A New Model Based Analysis Method for Regional Economic Development Effects

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ABSTRACT

It is the aim of this paper to provide a new method for the estimation and evaluation of transport infrastructure and policy measures. This requires before and after data on a small spatial aggregation level. The main problem consists in the separation of the overall economic development, from the spatial impact of the implemented measures. Therefore, time-series data of economic growth seem to be necessary, at least for some selected variables. However, long-term data series are rather difficult to find, and data uncertainties may lead to fluctuations in the estimated growth rates. In addition, it is an empirical fact that the spatial development of a region, even without any specific infrastructure investment, is not homogeneous.

In order to take into account the usual data restrictions and uncertainties as well as the further requirements mentioned above, the spatial dependency and the growth effect will be modeled. Of course, a specific investment may have different impacts on the considered socio-economic indicators, e.g. the rate of change of the regional growth factor depends on the kind of infrastructure investment implemented.

This paper is aimed to introduce an improved shift-share framework, without searching for a comparison region. The method is applied to the determination and separation of the economic development effects in the corridor Stuttgart – Herrenberg (light rail system S1 and motorway A81) belonging to the Stuttgart region.

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1 INTRODUCTION

A general and fundamental problem in Geography and Economy relates to the comparison of different case studies and the subtraction of general trends from specific regional peculiarities, based on e.g. transport investments. In general multi-criteria analysis and advanced methods of spatial statistics (Anselin 1995, Getis, Ord 1992, 1995) are used as a common analytical tool to bypass such obstacles. Another often applied analysis tool is the so called shift-share analysis (Blien, Wolf 2001, Berzeg, Korhan 1978, 1984). In this method the development of a comparison region (e.g. a region without investment but with all other relevant spatial characteristics similar) and the region under consideration are compared. However, it is in many applications a non detachable problem to find such a particular comparison region.

This paper is aimed to present an improved shift-share framework, which can be applied to a nested spatial system, without searching for a comparison region. As an example, the generalised shift-share analysis is applied to analysis the observed impacts and effects of the infrastructure investment (light-rail transport system) S1 on economic development effects within the transport corridor Stuttgart-Herrenberg-Singen. The analysis is part of the workpackage WP8 of the European project Transecon (www.transecon.org).

Spatial redistribution processes are the result of an interlinked process of spatial interaction where different agents (households, accommodation agencies, employees, firms,...) with different, partly inconsistent interests, are involved. The multiple decisions of the different agents result in migration flows of households (people), changes in commuter flows and, last but not least, in a redistribution of workplaces in an extending spatial region, due to firms decisions to search for an optimal location (Boekemann 1982, Bertuglia, Clark, Wilson 1987, Haag 1989).

Migration and commuting depend, among others, on accessibility measures (Bertuglia, Clarke and Wilson 1994, Kutter 1972, Pumain, Saint-Julien 1989). Therefore, the urban system and the transport system closely interact. As a consequence each investment into the transport system (new roads, new transport services, new lines in the public transport..) may lead to changes in accessibility measures of the different zones or communities – or more general in the magnitude and distribution of certain indicators influencing the choice processes of agents. It can be assumed, that the primary objective in location choice of firms and households is to minimise costs, which encompass not only the costs of land or rent, but also the lost travel time, the travel costs and the inherent risk of travel (Lakshmanan et al 2001). For this reason, any change in the conditions of transport would be expected to create new location options. The existence of new travel options enables new trade-offs between location and mobility. Hence, it is conducive to the concentration on particular activities in certain areas.

From a mathematical point of view those decision processes are highly non-linear and therefore difficult to take into account in the urban planning process (Pumain, Haag 1991, Bertuglia et al 1994). However, it is even more difficult to control these ongoing processes by political authorities, especially since quite different time scales are related to the underlying processes of the different subsystems involved. For example, the dynamics of migration of households (1 to 5 years) is much slower compared with a reorientation of commuter flows (1 week to 6 months). Changes in the work place distribution usually vary also on a rather large time scale.

In Section 2 a description of the analysis method for economic development effects is presented. Beside the generalised shift-share framework different indicators of growth are discussed. Section 3 is dealing with the application of the analysis method to the corridor Stuttgart – Herrenberg – Singen. Some results are summarised in Section 4.

2 A GENERALISED SHIFT-SHARE ANALYSIS

2.1 The Analysis Method for Socio-Economic Development Effects

The study area (region) is subdivided into L zones. The state vector

$$\vec{X}(t) = (\vec{X}^{a}(t)) = (X_1^a(t), X_2^a(t), ..., X_L^a(t)) \ , \qquad (2\text{-}1)$$

represents a set of indicators $\vec{X}^{a}(t)$ describing the socio-economic development effects of the study area (region), where a indicates time-series data of different socio-economic indicators $a = 1,...,A$ and $t = 0,1,2,...,T$.

Due to economic activities of the agents (firms, individuals,…) the distribution and the amount of the economic indicators may change.

Assuming a homogeneous growth process of all L zones of the region, the state vector may evolve due to the general law

$$\frac{d\vec{X}(t)}{dt} = \vec{\Lambda}(t)\vec{X}(t) \quad \text{or} \quad \vec{X}(t) = \vec{X}(0)\exp[\vec{\Lambda}(t)t] \qquad (2\text{-}2)$$

where $\vec{\Lambda}(t)$ describes the time-dependent growth rates.

In case of homogeneous growth it is indicated to introduce normalised variables (Indicators), according to

$$x_i^a(t) = \frac{X_i^a(t)}{\sum_{j=1}^{L} X_j^a(t)} \geq 0 \quad \text{with} \quad \sum_{i=1}^{L} x_i^a(t) = 1,$$

(2-3)

for $t = 0,1,2,...,T$ and $a = 1,...,A$.

It is easy to proof, that for homogeneous growth processes the scaled state vector fulfils

$$\frac{dx_i^a(t)}{dt} = 0 \tag{2-4}$$

Homogeneous growth does not change the spatial distribution of the scaled vector x_i^a. However, it is an empirical fact that the spatial development of a region, even without any specific infrastructure investment, is not homogeneous. Homogeneous growth is rather an exception than the rule. Therefore, an appropriate estimation procedure of the impacts of infrastructure investment should fulfil the following conditions:

- stable estimation algorithm (for different time series and zoning)
- data base (stock data for different time steps, not necessarily equal time steps)
- introduction of as little parameters as possible
- separation of "spatial" effects and "growth" effects in a specific zone
- estimation and separation of the "natural" growth effect

In order to take into account the usual data restrictions and uncertainties as well as the further requirements mentioned above, the spatial dependency and the growth effect will be modelled

$$\vec{X}(t) = \vec{X}(0)\exp[\vec{\Lambda}(t)t] \tag{2-5}$$

where the vector of the zone specific growth factors

$$\vec{\Lambda}(t) = (\vec{\Lambda}^a(t)) = (\Lambda_1^a(t), \Lambda_2^a(t), ..., \Lambda_L^a(t)) \tag{2-6}$$

consists of two components: a time dependent "general" growth rate $l^a(t)$, characteristic for the study area, and a zone and time depending factor $g_i^a(t)$, representing regional deviations from the average development.

Furthermore, it is reasonable to assume, that the impact of the implemented infrastructure depends on accessibility measures. In other words, we assume:

$$\Lambda_i^a = l^a(t) + g_i^a(t, d_{ik\in S}) \qquad \text{for } t = 0,1,2,..,T \text{ and } a = 1,2,...,A \tag{2-7}$$

where $g_i^a(t, d_{ik\in S})$ describes beside zonal particularities spatial effects of the infrastructure investment. Of course, a specific investment may have different impacts on the considered socio-economic indicators a.

1st step (estimation of the mean growth rate)

The estimation procedure of the average annual growth rate $l^a(t)$ is based on the definition

$$X^{a\,(emp)}(t+t) = X^{a\,(emp)}(t)\exp\left[\sum_{t'=0}^{t-1} l(t+t')\Delta t_{t+t'}\right] \qquad (2\text{-}8)$$

where
$$X^{a\,(emp)}(t) = \sum_{i=1}^{L} X_i^{a\,(emp)}(t) \qquad (2\text{-}9)$$

represents to total volume (stock) of the (empirical) variable $\vec{X}_i^{a\,(emp)}(t)$ (e.g. total population of the study area). As result of the first step (2-8) the average annual growth rate $l^a(t)$ of the study area is obtained.

$$l^a(t) = \frac{1}{\Delta t_t}\ln\left(\frac{X^{a\,(emp)}(t+1)}{X^{a\,(emp)}(t)}\right) \qquad (2\text{-}10)$$

The time step Δt_t takes into account that the length of the time intervals may differ. These growth rate $l^a(t)$ can be compared with the national growth rate or other specific growth rates in order to identify general evolutionary trends of the economic system.

2nd step (estimation of zonal growth differences)

In the second step zonal deviations $g_i^a(t)$ of the average growth path are estimated. For this aim the average growth rate $l^a(t)$ according (2-10) has to be inserted into the estimation formula (2-11) and the zonal deviations $g_i^a(t)$ are estimated via the error minimisation principle (2-11).

$$\sum_{t=0}^{T-1}\sum_{t=1}^{T-t}\sum_{i=1}^{L}\left(X_i^{a\,(emp)}(t+t) - X_i^{a\,(emp)}(t)\exp\left[\sum_{t'=0}^{t-1}(l^a(t+t') + g_i^a(t+t'))\Delta t_{t+t'}\right]\right)^2 = \min . \qquad (2\text{-}11)$$

The minimisation principal of $g_i^a(t)$ can be solved analytically. This leads to the determination of the zonal deviations $g_i^a(t)$ of the average growth

$$g_i^a(t) = \frac{1}{\Delta t_t}\ln\left(\frac{X_i^{a\,(emp)}(t+1)}{X_i^{a\,(emp)}(t)}\right) - l^a(t) \qquad (2\text{-}12)$$

3rd step (smoothing of $l^a(t)$ and $g_i^a(t)$)

The estimated parameters (2-10) and (2-12) exhibit fluctuations due to data uncertainties. Therefore it is indicated to apply an appropriate smoothing procedure. Due to this smoothing of the parameters the effect of different time steps in the comparison of time series data and seasonal effects can be smoothed out.

In the following a gaussian moving average procedure with a variance of one year has been proposed and applied according to (2-13) to (2-16).

$$\tilde{g}_i^a(t) = \sum_{t'=0}^{T-1} g_i^a(t') \cdot gauss(t,t') \qquad (2\text{-}13)$$

$$\tilde{l}_i^a(t) = \sum_{t'=0}^{T-1} l_i^a(t') \cdot gauss(t,t') \qquad (2\text{-}14)$$

$$gauss(t,t') = \frac{1}{N(t)} \exp\left(-\frac{1}{2}(t-t')^2 \right) \qquad (2\text{-}15)$$

$$\sum_{t'=0}^{T-1} gauss(t,t') = 1 \quad \text{for} \quad t = 0,\ldots,T-1 \qquad (2\text{-}16)$$

The smoothed parameters will be indicated by the sign „~". All further calculations and considerations are base on those smoothed growth rates. Of course, different other smoothing procedures can be applied too.

2.2 Indicators of Growth

On the basis of (2-13), (2-14) different indicators for the characterisation of zonal socio-economic development effects can be developed. This requires an appropriate normalisation, standardisation and/or weighting of the variables.

If all different zonal indicators should be considered with the same political mass, all indicators should exhibit the same zonal variance (Koller, Schwengler 1999). Therefore all zonal indicators are standardised (weighted z-transformed), according to

$$z_i^a(\tilde{g}_i^a) = \frac{w_i^a \tilde{g}_i^a - E(w_i^a \tilde{g}_i^a)}{\sqrt{s^2(w_i^a \tilde{g}_i^a)}}$$

(2-17)

where $E(w_i^a \tilde{g}_i^a) = \frac{1}{L}\sum_{i=1}^{L} w_i^a \tilde{g}_i^a$ and $s^2(w_i^a \tilde{g}_i^a) = \frac{1}{L}\sum_{i=1}^{L}\left(w_i^a \tilde{g}_i^a - E(w_i^a \tilde{g}_i^a)\right)^2$

$$\sum_{i=1}^{L} w_i^a = 1 \qquad (2\text{-}18)$$

This guarantees the statistical properties $E(z_i^a) = 0$ and $s^2(z_i^a) = 1$. The weights $w_i^a(t)$ have to be chosen according to the meaning of the variable α under consideration in order to compensate zonal size effects.

The result of this transformation (standardisation and value shift) is rather non-vivid, since all transformed variables vary within a small value range around zero. However, the order of priority and the distance between the zones remain unchanged.

1) ***temporal mean growth rate***

The mean growth rate of the study area and the mean deviation of the zonal growth rate are the result of a temporal averaging, according to (2-20)

$$\tilde{l}^a = \frac{1}{T}\sum_{t=0}^{T-1} \tilde{l}^a(t) \qquad \tilde{g}_i^a = \frac{1}{T}\sum_{t=0}^{T-1} \tilde{g}_i^a(t) \qquad (2\text{-}20)$$

One hypotheses of Transecon is that transport infrastructure investments can have an effect on real estate development at different phases of the investment life cycle. Therefore, it is indicated to compute the temporal mean values not only over the whole period but also over the different temporal phases of the investment projects

- planning and evaluation phase (“before”)
- design phase (“before”)
- construction phase (“during”)
- operation phase (“after”)

in order to identify anticipated effects, synchronic effects as well as delayed impacts in its spatial development.

2) ***growth concentration ratio***

In addition to classical time figures a *growth concentration ratio* (Gaschet 2002) can be used, defined as

$$G_i^a(t,t') = \frac{\tilde{g}_i^a(t)}{\tilde{g}_i^a(t')} \qquad (2\text{-}21)$$

However, this indicator (2-21) can only be used if both $\tilde{g}_i^a(t)$ and $\tilde{g}_i^a(t')$ have the same sign. Because the development of $\tilde{g}_i^a(t)$ could be positive as well as negative, it is more appropriate to use

$$\Delta\tilde{g}_i^a(t,t') = \tilde{g}_i^a(t) - \tilde{g}_i^a(t') \qquad (2\text{-}22)$$

as a measure of change of the growth deviations $\tilde{g}_i^a(t)$. Both measures $G_i^a(t,t')$ and $\Delta\tilde{g}_i^a(t,t')$ compare for each zone i the spatial growth indicators (rates) for two different years, namely t and t'.

3) modelling of the distance dependency of the infrastructure investment

Furthermore, it is reasonable to assume, that the impact of the implemented infrastructure exhibits a dependence on accessibility measures $d_{ik\in S}$. In other words, it is assumed $\tilde{\Lambda}_i^a = \tilde{l}^a(t) + \tilde{g}_i^a(t, d_{ik\in S})$. Since the overall growth of a particular study area may dominate the spatial growth process, only spatial deviations of the mean development should be related to the infrastructure investment. Different models for the determination and explanation of spatial growth deviations on the basis of infrastructure investment (changes in accessibility measures) are proposed and partially be tested, e.g.:

$$G_i^a(t,t') = f_i^a(t,t',d_{ik\in S}) \quad (2\text{-}23)$$

or

$$\Delta\tilde{g}_i^a(t,t') = f_i^a(t,t',d_{ik\in S}) \quad (2\text{-}24)$$

Furthermore, a relationship between deviations from the mean growth rate $\tilde{g}_i^a(t)$ and accessibility measures will be tested.

3 APPLICATION OF THE ANALYSIS METHOD

3.1 Zoning and time series for socio-economic development effects

In Transecon the project zone (Zproject), that is *the project direct catchment area* is defined as well as 2 concentric zones. The first zone deals with the inner city (Z1). The second zone (Z2) concerns a more extensive zone from Zproject with respect to population and employment densities or the administrative area.

Spatial breakdown is supposed to refer to cells (or zones) as well as the zones Z1 and Z2 and the whole case study-area (Z1+Z2). The spatial breakdown Z2 will be separated into Z2a and Z2b. Z2a is defined by the communities next to the investment project. Z2b is defined by the other communities of the case study area of Z2.

The study area of the case study Stuttgart within the Transecon project is presented in Figure 3.1. Table 3.1 describes briefly same details of the implemented infrastructures.

Table 3.1 The implemented infrastructure of the case study Stuttgart

Phases:	**Description:**
Evaluation phase: 1) 1958 - 1967 2) 1968 - 1978 3) 1978 – 1990 Design phase: 1) 1967 - 1978 2) 1978 - 1985 3) 1988 - 1991 Construction phase: 1) 1973 - 1978 2) 1985 - 1992 3) 1990 – 1992 Operation phase: 1) since 1978 2) since 1992 3) since 1992	1) Completion of the missing section of the Stuttgart-Herrenberg motorway A81 (length: 23.9 km from motorway crossing Stuttgart to exit Herrenberg, 7 exits, including 2 motorway crossings) 2) Completion of the light rail system S1 that runs parallel to this motorway (length: 16 km from Boeblingen to Herrenberg, 6 stations) 3) Creation of park and ride facilities (P&R) (6 park-and-ride facilities, 1563 parking spaces) in the metropolitan area of Stuttgart (Stuttgart Region) 1) investment not known 2) investment 30,2 million Euros (prices of 1990) 3) investment 12,4 million Euros (prices of 1990)

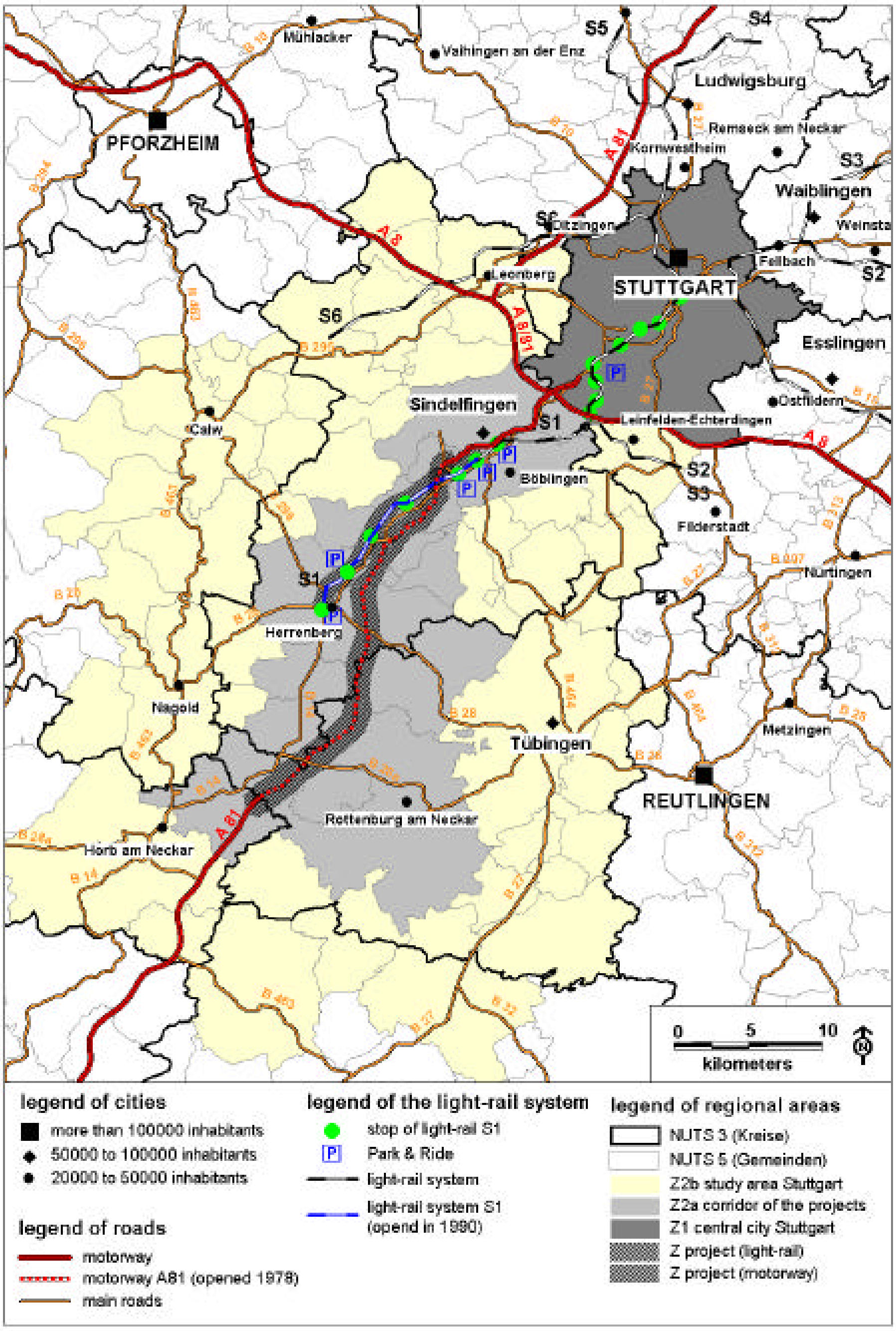


Figure 3.1 Study area of the Stuttgart case (62 communities)

3.2 Results of the generalised Shift-Share Analysis

In the following for demonstrational purposes, the shift-share analysis will be applied on population and employment development between 1974 and 2000.

3.2.1 Population development

In Fig. 3.2 the (smoothed) average annual population growth rate of the study area (Fig. 3.1) is depicted. It is remarkable, that during the construction phase of the infrastructure investment S1 (1985 – 1992) higher average growth rates are found. Especially, if we determine the average growth rates without Z1 (city of Stuttgart). Within the considered time interval 1978 to 2000, the city of Stuttgart is always behind the average development (Fig. 3.3). However, this effect can not completely be assigned to the extension of the A81 and/or the S1, since many other, also radial oriented investment projects have been realised in this region.

Communities crossed by the A81 and the S1 belong to the area Z2a. According Fig. 3.3 the area Z2a is above (0.5%) average development between 1978 and 1988, until the intensive construction phase of the S1 sets in (1988 to 1992). With the start of the operation phase the population growth is again slightly (0.3%) above average development. Communities belonging to Z2b (see Fig. 3.1) are not so much affected by the construction phase of the S1. However, the average population growth rate of Z2b seems to be slightly smaller compared with Z2a (Fig. 3.3).

The temporal mean growth rates of $\tilde{g}$ on the community level is presented in Figure 3.4 (left). With distance from the city centre of Stuttgart and in close vicinity of the infrastructure investments A81 and S1, higher population growth rates can be observed. This is in agreement with the hypothesis that transport infrastructure investments have a positive impact on population growth of suburban communities linked via radial components with the urban centre. The urban centre itself may loose population due to this investment activities. Therefore, for the case city Stuttgart mainly a shift of population growth rates can be stated due to the transport investments A81 and S1.

The impacts and effects of both transport investments A81 and S1 are superimposed and therefore only very difficult to separate e.g. by means of simulations.

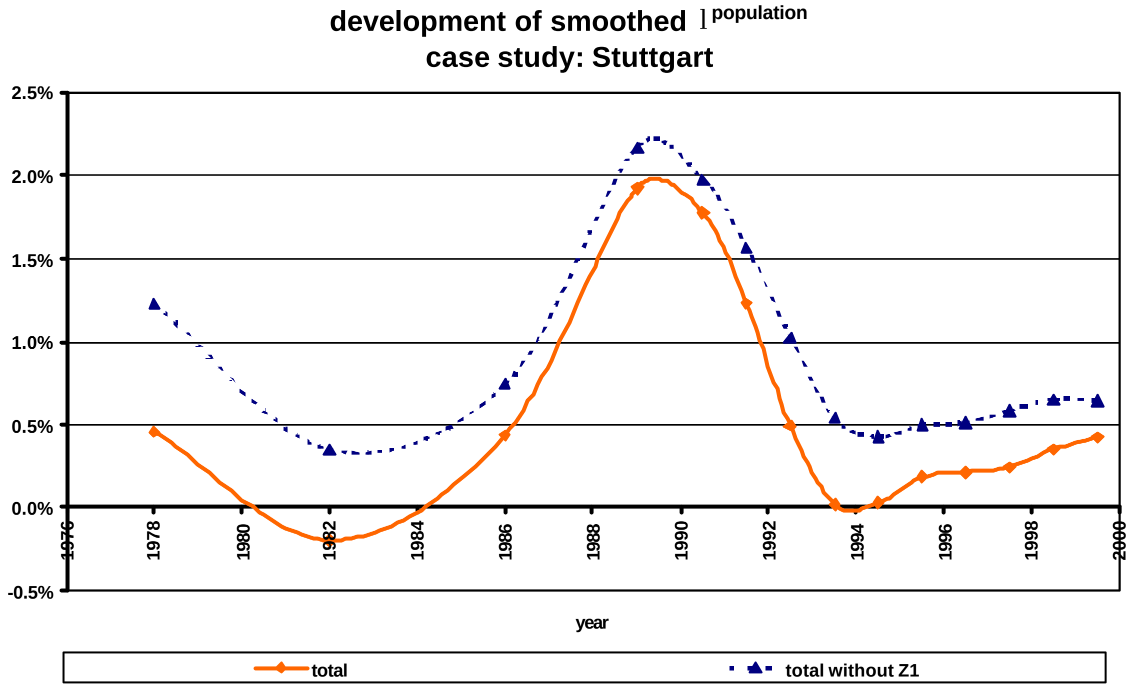


Figure 3.2 Average annual population growth rate $\tilde{l}^{\text{population}}(t)$

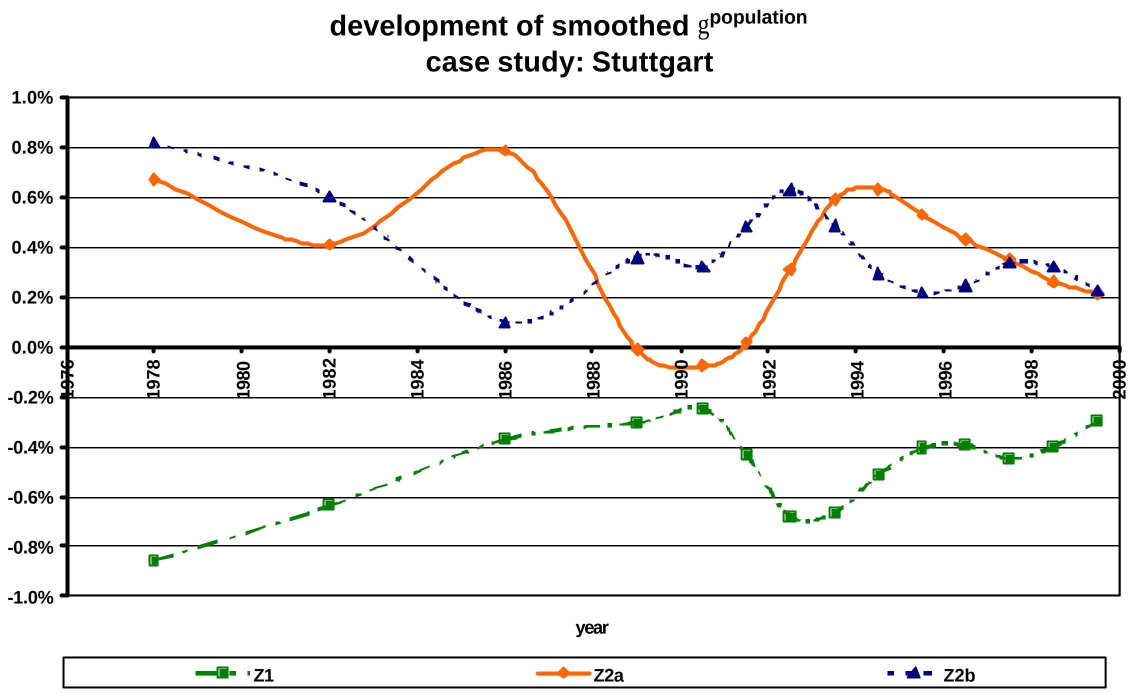
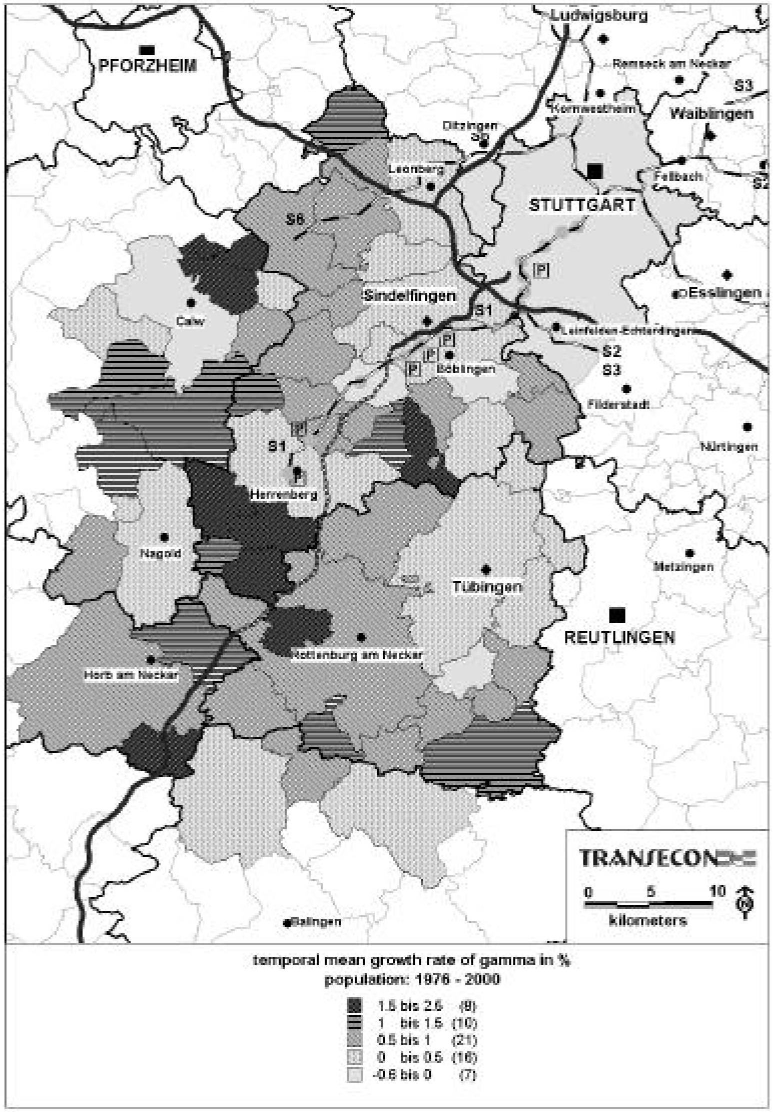


Figure 3.3 Annual deviations from the average growth $\tilde{g}^{\text{population}}(t)$



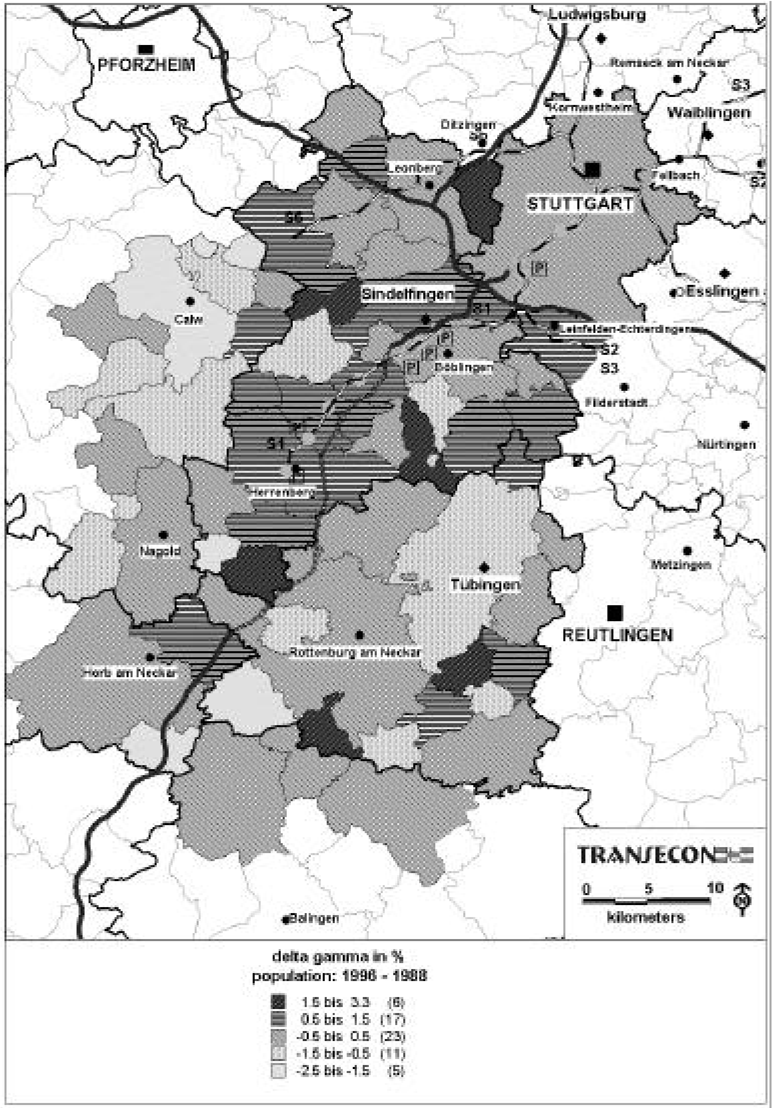


Figure 3.4 Temporal mean growth rate of $\tilde{g}^{\text{population}}(t)$ between 1976 and 2000 (left) and changes in the deviations from the mean growth rate between 1988 and 1996 (right)

3.2.2 Development of employees

In Figure 3.5 the (smoothed) average annual growth rate of employees is depicted. The average growth rate of employees exhibits a similar shape as the average population growth. However it should be mentioned, that the growth rate of employment has its maximum (with 3.8%) in 1986, during the construction phase of the S1, three years before the population development exceeds its maximum (with 2.0% in 1989).

This demonstrates, that mainly during the construction phase of the S1 employment in the study area has increased (Fig. 3.6). This is in contrary to population growth, were a second population growth wave with the start of the operation phase of the S1 can be identified (Fig. 3.3).

The comparison of the two Figures (Fig. 3.3) and (Fig. 3.6) clearly exhibits, that firms of that particular region have been anticipated the implementation of the infrastructure. This means that employment has increased before and during the construction phase of S1. A similar result has been found during the implementation of the motorway A17 Dresden – Prag (Haag et al 1999).

Deviations in the growth rate of employees on the level of communes compared to the average development are depicted in Fig. 3.7. All communes, close to the corridor of A81 and S1 exhibit higher growth rates of employees. Z2a mainly during the construction phase, Z2b mainly during the design and operation phase. However, Z1 is loosing employees.

Figure 3.7 (left) presents the temporal mean growth rates of $\tilde{g}^{\text{employees}}(t)$ on the community level. With distance from the city centre of Stuttgart and in close vicinity of the infrastructure investments A81 and S1, higher growth rates of employees can be observed. This is in agreement with the hypothesis that transport infrastructure investments have a positive impact on employment growth of suburban communities linked via radial components with the urban centre.

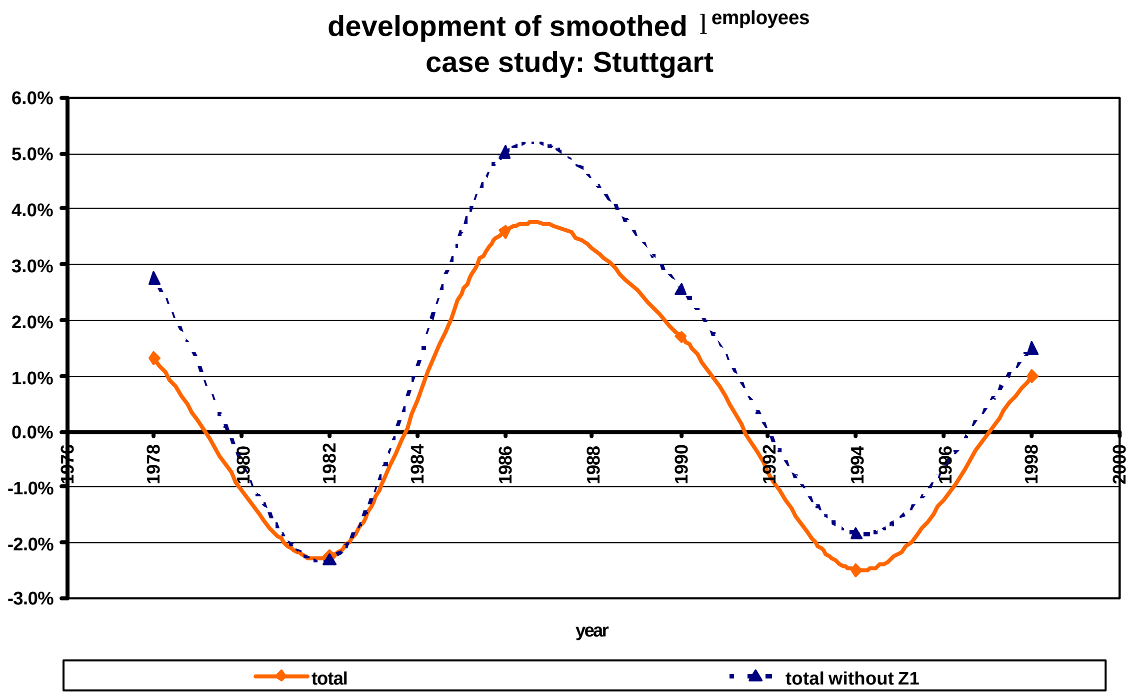


Figure 3.5 Average annual growth rate of employees $\tilde{l}^{\text{employees}}(t)$

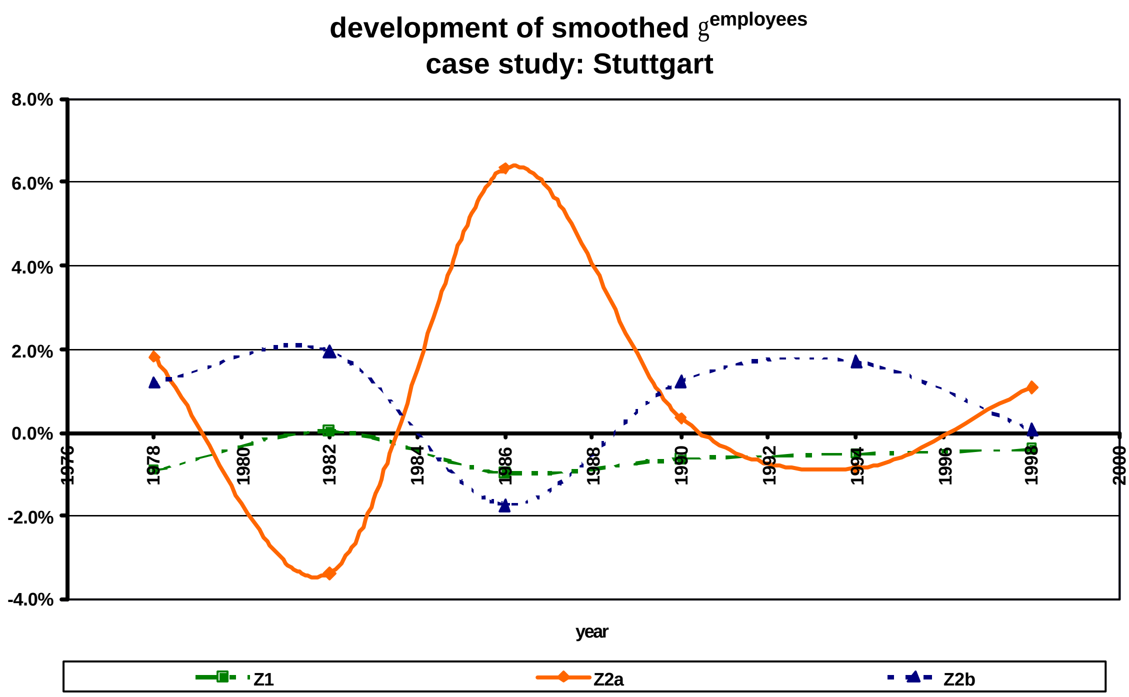
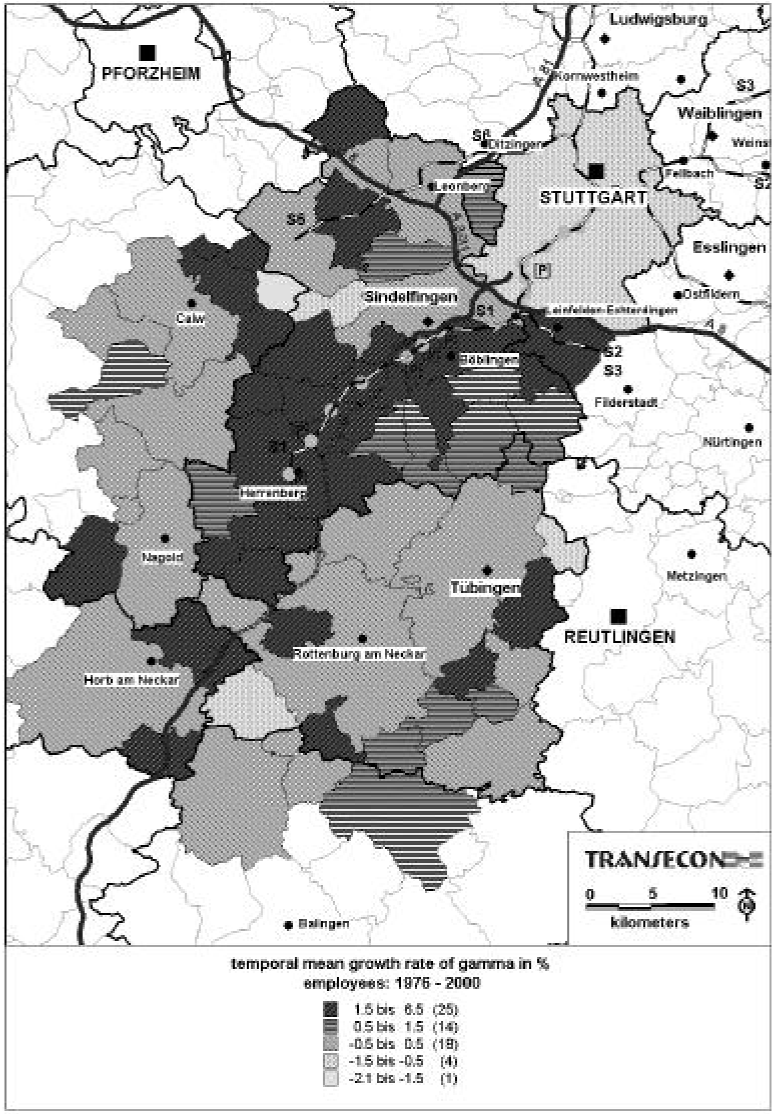


Figure 3.6 Annual deviations from the average growth $\tilde{g}^{\text{employees}}(t)$



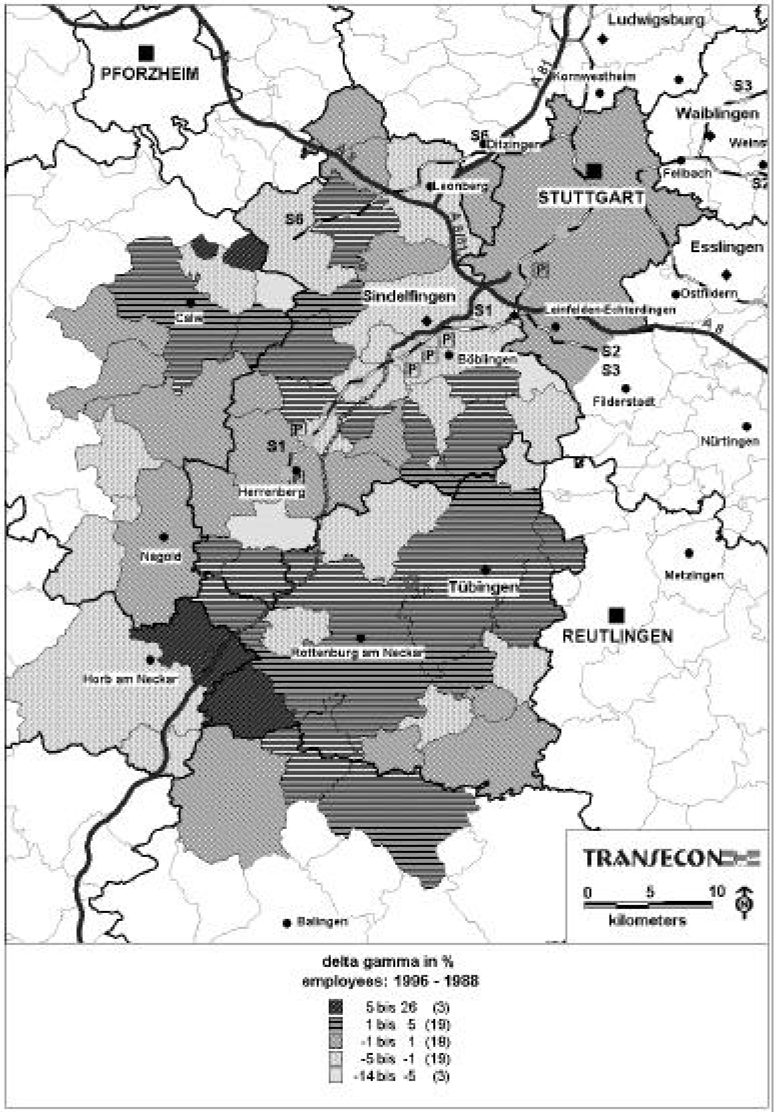


Figure 3.7 Temporal mean growth rate of $\tilde{g}^{\text{employees}}(t)$ between 1976 and 2000 (left) and changes in the deviations from the mean growth rate between 1988 and 1996 (right)

4 CONCLUSIONS AND RESULTS OF THE SHIFT-SHARE ANALYSIS

4.1 Results of the Shift-Share Analysis for the City of Stuttgart

The results of the shift-share analysis for the two variables population and employment of the city of Stuttgart is summarised in Table 4.1. The different “phases” are related to the S1 infrastructure investment.

Table 4.1 Summary of the Shift-Share Analysis for Stuttgart

				Z1	Z2a	Z2b
case study	**phase**	**years**	**smoothed** l	**smoothed** g	**smoothed** g	**smoothed** g
population	design	1978 - 1985	0.08%	-0.66%	0.54%	0.59%
	construction	1985 - 1992	1.17%	-0.35%	0.32%	0.26%
	operation 1	1992 - 1996	0.18%	-0.57%	0.51%	0.41%
	operation 2	1996 - 2000	0.31%	-0.39%	0.31%	0.28%
employees	design	1978 - 1985	-0.40%	-0.38%	-0.50%	1.21%
	construction	1985 - 1992	2.52%	-0.35%	0.32%	0.26%
	operation 1	1992 - 1996	-2.50%	-0.57%	0.51%	0.41%
	operation 2	1996 - 2000	1.00%	-0.39%	0.31%	0.28%

4.2 Conclusions from the Shift-Share Analysis for the City of Stuttgart

The shift-share analysis of the study area (Z1 and Z2a, Z2b) was performed on the basis of the official statistics. This analysis provides important evidence for socio-economic effects and impacts caused by the infrastructure investments A81 and S1.

- The indicators (population and employment) clearly demonstrate (Table 4.1) that development effects (deviations from the average growth rates) in those communities close to the transport corridor (A81 and S1), study area Z2a and Z2b, are partially much stronger than in the comparison area, or in the city of Stuttgart (Z1).
- With regard to population development (population growth rates), during the first years after the introduction of the A81 (following 4 years), mainly the area Z2a faced additional increases in population, whereas for the population numbers of the area Z2b smaller increases are registered and the population of the city of Stuttgart (area Z1) decreased slightly.
- Beginning with the operation phase (1992) of the S1 a slight additional increase in population growth in the areas Z2a and Z2b can be observed

(0,4% above average over the next 4 years). The city, Z1, has still a negative growth rate (-0.4% below average).

- Strong impacts of the A81 and the S1 are obvious in the development of workplaces and employment structures. Especially the A81 affects manufacturing trade, the sector of economy that is most dependent on convenient traffic connections, in the areas Z2a and Z2b. After the opening of the A81, this sector showed significantly higher growth dynamics in Z2a and Z2b than in Z1 or compared to the average development. The number of companies and the compulsory insured employees active in the manufacturing trade, increased not only relatively but also absolutely.

- The employment in the study area increased mainly during the construction phase of the S1. This is in contrast to population growth. Population growth increased mainly during the first years of the operation phase of the S1. The comparison of population and employment development clearly demonstrates, that firms of that particular region have been anticipated the implementation of the infrastructure S1. This means that employment has increased before and during the construction phase of the S1.

The obtained results of the generalised shift-share analysis indicate that this method could be very useful in the analysis of spatial data. It will be interesting to see how effective the method as statistical tool will be in the comparison of the 13 case studies within the Transecon project.

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