

# Forecasting Regional Employment in Germany: A Review of Neural Network Approaches

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## Objectives:

- To develop and apply Neural Network (NN) models in order to forecast regional employment growth in Germany
- To compare the statistical performance of the basic NN models
- To propose new NN models, as well as to update forecasts on more recent data
- To compare the NN results in terms of regional growth rate and relative change of employment share

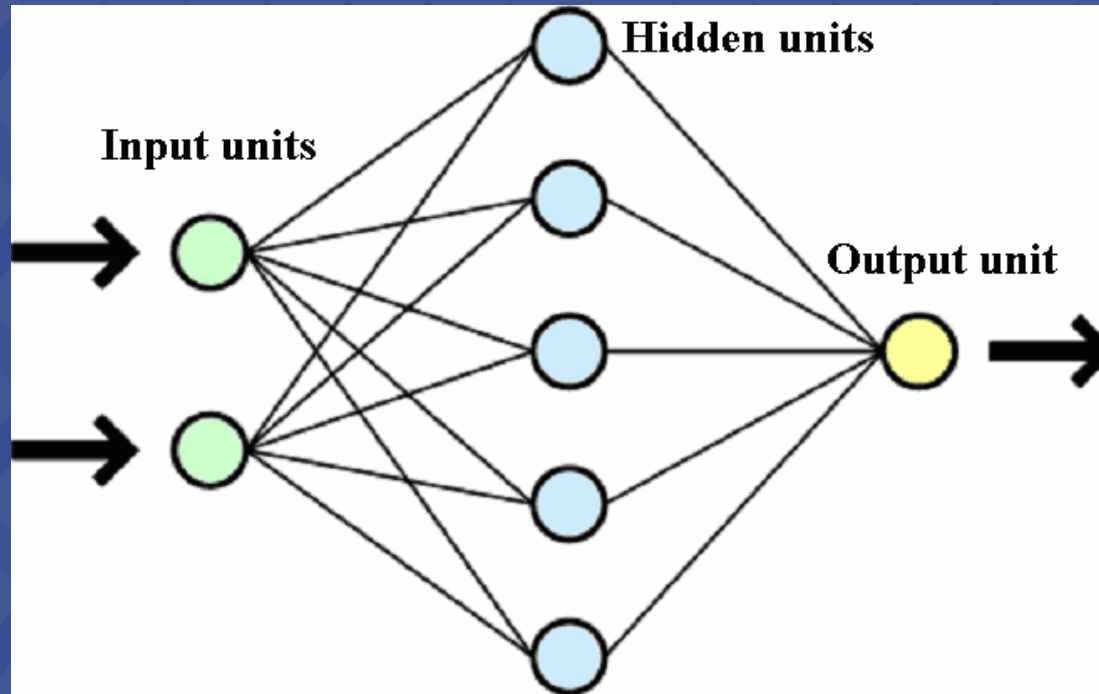
# Structure of the Paper

- **Neural Network Models for Forecasting Employment in Germany**
  - Neural Networks as a Flexible Optimization Tool
  - The Theory
- **The Data**
- **Empirical Application of Neural Network Models to Labour Market in West and East Germany**
  - Implementation of the Neural Networks Adopted
  - Results for West Germany: 2001 and 2003 *ex post* forecasts
  - Results for East Germany: 2001 and 2003 *ex post* forecasts
  - Evaluation of Neural Network Models Results
- **New Results in Neural Network Forecasting**
  - The Joint “Neural Network-Shift-Share Analysis” Approach
  - *Ex post* Forecasts for the Year 2004
  - Forecasts for the Years 2005 and 2006
- **Conclusions**

# Neural Network Models for Forecasting Employment in Germany: The Approach

- Artificial Neural Networks (NNs) are optimization algorithms based on:
  - Distribution of the computational activity on a high number of calculation **units** (the neurons), connected by **weights** and working in parallel
  - Ability to learn the functional relationships between the variables **from the data**
  - No modelling hypotheses necessary

# Neural Network Models for Forecasting Employment in Germany: The Theory



- The generic units  $u_i$  (represented by circles) are defined as a function of the previous calculation units and a set of **weights  $w$**
- An activation function computes the unit's output

# Neural Network Models for Forecasting Employment in Germany: The Adopted Methodology

## Evaluation of proposed NN models

- Comparison with widely-accepted conventional econometric models. Forecasts from the NN models should be at least as accurate as those generated by a naïve extrapolation, such as random walk
- Test of the models' out-of-sample performance for comparing different methodologies
- Use of an appropriate sample size (from the numerosity view point)

# The Data

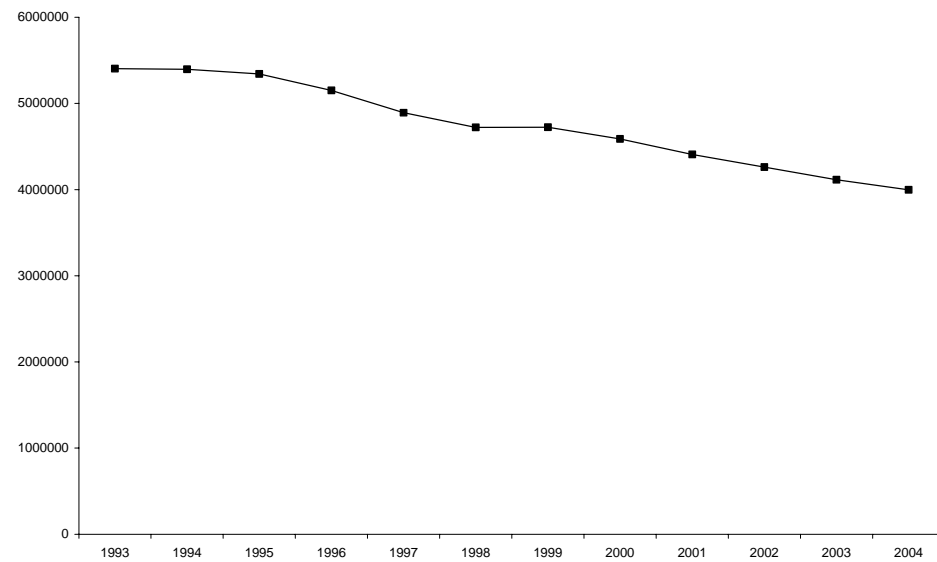
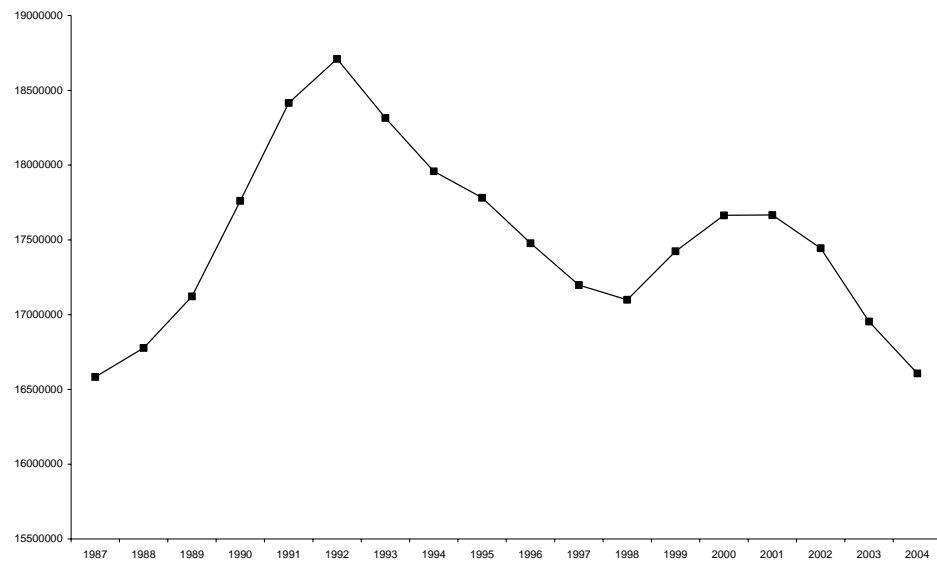
## Data available:

- Information about the total number of **persons fully employed** every year on June 30<sup>th</sup>
- The total number of employees is subdivided in **nine** economic sectors, from primary sector to services for society
- Average regional daily wages earned by full-time workers
- Type of economic region (different urbanization levels) (slide 7)
- Panel of 439 districts (326 for the former West Germany and 113 for the former East Germany) available for:
  - 18 years (1987 to 2004) for the former West Germany
  - 12 years (1993 to 2004) for the former East Germany

# Type of Economic Region (Details)

Group	Type
A. Regions with urban agglomeration	<ol style="list-style-type: none"><li>1. Central cities</li><li>2. Highly urbanized districts</li><li>3. Urbanized district</li><li>4. Rural districts</li></ol>
B. Regions with tendencies towards agglomeration	<ol style="list-style-type: none"><li>5. Central cities</li><li>6. Highly urbanized districts</li><li>7. Rural districts</li></ol>
C. Regions with rural features	<ol style="list-style-type: none"><li>8. Urbanized districts</li><li>9. Rural districts</li></ol>

# Trends in Full-Time Employment Data



## Aggregate trends for Germany

West Germany (left)  
1987-2004

East Germany (right)  
1993-2004



# First Empirical Applications of Neural Network Models to Labour Market in West and East Germany

## Outline

- *Ex post* NN forecasts of full-time employment for the years:
  - 2001
  - 2003
- Evaluation of regional results by means of statistical indicators (MSE, MAE, MAPE, Theil's U) (slide 12)
- Visualization of aggregate results

# Implementation of the Neural Networks Adopted

- We developed **seven** NN models, by using, as input variables, the lagged ( $t - 2$ ) growth rate of sectoral employment and time.
  - Other variables: type of district and/or wages.
- The output variable is **district employment growth rate**
- **Training:**
  - NN models for the f. West Germany: years 1991-1998
  - NN models for the f. East Germany: years 1997-1999
- **Validation (choice of NN structure):**
  - NN models for the f. West Germany: years 1999-2000
  - NN models for the f. East Germany: year 2000
- **Testing:**
  - (Re-training until the year 2000) Year 2001
  - (Re-training until the year 2002) Year 2003

# Implementation of the Neural Networks Adopted (2)

<i>Model</i>	<i>Input Variables</i>
Model A	Growth rate of sectoral employment; time <b>dummies</b>
Model AD	Growth rate of sectoral employment; time <b>dummies</b> ; type of economic region fixed effects
Model DW	Growth rate of sectoral employment; time <b>dummies</b> ; type of economic region fixed effects; growth rate of daily wages
Model AW	Growth rate of sectoral employment; growth rate of daily wages; time <b>dummies</b>
Model B	Growth rate of sectoral employment; time <b>fixed effects</b>
Model BD	Growth rate of sectoral employment; time <b>fixed effects</b> ; type of economic region fixed effects
Model BW	Growth rate of sectoral employment; growth rate of daily wages; time <b>fixed effects</b> ;

# Evaluation of the NN Models' Performance

- We evaluated the performance of the NN models by means of **four** statistical indicators:
  - Mean Squared Error:
    - $MSE = 1/N * [\sum_i (y_i - y_i^f)^2]$
  - Mean Absolute Error:
    - $MAE = 1/N * [\sum_i |y_i - y_i^f|]$
  - Mean Absolute Percentage Error:
    - $MAPE = 1/N * [\sum_i |y_i - y_i^f| * 100 / y_i]$
  - Theil's U statistic:
    - $MSE (NN \text{ model}) / MSE (random \text{ walk})$

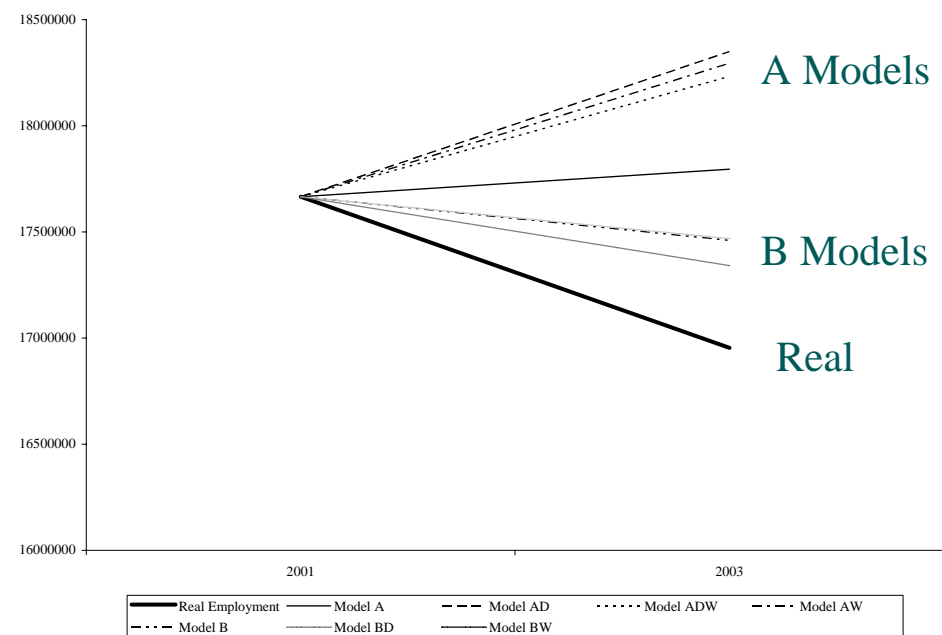
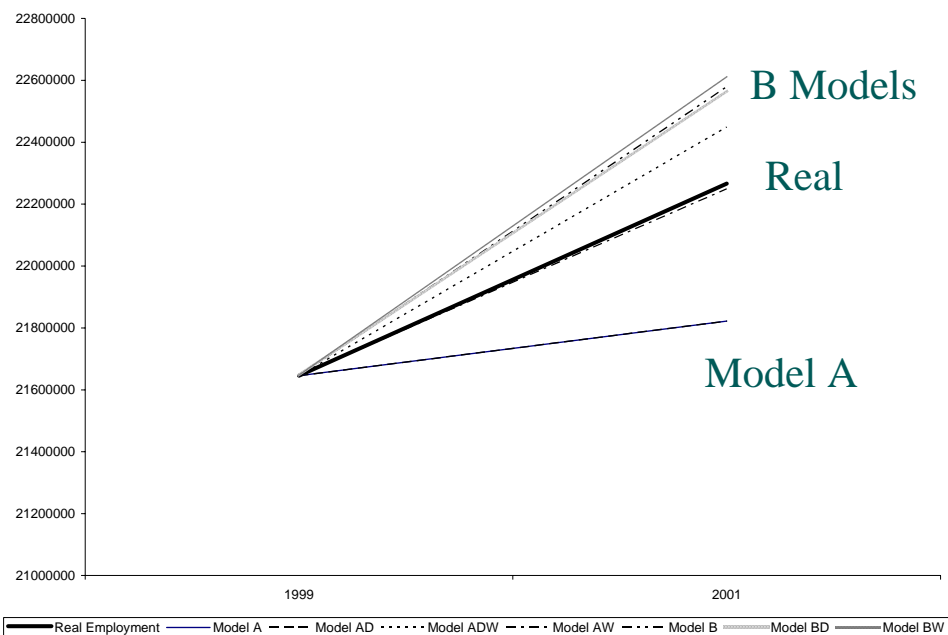
# Results for West Germany: 2001 and 2003 *ex post* Forecasts

<i>Indicator</i>	<i>Model A</i>	<i>Model AD</i>	<i>Model ADW</i>	<i>Model AW</i>	<i>Model B</i>	<i>Model BD</i>	<i>Model BW</i>
MSE	20813437	36811629	23468487	29222080	<b>8395425</b>	<b>8913146</b>	<b>7369825</b>
MAE	2183.24	3033.47	2674.87	2741.00	<b>1624.39</b>	<b>1643.27</b>	<b>1513.61</b>
MAPE	3.5393	5.0899	4.9141	4.9173	<b>2.9819</b>	<b>2.8674</b>	<b>2.7663</b>
Theil's U	1.1577	2.2083	1.4969	1.8401	<b>0.4722</b>	<b>0.5109</b>	<b>0.4079</b>

## Average statistical performance for 2001 and 2003

- The B-type models seem to outperform the A-type models
- The NN models outperform a naive no-change-hypothesis random walk model (see Theil's U)

# Aggregate West German *ex post* Results



Aggregate results for West Germany:

2001 (left)

2003 (right)

In 2003, only the B-type models estimate the right trend (negative)

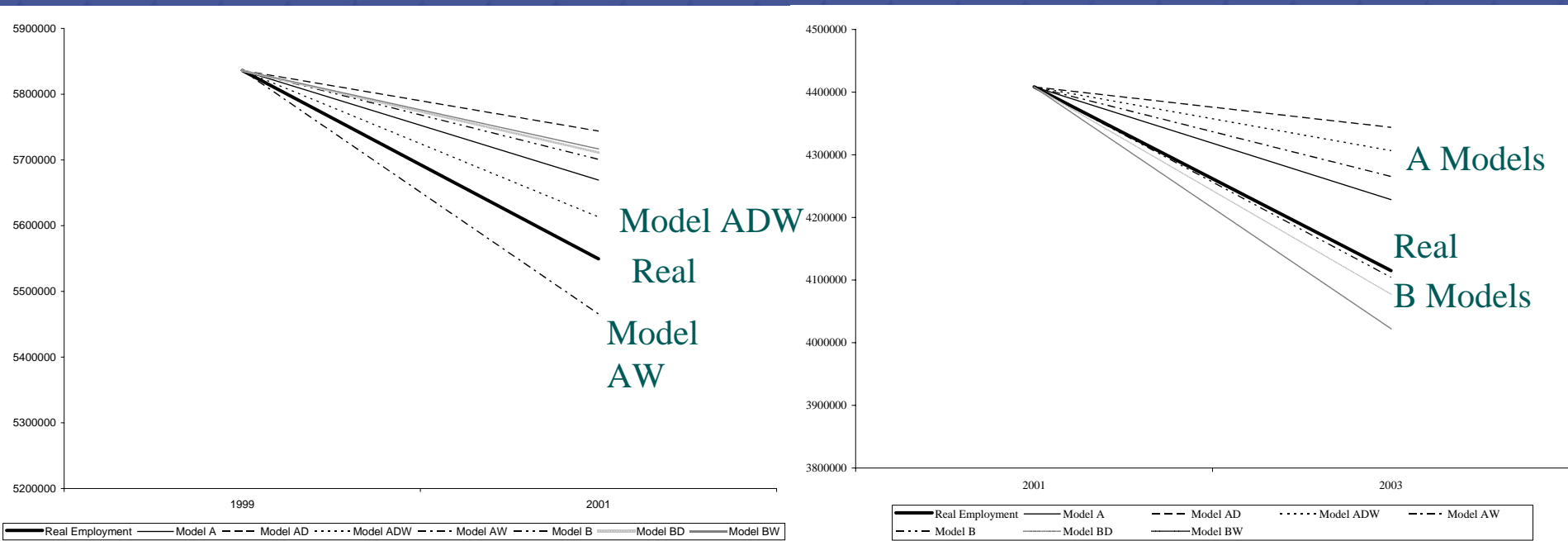
# Results for East Germany: 2001 and 2003 *ex post* Forecasts

<i>Indicator</i>	<i>Model A</i>	<i>Model AD</i>	<i>Model ADW</i>	<i>Model AW</i>	<i>Model B</i>	<i>Model BD</i>	<i>Model BW</i>
MSE	11735072	22200869	21108442	32489364	<b>5760466</b>	<b>5504239</b>	<b>6816745</b>
MAE	1534.36	2147.65	1712.01	1598.35	<b>1312.86</b>	<b>1370.54</b>	1502.80
MAPE	3.9248	5.5472	4.1054	<b>3.3474</b>	3.6260	3.8070	4.0034
Theil's U	0.8892	0.9954	1.2933	2.9720	<b>0.5940</b>	<b>0.5501</b>	<b>0.5177</b>

## Average statistical performance for 2001 and 2003

- The B-type models seem to outperform the A-type models
- Model AW is competitive only when error is computed as percentage (MAPE)
- The NN models again outperform the no-change-hypothesis random walk model

# Aggregate East German *ex post* Results



Aggregate results for East Germany:

2001 (left)

2003 (right)



# Evaluation of Neural Network Models Results

- The **B-type models** seem to be winning, for 2001 and 2003, over the A-type models for both West and East Germany
- The stability of the models' performance can be measured by analysing their **ranks**, over time and different statistical indicators:
  - Analyses by means of **Friedman's rank correlation statistic** (Patuelli et al. 2004). The NN models tend to have a consistent rank under different statistical indicators, as well as over different forecasting years
- **Multi-objective** evaluation tools can be employed, such as **MCA**:
  - MCA of a set of NN models (Patuelli et al. 2003). MCA can be a helpful tool in assessing the NN models' performance

# Recent Results in Neural Network Forecasting: Years 2004-06

- **New models proposed:**
  - The Joint “Neural Network-Shift-Share Analysis” Approach
- **New forecasts on the basis of more recent data:**
  - Ex post forecasts for the year 2004
  - Forecasts for the years:
    - 2005
    - 2006
- **Only B-type models considered, given the previous results**

# The Joint 'Neural Network-Shift-Share Analysis' Approach

- Shift-share analysis (SSA):
  - A tool for improving the understanding of changes in economic variables at the regional level.

Dunn (1960); Esteban-Marquillas (1972); Nazara and Hewings (2004)

Classical formulation:

$$\Delta e_i = [G + (G_i - G) + (g_i - G_i)]e_i$$

- National effect ( $G$ )
  - Sectoral effect ( $G_i - G$ )
  - Competitive effect ( $g_i - G_i$ )
- Shift-share regression (Patterson 1991)
  - Joint approach: NNs embedding shift-share components

# The Joint 'Neural Network-Shift-Share Analysis' Approach (2)

- Model BSS: based on the **conventional, deterministic SSA**. The 'competitive effect' component,  $(g_i - G_i)$ , computed for each of the nine sectors  $i$  and for all regions, is added, to Model B
- Model BSSN: based on Nazara and Hewings' extension (2004) ('spatial shift-share'). Takes into account the **spatial aspects** of regional growth. The national growth rate of sector  $i$ ,  $G_i$ , is substituted by the component

$$\Delta e_i = [G + (\vec{g}_i - G) + (g_i - \vec{g}_i)]e_i,$$

defined, for each region  $r$ , as the **growth rate**, in sector  $i$ , of **region  $r$ 's neighbours**.

Neighbours are defined as the three regions that provide the larger number of commuters to the region considered.

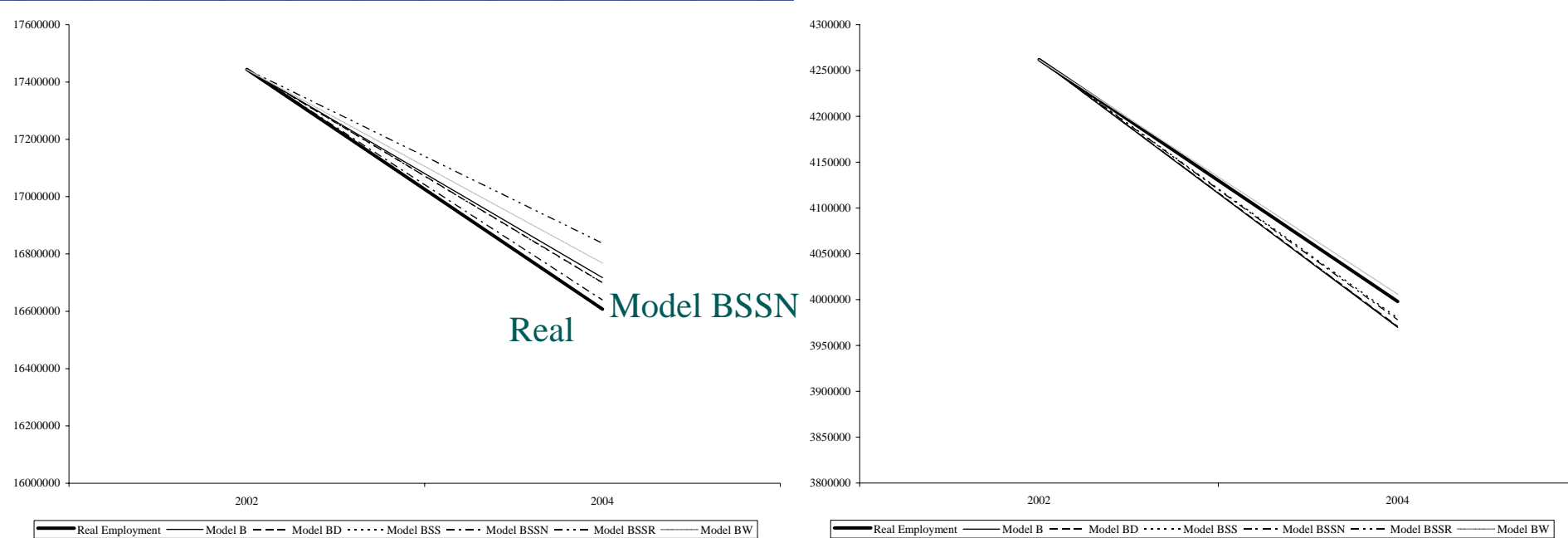
- Model BSSR: based on **regression techniques equivalent to SSA**. Overcomes SSA's lack of hypothesis testing. Simplification of Blien and Wolf's approach:
  - Regressors: Competitive effect components computed in deterministic SSA
  - Dependent variable: Overall district employment growth rates
  - Statistical tests were carried out separately for each 2-year period
  - The competitive components were multiplied, for each year, for their corresponding regression coefficient → 'fine-tuning' of the variables introduced in Model BSS
- In all cases, only the competitive effect components are employed in the NN models, because **region-specific**

# Ex post Forecasts of NN and NN-SS Models for the Year 2004

	<i>NN Models</i>			<i>NN-SS Models</i>		
<i>West Germany</i>	<i>Model B</i>	<i>Model BD</i>	<i>Model BW</i>	<i>Model BSS</i>	<i>Model BSSN</i>	<i>Model BSSR</i>
<i>MSE</i>	2213570	2612326	3137475	2194846	<b>2001280</b>	4802468
<i>MAE</i>	850.39	923.52	992.63	842.78	<b>800.14</b>	1128.57
<i>MAPE</i>	1.8947	1.9818	2.1820	1.8677	<b>1.7842</b>	2.3349
<i>Theil's U</i>	0.1049	0.1238	0.1487	0.1040	<b>0.0949</b>	0.2277
<i>East Germany</i>	<i>Model B</i>	<i>Model BD</i>	<i>Model BW</i>	<i>Model BSS</i>	<i>Model BSSN</i>	<i>Model BSSR</i>
<i>MSE</i>	1081583	1632222	1702475	1171623	1218817	<b>1067005</b>
<i>MAE</i>	<b>732.01</b>	818.68	774.38	733.07	760.70	734.42
<i>MAPE</i>	2.6044	2.7859	2.6605	<b>2.5831</b>	2.6894	2.6312
<i>Theil's U</i>	0.0298	0.0450	0.0470	0.0323	0.0336	<b>0.0294</b>

- All models show a rather homogeneous performance
- No model wins over the others at all times
- The NN-SS models seem to perform slightly better than older models

# Aggregate West and East German Results (2004)

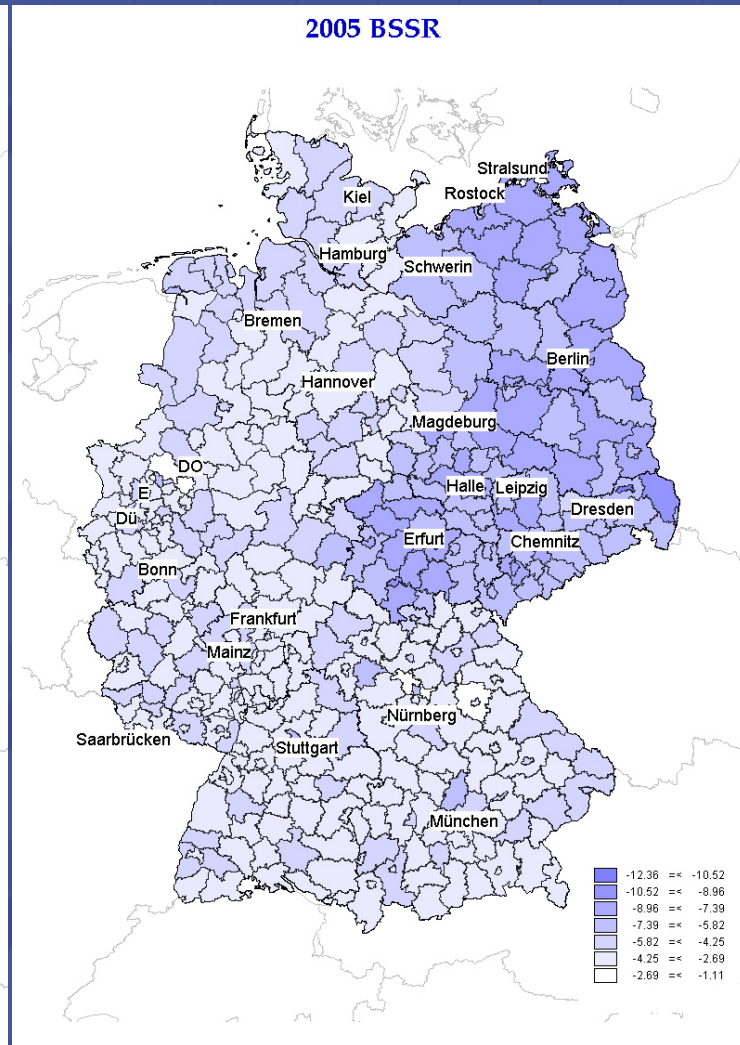
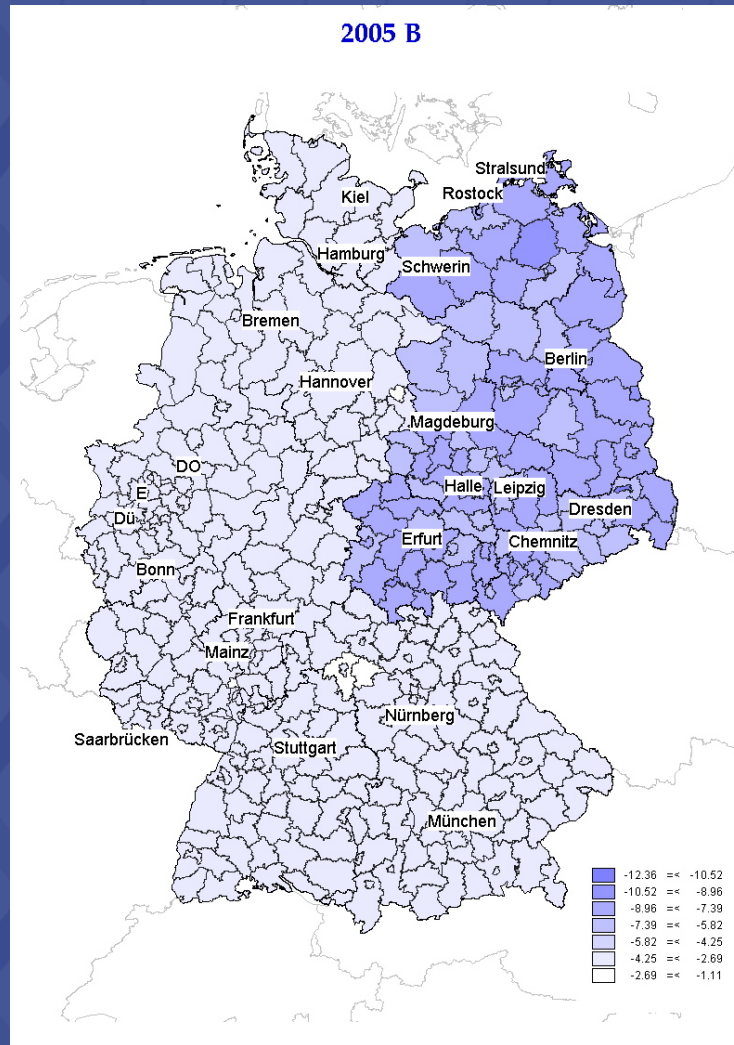


Aggregate results West and East Germany:

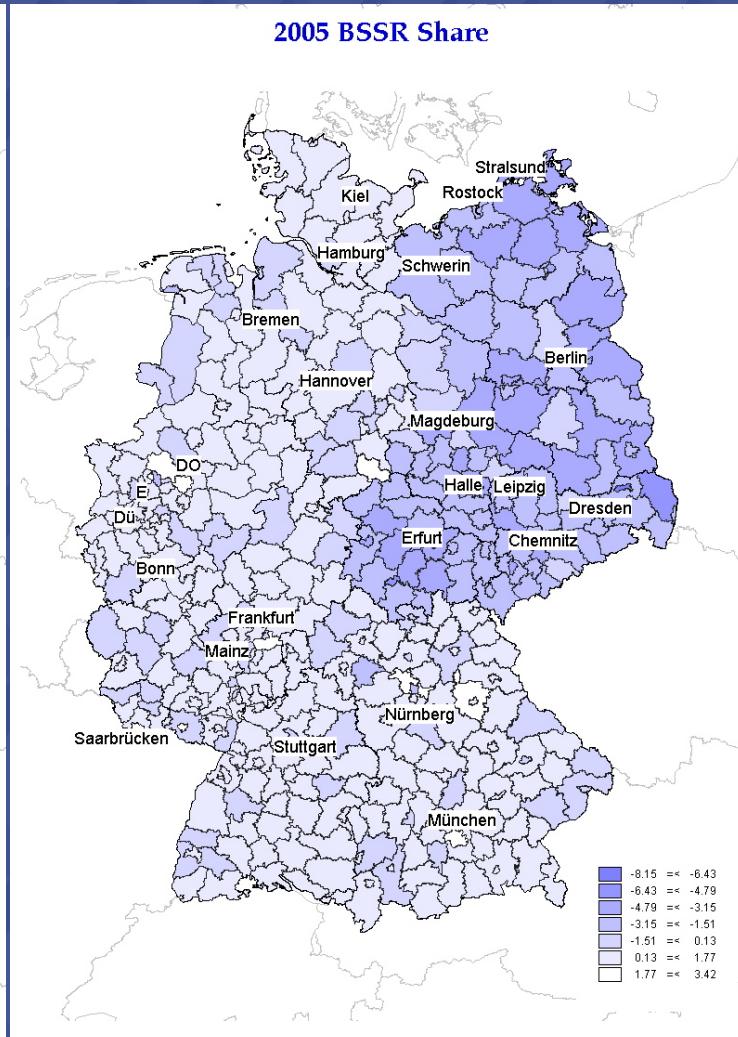
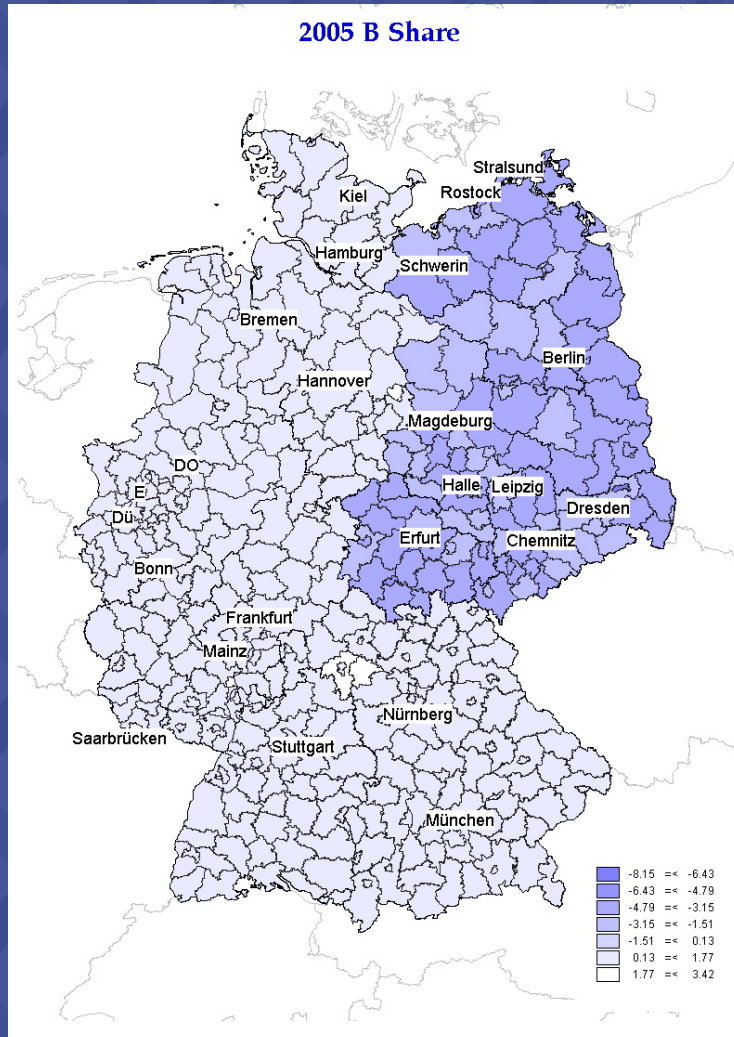
West Germany (left)

East Germany (right)

# Forecasts for the Year 2005 (growth rate): Model B and Model BSSR

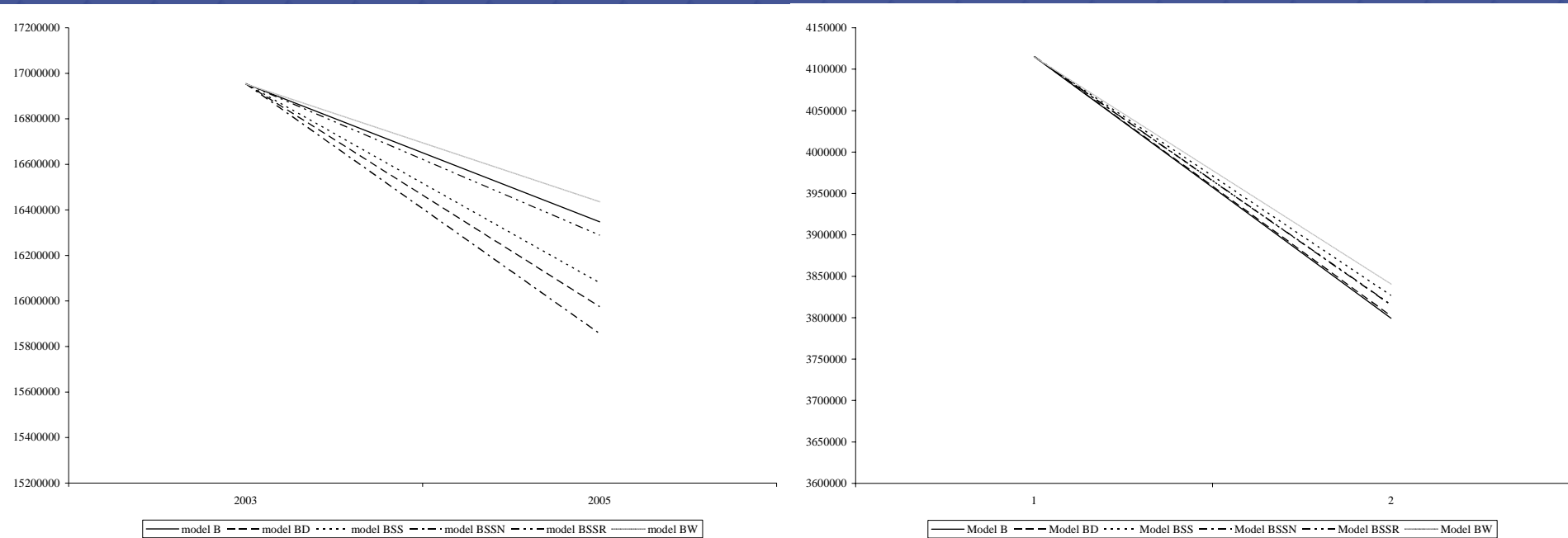


# Forecasts for the Year 2005 (relative share change): Model B and Model BSSR





# Aggregate West and East German Forecasts (2005)

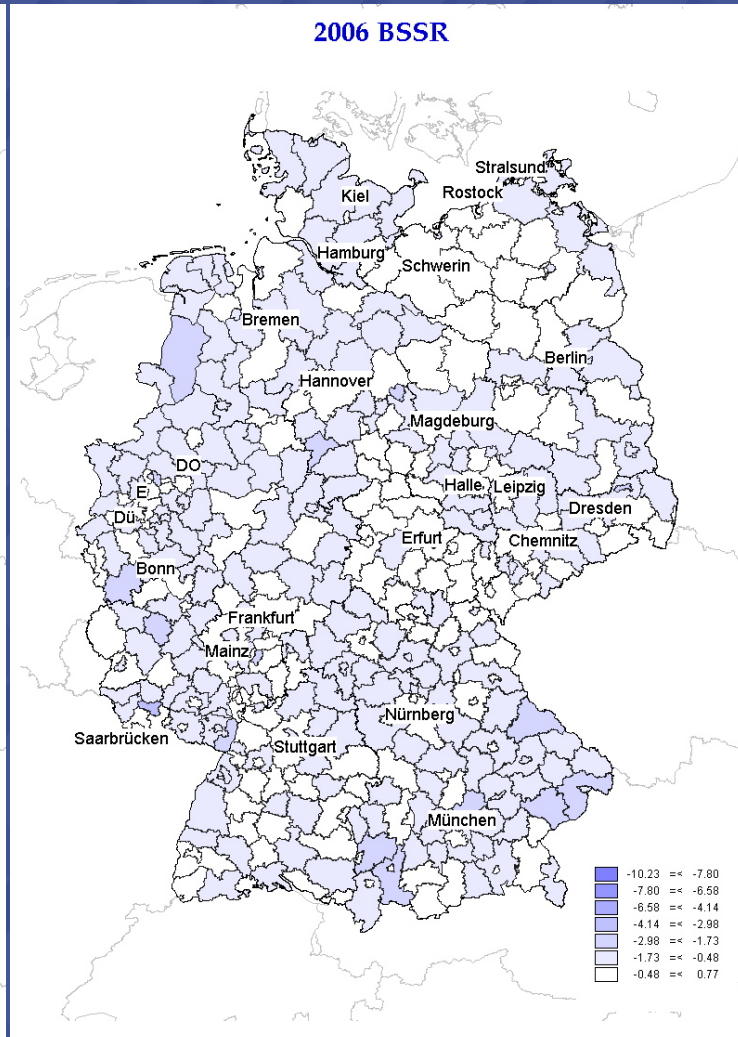
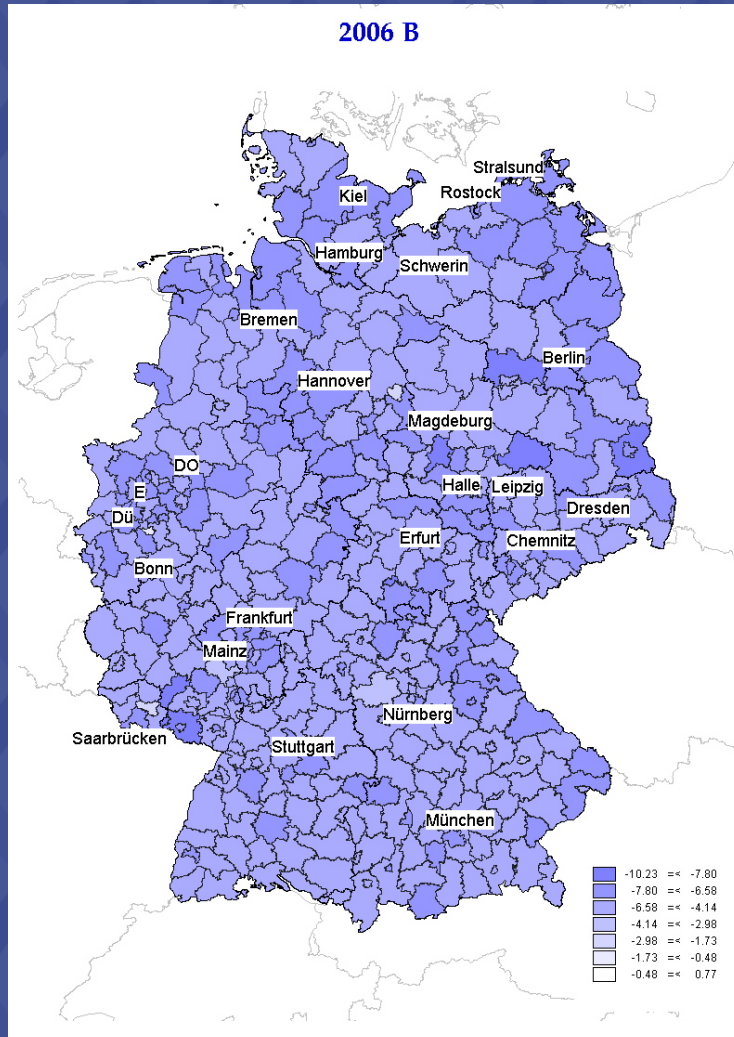


Aggregate results West and East Germany:

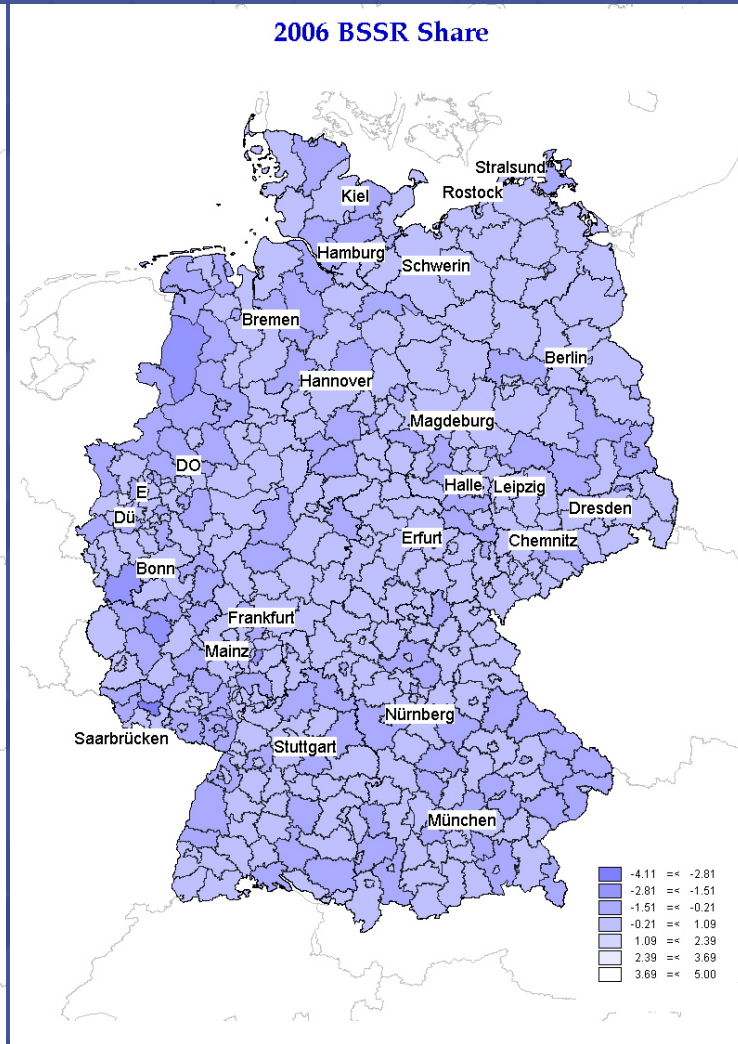
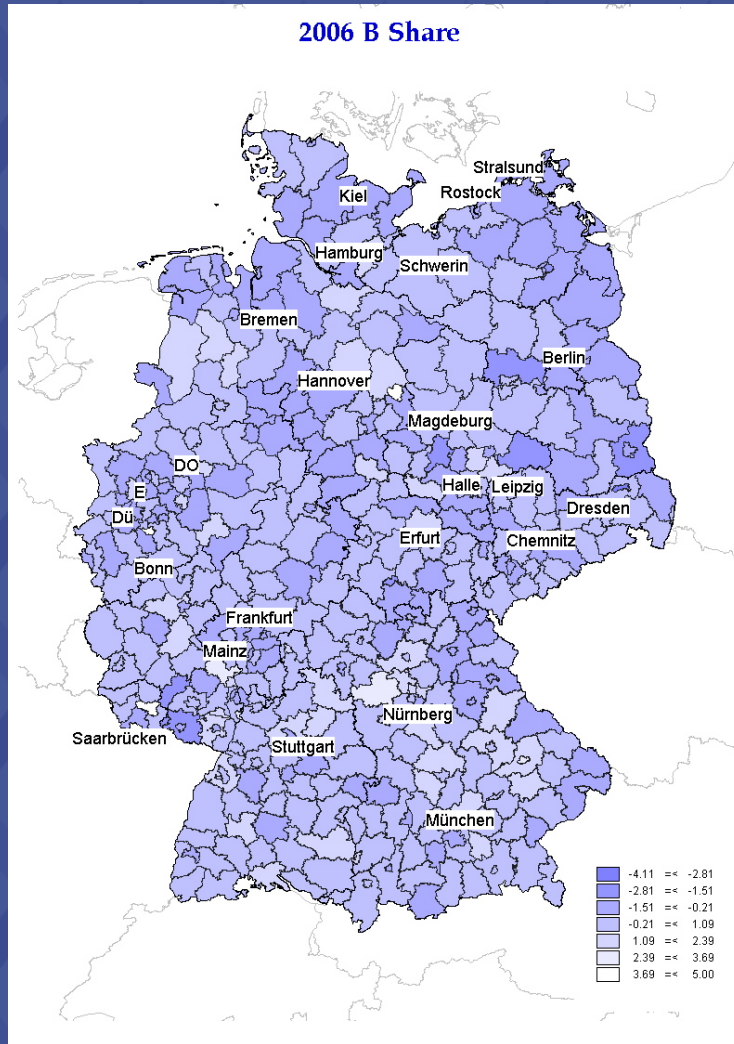
West Germany (left)

East Germany (right)

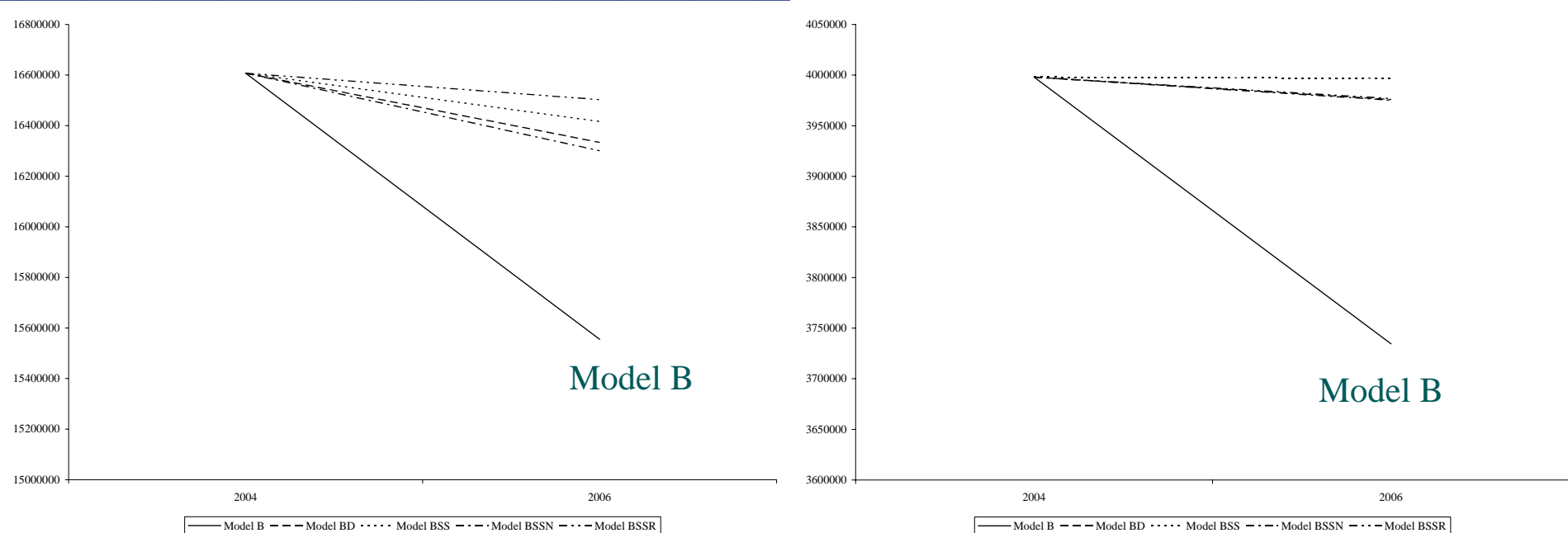
# Forecasts for the Year 2006 (growth rate): Model B and Model BSSR



# Forecasts for the Year 2006 (relative share change): Model B and Model BSSR



# Aggregate West and East German Forecasts (2006)



Aggregate results West and East Germany:

West Germany (left)

East Germany (right)

Model B gives a pessimistic forecast for both West and East Germany

# Conclusions

- This presentation reviewed NN experiments carried out in order to forecast full-time **employment variations** in Germany, at the regional level

## YEARS 2001 AND 2003

- Two types of NN models developed:
  - A-type: based on time dummies
  - B-type: based on time fixed effects
- The B-type models clearly outperform the A-type models, for 2001 and 2003, West and East Germany
- B-type NN models outperform a naïve no-change-hypothesis random walk

## YEARS 2004-06

- NN models embedding shift-share seem to slightly improve Model B's forecasting power (*ex post* forecasts for 2004)
- Comparison of results in terms of growth rate and relative share change
- Forecasts for the year 2005 show homogeneously negative trends
- Forecasts for the year 2006 (minus Model B) suggest less negative trends, and hence a possible cycle inversion, in particular for East Germany

# Future Research Directions

## THEORETICAL AND METHODOLOGICAL VIEW POINT

- **Exploration of NN families alternative to feedforward NNs, such as recurrent or stochastic NNs**
- **A more thorough implementation of shift-share regression in the NN models**
- **A combined spatial and regression shift-share approach**
- **Integration of NNs and other spatial techniques, such as spatial filtering (Griffith, 2000) – use of spatial patterns as explanatory variables**
- **Definition of dedicated NN evaluation indices for panel data forecasting, in order to assess:**
  - The overall generalization properties of the models
  - The accuracy of the single regional forecasts

# Future Research Directions (2)

## EMPIRICAL VIEW POINT

- Investigation – by means of the above NNs – of employment forecasts at time (t+1)
- Study of unemployment forecasts at both times (t+1) and (t+2)

## POLICY VIEW POINT

- Choice/Use of results – concerning (un)employment variations – in terms of either growth rate or relative share change will be a critical issue
- Robustness of results under varying future socio-economic and technological scenarios

Thank You for your attention

Questions and comments  
are welcomed