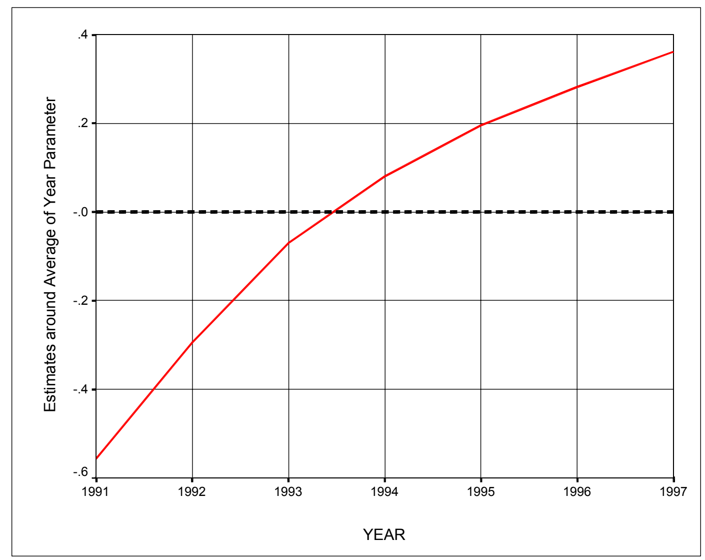
$$
\begin{pmatrix} \ln(\hat{\mu}_{11}) \\ \ln(\hat{\mu}_{12}) \\ \ln(\hat{\mu}_{13}) \\ \ln(\hat{\mu}_{14}) \\ \ln(\hat{\mu}_{21}) \\ \ln(\hat{\mu}_{22}) \\ \ln(\hat{\mu}_{23}) \\ \ln(\hat{\mu}_{24}) \\ \ln(\hat{\mu}_{31}) \\ \ln(\hat{\mu}_{32}) \\ \ln(\hat{\mu}_{33}) \\ \ln(\hat{\mu}_{34}) \\ \ln(\hat{\mu}_{41}) \\ \ln(\hat{\mu}_{42}) \\ \ln(\hat{\mu}_{43}) \\ \ln(\hat{\mu}_{44}) \end{pmatrix}
=
\begin{array}{cccccccc} \mathbf{1} & \mathbf{x}_1^O & \mathbf{x}_2^O & \mathbf{x}_3^O & \mathbf{x}_1^D & \mathbf{x}_2^D & \mathbf{x}_3^D & \mathbf{x}_d \end{array}
\begin{pmatrix}
1 & 1 & 0 & 0 & 1 & 0 & 0 & f(d_{11}) \\
1 & 1 & 0 & 0 & 0 & 1 & 0 & f(d_{12}) \\
1 & 1 & 0 & 0 & 0 & 0 & 1 & f(d_{13}) \\
1 & 1 & 0 & 0 & 0 & 0 & 0 & f(d_{14}) \\
1 & 0 & 1 & 0 & 1 & 0 & 0 & f(d_{21}) \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & f(d_{22}) \\
1 & 0 & 1 & 0 & 0 & 0 & 1 & f(d_{23}) \\
1 & 0 & 1 & 0 & 0 & 0 & 0 & f(d_{24}) \\
1 & 0 & 0 & 1 & 1 & 0 & 0 & f(d_{31}) \\
1 & 0 & 0 & 1 & 0 & 1 & 0 & f(d_{32}) \\
1 & 0 & 0 & 1 & 0 & 0 & 1 & f(d_{33}) \\
1 & 0 & 0 & 1 & 0 & 0 & 0 & f(d_{34}) \\
1 & 0 & 0 & 0 & 1 & 0 & 0 & f(d_{41}) \\
1 & 0 & 0 & 0 & 0 & 1 & 0 & f(d_{42}) \\
1 & 0 & 0 & 0 & 0 & 0 & 1 & f(d_{43}) \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & f(d_{44})
\end{pmatrix}
\cdot
\begin{pmatrix} \hat{\lambda} \\ \hat{\lambda}_{O_1} \\ \hat{\lambda}_{O_2} \\ \hat{\lambda}_{O_3} \\ \hat{\lambda}_{D_1} \\ \hat{\lambda}_{D_2} \\ \hat{\lambda}_{D_3} \\ \hat{\lambda}_d \end{pmatrix}
$$

# Temporal Trends

- The population in both parts of the City of Berlin is decreasing since 1995.
- This is primarily due freedom of movement which leads to sub-urbanization, i.e., migration from the city into its surrounding periphery.
- This loss of population opens up new opportunities on Berlin's the real estate market and rental apartment sector.
- The migration volume within Berlin is systematically increasing since the unification



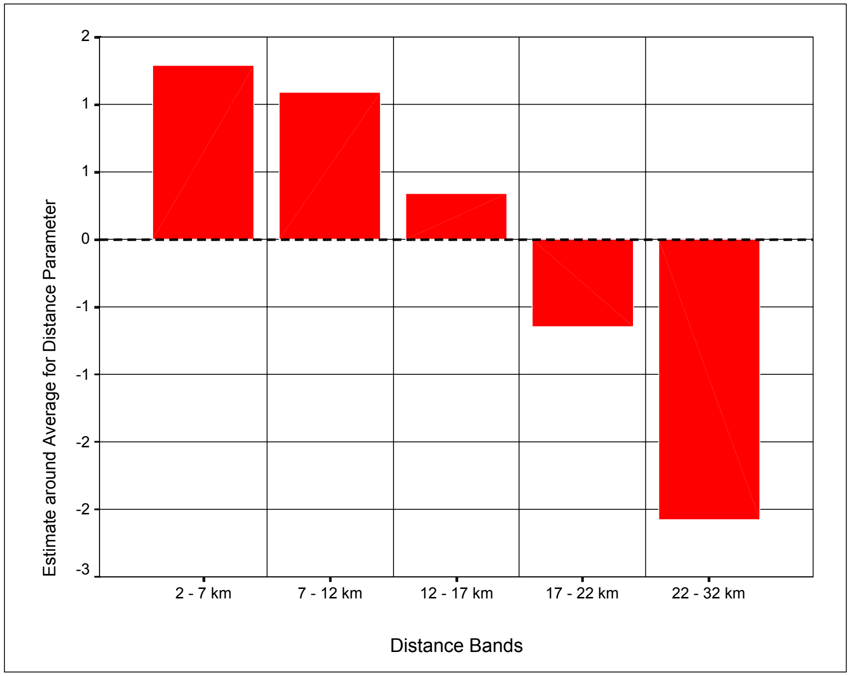

Population dynamics in Berlin 1991 to 1986




Parameter $\lambda_t$ of the log-linear migration model

# Global Friction of Distance

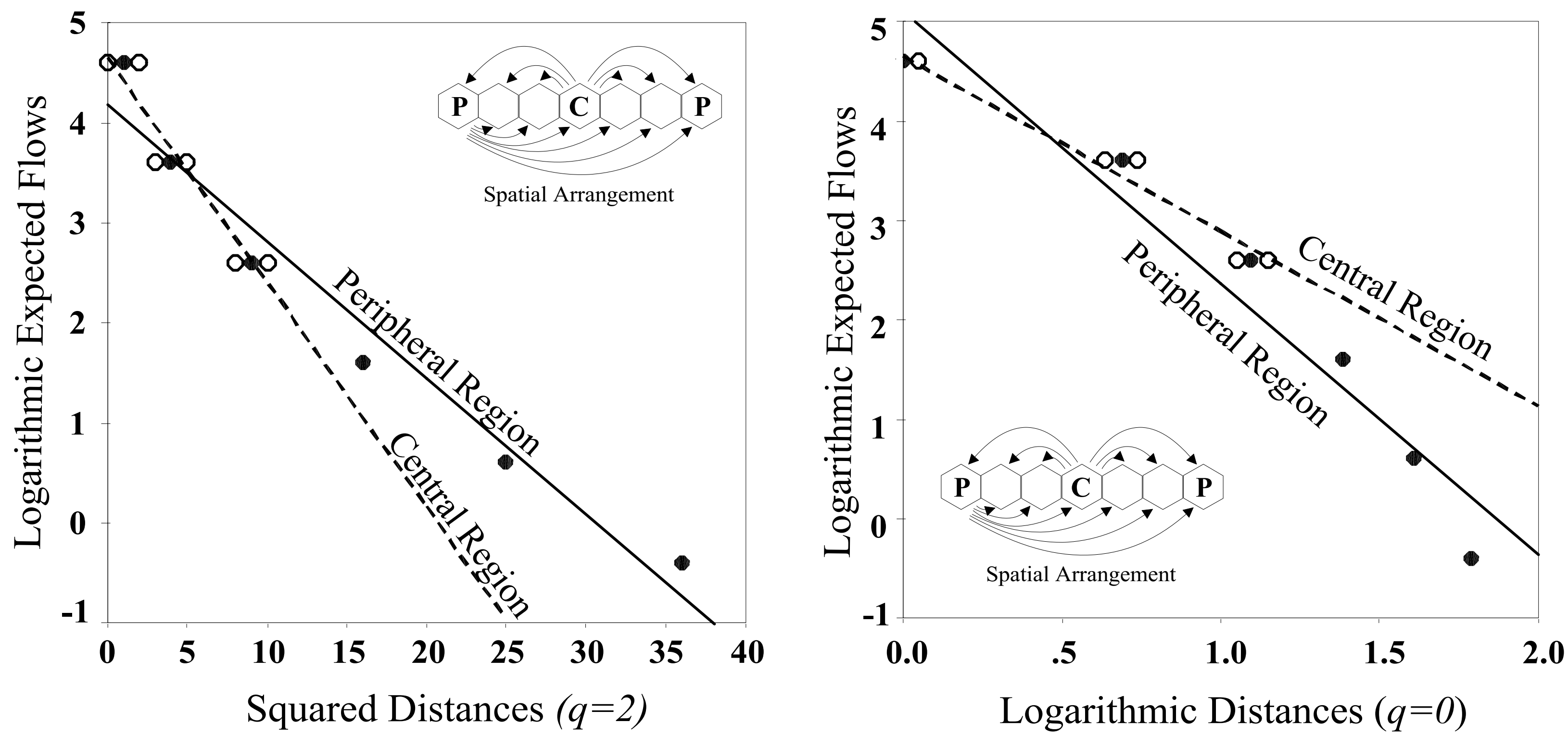
- The spherical distance is based on the district's population centroids (i.e., excluding lakes and forests).
- The estimated distance parameters $\hat{\lambda}_d$ and $\lambda_{d|i}$ are measured overall accounting periods (1991–1997).
- The *larger the distance*, the *less the propensity* to migrate (i.e., $\hat{\lambda}_d = -0.11$).
- However, by breaking the global distance parameter into distance bands, some degree of non-linearity is apparent.




- This suggest a logarithmic distance decay relationship $f(d_{ij}) = \ln(d_{ij})$

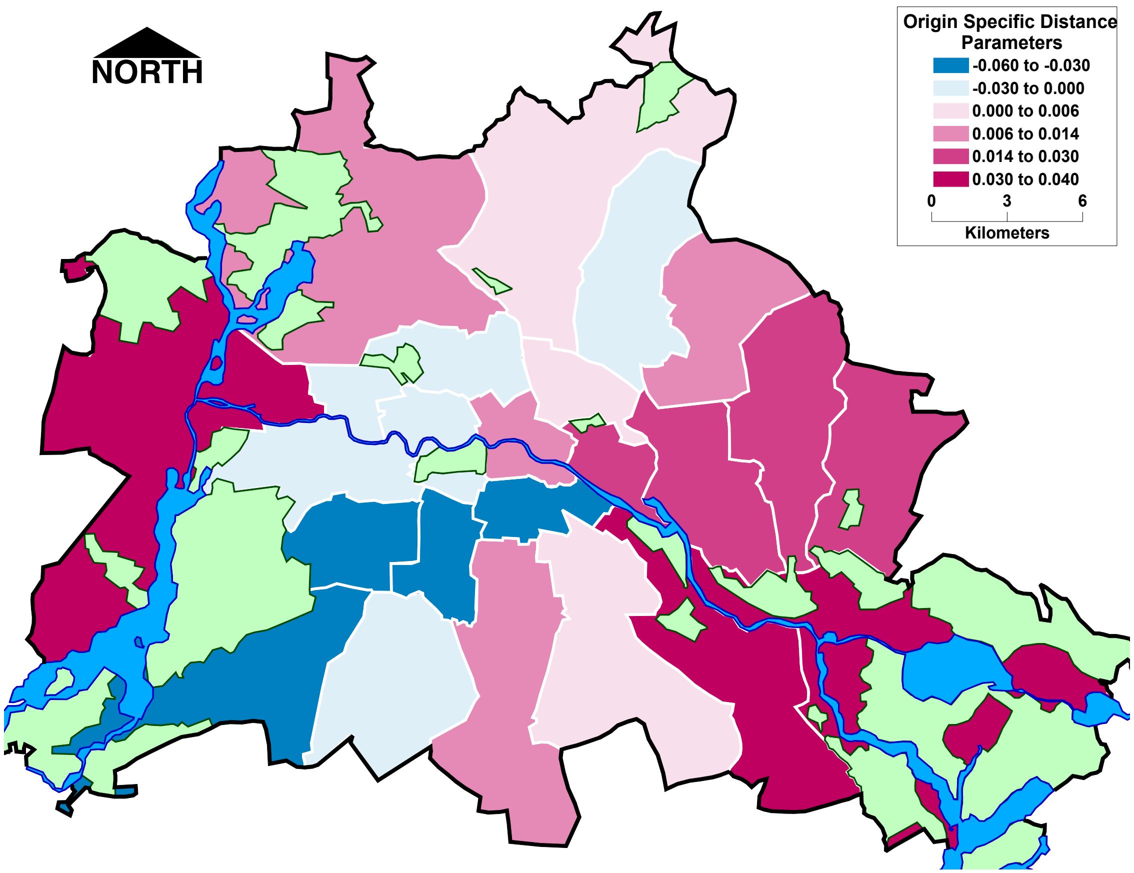
# Mis-specification of the distance decay function

- Data generating model: $\mu_{ij} = \exp(\ln(10) + \ln(10) - 1 \cdot d_{ij})$



# Origin Specific Distance Decay Parameters

- The origin specific distance parameters $\hat{\lambda}_{d|i}, i \in \{1,\ldots,23\}$, measure the *district specific variation* around the overall distance parameter $\hat{\lambda}_d$.




Some Western districts indicate short range migration

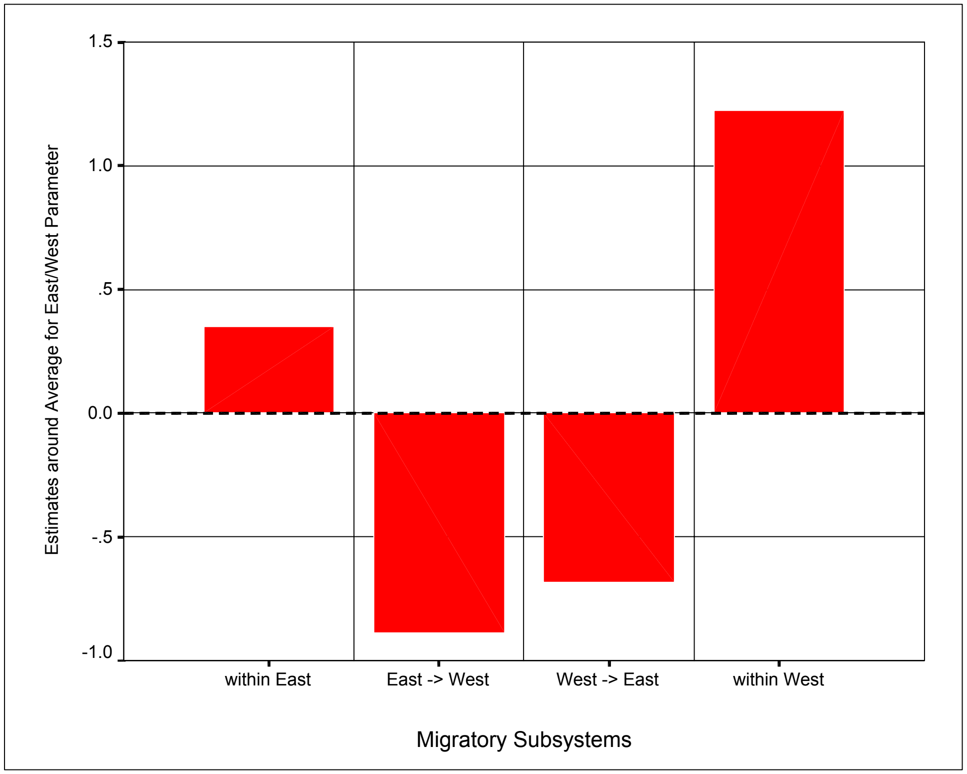
Most Eastern districts indicate longer range migration

# Fusion of the East/West Migratory Subsystems

## 1. Research Question: Convergence Towards a Joint Equilibrium

## Overall Years

- The internal, subsystem specific, base level migration propensity is larger than expected within the Eastern and the Western parts.
- Compared to the Eastern part people in the Western part are more mobile.
- In contrast, the interaction levels across the subsystem boundaries are below expectation. This indicates that *psychological barriers* are still present.

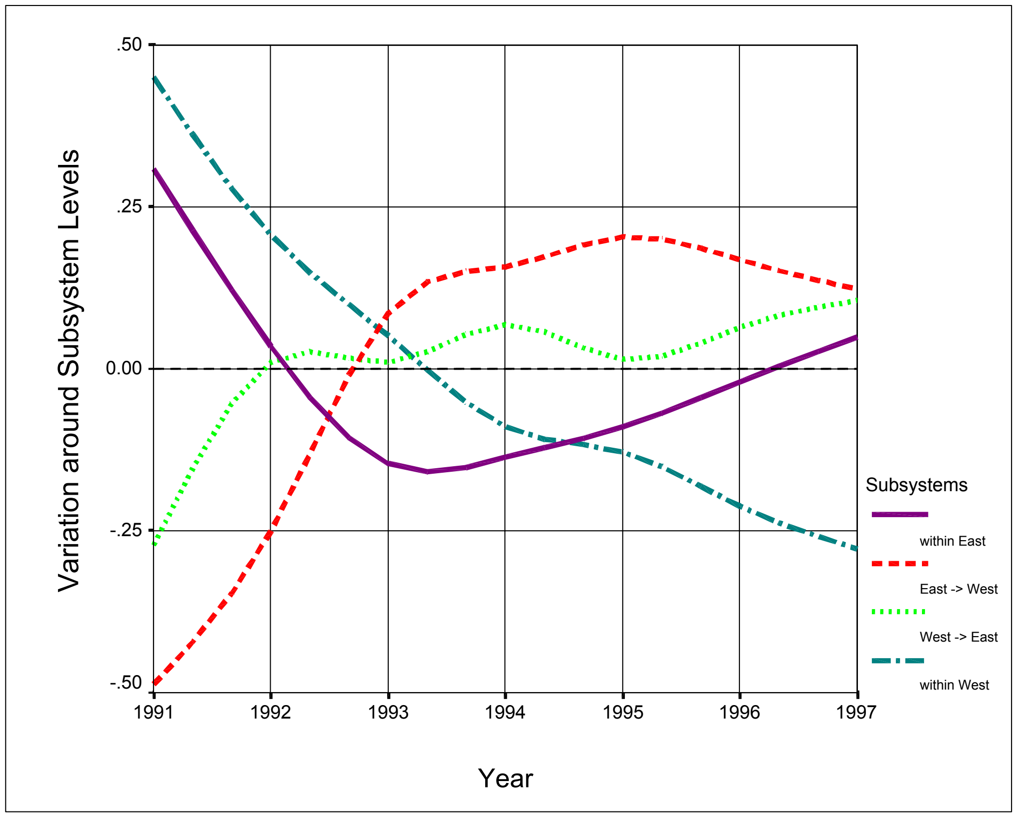


# Fusion of the East/West Migratory Subsystems

## 1. Research Question: Convergence Towards a Joint Equilibrium

### Temporal Trends

- However, the gaps among the interaction within and across the subsystems are narrowing over time.




- The estimated time-space interaction parameter $\hat{\lambda}_{st}$ captures the variation around each accounting period $\hat{\lambda}_t$ and spatial subsystem base levels $\hat{\lambda}_s$.

# Urban Structure and Theoretical Migration Residual Pattern

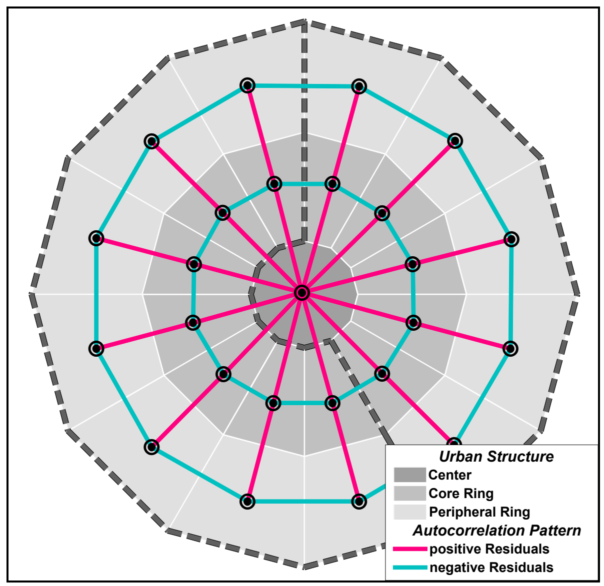
## 2. Research Question: Impact of Urban Structure

### Basic Assumptions:

- Migration decisions are not independent from the urban structure
- Migration decisions follow a spatial sequence within urban sectors
- Outward forces are usually stronger than inward forces

### Consequences:

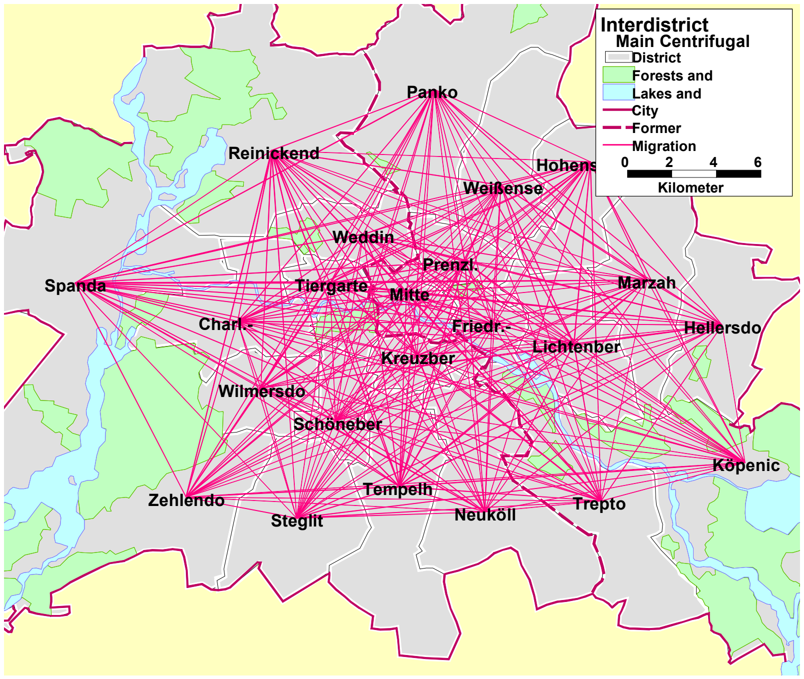
- A migration model that ignores the urban structure under-predicts the flows along the sectors. Therefore, the residuals are *positive*, i.e., $m_{ij} > \hat{\mu}_{ij}$.
- In contrast, residuals along concentric rings are *negative*, i.e, $m_{ij} < \hat{\mu}_{ij}$.



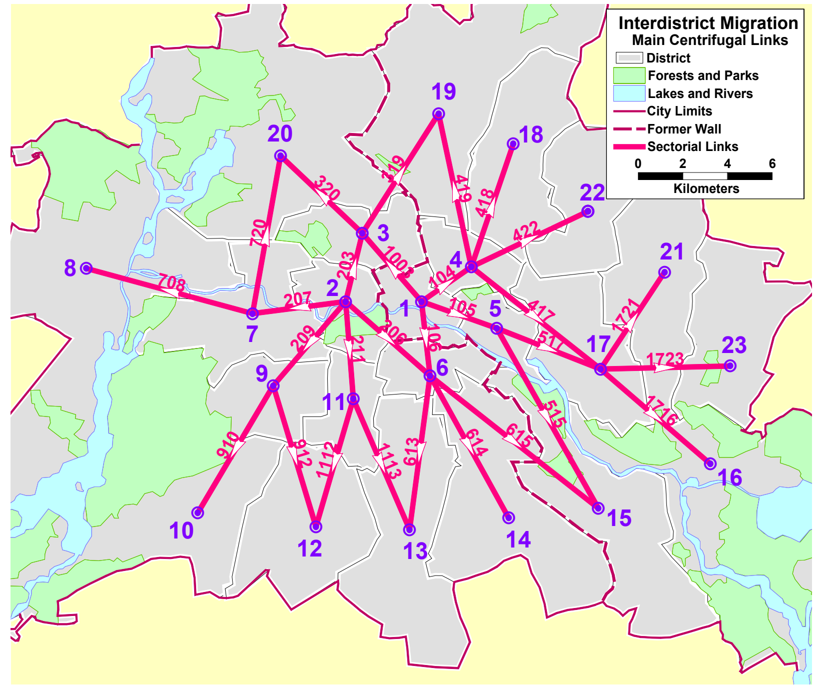

- This *mis-specification* of the model can be tested by comparison of the average residual magnitude within each urban migration sub-graphs

# Specification of Sectorial Centrifugal Links

- Theoretical considerations help to determine from all possible links a subset of links in accordance with the underlying urban theory




All 506 potential bi-directional pathways




Centrifugal (uni-directional) one step pathways along the urban sectors

# Temporal Trends in the Centrifugal Network Residuals

- The 506 residuals of the full network have a mean of zero.
- Do the selected residuals of the centrifugal network exhibit a specific pattern in line with the urban structure?

| Year | Mean of Residuals | observed Moran's $I_0$ | Normal approximation (z-score) | exact probability $\Pr(I<I_0)$ |
|---|---|---|---|---|
| 1991 | -0.3419 | 0.2209 | 1.766 | 0.9531 |
| 1992 | -0.2566 | 0.4614 | 3.673 | 0.9981 |
| 1993 | -0.1565 | 0.2341 | 1.870 | 0.9602 |
| 1994 | 0.2195 | -0.0647 | -0.4981 | 0.3106 |
| 1995 | 0.5359 | 0.2272 | 1.816 | 0.9567 |
| 1996 | 0.9272 | 0.8749 | 6.951 | 0.9999 |
| 1997 | 1.9717 | 1.2354 | 9.809 | 0.9999 |

- Discussion:
    - Negative signs of the residual means and inconsistent network autocorrelation for 1991 to 1994 indicate that the migratory system of Berlin was in a chaotic state with respect to the urban structure.
    - However, there is a consistent trend towards a centrifugal migration pattern and the system appears to be stable since 1995.

# Conclusions

## Results

- A *mental wall* still separates the Eastern and the Western parts of Berlin. However, the economic and psychological barriers are slowly disappearing.
- After the perturbation (with respect to migration) of the unification, the migration patterns within and between Berlin's subsystems seem to *stabilize at a new steady state.*
- *Urban structure again matters* and migration follows a sectorial pattern.

## Shortcomings

- *Push and pull factors* such as economic information and the housing stock characteristics have been ignored. This is, in parts, due to a lack of relevant variables.
- The continuing trend of *sub-urbanization* beyond the city limits has been ignored due to a lack of spatially disaggregated migration information.
- The present study used pooled data of Germans and Non-Germans. Berlin has a high proportion of international inhabitants, which are expected to exhibit a different migration patterns (approximately 13 % primarily living in the Western part)

# Potential Extensions

## Contextually

- German and Non-German migration flows for 1998 to 2000 are now available. Are the observed trends towards a new steady state still observable.
- This will be the last analysis of this kind, because
  - The parameters and constraints of the city have changed again after the *de facto* move of the German government from Bonn to Berlin in 2000.
  - The city council of Berlin has decided as of 2001 to merge hierarchically the 23 districts of Berlin into 12 new administrative units. It is hoped that this move will save the city administrative and financial overhead.

## Methodologically

- Addressing multicollinearity and specification issues
- Handling of network autocorrelation among the migration flows