A New Central Station for a Unified City: Predicting Impact on Property Prices for Urban Railway Network Extensions in Berlin

Gabriel Ahlfeldt, University of Hamburg
Contents

A. Research Motivation & Basic Ideas
B. Empirical Model and Results
C. Simulating Impact of Network Extensions
D. Summary
Research Motivation & Basic Ideas
An Empirical Model for Urban Economists and Planners  
(Aims & Scope)

Developing the Model

- Completely decentralized employment land value relationship on the basis of the effective urban rail transport network
- Station are no perfect substitutes
  Assessment of impact of network extensions for the whole of Berlin

Calibrating the Model

- Testing urban economic models
  Role of commuting cost and production externalities

Counterfactual Scenarios

- Extended Networks for Connection of the Berlin Central Station
Highly Disaggregated Data
(Empirical Framework)

- Standard land values (Bodenrichtwerte) indicate value of urban land (2005)
- FSI (GFZ) and land use from zoning regulations (2005)
- Employment at workplace from “Unternehmensregister” (end 2003)
- Data refers to the level of 15,937 statistical blocks (statsitische Blöcke) (11,045 built up blocks)
- Merged with metro and suburban railway stations and network (U-/S-Bahn) within a GIS environment
Empirical Model and Results
Monocentric Urban Economy
Alonso (1964), Mills (1972) and Muth (1969)

- Residents trade commuting cost against cost of residential land along a gradient to an exogenous centre.
Evident Short Fallings
Model Limitations

- 1 useful feature and 2 major limitations

- Accessibility matters!
  Households value locations with access to employment / economic activity

- Why are firms pulled together in to the “urban core” ?

- What about Polycentricity?
  Employment is almost as dispersed as residences (Wheaton, 2004)
Recent Advances in Theory and Empirics

Methodological Issues

- **Theory: Production Externalities**
  Firms receive a positive externality from neighboring firms that raises productivity (Borukhov & Hochman, 1977, Fujita & Ogawa, 1982, Lucas, 2001, Ten Raa, 1984)

  ⇒ Externalities pull firms into agglomerations, raising location productivity and value

  ⇒ Low commuting cost and highly localized externality lead to “Mills map” of the city (Lucas & Rossi-Hansberg, 2002)

- **Empirics: New methods that allow for endogenous identification and consideration of (sub-)centres. (Giuliano & Small, 1991; McDonald, 1987; McMillen, 1996, 2001; Plaut & Plaut, 1998).**

  ⇒ Unbiased land gradient estimates
A Decentralized Model
Developing the Model

→ Assumption: A simple equilibrium city
→ Attractiveness of location capitalizes into land values
→ Land value is a function of zoning (FSI, land use)
→ and employment accessibility
  (captures production externalities and commuting cost)

\[ LV = f(Z, EP) \]

\[ EP_i = \sum_j E_j \exp(-\delta \times t_{ij}) \]

Decy parameter: Determines spatial discount
(transport / communication cost)

Exponential cost function
(Lucas & Rossi-Hansberg, 2002)

Employment concentrated at one "core"
⇒ "classical" monocentric city

Attractiveness of any location related to all other locations
⇒ (Sub-)centres do not need to be implicitly or explicitly defined
Computation Constraints
Developing the Model

- **Ideally:** $N \times N$ travel time matrix for 11,054 blocks

- **Shortcut:** Due to constraints in computer power and data management tools

- Walking Employment Potentiality ($WEP$)

- Station Employment Potentiality ($SEP$)

- Rail Employment Potentiality ($REP$)

- $EP = WEP + SEP$

- Block internal distance measure (Crafts 2005, Keeble et. al., 1982)

- Train velocity: 33 km/h
- Walking speed: 4 km/h
- Waiting time: 2.5 min

- $WEP_i = \sum_j E_j \exp(-a \times d_{ij}) \rightarrow d_{ii} = 1/3 \sqrt{\frac{A_i}{P_i}}$

- $SEP_s = \sum_j E_j \exp(-a \times d_{sj})$

- $REP_i = \sum_s SEP_s \exp(-\delta \times t_{is})$, $s \neq m$

- $a = 2 \Rightarrow 2$ km catchment area

Gibbons & Machin (2005)
The Model
Calibrating the Model

- **Empirical model to be estimated:**

\[
LV_i = \alpha + \beta_1 COM_i + \beta_2 FSI_i + \beta_3 FSI^2_i + \beta_4 COM_i \times FSI_i + \beta_5 COM_i \times FSI^2_i
\]

\[
+ \gamma_1 \left( WEP_i + \sum_{k} SEP_k \exp\left(-\delta_1 \times t_{ik}\right) \right)
\]

\[
+ \gamma_2 \left( COM_i \times \left( WEP_i + \sum_{k} SEP_k \exp\left(-\left(\delta_1 + \delta_2\right) \times t_{ik}\right) \right) \right)
\]

Decay parameter: residential

Decay parameter: difference residential and commercial

Autonomous land value and zoning

Price effect of employment potentiality

Difference: residential commercial

residential

EP
Empirical Results (1)
Calibrating the Model

Impact stronger for commercial areas

Coeff. of interest statistically significant

Effect more localized for commercial areas

<table>
<thead>
<tr>
<th></th>
<th>(LV)</th>
<th>(NLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coefficient</td>
<td>S.E.</td>
</tr>
<tr>
<td>α</td>
<td>147.10***</td>
<td>12.92</td>
</tr>
<tr>
<td>β₁</td>
<td>909.17***</td>
<td>85.70</td>
</tr>
<tr>
<td>β₂</td>
<td>-57.17***</td>
<td>20.89</td>
</tr>
<tr>
<td>β₃</td>
<td>34.91***</td>
<td>7.45</td>
</tr>
<tr>
<td>β₄</td>
<td>-1043.64***</td>
<td>66.27</td>
</tr>
<tr>
<td>β₅</td>
<td>279.65***</td>
<td>13.31</td>
</tr>
<tr>
<td>γ₁</td>
<td>0.0020***</td>
<td>0.0002</td>
</tr>
<tr>
<td>γ₂</td>
<td>0.0265***</td>
<td>0.0049</td>
</tr>
<tr>
<td>δ₁</td>
<td>0.0530***</td>
<td>0.0049</td>
</tr>
<tr>
<td>δ₂</td>
<td>0.2258***</td>
<td>0.0382</td>
</tr>
<tr>
<td>λ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obs.</td>
<td>11,054</td>
<td></td>
</tr>
<tr>
<td>R sq.</td>
<td>0.6651</td>
<td></td>
</tr>
</tbody>
</table>
Commuting Cost vs. Production Externalities

Calibrating the Model

\[ \exp(-\delta_1 x t) \exp(-\delta_2 x t) \]
Empirical Results (2)
Calibrating the Model

Spatial error correction model controls for error terms and omitted variables that are correlated across space (weight matrix: 250m)

<table>
<thead>
<tr>
<th></th>
<th>(LV) (NLS)</th>
<th></th>
<th>(LV) (SAR)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coefficient</td>
<td>S.E.</td>
<td>coefficient</td>
<td>S.E.</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>147.10***</td>
<td>12.92</td>
<td>129.24***</td>
<td>18.64</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>909.17***</td>
<td>85.70</td>
<td>530.10***</td>
<td>68.30</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>-57.17***</td>
<td>20.89</td>
<td>4.44***</td>
<td>33.43</td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>34.91***</td>
<td>7.45</td>
<td>23.58***</td>
<td>10.92</td>
</tr>
<tr>
<td>$\beta_4$</td>
<td>-1043.64***</td>
<td>66.27</td>
<td>-632.56***</td>
<td>57.72</td>
</tr>
<tr>
<td>$\beta_5$</td>
<td>279.65***</td>
<td>13.31</td>
<td>188.68***</td>
<td>13.42</td>
</tr>
<tr>
<td>$\gamma_1$</td>
<td>0.0020***</td>
<td>0.0002</td>
<td>0.0014***</td>
<td>0.0002</td>
</tr>
<tr>
<td>$\gamma_2$</td>
<td>0.0265***</td>
<td>0.0049</td>
<td>0.0249***</td>
<td>0.0022</td>
</tr>
<tr>
<td>$\delta_1$</td>
<td>0.0530***</td>
<td>0.0049</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\delta_2$</td>
<td>0.2258***</td>
<td>0.0382</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\lambda$</td>
<td></td>
<td></td>
<td>0.76***</td>
<td>0.0056</td>
</tr>
<tr>
<td>Obs.</td>
<td>11,054</td>
<td></td>
<td>11,054</td>
<td></td>
</tr>
<tr>
<td>R sq.</td>
<td>0.6651</td>
<td></td>
<td>0.8667</td>
<td></td>
</tr>
</tbody>
</table>

Impact weaker but still highly significant
Location Premium Surface
Calibrating the Model

- Location premium peaks in “core” office areas
- Location premium smoothly descents within “peripheral” residential areas
Location Premium: Residential vs. Commercial
Calibrating the Model

- Firms bid out residents for central locations (up to 4 km)
- Low commuting cost and localized production externalities lead to “Mills Map”
From Theory to Practice
Simulating Effects of Network Extensions

- Impact of metro-rail systems on property prices heavily researched (Bowes & Ihlanfeldt, 2001; Damm, Lerner-Lam, & Young, 1980; Gatzlaff & Smith, 1993; Gibbons & Machin, 2005; Grass, 1992; McMillen & McDonald, 2004; Voith, 1991)

- Completely “decentralized” model that links accessibility to attractiveness of location

- Stations are not treated as perfect substitutes

⇒ Theory based ex-ante assessment of impact on land value possible for the whole metropolitan area

⇒ Comparing location premiums for different scenarios
Comparing Location Premiums
Simulating Effects of Network Extensions

- Expected change in land value corresponds to difference between location premium in the current and the counterfactual scenario

\[ \Delta L V_i = L P_i^{\text{sim}} - L P_i^{\text{cur}} \]

⇒ For residential areas

\[ \Delta L V_i^R = \hat{\nu}_1 \left\{ \sum_s SEP_s^{\text{sim}} \exp(-\hat{\delta}_1 \times t_{is}^{\text{sim}}) - \sum_s SEP_s^{\text{cur}} \exp(-\hat{\delta}_1 \times t_{is}^{\text{cur}}) \right\} \]

⇒ For commercial areas

\[ \Delta L V_i^B = (\hat{\nu}_1 + \hat{\nu}_2) \left\{ \sum_s SEP_s^{\text{sim}} \exp\left(-\left(\hat{\delta}_1 + \hat{\delta}_2\right) \times t_{is}^{\text{sim}}\right) - \sum_s SEP_s^{\text{cur}} \exp\left(-\left(\hat{\delta}_1 + \hat{\delta}_2\right) \times t_{is}^{\text{cur}}\right) \right\} \]
Effects of Northern Extension
Simulating Effects of Network Extensions
Effects of Northern and Eastern Extension
Simulating Effects of Network Extensions
Effects of Northern, Eastern and Western Extension
Simulating Effects of Network Extensions
Expected Aggregated Impact on Land Value
Simulating Effects of Network Extensions

<table>
<thead>
<tr>
<th>Extension</th>
<th>Aggregated Impact (€) on Residential Areas</th>
<th>Aggregated Impact (€) on Business Areas</th>
<th>Total Aggregated Impact (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern (Suburban Railway)</td>
<td>19,768,416</td>
<td>5,212,554</td>
<td>24,980,970</td>
</tr>
<tr>
<td>Western (Metrorail)</td>
<td>76,783,152</td>
<td>9,247,327</td>
<td>86,030,477</td>
</tr>
<tr>
<td>Eastern (Metrorail)</td>
<td>60,283,580</td>
<td>32,227,080</td>
<td>92,510,656</td>
</tr>
<tr>
<td>Northern and Eastern (Suburban and Metrorail)</td>
<td>75,198,752</td>
<td>33,502,308</td>
<td>108,701,050</td>
</tr>
<tr>
<td>Northern, Eastern and Western</td>
<td>137,515,520</td>
<td>38,299,156</td>
<td>175,814,670</td>
</tr>
</tbody>
</table>

Note: Impact aggregated on the basis of built-up area of approx. 557,000 buildings
What Can We Learn from the Model?

Conclusions

*For theorists*

- Evidence for *production externalities* and commuting cost as determinants of urban land value in a decentralized micro-level empirical model
- As predicted by theory: “Mills map” emerges from *low commuting cost* and *localized production externalities*

*For practitioners*

- *Impact not only* in proximity to new stations
- *Largest* impact in proximity to new stations
- If residential areas are connected: *Large* impact at metropolitan level, *small* impact at local level
- If commercial areas are connected *Small* impact at metropolitan level, *very large* impact at local level

⇒ May be relevant when authorities consider compensations for external benefits