Project funded by the European Commission under the « Energy, Environment and Sustainable Development Programme » of the 5th Framework Programme, Key Action 4: City of Tomorrow and Cultural Heritage

SCATTER

Sprawling Cities And TransporT: from Evaluation to Recommendations

Deliverable 3: Work package 3

Statistical Analysis in the Case Cities

Contract number: EVK4-CT-2001-00063

Date: 20 December 2002

Project Co-ordinator: STRATEC S.A. (BE)

Partners: STASA (DE)
University College of London (UK)
LT Consultants (FI)
CERTU (FR)
TRT (IT)
STRAFICA (FI)
CETE de l'Ouest (FR)

This report is completed by one annexe presenting the detailed results of WP2 and WP3 for the 6 case cities: Bristol, Brussels, Helsinki, Milano, Rennes and Stuttgart

SCATTER

Sprawling Cities And TransporT: from Evaluation to Recommendations

Document Information:

Document Title:	Statistical Analysis in the case cities
Authors:	Günter Haag, Jan Binder
	with contributions of Michael Batty, Nancy Chin (sections 4.2.2, 4.2.3)
Nature:	Deliverable Report RE
Reference:	D3
Workpackage:	3
Dissemination Level:	PU – Public Usage
Version nr:	1.0
Submission date:	December 20 2002

Quality verification:

WP leader:	Günter Haag (STASA)
Peer review:	Angelo Martino, Silvio Angelini, Patrizia Malgieri (TRT)
	Sylvie Gayda, Nathalie Schaillée, (STRATEC)

TABLE OF CONTENTS

List of Figures

List of Tables

1 EXECUTIVE SUMMARY

In WP1 a state of the art review of definitions and mechanisms of urban sprawl, different measures used for its description and a list of possible or assumed impacts of urban sprawl to all levels of society were given. On the basis of interviews in WP2, the level of awareness of the local authorities was investigated. The interviews also collected a descriptive, qualitative and systemic analysis of the mechanisms behind this phenomenon. The important task of WP3 is the design and application of a statistical analysis framework to all six case studies: Milan, Brussels, Stuttgart, Bristol, Helsinki and Rennes. The main objective of WP3 is to identify and quantify particular features of the urban sprawl by means of this statistical analysis.

The developed statistical framework consists of:

- a specially designed generalized shift-share analysis;
- a new concentration measure, called *H*- measure;
- the application of local spatial autocorrelation statistics;
- as well as the interpretation of classical measures and some basic indicators shown on maps.

This seems to provide sufficient and necessary conditions for the identification of different urban pattern, including urban sprawl.

As a first conclusion, the application of the statistical analysis method shows, that the development of the urban centres of all six case studies Milan, Brussels, Stuttgart, Bristol, Helsinki and Rennes are behind the average growth path of the whole conurbation areas over the last decades, while the deviations of the outer urban ring and often also of the hinterland are above the average growth path.

The global Moran's *I* for the different case study areas provide a ranking of spatial autocorrelation: The communes belonging to the Brussels study area are much more similar in population density and workplace density than communes of Rennes and Bristol. Milan, Helsinki and Stuttgart are in-between.

The pattern of local Moran's *I* indicates that the urban centres of Brussels and Helsinki and some neighbouring communities show strong spatial autocorrelation in population density and density of workplaces.

The shift-share analysis indicates that in all case studies the main growth poles of population and employment are situated in the outer urban ring or the hinterland or in both. This leads to an increase of the investigated stock variables (population, employment, commuters, dwellings and residential buildings) mainly in the outer urban ring accompanied by an increase of the investigated density variables (income per capita, commuter trip length and house prices) in some but not all zones belonging to the outer urban ring and the hinterland. Milan is in so far an exceptional case, since total population and commuters are decreasing (stagnating). However, this could be related to the fact that the conurbation area for Milan seems to be too small.

Urban sprawl can be identified per definition, if the growth of the investigated indicators are more or less scattered over the whole region, with the urban centre of the region as source. The detailed statistical analysis indicates urban sprawl in the case studies of Milan and Bristol. Here, the necessary condition for urban sprawl, namely a strong de-concentration effect must be stated as well as scattered growth rates, distributed over the whole study areas.

In the case studies of Stuttgart and Brussels only a moderate to stagnating de-concentration is observed. The scattered growth rates of all indicators of Stuttgart and the spatial autocorrelation pattern exhibits that urban sprawl in the Stuttgart Region exists but is rather moderate. The spatial re-orientation of Brussels follows more a diffusion pattern ("normal" growth phenomenon of a city) with some implemented scattered structures. Several poles exist in Brussels periphery. A moderate sprawl phenomenon of jobs and population can be identified.

Helsinki and Rennes still tend to concentrate its activities close to their city centres. In so far both case studies do not exhibit all conditions of urban spawl. Nevertheless, Rennes and Helsinki show some typical aspects of urban sprawl, e.g. scattered spatial development of population and of workplaces. However, the spatial autocorrelation analysis and the shift-share analysis shows that for both variables only around the rather small urban centre a high spatial correlation can be found, despite the unbalanced and widely spread growth of population and workplaces in the outer urban ring of Rennes and Helsinki.

The statistical analysis shows so far that the six case study areas can be clustered according to its spatial-temporal development into three groups:

- Milan, Bristol: *continuing and rather strong spatial de-concentration of activities* (activities include population and employment), with local specificities such as:
  - Milan: population and employment are out-migrating to areas which are more and more distant from the centre;
  - Bristol: it exhibits a more polycentric pattern, with 2 other urban poles included in the hinterland;

- Stuttgart, Brussels: *moderate spatial de-concentration of activities, tending towards a stagnation of the pattern*; in the case of
  - Brussels: it seems that the sprawl, as regards population, has slowed down these last years, and even stopped very recently;
  - Stuttgart: sprawl can be stated for population on a low level but in case of employment sprawling seems to stagnate.

- Rennes, Helsinki: *continuing spatial concentration of activities*: these two metropolitan areas do not exhibit all conditions of urban sprawl, but the growth of the population and of the employment is nevertheless scattered to a certain extent. In both areas, there is in the same time an out-migration of the rural population towards the urban centre and especially the outer urban ring, and a scattered growth pattern, but at a lower level than in the 4 other cities.

2 INTRODUCTION

The first stage of SCATTER consists in the improvement of the understanding of the mechanisms behind urban sprawl and its impacts. In WP1 a state-of-the-art review of urban sprawl impacts and urban sprawl measurement techniques was achieved. In WP2 interviews of experts and decision makers were carried out, to perform a qualitative systemic analysis of the mechanisms of sprawl.

This Deliverable D3 reports the results of the Work Package 3 of SCATTER: the aim of WP3 was to identify urban sprawl and to quantify the effects of urban sprawl by statistical methods. In addition to existing measures, a new measure for the quantification of urban sprawl, the *H*-measure, is introduced and tested.

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. inhomogeneous developments, specific investments in a region or regional policy programs. 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 and the region under consideration are compared. However, it is in many applications a non detachable problem to find such a particular comparison region.

The chapter 3 of this report is aimed to develop an improved shift-share framework, which can be applied to a nested spatial system, without searching for a comparison region. The framework will then be applied to the six case cities of the SCATTER project: Bristol, Brussels, Helsinki, Stuttgart, Milan and Rennes. The standard shift-share analysis is a method of comparative statistics of estimating the relative importance of different elements in any growth or decline of regional industrial employment. Shift-share accomplishes this by comparing the actual growth rate of the region to the growth rate that would have occurred if every industry in the region under consideration had grown at the national growth rate for that industry. The shift-share technique is only a descriptive tool. A shift-share analysis is a "snap-shot" of a local economy at two points in time. Thus, the analysis may not offer a clear picture of the local and national economies since the results are sensitive to the time period chosen. For Scatter it is therefore necessary to generalise the shift-share procedure in order to deal with time-dependent and even cyclical socio-economic development effects and to separate regional disparities from national or regional trends.

WP3 analyses, for each case city, the features and effects of urban sprawl, by performing a statistical analysis of time series of socio-economic data, concerning a period characterised by a sprawl of the urban activities (households, jobs, retail shops and other services). When possible, the related effects on the pattern of trip demand are also analysed.

The variables dealt with in the database are for example: population, employment, commuters, income, data on the housing market… .

The statistical analysis comprises 2 stages:

- designing a common analysis framework;
- carrying out the analysis itself, for each case city.

The design of the common analysis framework starts by selecting a common definition for the metropolitan area (e.g. the functional urban region) and for structural rings inside the metropolitan area, such as: the urban centre, the outer urban ring and the rest, named as hinterland. In practice, the definition of the 3 macro-zones depends on the availability of data and appropriate administrative boundaries (see section 4.1.1 for more detail).

The issues to be considered are related to the aim of identifying urban sprawl by statistical methods. However, quantitative data analysis by statistical methods can only partially disclose the interactions between causes and effects, factors and consequences. As highlighted by WP2, qualitative information is in addition essential to understand the mechanisms, behind urban sprawl.

Chapter 3 of this report describes in detail the statistical analysis method which was implemented and provides the definition of the indicators which were calculated. In Chapter 4, the first section 4.1 presents the zoning system which was adopted for all six case cities, as well as the data sources used. Section 4.2 presents some basic statistical indicators giving a general overview on the evolution of population and employment in the last decades, in the six cities. In addition some basic indicators on the national level are introduced. In section 4.3 are the results of the shift-share analysis, for the different case cities presented. In this section some results at the European level, e.g. a comparative analysis focussing on similarities and dissimilarities between the six cities, in an attempt to set up a typology are also presented. Section 4.4 contains the essential conclusions of the statistical analysis of the case studies.

The detailed results at city-level, for the six case cities, are given in six monographic reports which also include the detailed results of WP2. This six monographic reports make up a common Annexe to Deliverable 2 and Deliverable 3.

3 DESCRIPTION OF THE STATISTICAL ANALYSIS METHOD IMPLEMENTED TO IDENTIFY URBAN SPRAWL

The statistical analysis of urban sprawl impacts (population and jobs location, trip demand pattern) has been applied to the six case cities Brussels, Stuttgart, Bristol, Helsinki, Rennes and Milan. This requires time series data on a small spatial aggregation level for each case study involved. The main problem consists in the measurement and separation of the effects of urban sprawl from general development effects. Therefore, an improved shift-share analysis was developed and applied.

An appropriate modelling tool was therefore developed, which is rather robust and requires as less as possible data input from the case studies.

For the statistical analysis, the region of the particular case study under investigation is subdivided into *L* zones or areas (e.g. communities).

The state vector

$$\vec{X}(t) = (\vec{X}^a(t)) = (X_1^a(t), X_2^a(t), \ldots, X_L^a(t)), \qquad (3\text{-}1)$$

where a describes the different socio-economic indicators[1] or variables $a = 1, \ldots, A$ (e.g. population, work places,…) and $t = 0,1,2,\ldots,T$ indicates the time steps of the indicator $\vec{X}^a(t)$ of the study area of the case city.

Due to economic activities of the agents (firms, individuals,…) as well as external influences (e.g. neighbourhood, general economic development of the country, political changes) the spatial distribution of the indicators will change.

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

$$\frac{d\vec{X}^a(t)}{dt} = \vec{\Lambda}^a(t)\vec{X}^a(t) \quad \text{or} \quad \vec{X}^a(t) = \vec{X}^a(0)\exp[\vec{\Lambda}^a(t)t] \qquad (3\text{-}2)$$

where $\vec{\Lambda}^a(t)$ describes the time-dependent growth rates. In this case only one growth rate per socio-economic indicator a exists. In case of homogeneous growth it is useful to introduce normalised variables (indicators), according to

$$x_i^a(t) = \frac{X_i^a(t)}{\sum_{j=1}^{L} X_j^a(t)} \geq 0 \quad \text{with} \quad \sum_{i=1}^{L} x_i^a(t) = 1, \qquad (3\text{-}3)$$

for $t = 0,1,2,\ldots,T$ and $a = 1,\ldots,A$. It is easy to prove that for homogeneous growth processes the scaled state vector fulfils

---

[1] Of course those variables can be related to the e.g. zonal areas by appropriate weights. In this way densities are also considered.

$$\frac{dx_i^a(t)}{dt} = 0 \qquad (3\text{-}4)$$

Homogeneous growth does not change the spatial distribution of the scaled vector x_i^a.

The growth rates for the specific zones *i* are influenced by spatial disparities in the development. Many studies have analysed factors of local economic development, but there has been little consensus about the relevance of specific factors in explaining relative economic performance (Barff, Knight 1988). Among the many in economic theory considered and discussed influencing variables were taxes, wages, education (Perloff et al 1960, Loveridge, Selting 1998), local tax revenue per capita, human capital, job qualification, public goods and services, but also local innovation activities, and subsidies (Scherer, Perlman 1992). Another source of explaining factors – more related to regional science and transport theory - are for example the different accessibilities measures to the city core, different residential attractiveness, and leisure time services, or local infrastructure investments, a restructuring of the economy due to location changes of households and companies (Hayter 1997, Haisken 1996), to mention a few but relevant causes (Bertuglia, Clark, Wilson 1994; Hauer, Timmermans, Wrigley 1989). The amount of the change of the different zone specific growth factors varies and may show a distance dependency or a dependency on accessibility measures.

As WP 2 has shown, in all the six study areas, public planning has played a significant role in determining the current spatial and functional structure.

Let us assume that a more localised intervention such as a new residential, industrial or business development area starts to expand at time t_0, with $0,1,...,t_0,...,T$. Therefore, it can be expected, that in the course of time the zone specific growth factors will be influenced (see Figure 1) in the neighbouring areas. For example: if the area under consideration becomes more attractive for a certain economic sector, it is reasonable to assume that the corresponding growth rates are positively effected. In case of an increase of negative externalities, e.g. due to an increase of noise or pollution which could be related to the economic growth, the growth rates of other indicators, e.g. population may decline.

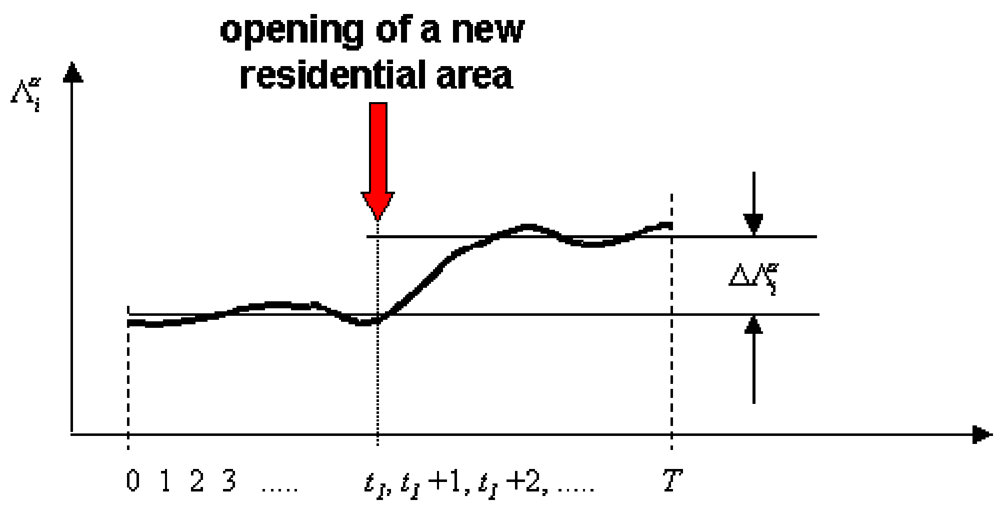


Figure 1 : Development of a zone specific growth factor e.g. due to an opening of a new residential area at time t_0

Because WP3 is focused on the statistical analysis of urban sprawl, the spatial development of an sufficiently extended area covering the whole city and its hinterland has to be considered.

The interaction of the decision makers of the different levels of the socio-economic system like firms, households, politicians are highly interwoven and non-linear. On the level of a single decision maker (micro-level) a complex mixture of fluctuating rational considerations, professional activities and emotional preferences and motivations finally merge into one of relatively few well demarcated resultant attitudes. To change the apartment or to change the place of work, or to change the location of a firm, or to offer more or less work places at a certain location, could be the reaction of a household or a firm to a planned or realised regional policy (Weidlich, Haag 1983). On the other hand, all realised investments are also the outcome of a sequence of decisions of different decision makers within a complex interplay of rational and emotional, conscious and subconscious and environmental influences. The obviously non-linear structure of the interactions between individuals implies that there exists a cyclic coupling between causes and effects in society. Learning processes of individuals and organisations as well as speculations may lead to retarded or even anticipated effects on the micro-level (level of individuals) as a result of a planned local activity (macro-level).

With respect to the aim of WP3 this cyclic coupling of causes and effects makes it difficult if not impossible to separate different types of effects (see for example: the European project TRANSECON GMA1-2000-27049, where direct effects, direct network effects, indirect effects and indirect network effects have been distinguished) and their impacts on the spatial distribution of the state vectors. However, it is the aim of WP3 to develop a statistical analysis method for urban sprawl and to perform a comparison of all available case studies using a standardised methodology on the basis of this statistical analysis method.

The statistical analysis method used in WP3 is based on a comparison of basic statistical indicators and an advanced shift share procedure on the case cities. The development and use of the statistical method is the focus of the next section.

3.1 Generalised Shift-Share-Analysis

The standard shift-share analysis is a method of comparative statistics of estimating the relative importance of different elements in any growth or decline of regional industrial employment (Houston, 1967, Blair 1995, Blien, Wolf 2001). This change could be due to the national rate of change in manufacturing, or the industrial structure of the region itself and its locational advantages or disadvantages. In so far, the shift-share analysis examines the recent performance of a region’s economy. It separates the growth effects explained by the mix of industries located within the region (e.g., the region’s industrial structure) and the growth attributed to particular regional influences. Shift-share accomplishes this by comparing the actual growth rate of the region to the growth rate that would have occurred if every industry in the region under consideration had grown at the national growth rate for that industry.

The shift-share technique is only a descriptive tool (Stevens, Moore 1980). It should be used in combination with other analyses to determine a region's economic potential. Shift-share does not account for many factors including the impact of business cycles, identification of actual comparative advantages, and differences caused by levels of industrial detail. A shift-share analysis is a "snap-shot" of a local economy at two points in time. Thus, the analysis may not offer a clear picture of the local and national economies since the results are sensitive to the time period chosen. On the other hand, the shift-share technique provides a simple, straightforward approach to separating out the national and industrial contributions from local growth. It is also useful for targeting industries that might offer significant future growth opportunities.

For Scatter it is therefore necessary to generalise the shift-share procedure in order to deal with time-dependent and even cyclical socio-economic development effects and to separate regional disparities from national or regional trends. This means, that the method is shifted from an economic target towards a more geographic target, without specifying regional explanatory variables from the very beginning.

Because that, it seems to be reasonable that the rate of change of the growth factor $\Delta\Lambda_i^a$ of a region *i* depends on the overall economic development and spatial disparities which might be related to a bundle of socio-economic factors. In general, it can be assumed, that in case of sprawl, the growth factors of the peripheral regions are different from those of the city centre and exhibit a time-dependence. The next section is dealing with the estimation of time-dependent growth effects and the separation of regional and average growth factors.

3.1.1 Estimation of the Growth Factors and Definition of Growth Indicators

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 investment or political intervention is not homogeneous. Homogeneous growth is rather an exception than the rule. Therefore, an appropriate estimation procedure of the impacts of urban sprawl should fulfil the following conditions:

- stable estimation algorithm (for different time series and zoning)
- flexible to the structure of the data base (stock data for different time steps, not necessarily equal time steps)
- introduction of as little parameters as possible
- estimation and separation of the average development (average 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 as:

$$\vec{X}(t) = \vec{X}(0)\exp[\vec{\Lambda}(t)t] \xrightarrow{|\vec{\Lambda}(t)| \ll 1} \vec{X}(0)\,(1+\vec{\Lambda}(t))^t \qquad (3\text{-}5)$$

where the vector of the zone specific growth factors

$$\vec{\Lambda}(t) = (\vec{\Lambda}^a(t)) = (\Lambda_1^a(t), \Lambda_2^a(t), \ldots, \Lambda_L^a(t)) \qquad (3\text{-}6)$$

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

$$\Lambda_i^a = l^a(t) + g_i^a(t) \quad \text{for} \quad t = 0,1,2,\ldots,t_0,\ldots,T \tag{3-7}$$

In so far $g_i^a(t)$ describes beside zonal particularities possible spatial effects, e.g. because of specific regional policies to mitigate zonal disparities, or the decreasing impact with distance of a specific investments. Of course, urban sprawl may have different impacts on the considered bundle of socio-economic indicators of the different case studies. This is reflected via the index a.

1st step (estimation of the average growth rate)

The estimation procedure of the average annual growth rate $l^a(t)$ is based on the definition of the growth rate (3-5), leading to

$$X^{a\,(emp)}(t+t) = X^{a\,(emp)}(t)\exp\left[\sum_{t'=0}^{t-1} l(t+t')\Delta t_{t+t'}\right] \tag{3-8}$$

where $X^{a\,(emp)}(t)$ represents the total volume of the variable $\vec{X}^a(t)$ for the whole study area[2], if $\vec{X}^a(t)$ is a stock variable (e.g. total population of the study area). In case $\vec{X}^a(t)$ is a density variable (e.g. income per capita), $X^{a\,(emp)}(t)$ represents the spatial average of the considered variable $\vec{X}^a(t)$. As result of the first estimation step, (3-8) finally leads to the average annual growth rate $l^a(t)$ of the study area:

$$l^a(t) = \frac{1}{\Delta t_t}\ln\left(\frac{X^{a\,(emp)}(t+\Delta t_t)}{X^{a\,(emp)}(t)}\right) \tag{3-9}$$

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 (3-9) has to be inserted into (3-10) and the zonal deviations $g_i^a(t)$ are estimated via the error minimisation principle (3-10):

---

[2] "emp" means "empirical" (observed)

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

(3-10)

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

$$g_i^a\,(t) = \frac{1}{\Delta t_t}\ln\left(\frac{X_i^{a\,(emp)}(t+\Delta t_t)}{X_i^{a\,(emp)}(t)}\right) - l^a\,(t) \tag{3-11}$$

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

The estimated parameters via (3-9) and (3-11) may exhibit some noisy structure, e.g. due to possible data uncertainties. Therefore it seems to be appropriate to filter the mean growth rates and the deviations of the growth rates in order to smooth out such artefacts. Hence, in the following a gaussian moving average procedure is applied, according (3-12) to (3-15):

$$\tilde{g}_i^a\,(t) = \sum_{t'=0}^{T-1} g_i^a\,(t')\cdot gauss(t,t') \tag{3-12}$$

$$\tilde{l}^a\,(t) = \sum_{t'=0}^{T-1} l^a\,(t')\cdot gauss(t,t') \tag{3-13}$$

$$gauss(t,t') = \frac{1}{N(t)}\exp\left(\frac{1}{2}(t-t')^2\right) \tag{3-14}$$

$$\sum_{t'=0}^{T-1} gauss(t,t') = 1 \quad \text{for} \quad t = 0,\ldots,T-1 \tag{3-15}$$

The smoothed parameters will be indicated by the sign „~". All further calculations and considerations are base on those smoothed variables.

In Figure 2 the smoothing effect of the gaussian moving average procedure is shown by means of an example, namely the population growth of the case study Stuttgart. As required, only short-time temporal effects with a duration below of 2 years are smoothed.

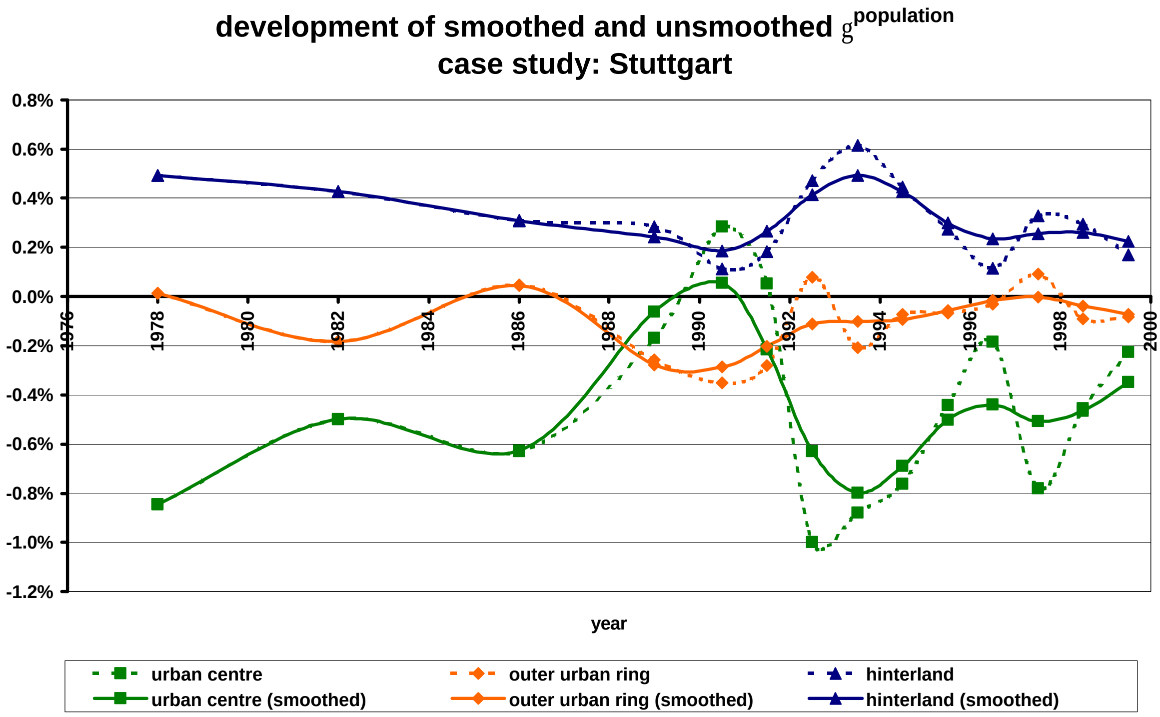


Figure 2 : Comparison of the time-development of smoothed and unsmoothed growth rates (example: $g_i^{Population}(t)$ of the case study Stuttgart)

3.2 Indicators

For the identification of urban sprawl different indicators have to be considered. Those indicators for the characterisation of zonal development effects are partially defined on the basis of (3-12), (3-13). Other indicators as the *H*-measure and measures concerning the local statistics are related to the original data base.

3.2.1 Temporal Mean Growth Rate

As indicators of growth, the temporal mean growth rates $\tilde{l}^a$ and $\tilde{g}_i^a$ are introduced. The mean growth rate of the study area and the mean deviation of the zonal growth rate are the result of a temporal average procedure, according to (3-16) over the whole time interval

$$\tilde{l}^a = \frac{1}{T}\sum_{t=0}^{T-1}\tilde{l}^a(t) \qquad \tilde{g}_i^a = \frac{1}{T}\sum_{t=0}^{T-1}\tilde{g}_i^a(t) \tag{3-16}$$

These indicators give some hints about the “stability” of the average and zonal growth processes. Since the temporal development of the growth rates for the six case studies differ considerably, those temporal mean growth rates are measures which can be listed in tables for comparison purposes.

3.2.2 The Concentration-Measure H: A new Indicator for the Identification of Urban Sprawl

Urban sprawl has a spatial and temporal dimension. WP1 showed that there are many various types of urban sprawl (thus gave a sketch of a typology) and that the typology was multi-dimensional (spatial typology):

- form: suburban contiguous growth, scattered or leapfrog development, linear development along a transport axis, network of small cities, polycentric system, …;
- function: homogeneity or mix of land uses; level of independency with regard to the central urban core, etc;
- social: more or less social segregation;
- transport: small centres organised around public transport nodes or high use of private car in scattered settlements;
- etc.

There is also a temporal dimension in this issue. It is likely that the different forms and the different organisations of functions correspond to various “ages” of the phenomenon of sprawl. For example:

- first age: very scattered – only residential
- second age: progressive densification – addition of retail and public services (schools, etc)
- third age: still densification – addition of jobs - evolution towards autonomous centres also providing jobs to their residents.

Therefore, it seems worthwhile to analyse the process of creation of sprawl by introducing a general spatio-temporal typology. The possible complicated spatial pattern reflecting the phenomenon of urban sprawl require different measures or indicators for its sufficiently comprehensive classification. Beside basic statistical indicators as introduced and discussed in section 4.2, measures describing its spatial shape or concentration effects are of importance.

In the following a new indicator is proposed, called *H*-measure, which considers the spatial and temporal dimension of urban sprawl in a much more simplified way. The *H*-measure quantifies concentration or de-concentration effects in the urban system. It does not consider the organisational function of the urban area or the age dimension of sprawl.

The *H*-indicator is based on the observation that the process of densification is rather inhomogeneous in space and depicts quite different growth rates in time and space. Furthermore, the densification and the effect of urban sprawl is a phenomenon occurring rather on the margin of a city, than homogeneously distributed over the total area under consideration.

Inspired by physics, the new measure is introduced, called concentration-measure *H*, where the density (e.g. population density) $r(\vec{r})$ at distance $\vec{r}$ from city centre is weighted with distance^2 from the city centre:

$$H = \int r(\vec{r})\,\vec{r}^{\,2}\, dA(\vec{r}) \qquad (3\text{-}17)$$

The integration $dA(\vec{r})$ has to be performed over the whole case study area (*A* being the urban area). In discrete terms we have:

$$\begin{aligned} H &= \sum_{\vec{r}} r(\vec{r})\, \vec{r}^{\,2} A(\vec{r}) \\ &= \sum_{i=1}^{L} r_i\, \vec{r}_i^{\,2} A_i = H_X + H_Y \end{aligned} \tag{3-18}$$

with $$H_X = \sum_{i=1}^{L} r_i\, x_i^2 A_i \quad \text{and} \quad H_Y = \sum_{i=1}^{L} r_i\, y_i^2 A_i \tag{3-19}$$

In chapter 3 the *concentration*-measure *H* is computed for the different case studies. As origin of the coordinates $\vec{r}$ the centre of gravity of the city areas is used. The *H*-measure is performed for the following measures:

a) density indicators $$r(\vec{r},t) = \frac{X_i^a(t)}{A_i} \tag{3-20}$$

b) relative indicators $$r(\vec{r},t) = \frac{1}{A_i} \frac{X_i^a(t)}{\frac{1}{L}\sum_{j=1}^{L} X_j^a(t)} \tag{3-21}$$

From the definition (3-17) it follows that an increase in the relative concentration-measure H^{rel} with time, using (3-21), indicates that the outer urban ring or the hinterland is growing in relative terms faster than the urban centre. For a temporal constant relative concentration-measure H^{rel} the development in space is homogeneous. This does not imply that *H* remains also temporally constant. In case of a temporally growing (declining) *H* – and a temporally constant H^{rel} – the considered total stock or density variable would homogeneously increase (decrease) over the total conurbation area. Spatial concentration effects in the urban centre lead to a decrease of the relative concentration-measure H^{rel}. The absolute values of *H* and H^{rel} for a selected variable represent the current state of the urban system with respect to its spatial concentration. If the temporal development of sprawl for a specific urban system is considered *H* and H^{rel} have to be compared for different points in time. Therefore, it is indicated to scale the concentration measures *H* and H^{rel} to the first year t_0 of the analysis, according (3.22) and (3.23).

$$\hat{H}(t) = \frac{H(t) - H(t_0)}{H(t_0)} \tag{3.22}$$

$$\hat{H}^{rel}(t) = \frac{H^{rel}(t) - H^{rel}(t_0)}{H^{rel}(t_0)} \tag{3.23}$$

In case of $\hat{H}(t) > 0$ sprawl is likely to occur, for $\hat{H}(t) < 0$ concentration effects may dominate. However, an increase of the $\hat{H}$– measure in the course of time is only a necessary condition for the occurrence of urban sprawl, and not a sufficient condition. For example, in case of a homogeneous growth process of a suburban ring-like structure, the *H*-measure may also increase. This kind of a decentralisation is rather related to a diffusion process, formed by centrifugal forces typical for a city meeting the conditions of a central place (Lösch 1962, Christaller 1933). Therefore, additional local measures, such as those basic statistical indicators introduced in section 4.2, have to be considered in parallel, in order to be able to identify further typical spatial structures, which are related to urban sprawl.

3.2.3 Global and Local Indicators of Spatial Autocorrelation (LISA)

In spatial data analysis, especially in order to get additional hints for the existence of urban sprawl, it is necessary to determine whether or not an identifiable spatial pattern exist. In so far the identification of urban sprawl can be seen as a pattern recognition problem. Nevertheless, beside the morphological (e.g. pattern recognition) aspects the spatial organisation and its function are of importance – and this is not simply a pattern problem. Of course, the spatial organisation of the urban system is reflected, at least partially, in its spatial structure, due to cyclical interactions (chicken – egg problem).

To identify local spatial-temporal pattern of variables the correlations between nearby values of the statistics are derived and verified by simulations. There are many possibilities to test for the existence of such pattern. One of the most popular one is Moran´s *I* statistic, which is used to test the null hypothesis that the spatial autocorrelation of a variable is zero. If the null hypothesis is rejected, the variable is said to be spatially auto-correlated. Some other standard global statistics and new measures of local spatial statistics have been developed recently (LISA). These methods include Geary C (see Cliff and Ord 1973, 1981), G statistics (Getis 1992), local Moran's *I* (Anselin 1995) and GLISA (Bao and Mark 1996). There are two aspects in common for all those spatial analytical techniques. First, they start from the assumption of a randomised distribution of spatial pattern. Second, the spatial pattern, spatial structure, or kind of spatial dependence are derived from the statistical data only, without any pre-conceived theoretical notion (Bao 1998).

In identification of local spatial patterns, there are usually two issues in concern:

1) Is the observed value at location *i* surrounded by a cluster of high or low value?
2) Is the observed value at location *i* associated positively with the surrounding observations (similarity) or negatively with the surrounding observations (dissimilarity)?

The *G* statistics (Ord and Getis 1992; Getis and Ord 1994), and LISA (Anselin 1995) provide measures for the tests of the local spatial association which are of importance in the identification process of urban sprawl for the six case studies. The *G*-statistics can be used to identify spatial agglomerative patterns with high-value clusters or low-value clusters. The local Moran's $I_i(d)$ identifies pattern of spatial autocorrelation within the spatial system independent whether or not high or low value clusters are considered. This specific property of local Moran's *I* is of importance for the identification of specific spatial pattern which can be related to urban sprawl and will be considered in the next section.

3.2.4 Local and Global Moran's *I*

The local Moran's $I_i(d)$ for each observation *i* is defined as (Anselin 1995)

$$I_i(d) = z_i \sum_{j,j\neq i}^{L} \tilde{w}_{ij}\, z_j \quad \text{with} \quad \tilde{w}_{ij} = w_{ij} \Big/ \sum_{j,j\neq i}^{L} w_{ij} \tag{3-27}$$

where the observations $z_i = \dfrac{x_i - \langle x \rangle}{s\,(x)}$ and z_j are in standardized form (with mean of zero and variance of one). The spatial weights $\tilde{w}_{ij}$ are in row-standardized form. In WP3 we use for the spatial weights w_{ij} an exponentially decreasing distance function, according to

$$w_{ij} = C \cdot \exp\left(-\frac{d_{ij}}{d_{1/2}}\right) \tag{3-28}$$

where $d_{1/2}$ describes the distance of influence of the zones and C is fixed by

$$\sum_{j=1}^{L} w_{ij} = 1 \text{ (row- standardized).} \tag{3-29}$$

So, $I_i(d)$ is a product of z_i and the spatial average of z_j in the surrounding locations.

The local Moran's $I_i(d)$ indicates the spatial correlation of a zone *i* with all other zones whereas the neighbouring zones have the strongest influence. Therefore the local Moran's $I_i(d)$ can be seen as a Local Indicator of Spatial Autocorrelation (LISA). A significant high value $I_i(d)$ (e.g. $I_i(d) > 1$) of the region indicates a high value of autocorrelation, $I_i(d) \approx 0$ indicates a heterogeneous or inhomogeneous neighbourhood of the zones, significant negative values of $I_i(d)$ (e.g. $I_i(d) < -0.2$) indicate that the neighbouring regions are quite different in its values (possible indication of "hot spots" or poles, e.g. like an urban employment pole in a rather rural hinterland).

Global Moran's $I_0(d)$ is defined as spatial mean value of the local measure, by

$$\begin{aligned} I_0(d) &= \frac{1}{L}\sum_{i}^{L} I_i(d) = \frac{1}{L}\sum_{i}^{L} z_i \sum_{j,j\neq i}^{L} \tilde{w}_{ij}\, z_j \\ &= \frac{\sum_{i}^{L}\sum_{j,j\neq i}^{L} w_{ij}\,(x_i - \langle x \rangle)(x_j - \langle x \rangle)}{s^2(x)\sum_{i}^{L}\sum_{j,j\neq i}^{L} w_{ij}} \end{aligned} \tag{3-30}$$

The expectation value $E(I_0(d))$ and variance $s^2(I_0(d))$ of global Moran's $I_0(d)$, for a sample size *n,* can be calculated on the basis of the spatial data distribution (Cliff and Ord 1981, Goodchild 1986).

The test on the null hypothesis, namely that there is no spatial autocorrelation between the observed values (*n* locations) can be calculated based on the standardized statistics via

$$Z\left(I_0(d)\right) = \frac{I(d) - E\left(I_0(d)\right)}{\sqrt{s^{2}\left(I_0(d)\right)}} \tag{3-31}$$

The Moran $I_0(d)$ is significant and positive when the observed values for locations within a certain distance *d* tend to be similar, negative when they tend to be dissimilar, and close to zero when the observed values are arranged randomly and independently over space (Goodchild 1986). Therefore, global Moran's $I_0(d)$ can be seen as a measure of spatial autocorrelation within the whole study area.

4 STATISTICAL ANALYSIS OF THE CASE CITIES

4.1 Zoning System and Data Base

4.1.1 Spatial Aggregation and Zoning System of the Case Studies

For the comparative analysis of the occurrence of urban sprawl (sections 4.3 and 4.4), and the detection of socio-economic similarities and differences between the six case studies, two different zoning systems were used. Both zoning systems were adopted to address specific issues within WP 3:

1. First zoning system: subdivision of the case study area into three macro-zones. This zoning system gives some more aggregate hints, with respect to the dynamics of the urban and regional system. For this aim a subdivision into
   - urban centre,
   - outer urban ring,
   - hinterland.

   was chosen[3]. The first zone deals with the urban centre of the study area. The second zone concerns a more or less concentric ring around the urban centre (outer urban ring), the hinterland (third zone) represents the remaining areas of the study area. It depends on the case study, if the outer urban ring is defined by commuter trips (e.g. average commuter length and/or time) or by administrative boarder lines of the communities of the study area. The general framework has been adjusted to fit, as far as possible the local particularities and interest of each case city. The definitions of the macro-zones in the six case cities are given in the Table 12 in Annexe A.

2. Second zoning system: spatial breakdown of the catchment area (case study area) into *L* spatially disaggregated zones (regional units, cells, e.g. traffic cells). This spatial subdivision must allow to specify spatial dissimilarities and differences in the space-time development of zones in order to identify disaggregated growth differentials as possible sources of urban sprawl. It is obvious that the spatial breakdown should comprise at least 20 regional units, surrounding the city centre of the case study under consideration. The spatial breakdown of each case study area is summarized in each monographic report (common Annexe to D2 and D3).

4.1.2 Spatial-Temporal Data used for the Statistical Analysis of the Case Studies

All spatial data were to be provided in a minimum of five time steps, in order to be able to identify general spatial development effects. This means that a minimum of four

[3] Based on the definition of urban rings by Pumain, Guérois (2001) "Urban Sprawl in France (1950-2000)", FrancoAngeli, Milan

development periods can be considered. In addition, the whole time series had to cover a period of at least 10 (better 20) years, for the possible extraction of urban sprawl.

The economic data used can be combined into 3 sets of indicators:

indicators of urban development

- population development
- development of the number of dwellings
- development of the number of residential buildings
- development of land use

indicators of the labour marked development

- development of workplaces/jobs and/or employees registered at the workplace
- development of labour force and/or employees registered at the place of home
- development of commuters
- development of commuter trip length

indicators of economic development and welfare

- development of annual income per capita
- development of land prices and house prices
- development of rents of housing units and offices

Not all case studies were able to provide all the data sets. The available datasets of all case studies are summarised in Table 13 in Annex A.

Other data sets like environmental and land use data were not analysed for the case studies. Environmental data sets are based normally on a much bigger aggregation level (regions or states) than cells.[4] Furthermore, land use data by cells were not available or were only available for less than three data points in time for all case studies. Therefore, it was not appropriate to analyse environmental and land use data within this work package.

4.2 Basic Statistical Indicators of the Case Cities

At the beginning of the analysis, at first some basic indicators of change for each country of our case cities are introduced. The variables considered are population, economic output and measures for transport. These data base is used in comparison with the case cities

[4] E.g. an increase in the pollution for the whole region must not be related to urban sprawl.

development in order to identify changes in the overall development of the case cities. For comparison reasons, the Eurostat data base has been used.

4.2.1 Analysis of the National Indicators: Population and Gross Domestic Product

The total population of the European Union had been just above 376 million in 2001. The gross rate of increase in the EU has increased slightly: 2.8‰ in 2000 compared with 2.6‰ in 1999. The net migration is one of the main components of demographic growth in the EU. In the 60's, it accounted for less than 5% of total population growth. Its significance in relation to natural growth has steadily increased. During the last 10 years the net migration has accounted for about 70% of the EU's total population growth.

In Figure 3 the yearly growth between 1990 and 2000 of the total population of the countries of the 6 case cities is depicted.

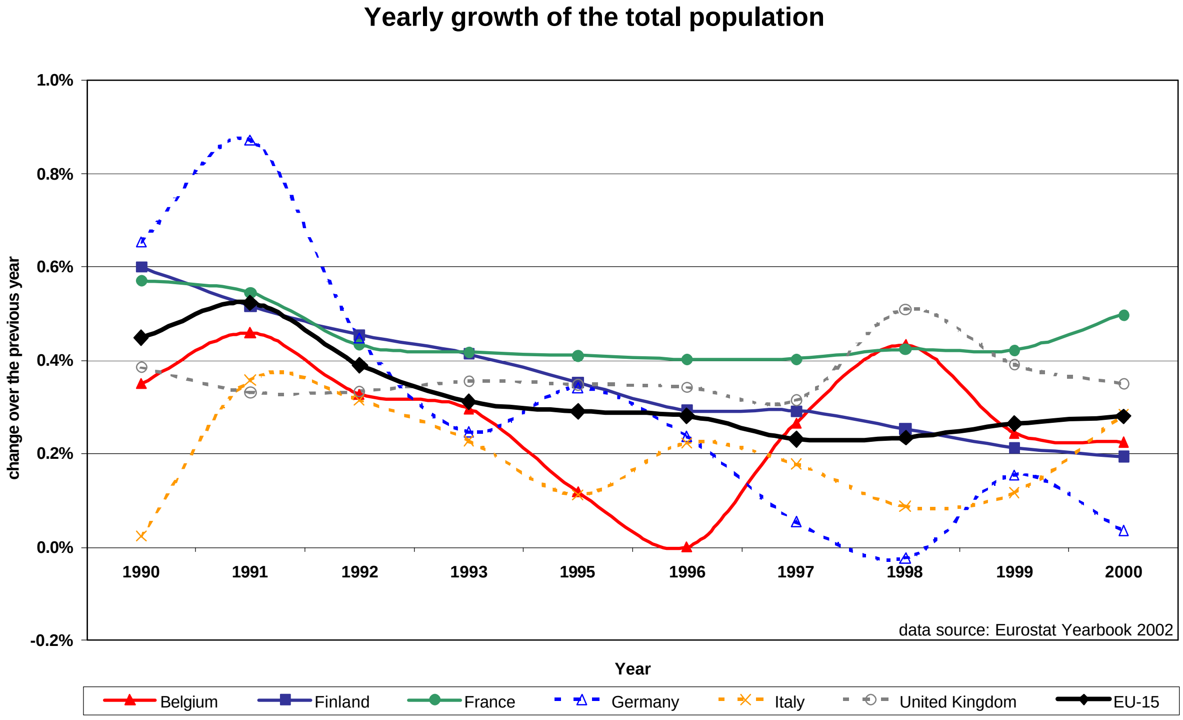


Figure 3 : Yearly growth of the total population on national level

In the following Table 1 and Figure 4, the gross domestic product (GDP) corresponds to the economy's output of goods and services less intermediate consumption, plus VAT[5] on products and net taxes (e.g. taxes less subsidies) linked to imports. Valuation at constant prices means valuing the flows and stocks in an accounting period at the prices of the

[5] VAT: value added tax

reference period (ESA[6] 95, 1.56). In particular GDP per capita (Figure 5) is one of the main indicators for economic international comparisons. This indicator is used in section 4.3 in order to compare the development of the average growth rates of the different case studies, with corresponding up and down movements of the whole national economy.

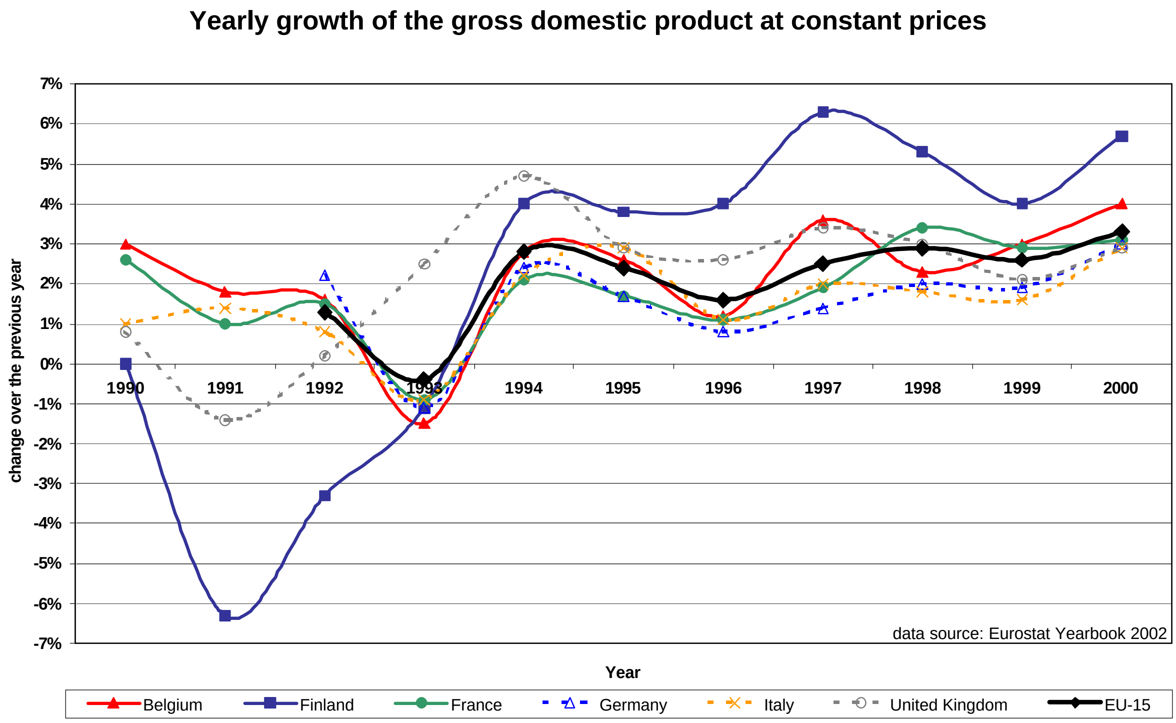


Figure 4 : Yearly growth of the gross domestic product at constant market prices

Table 1 : Gross domestic product per inhabitant at market prices

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
EU-15	15'815 €	16'414 €	16'375 €	17'100 €	17'730 €	18'569 €	19'501 €	20'375 €	21'352 €	22'644 €
Belgium	16'465 €	17'533 €	18'334 €	19'517 €	20'897 €	20'966 €	21'335 €	22'056 €	23'060 €	24'254 €
Finland	19'970 €	16'673 €	14'553 €	16'615 €	19'396 €	19'645 €	21'058 €	22'393 €	23'351 €	25'463 €
France	17'352 €	18'186 €	18'936 €	19'719 €	20'477 €	21'020 €	21'219 €	22'095 €	22'893 €	23'719 €
Germany	17'963 €	19'455 €	20'634 €	21'684 €	23'059 €	22'956 €	22'722 €	23'354 €	24'065 €	24'652 €
Italy	16'559 €	16'759 €	14'906 €	15'110 €	14'651 €	16'937 €	17'925 €	18'568 €	19'228 €	20'209 €
United Kingdom	14'495 €	14'301 €	14'174 €	15'064 €	14'833 €	15'955 €	19'889 €	21'511 €	23'037 €	25'962 €

Data source: Eurostat Yearbook 2002

[6] ESA: European system of integrated accounts

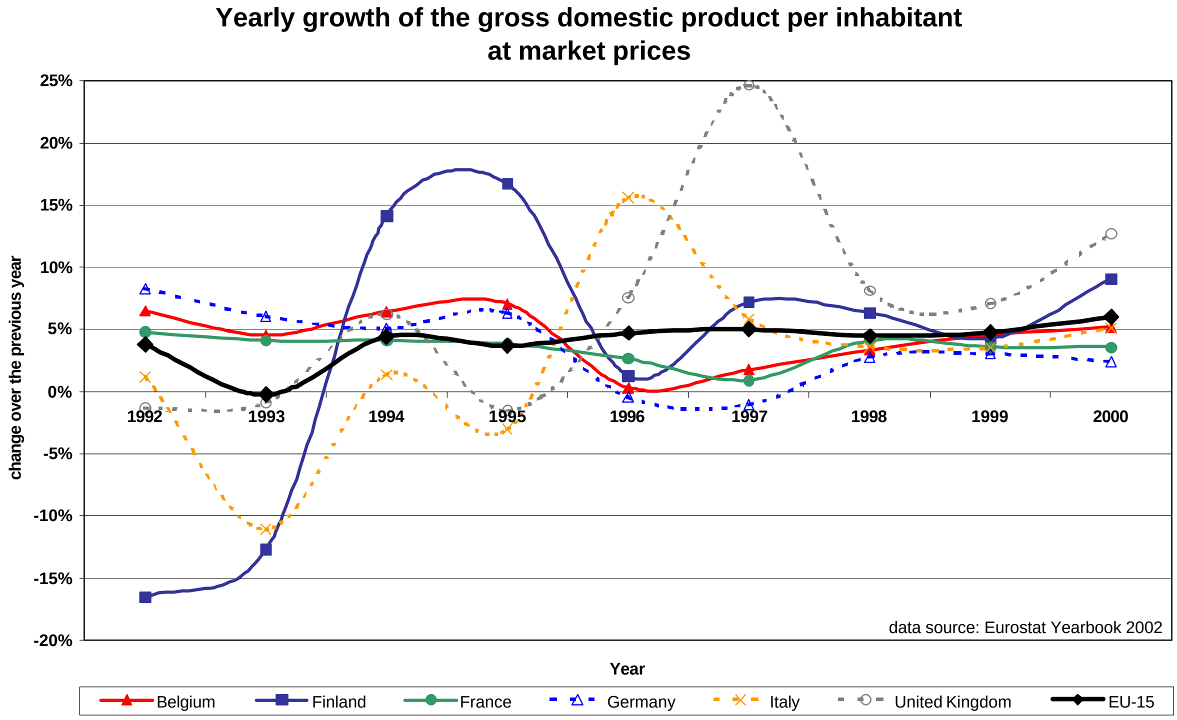


Figure 5 : Yearly growth of the GDP per inhabitant at constant market prices

According Figure 4 and Figure 5 it is obvious, that the national European economies show tremendous fluctuations. Of course, those temporal shifts in the economic situation (business cycles) on the national level will influence the regional development of the different case studies.

In Figure 6 the development of the number of passenger cars per 1000 inhabitants is shown. Most of the countries, with an exception of Finland show a steady increase. However, the growth rate of the car stock exhibits tremendous fluctuations (Figure 7). It is also remarkable that the yearly increase of passenger car transport in passenger kilometres in general exceeds the growth rate of the car stock. This indicates that the travel length may slightly increase with time. Compared with the growth rate of passenger car transport (Figure 7, in passenger kilometres) seems the yearly growth of bus transport of passengers (passenger kilometres) to stagnate in Germany, to decline in Finland, France, Belgium and Italy and to increase in United Kingdom. The yearly growth of rail transport of passengers in passenger kilometres indicates partly tremendous changes in the different EU-countries under consideration.

In the following section those general and global pictures of development are compared with the ongoing economic development in the selected case studies.

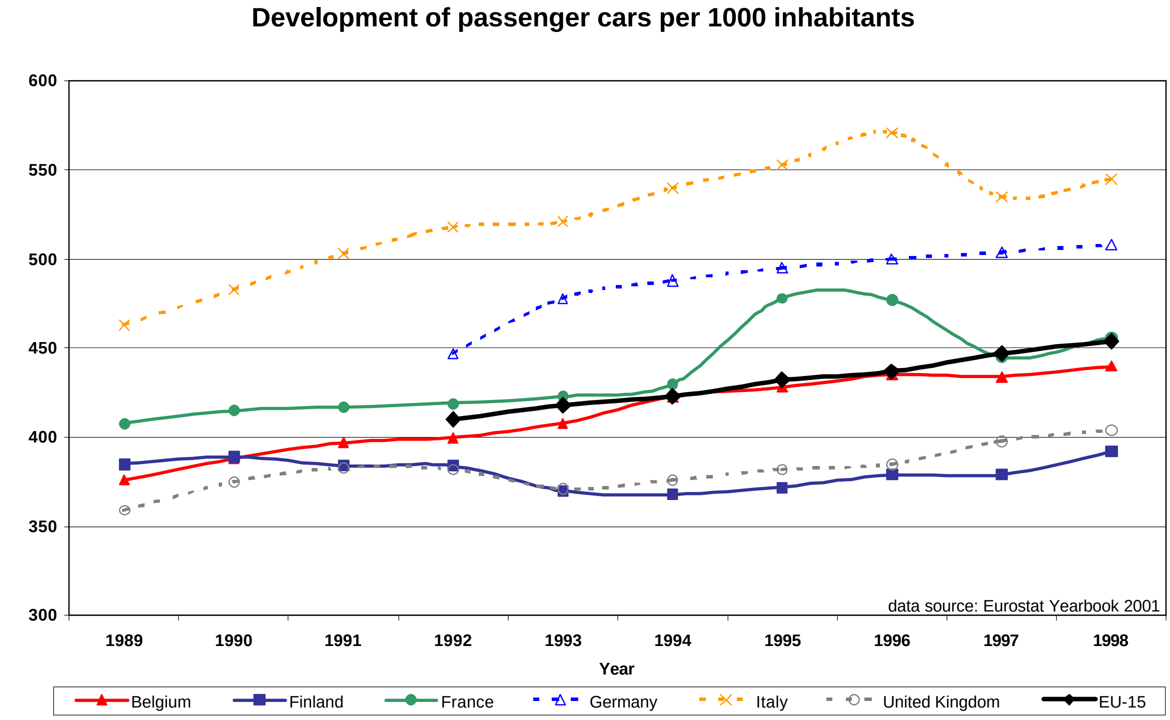


Figure 6 : Development of passenger cars per 1000 inhabitants

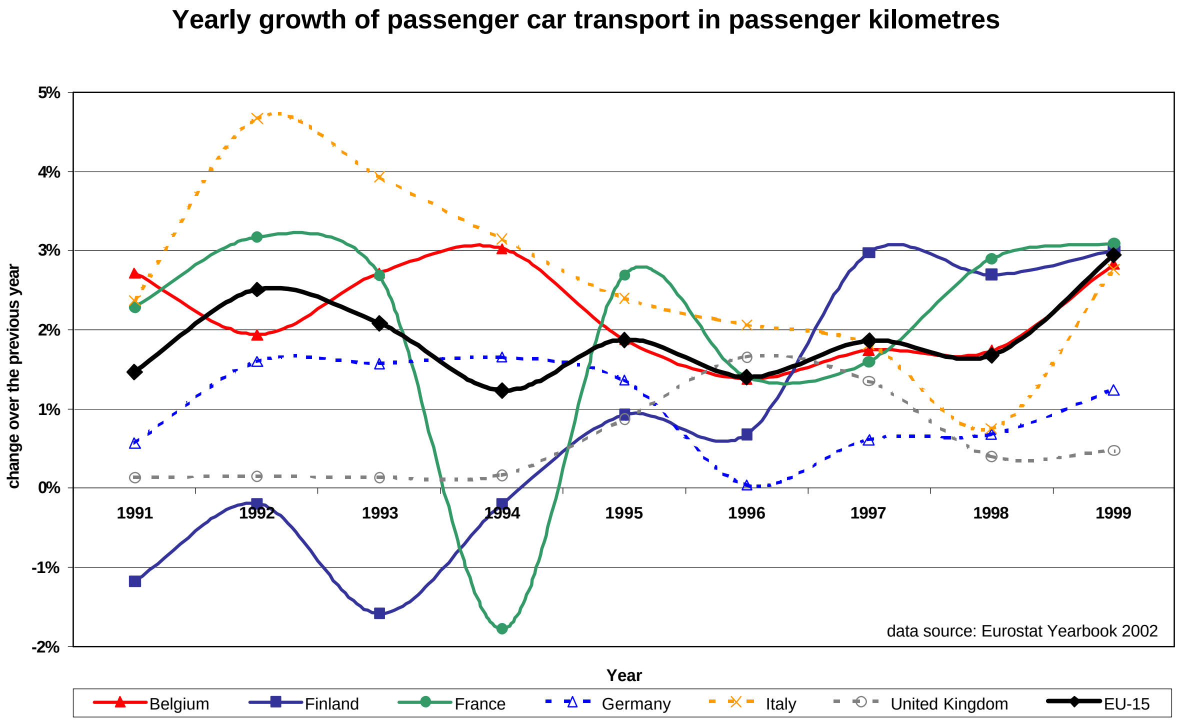


Figure 7 : Development of yearly growth of passenger car transport in passenger kilometres

In the following section, some simple indicators of change for each case city are developed in such a way that direct and intuitive comparisons between each of them can be made. The variables used are population and employment measured for each of the zones at three points in time. From these data absolute changes, percentage changes, densities and changes in density can be computed as well as ratios such as the activity rate (labour force participation rate) which measure the ratio of employment to population giving some indication of the extent to which the population is mobilised within the labour force. Beginning with an analysis of totals for each city region the analysis of their spatial distribution follows.

4.2.2 Analysis of Aggregate Population-Employment Structure and Change

In this section, some simple indicators of change for each case city are developed in such a way that direct and intuitive comparisons between each of them can be made. The variables used are population and employment measured for each of the zones at three points in time. From these data absolute changes, percentage changes, densities and changes in density can be computed as well as ratios such as the activity rate (labour force participation rate) which measure the ratio of employment to population giving some indication of the extent to which the population is mobilised within the labour force. Beginning with an analysis of totals for each city region the analysis of their spatial distribution follows in the next section.

Total population at each point in time is defined as P_t, population change from time t to $t+1$ as $P_{t+1} - P_t$, and the growth rate as $l = P_{t+1}/P_t$. This growth rate relates population at time $t+1$ to time t via $P_{t+1} = l\ P_t$. Through the recursion on time which gives population at time $t+n$ as $P_{t+n} = l^n\ P_t = l\ P_{t+n-1}$, one can define the single step growth rate as $l = \sqrt[n]{[P_{t+n}/P_t]}$. In the case, for example, where data are available at ten yearly time periods, such as the decennial census, these growth rates are based on $n = 10$. All the rates can be computed accordingly. These definitions are directly related to the more sophisticated analysis of growth rates in the shift-share analysis (3-9), (3-11). The same method can be applied for the calculation of the other growth rates, e.g. of employment E_t.

These overall data base provides an immediate comparison of the scale of the different case study regions and the rate at which those variables are growing or declining. To give an idea of intensity of development, the population and employment densities are computed at the various time periods as $r_t = P_{t+1}/A$ and $d_t = E_{t+1}/A$, where A describes the area of the region (zone).

These data provide the basic indicators for each case city and enable comparisons not only between cities but also with respect to the individual zones within which e.g. population and employment are changing. To relate population and employment, we compute the labour force participation rate at each point in time. The labour force participation rate is defined as the ratio of total employment to total population and measures the extent to which those who live in the city region are active in the labour market. There are a number of secular trends which must be noted in affecting how these rates change. In general in western societies, this rate has been increasing over the last 40 years as more and more woman have entered into the labour force. However it is also affected by cyclical economic recessions which reduce the rate in times of bust and increase it in times of boom. A demographic component is also of importance. Moreover, it reflects the degree of closure of the city region. If for example, there are many people commuting into the region which are not captured as population living in the region these rates will tend to be higher than they actually are if this commuting is excluded.

In Table 2 the absolute and relative totals as well as their associated rates for each of the six cities are presented. There are some rather obvious immediate differences and these relate to two issues: first actual differences in growth due to different cultural and economic conditions and second differences in aerial definitions which are reflected in densities. Three of the cities – Bristol, Brussels and Stuttgart seem to be quite similar in terms of overall rates of growth, labour force participation, and density despite Brussels and Stuttgart being about 3 times larger than Bristol in area, population and employment. Each of these cities has grown very slowly over the period with population and employment growth rates a fraction of a percentage point when taken on an annual basis. Brussels is nearly 3 million in population, a little more than Stuttgart Region with some 2½ million in comparison with Bristol, which is a little less than 1 million. Densities increase for employment and population in each of these three cities over the period but they are quite similar at an average of around 650 to 700 inhabitants per square kilometre in population terms and around 250 to 300 persons per km^2 for employment. We consider that these three cities are bounded quite well in that they capture most of the activity associated with their regions.

Table 2a : Aggregate demographic and economic characteristics of Bristol

BRISTOL **Area = 1346.41 km2**	**1971**	**(n=10) 1981**	**(n=10) 1991**
Population	905498	901012	932694
Population Change t → t+n		-4486	31682
Pop Growth Rate t → t+1		0.9995	1.0035
Employment	392923	394141	429524
Employment Change t → t+n		1218	35383
Emp Growth Rate t → t+1		1.0003	1.0086
Participation Rate	0.4339	0.4374	0.4605
Population Density	672.53	669.20	692.73
Pop Density Change t → t+n		-3.33	23.53
Employment Density	291.83	292.73	319.01
Emp Density Change t → t+n		0.90	26.28

Table 2b : Aggregate demographic and economic characteristics of Brussels

BRUSSELS **Area = 4331.35 km^2**	**1981**	**(n=10) 1991**	**(n=10) 2001**
Population	2820181	2842615	2944716
Population Change t → t+n		22434	102101
Pop Growth Rate t → t+1		1.0008	1.0035
Employment	946797	1059866	1135086
Employment Change t → t+n		113069	75220
Emp Growth Rate t → t+1		1.0113	1.0069
Participation Rate	0.3357	0.3728	0.3855
Population Density	651.11	656.29	679.86
Pop Density Change t → t+n		5.18	23.57
Employment Density	218.59	244.70	262.06

Emp Density Change t → t+n		26.10	17.37

Table 2c : Aggregate demographic and economic characteristics of Helsinki

HELSINKI **Area = 15135.96 km^2**	**1990**	**(n=4) 1994**	**(n=5) 1999**
Population	1392926	1453806	1541397
Population Change t → t+n		60880	87591
Pop Growth Rate t → t+1		1.0108	1.0147
Employment	623680	510256	644473
Employment Change t → t+n		-113424	134217
Emp Growth Rate t → t+1		0.9511	1.0601
Participation Rate	0.4477	0.3510	0.4181
Population Density	92.03	96.05	101.84
Pop Density Change t → t+n		4.02	5.79
Employment Density	41.21	33.71	42.58
Emp Density Change t → t+n		-7.49	8.87

Table 2d : Aggregate demographic and economic characteristics of Milan

MILAN **Area = 1966.71 km^2**	**1971**	**(n=10) 1981**	**(n=20) 2001**
Population	3720058	3831861	3606926
Population Change t → t+n		111803	-224935
Pop Growth Rate t → t+1		1.0015	0.9970
Employment	1356876	1637648	1579720
Employment Change t → t+n		280772	-57928
Emp Growth Rate t → t+1		1.0190	0.9982
Participation Rate	0.3647	0.4274	0.4380
Population Density	1891.51	1948.36	1833.99
Pop Density Change t → t+n		56.85	-114.37
Employment Density	689.92	832.68	803.23
Emp Density Change t → t+n		142.76	-29.45

Table 2e : Aggregate demographic and economic characteristics of Rennes

RENNES **Area = 2550.82 km^2**	**1982**	**(n=8) 1990**	**(n=9) 1999**
Population	422507	463366	521188
Population Change t → t+n		40859	57822
Pop Growth Rate t → t+1		1.0116	1.0132
Employment	180228	201897	227315
Employment Change t → t+n		21669	25418
Emp Growth Rate t → t+1		1.0143	1.0133
Participation Rate	0.4266	0.4357	0.4361
Population Density	165.64	181.65	204.32
Pop Density Change t → t+n		16.02	22.67
Employment Density	70.65	79.15	89.11
Emp Density Change t → t+n		8.49	9.96

Table 2f : Aggregate demographic and economic characteristics of Stuttgart

STUTTGART **Area = 3653.88 km^2**	**1976**	**(n=12) 1988**	**(n=12) 2000**
Population	2327860	2402023	2613379
Population Change t → t+n		74163	211356
Pop Growth Rate t → t+1		1.0026	1.0071
Employment	924290	1049883	1056363
Employment Change t → t+n		125593	6480
Emp Growth Rate t → t+1		1.0107	1.0005
Participation Rate	0.3971	0.4371	0.4042
Population Density	637.09	657.39	715.23
Pop Density Change t → t+n		20.30	57.84
Employment Density	252.96	287.33	289.11
Emp Density Change t → t+n		34.37	1.77

This is not the case for Milan or Helsinki. The population density of Helsinki is some 11 times less than Bristol (Brussels and Stuttgart), while the density for Milan is much greater at 18 times that of Helsinki. Milan is the largest city region with over 3½ million people, but with a relatively small area and a declining population and employment over the overall time period. In essence, this suggests that the city region is much wider than that we have used. It is the major hub in northern Italy with considerable in-commuting and cross-commuting which complicates the pattern. In contrast, the Helsinki region covers a very wide capital region taking in all associated activity. Physically densities are likely to be lower in any case given the landscape of southern Finland but the growth here is a little greater in population and employment than in the cities discussed so far. Finally Rennes seems quite different from all the others. It is by far the smallest but the fastest growing city with rates of change in population and employment up to 1 percent per annum. It is clearly bounded at its widest extent taking in all activity in the region and thus its densities approach those of the Helsinki region.

There are also differences in the labour force participation rates. In general the participation rates are increasing in all case studies. Brussels is a little lower but by the last date we have for each city, these differences have narrowed substantially with Bristol a little higher than the rest at around 46% of the population working with the other cities between 38% and 43%. In summary, we consider that Rennes and Helsinki are the most different cities in terms of growth rates and densities, while the hinterland of Milan clearly extends beyond that which we have data for.

4.2.3 Analysis of Spatial Population-Employment Structure and Change

Aggregate comparisons provide differences caused by scale, culture and economy but in terms of the current pattern of urbanisation world-wide, one would expect there to be a spreading out of cities everywhere due to global trends in technology and increasing real income. In general in the six cities considered, disposable incomes have been increasing and this leads to increasing consumption of space in terms of housing as well as increased access to faster transport technologies. The classic trade-off between space and transport cost which leads to households with greater incomes purchasing more space at greater distances from the traditional city core, is something that is generic to current patterns of urbanisation in western cities, and one would thus expect there to be a redistribution of population and employment which is at the basis of urban sprawl. Thus regardless of growth, we would expect this pattern of redistribution to show a greater proportion of activity in the outer rings and hinterland through time. This is our intension in demonstrating in this section. In the next section 4.3, a more consistent and through analysis of such shifts through shift share analysis will be developed, which compares local growth or decline with the overall average change.

The spatial distributions of the same variables dealt with above in aggregate terms, will be presented with the exception of the labour force participation rates, that are too influenced by internal commuting to be meaningful at the local scale.

On the one hand, population and employment distribution and their densities distributions at each time period will be shown and compared. On the other hand, growth rates at the local level will be discussed later on the basis of the shift-share analysis in section 4.3. This leads to the definition of two kinds of maps based on the actual structure of activities in zones at a given point in time and maps comparing changes in the same structure between different points in time. Now for an activity which is based on absolute raw data like population or employment, simple maps of such variables for unequal zones or areas are not meaningful. We need to normalize them to some kind of relative base.

In case of population and employment it is suggested first to compute the percentage share of population in each zone at different dates. Comparing these percentages over time, in case if a zone captures more of the percentage of population, this would show it was becoming more dominant in the region. This can be directly shown by computing differences in the percentage share which show zones that are gaining and those that are losing. Now none of this takes account of whether the overall population or activity is growing or declining because percentage shares are considered. In so far population can redistribute themselves in regions which are declining as well as growing.

The population number in zone *i* at time *t* is defined as P_{it}, employment as E_{it} and the area of each zone as A_i. The percentage share of population in each zone is denoted as $p_{it} = P_{it} / P_t$, employment share as $e_{it} = E_{it} / E_t$, and the changes in these shares as $\left[(p_{it+1} - p_{it}) / p_{it}\right]$ and $\left[(e_{it+1} - e_{it}) / e_{it}\right]$. These relative percentage shifts are scaled by 100 in the maps that follow.

Another set of normalized maps is based on densities. Here densities at different points in time are computed and this shows how zones are intensifying or de-intensifying. Changes in these densifications over time can also be computed in order to show losses and gains.

On the level of zones population densities $r_{it} = P_{it} / A_i$ and employment densities $d_{it} = E_{it} / A_i$ can be calculated, according to the aggregate level. In addition changes in these densities $\left[(r_{it+1} - r_{it}) / r_{it}\right]$ and $\left[(r_{it+1} - r_{it}) / r_{it}\right]$ each scaled by 100, can be computed, respectively. If sprawl were increasing in the periphery of the city region, then for both set of variables – percentage change in populations and employment and density change in these same variables, one would expect the central zones of mono-centric regions to loose share in total population and to lead to decline in densities while the edges of those regions would increase their share and densities.

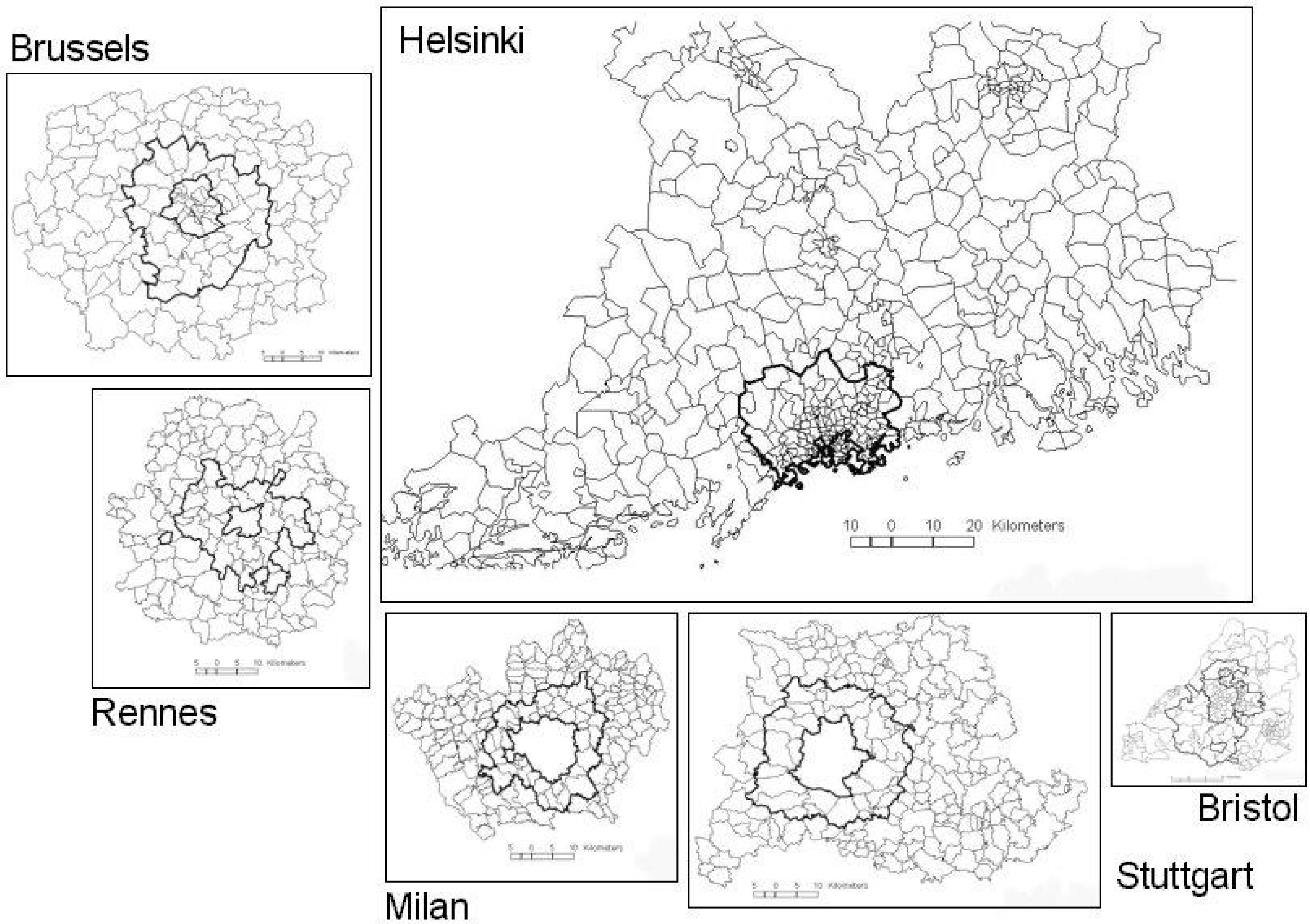


Figure 8 : The Six Cities subdivided into macro-zones representing the urban centre, outer ring, and hinterland (all maps are in the same scale)

Before the structural differences in terms of the spatial distribution and changes in population and employment through time are illustrated, once again the major differences in size for each of the six cities should be considered. In Figure 8, the six cities, their subdivisions into smaller zones, and the definition of the urban centre, the outer ring and the hinterland are shown. These maps are all at the same scale but in the subsequent figures for the simple maps that are plotted, these scales will differ due to the difficulty of organising these maps so that one can make direct comparisons. In fact each map will be kept the same size in terms of their illustration in this section and readers need to keep in mind that there are substantial differences in areas as revealed in Figure 8.

To get some overall sense of the concentration of population and employment and their spatial variation, employment and population densities are plotted for the six city regions in Figure 9. These confirms all what is presented so far in this section as well as the sketches of each city given in the annexes that accompany the present Deliverable D3 and the Deliverable D2.

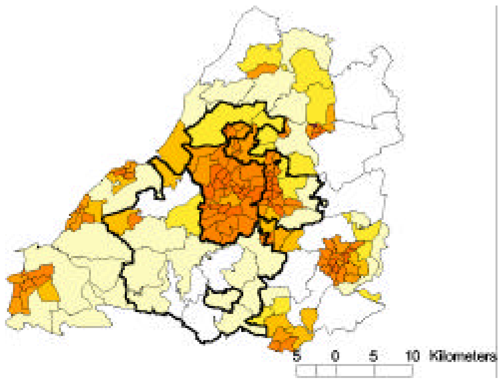
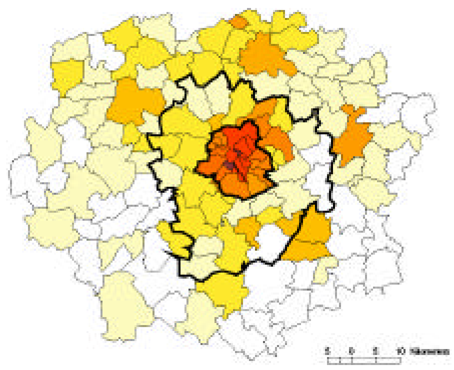
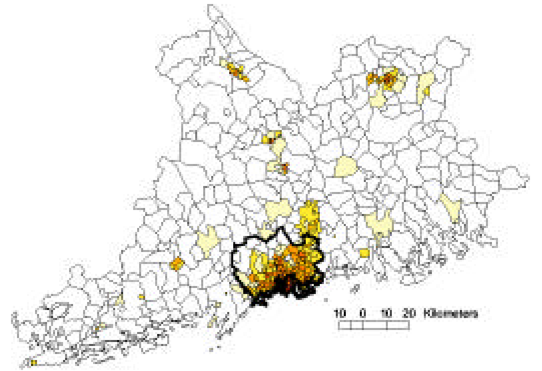
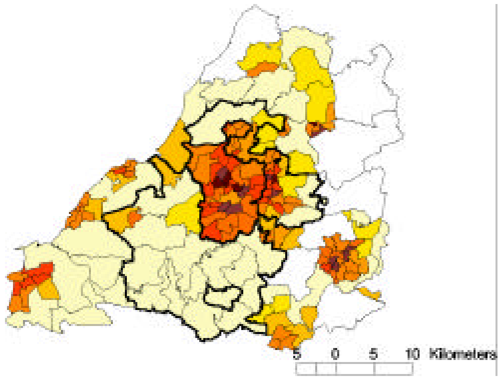
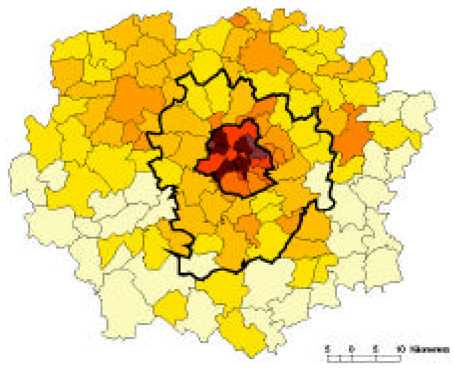
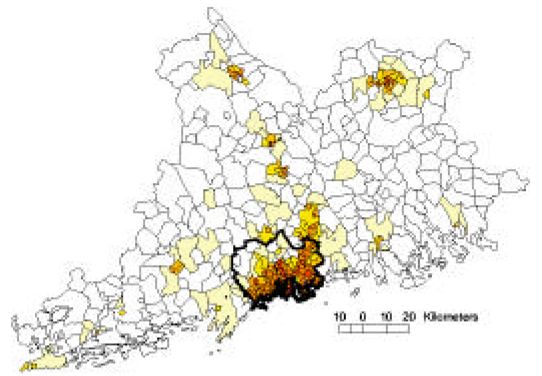
Bristol Employment Density 1991	Brussels Employment Density 1999	Helsinki Employment Density 1999	Legend (employees / km^2)
			0 - 40 41 - 120 121 - 280 281 - 470 471 - 580 581 - 1060 1061 - 2060 2061 - 4000 4001 - 9030 9031 - 18010 18011 - 36521
Bristol Population Density 1991	**Brussels Population Density 2001**	**Helsinki Population Density 1999**	**Legend (persons / km^2)**
			0 - 50 51 - 250 251 - 530 531 - 920 921 - 1430 1431 - 2850 2851 - 3850 3851 - 5340 5341 - 6980 6981 - 24405

Figure 9a : Comparisons of employment and population densities

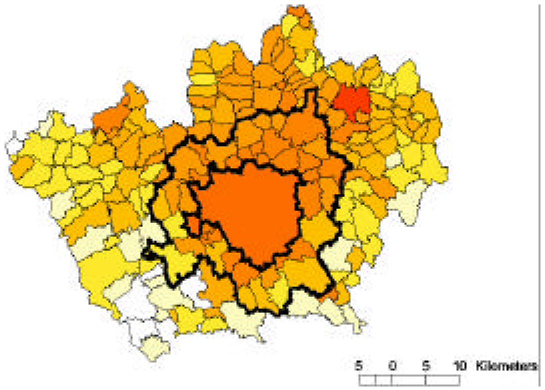
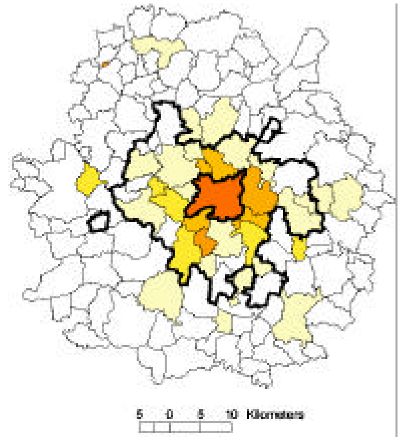
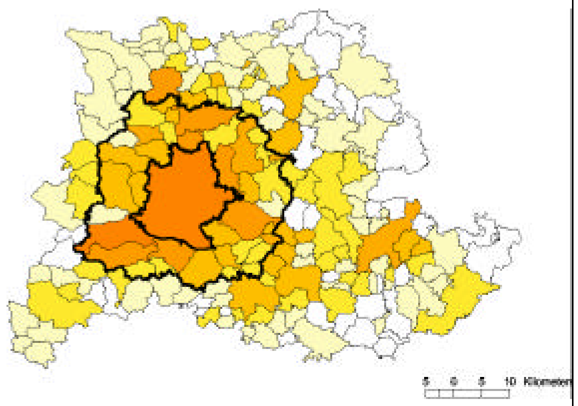
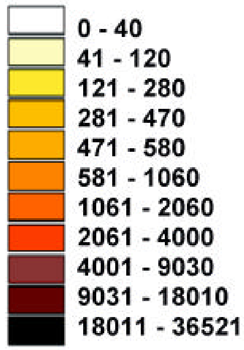
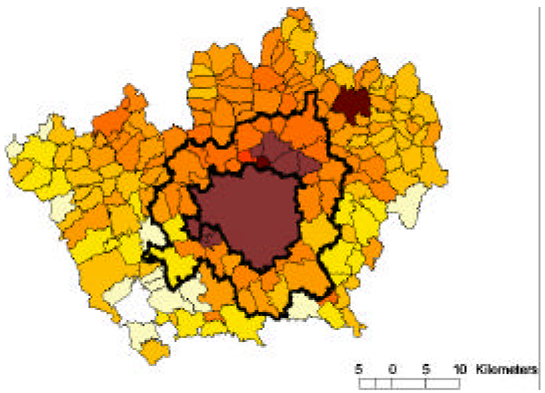
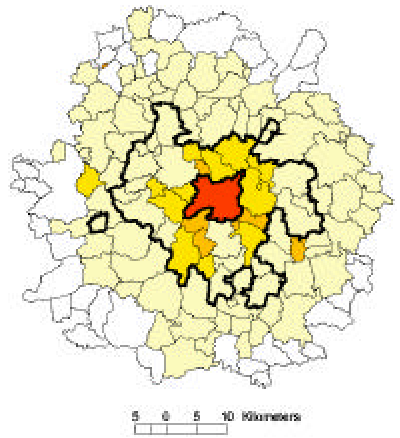
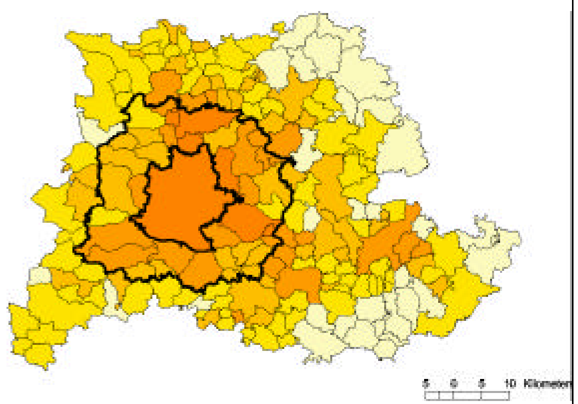
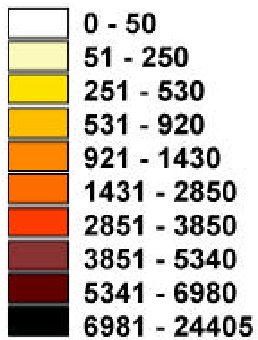
<table>
<tr><th>Milan Employment Density 2001</th><th>Rennes Employment Density 1999</th><th>Stuttgart Employment Density 2000</th><th>Legend (employees / km²)</th></tr>
<tr>
<td>
</td>
<td>
</td>
<td></td>
<td>
</td>
</tr>
<tr><th>Milan Population Density 2001</th><th>Rennes Population Density 1999</th><th>Stuttgart Population Density 2000</th><th>Legend (persons / km²)</th></tr>
<tr>
<td>
</td>
<td>
</td>
<td></td>
<td>
</td>
</tr>
</table>

Figure 9b : Comparisons of employment and population densities

Essentially each city region is monocentric with a major core – the urban centre, and with employment and population declining inversely with distance to this core. Helsinki and Rennes are closest to the classic pattern of high densities in the urban centre, medium in the outer ring and lowest in the hinterland. Helsinki is at greater scale with the existence of small key towns in its hinterland being clearly visible but not yet integral to the growing urban area. Brussels, Stuttgart and Milan follow the same pattern but with higher densities to the north of the centre through the outer ring and hinterland in Brussels, the north, south-east and south-west corridors in Stuttgart and the same to the north and northeast in Milan. Bristol is clearly more polycentric.

Spatial shifts in population in terms of the percentage of population living in different areas which is presented in Figure 10, show a fairly classic patterns of decline in the urban centre and outer rings in Bristol and Milan. In Brussels, there is patchy decline in the hinterland and increasing decline in the core during the last decade, while in Helsinki, there is the same kind of pattern on a large scale but with significant increase in the outer ring in the last 5 years. Stuttgart is rather curious in that there is decline in the core and outer ring in the late 1970s and early 1980s, but this turns to an increase in the dominance of the core and outer ring in the last 10 years. Rennes has an equally strange pattern with all the decline being in the periphery – the hinterland – which is reminiscent of rural depopulation. For percentage employment shift, shown in Figure 11, the same kinds of pattern are clear with the exception again of Stuttgart, where there is a systematic loss of employment share in the core and parts of the outer ring accompanied with an increase in the hinterland between 1988 and 2000 across the entire region. In all these cases, the patterns are not clear cut with the exception of Rennes. At the zonal level, the patterns are much affected by the growth of particular locations for housing and industry which tend to be specific to more idiosyncratic locational factors which are hard to generalise in the absence of specific knowledge of the cases in questions. The annexes to this Work Package 3 and Working Paper 2 give additional information about this.

The spatial changes in density in the six cities tend to reinforce the patterns shown by shifting percentages of population and employment. With the exception of Rennes, the population densities of the urban centre and outer ring all fall during the two time periods examined as illustrated in Figure 12. In Helsinki, this is compounded by falls in density in the wider hinterland and an increase in the outer ring but it is Rennes again that goes against the grain. The earlier period from 1982 to 1990 is dominated by falls in density in the hinterland and increasing densities everywhere else. In the later period from 1990 to 1999, the densities increase everywhere although least in the centre while the only falls are on the edge of the region. From these patterns, it does not appear that the inner city is losing population in quite the same way as all the others. In terms of employment in Figure 13, the density shifts are broadly similar to those of population. In Bristol, both core and outer ring decline although the pattern is patchy as it is in Stuttgart and Brussels where employment loss throughout these regions seems to dominate the later periods. Milan is more classic in that density falls in the core and outer rings while in Rennes and Helsinki, it is the hinterlands once again that seem to experience the greatest falls.

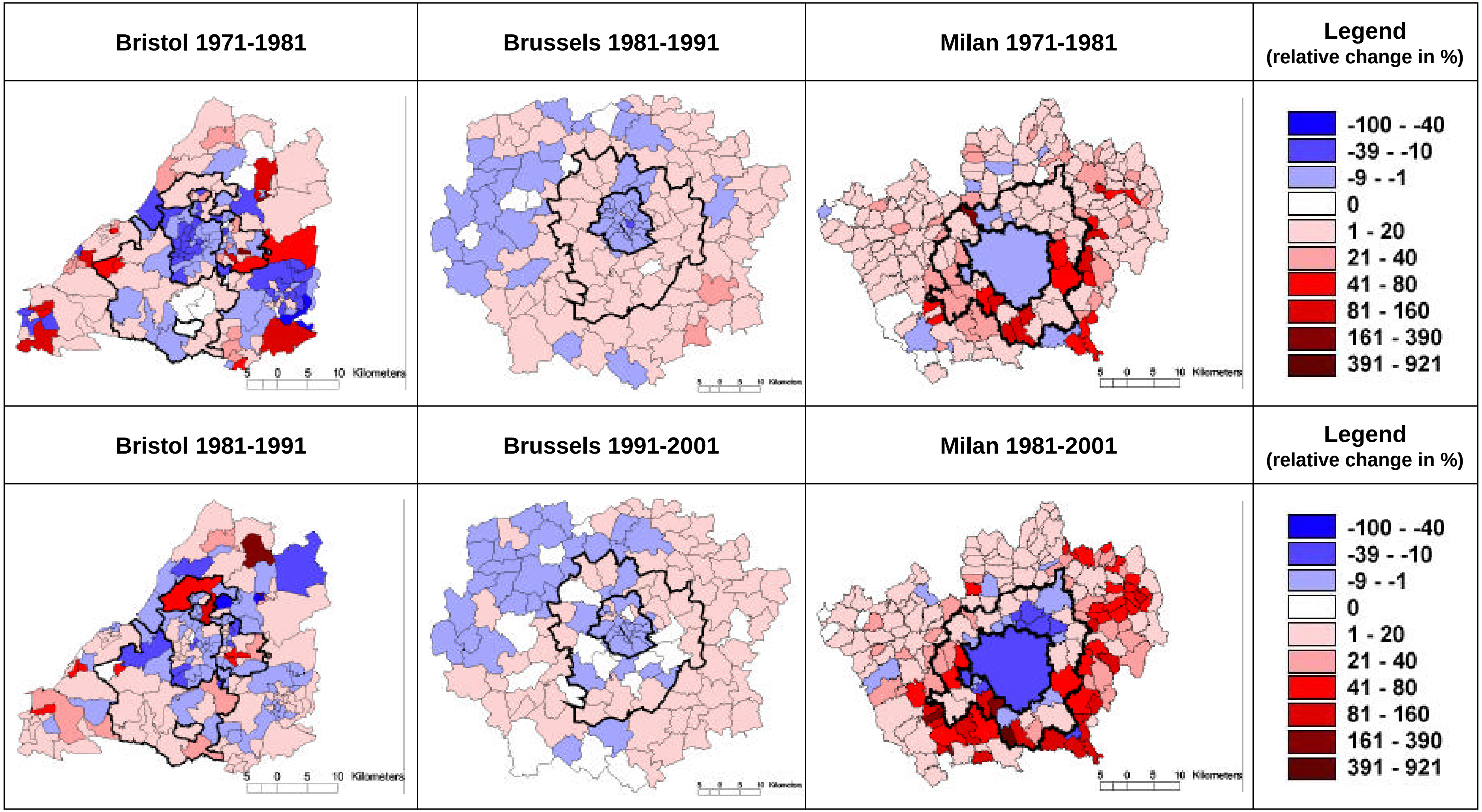


Figure 10a : Change in percent population by small area

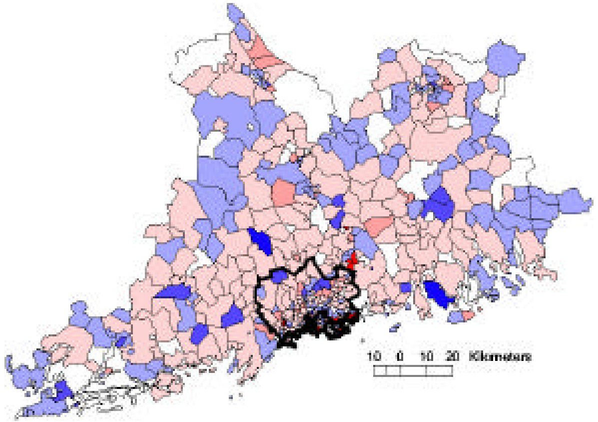
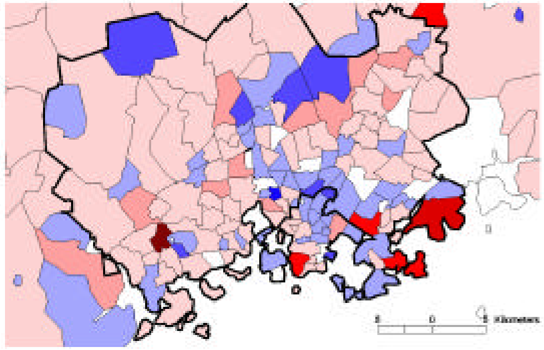
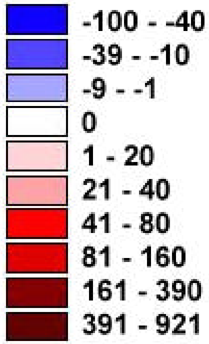
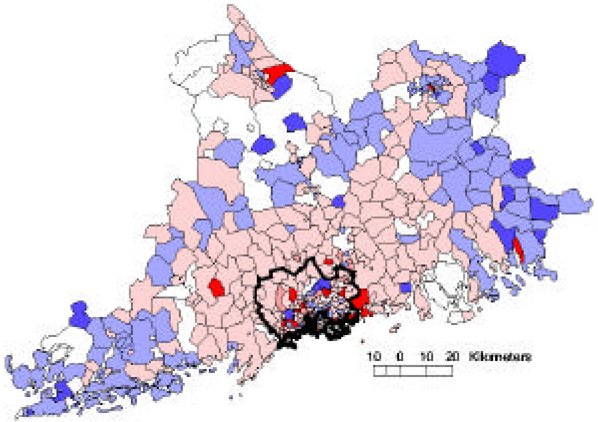
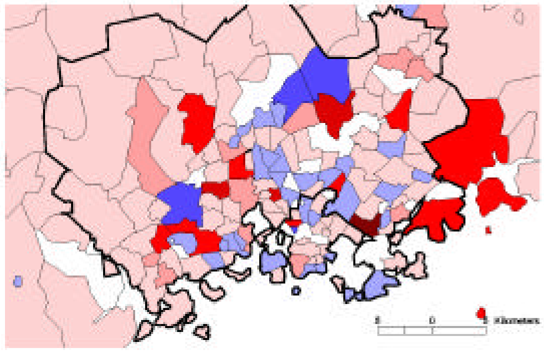
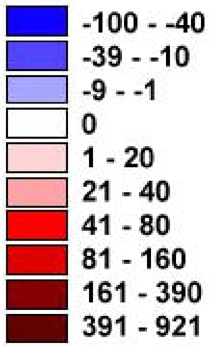
<table>
<tr><th>Helsinki 1990-1994</th><th>Inner Helsinki 1990-1994</th><th>Legend
(relative change in %)</th></tr>
<tr><td>
</td><td></td><td>
</td></tr>
<tr><th>Helsinki 1994-1999</th><th>Inner Helsinki 1994-1999</th><th>Legend
(relative change in %)</th></tr>
<tr><td>
</td><td></td><td>
</td></tr>
</table>

Figure 10b : Change in percent population by small area

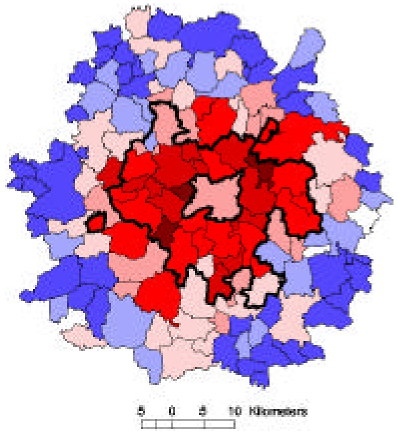
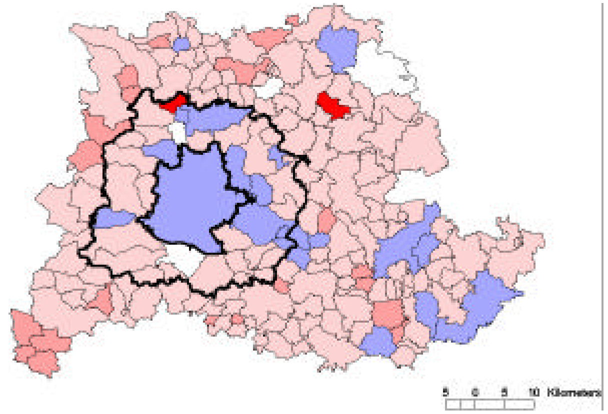
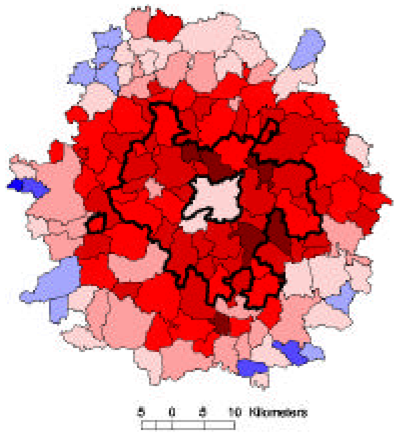
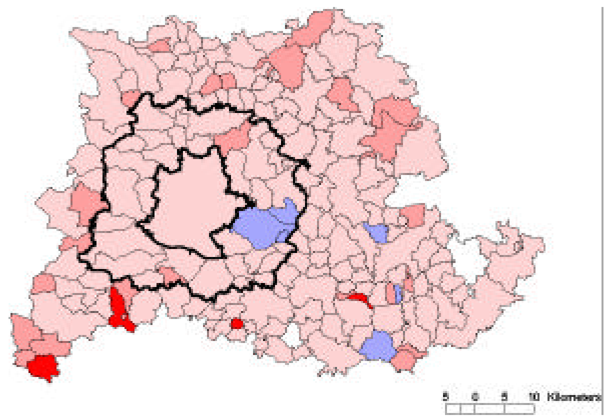
Rennes 1982-1990	**Stuttgart 1976-1988**	**Legend** (relative change in %)
		-100 - -40 -39 - -10 -9 - -1 0 1 - 20 21 - 40 41 - 80 81 - 160 161 - 390 391 - 921
Rennes 1990-1999	**Stuttgart 1988- 2000**	**Legend** (relative change in %)
		-100 - -40 -39 - -10 -9 - -1 0 1 - 20 21 - 40 41 - 80 81 - 160 161 - 390 391 - 921

Figure 10c : Change in percent population by small area

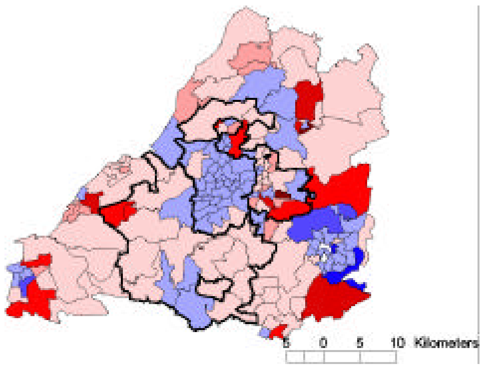
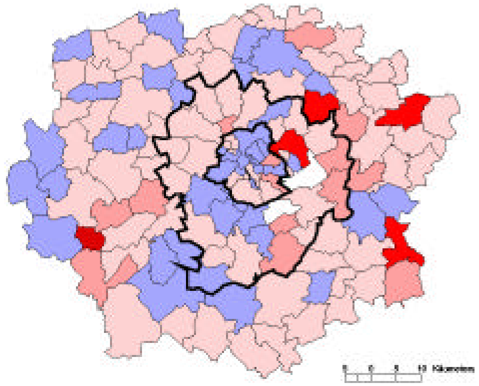
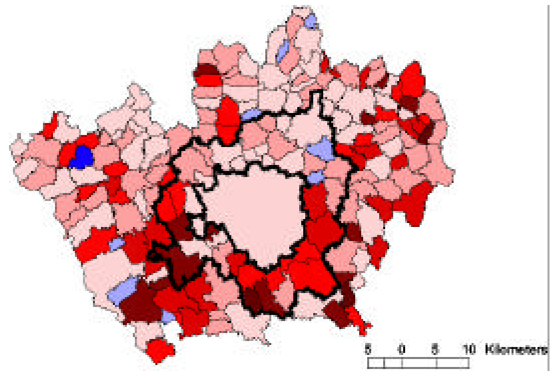
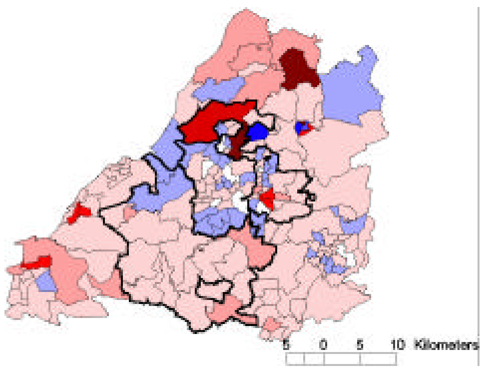
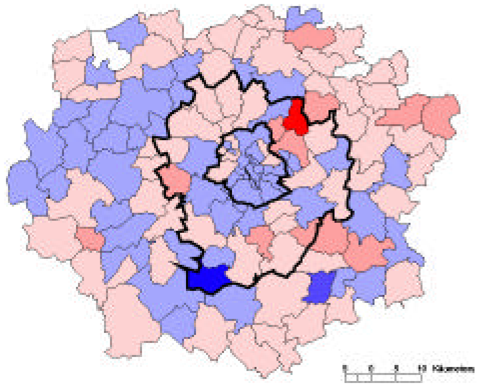
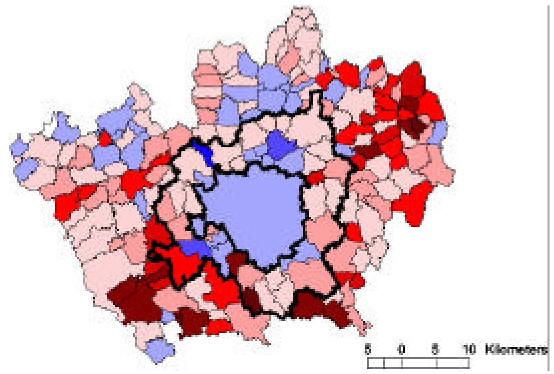
Bristol 1971-1981	Brussels 1981-1991	Milan 1971-1981	Legend (relative change in %)
			-100 - -40 -39 - -30 -29 - -1 0 1 - 30 31 - 60 61 - 100 101 - 170 171 - 360 361 - 1096
Bristol 1981-1991	**Brussels 1991-2001**	**Milan 1981-2001**	**Legend** **(relative change in %)**
			-100 - -40 -39 - -30 -29 - -1 0 1 - 30 31 - 60 61 - 100 101 - 170 171 - 360 361 - 1096

Figure 11a : Change in percent employment by small area

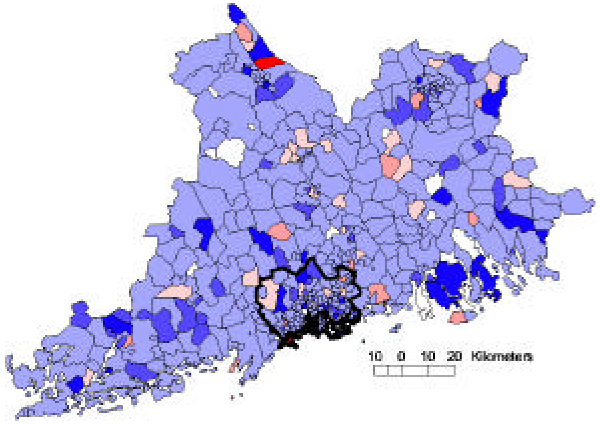
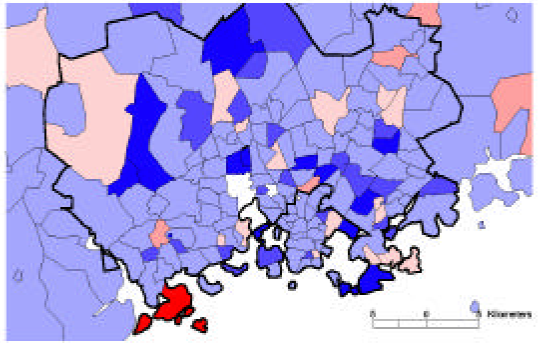
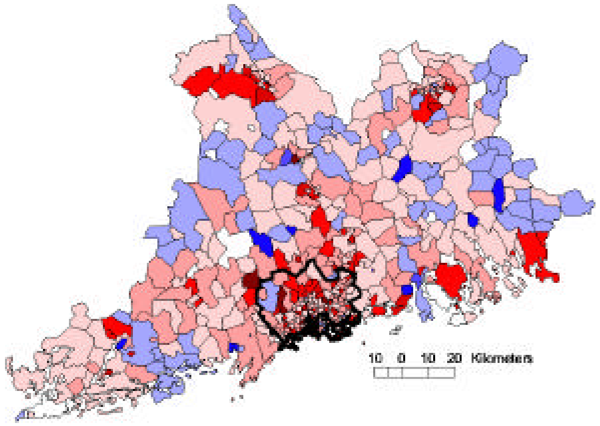
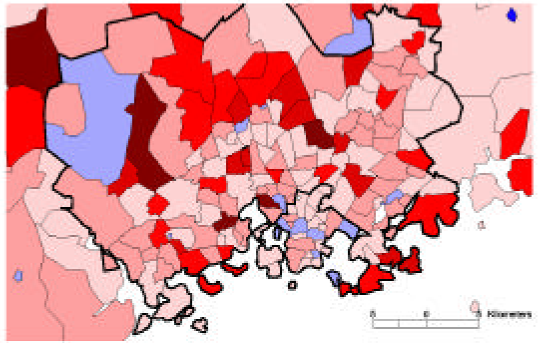
Helsinki 1990-1994	Inner Helsinki 1990-1994	Legend (relative change in %)
		-100 - -40 -39 - -30 -29 - -1 0 1 - 30 31 - 60 61 - 100 101 - 170 171 - 360 361 - 1096
Helsinki 1994-1999	**Inner Helsinki 1994-1999**	**Legend (relative change in %)**
		-100 - -40 -39 - -30 -29 - -1 0 1 - 30 31 - 60 61 - 100 101 - 170 171 - 360 361 - 1096

Figure 11b : Change in percent employment by small area

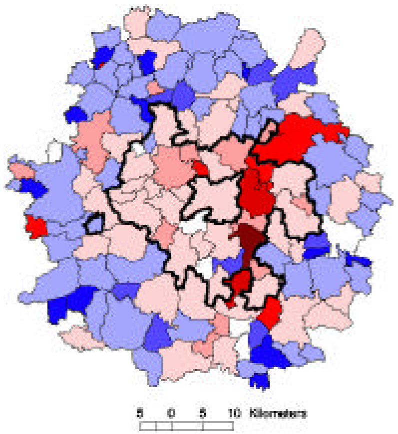
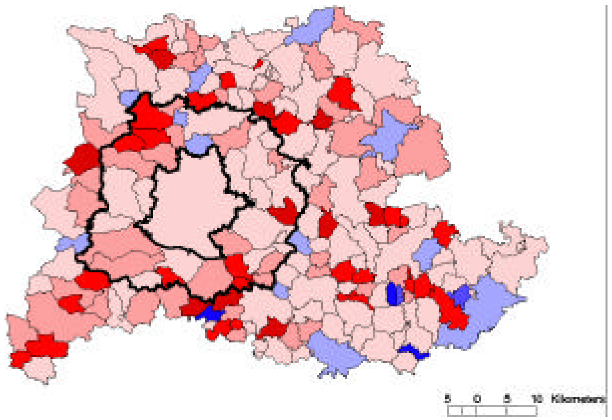
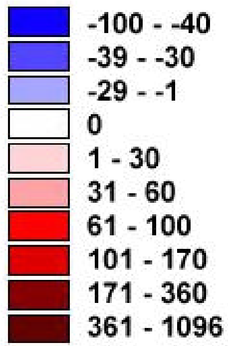
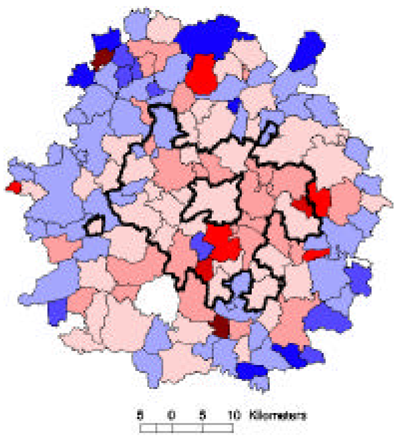
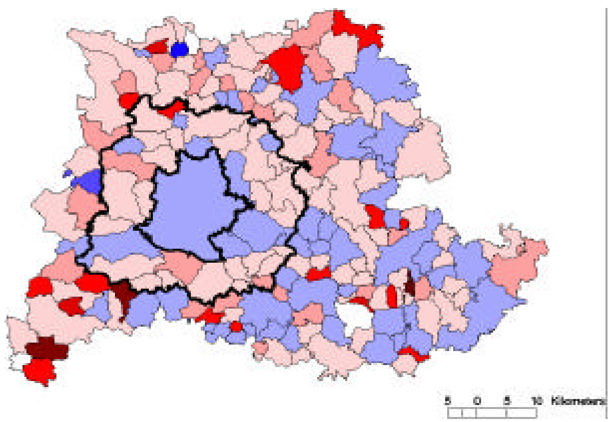
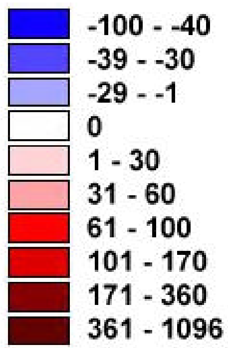
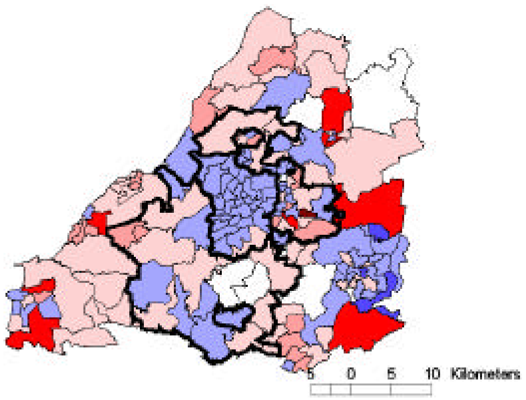
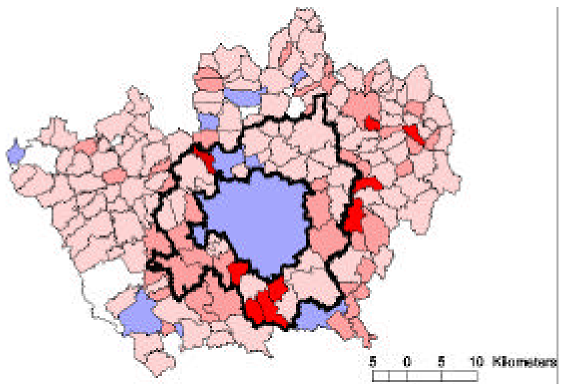
<table>
<tr><th>Rennes 1982-1990</th><th>Stuttgart 1976-1988</th><th>Legend
(relative change in %)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><th>Rennes 1990-1999</th><th>Stuttgart 1988- 2000</th><th>Legend
(relative change in %)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
</table>

Figure 11c : Change in percent employment by small area

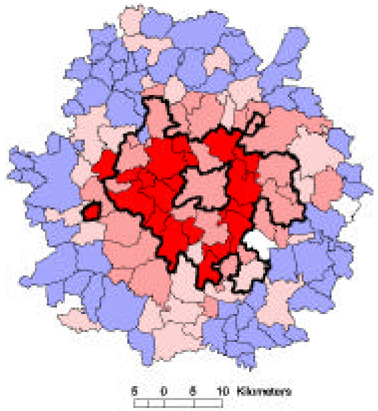
Bristol 1971-1981



Milan 1971-1981



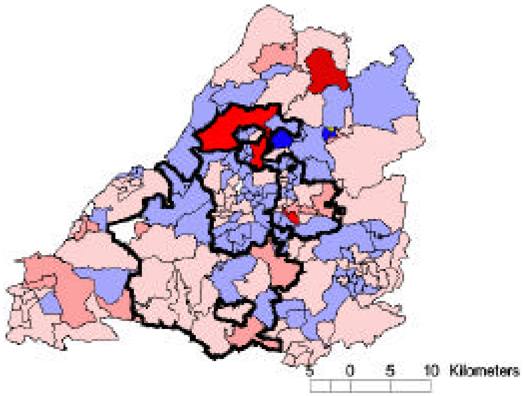
Rennes 1982-1990



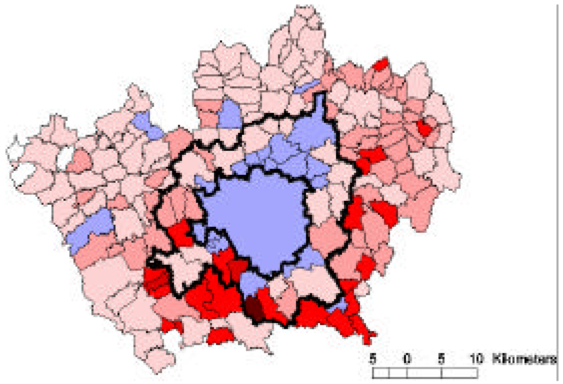
Legend
(relative change in %)

- -71 - -50
- -49 - -30
- -29 - -1
- 0
- 1 - 20
- 21 - 70
- 71 - 170
- 171 - 240
- 241 - 390
- 391 - 919

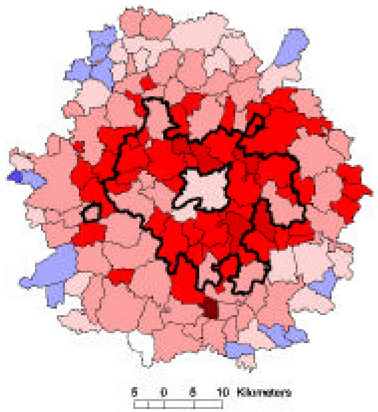
Bristol 1981-1991



Milan 1981-2001



Rennes 1990-1999



Legend
(relative change in %)

- -71 - -50
- -49 - -30
- -29 - -1
- 0
- 1 - 20
- 21 - 70
- 71 - 170
- 171 - 240
- 241 - 390
- 391 - 919

Figure 12a : Change in density of population by small area

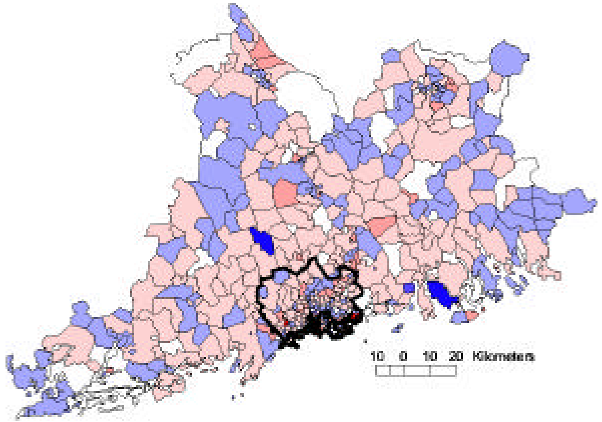
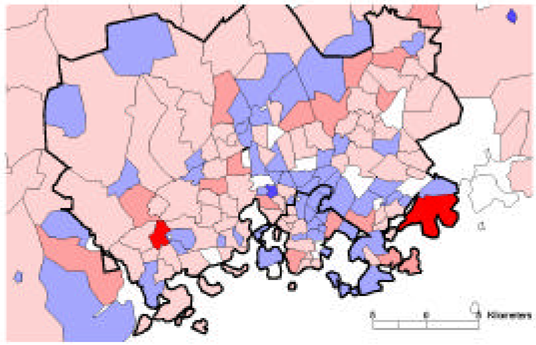
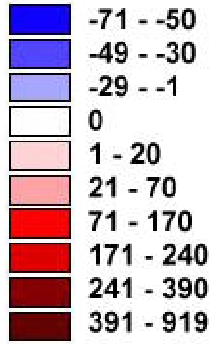
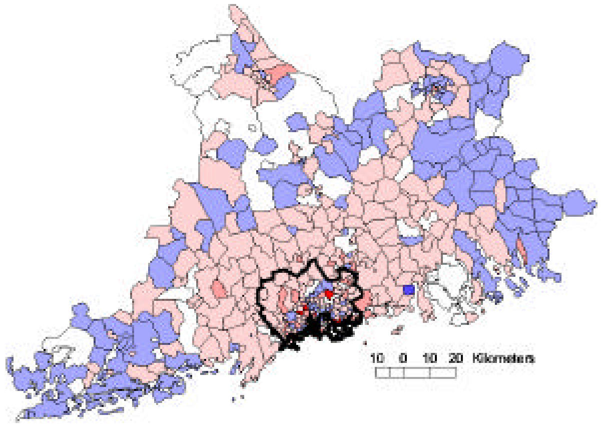
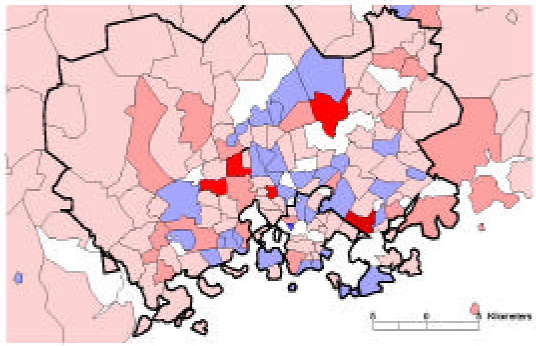
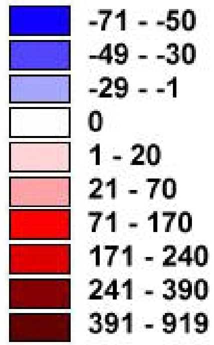
Helsinki 1990-1994	Inner Helsinki 1990-1994	Legend (relative change in %)
		
Helsinki 1994-1999	**Inner Helsinki 1994-1999**	**Legend (relative change in %)**
		

Figure 12b : Change in density of population by small area

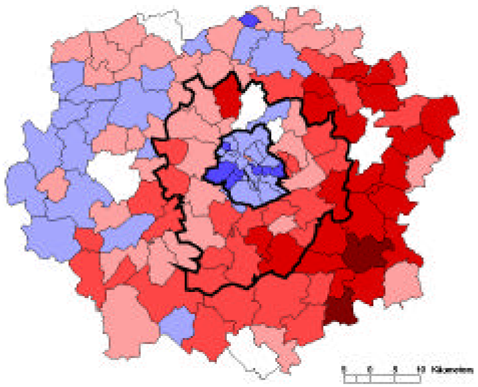
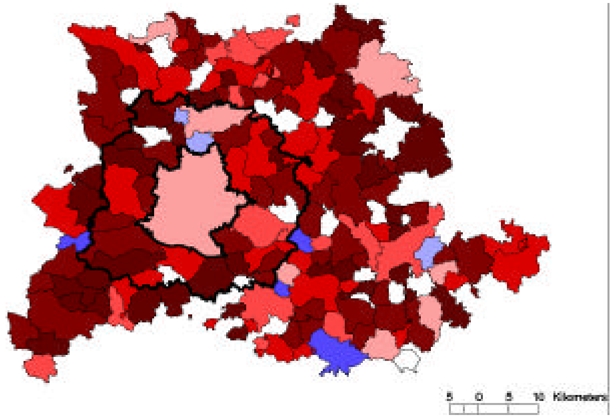
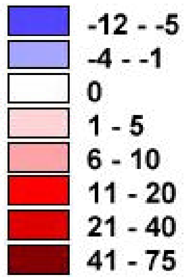
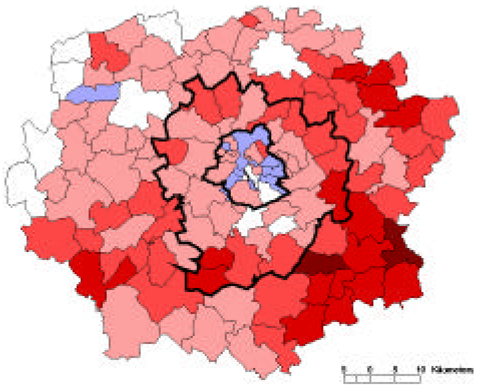
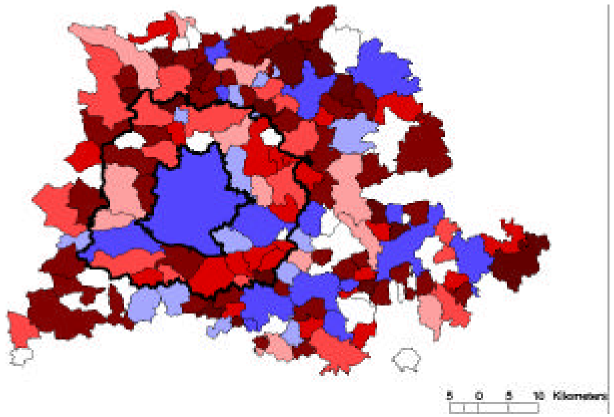
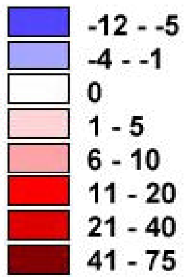
Brussels 1981-1991	Stuttgart 1976-1988	Legend (relative change in %)
		
Brussels 1991-2001	**Stuttgart 1988- 2000**	**Legend (relative change in %)**
		

Figure 12c : Change in density of population by small area

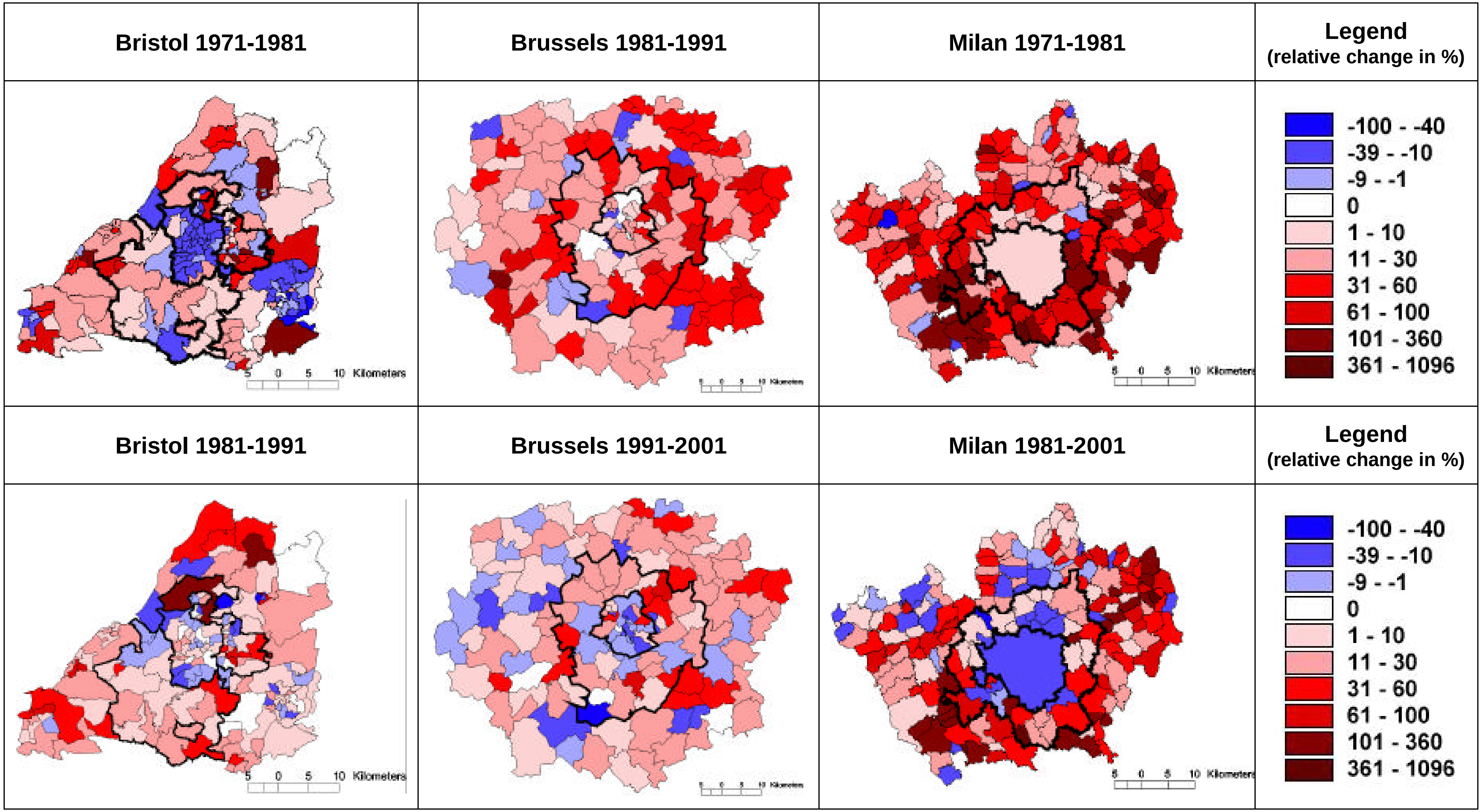


Figure 13a : Change in density of employment by small area

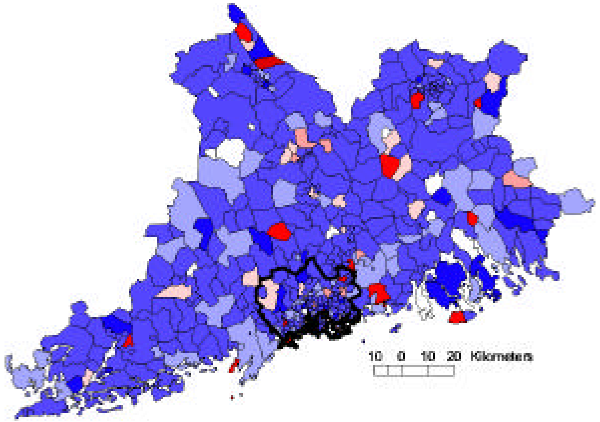
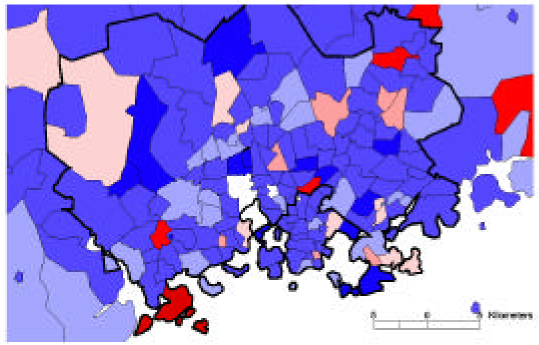
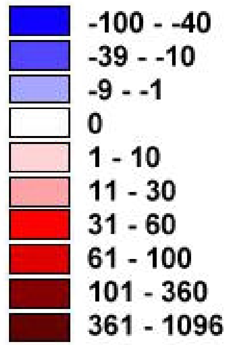
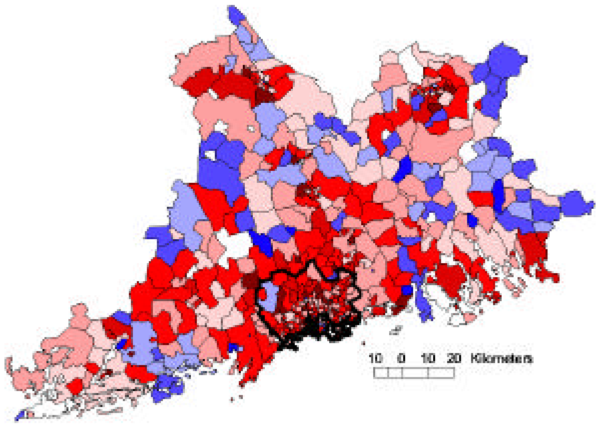
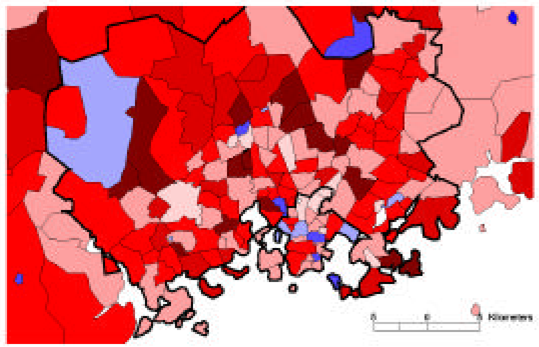
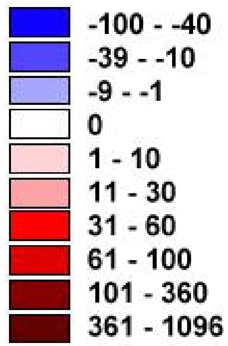
<table>
<tr><th>Helsinki 1990-1994</th><th>Inner Helsinki 1990-1994</th><th>Legend
(relative change in %)</th></tr>
<tr><td>
</td><td></td><td>
</td></tr>
<tr><th>Helsinki 1994-1999</th><th>Inner Helsinki 1994-1999</th><th>Legend
(relative change in %)</th></tr>
<tr><td>
</td><td></td><td>
</td></tr>
</table>

Figure 13b : Change in density of employment by small area

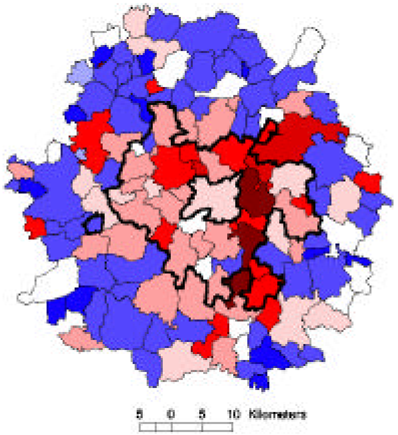
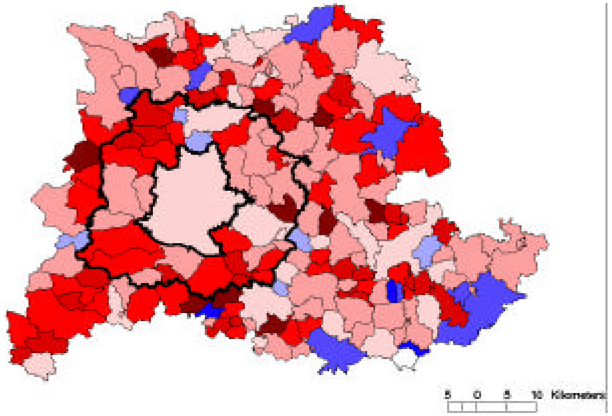
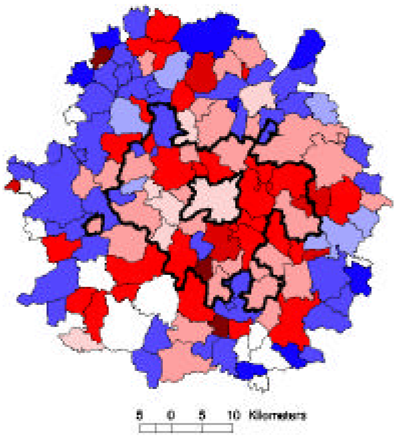
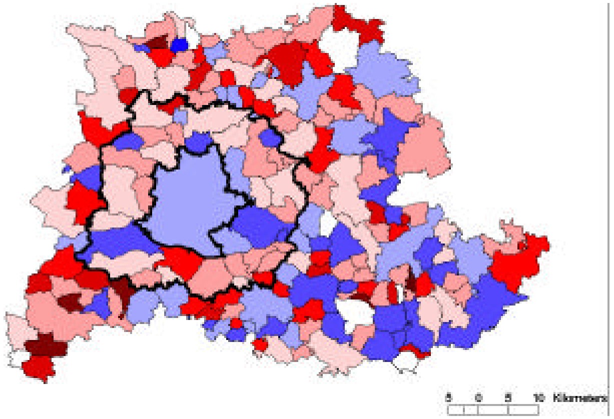
Rennes 1982-1990	Stuttgart 1976-1988	**Legend** (relative change in %)
		-100 - -40 -39 - -10 -9 - -1 0 1 - 10 11 - 30 31 - 60 61 - 100 101 - 360 361 - 1096
Rennes 1990-1999	**Stuttgart 1988- 2000**	**Legend** (relative change in %)
		-100 - -40 -39 - -10 -9 - -1 0 1 - 10 11 - 30 31 - 60 61 - 100 101 - 360 361 - 1096

Figure 13c : Change in density of employment by small area

4.3 Results of the Shift-Share Analysis and H-Indicators of Concentration

4.3.1 Comparison of the Results of the Shift-Share Analysis for the six Case Cities

The insights obtained by considering some basic statistical indicators on the case cities have to be combined with the results of the shift-share analysis in order to provide convincing hints for the existence of urban sprawl. The consideration of the evolution of one indicator alone provides not a sufficient condition for a clear classification of the different urban patterns found in the six case cities.

In the process of comparison of the case cities, the results of the shift-share analysis and the *H*-measures are compared in this section 4.3, the local indicators of spatial autocorrelation are discussed in section 4.4. In section 4.5 the final considerations and a final comparison of the case cities are given in form of a summary.

The annual temporal mean growth value of $\tilde{l}$, $\tilde{g}$, H and H^{rel} are summarized for all indicators used and case studies in the Tables 3 to 11. These tables contain in a very condensed manner the outcome of the shift-share analysis. In addition the evolution of the annual average growth rates $\tilde{l}$ of population and employment are depicted in Figure 14 and Figure 15 and the evolution of the corresponding spatial deviations from the average growth rates $\tilde{g}$ in Figure 16 and 17, respectively. The evolution of the concentration measure H^{rel}, is depicted in Figure 18 and 19 for population and employment.

The total time period covered by the analysis of the 6 cities is about 20 to 30 years. Only Helsinki provides data for a time-span of only 10 years. In so far the case cities provide a sufficient data base for a medium- to long-term analysis of socio-economic development effects.

The annual temporal mean growth rates $\tilde{l}$ for population, workplaces, income, number of commuters, trip length, house prices, dwellings, residential buildings and jobs directly induced by the population show strong temporal variations for all variables and in all case studies over the last decades. Comparing those growth rates with the corresponding national economic situation shows clearly that the European cities Milan, Brussels, Stuttgart, Bristol, Helsinki and Rennes are participating in the general socio-economic growth process.

In more detail, comparing the yearly growth rates of population on the national level (Figure 3) with the average growth rates of the study areas (Figure 14) shows that Rennes and Helsinki are growing 3 times larger than their national level (France and Finland). With respect to population, Helsinki (1.2%) and Rennes (1.4%) show the strongest stable growth rates (Table 3). In relation to this evolution, these two cities show an over-proportional increase in its commuter flows (Table 6), but also an increase in its corresponding trip length (Table 7). In addition, the growth rate of the average income per capita in the study areas of Rennes and Helsinki were above 3% over the last ten years.

The yearly growth rate of population of the Brussels case study is comparable with its national level. The growth rate of the Stuttgart Region is also clearly above its national average, but follows rather strictly the national up- and downs of the population growth rate. Between 1990 and 2000 a small population growth (0,2% per year) in Italy must be stated.

Contrary to this development the study area of Milan has lost population (average growth rate per year -0,1%)[7] As mentioned in section 4.2.2 this suggests that the city region of Milan is much wider than the used case study area.

The growth rate of employment (Figure 15) and the growth of the GDP (Figure 4) are considered next. In Rennes the growth of employment is on the same level as the growth rate of the GDP of France. In Brussels the growth of employment follows more or less directly the development of the growth rate of the GDP of Belgium. The annual growth rates in employment (workplaces) are 1.2% and 1.3% in Brussels and Rennes, at least double as high as in the other case cities.

A strong increase in the growth of employment in Helsinki and the GDP of Finland must also be stated. The development of the growth rate of employment in the Stuttgart Region exhibits a clear cyclical movement, much more enhanced as the growth rate of the GDP in Germany, which lags behind the EU-15 average. This shows the strong dependence of the Stuttgart Region on export activities. According Figure 15, the growth rate of employment in Milan in the long time average (1961 – 2001) is about 0,7%, since 1986 it about 0% and lags behind the GDP growth rate of about 2% of Italy.

Furthermore, for all case studies, the average growth rates of the urban centre lag behind the average growth of the region. This applies for population growth and employment growth for all cities (Table 3 and Table 4).

In the urban centre, the mean deviations from the average growth path $\tilde{g}$ of dwellings is also negative[8] and, as expected, the growth rate in the number of commuters of the urban centres of Milan, Bristol, Helsinki and Rennes are decreasing as well[9]. This statement means that there is less population from the centre of the case study area commuting to the outer urban ring and the hinterland. In contrary, in most of these case studies, the number of commuters from the hinterland and the outer urban ring are increasing.

Beside the smaller average growth rates in the urban centres of the six case cities, their corresponding outer urban ring and hinterland are above the average growth rate of the whole region (Figure 16 - 17) and also in general of the national level (Figure 3 – 5). Only Helsinki shows a different development. In the study area of Helsinki the outer urban ring is gaining population (Figure 16) and also urban centre for some years, whereas the hinterland is losing population during the whole time period 1992 – 1998. This means, that a population redistribution towards the outer urban ring must be stated. In case of employment, Helsinki behaves more similar as the other case cities. Only during the last years (1996) a stronger increase in workplaces in the outer urban ring and simultaneously a decrease of workplaces in the hinterland can be observed, also indicating a shift of employment from the more rural areas towards the more industrial organised areas.

[7] The time series of population growth for the Bristol study area are to short to be comparable with the data of the United Kingdom.

[8] Data for Milan, Stuttgart and Rennes

[9] There are no data available for Stuttgart and Brussels

In case of Stuttgart a strong competition between its hinterland and its outer urban ring with respect to employment must be stated (Figure 17), and between its urban centre and its hinterland in case of population.

The outer urban ring of Rennes is growing with a growth rate at least twice as high as in the other case studies, but also the urban centre lags far behind the average growth path (-0,7%). In so far within the study area of Rennes a strong reorganisation of the urban system is under way.

The shift-share analysis indicates (Figure 16 – 17) that in all case studies the main growth poles of population and employment are situated in the outer urban ring or the hinterland or in both. This leads to an increase of the investigated stock variables (population, employment, commuters, dwellings, residential buildings and directly induced jobs) mainly in the outer urban ring accompanied by an increase of the investigated density variables (income per capita, commuter trip length and house prices) in some not all zones belonging to the outer urban ring and the hinterland. Milan is in so far an exceptional case, since total population and commuters are decreasing (stagnating). However, this could be related to the fact that the conurbation area for Milan is too small (see section 4.4.1).

In the next section development of spatial concentration for the six case cities will be investigated, by means of the introduced *H*-measure.

4.3.2 Comparison of the Results of the Concentration Measure *H* for the six Case Cities

Changes in the overall spatial concentration of population and employment are discussed in this section on the basis of the Figures 18 and 19 and the corresponding mean values, shown in the Tables 3 to 11. From those figures it becomes obvious, that the six case studies can be clustered into three groups: 1) Milan and Bristol showing a permanent and strong de-concentration, 2) Stuttgart and Brussels with small to moderate spatial shifts, and 3) Helsinki and Rennes still favouring population and employment concentration effects.

In detail: despite the almost zero growth of total population and the small increase in total employment in the Milan case study, a strong permanent de-concentration must be stated. This de-concentration effects of population and workplaces are dramatic and were already on the way at the beginning of our data base in 1961. Only during the recession in Italy (1992 – 1994) the redistribution of workplaces in space was stagnating.

Bristol follows the same de-concentration process in both, population and employment. The development of H exhibits same slope as in case of Milan, also Brussels follows the same spatial employment de-concentration pattern (the same slope).

In contrary to all the other case studies, the spatial re-organisation of Rennes and Helsinki seems to favour the concentration of population and employment towards the city centre (Figure 18, Figure 19). This is pointing to an increase of concentration of activities in the inner regions of the study areas (urban centre and urban ring). The main growth centres of the case city Helsinki and Rennes are situated in the outer urban ring. The negative temporal mean value of $\hat{H}^{rel}$ is therefore based mainly on the evolution of population and employment pattern of the hinterland with its negative growth rates. Furthermore the negative $\hat{H}^{rel}$ for all variables of Helsinki may be based on the very short time intervals were data are available (only 10 years) and the huge rural hinterland.

Compared with Milan and Bristol the case study areas of Stuttgart and Brussels show only a moderate spatial de-concentration of population. Stuttgart shows almost no de-concentration in its employment figures. This may indicate that the whole Stuttgart Region is developing in a similar way.

Table 3 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for population

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Milan	1971 - 2001	7	-0.1%	-1.2%	0.6%	0.9%	0.8%	1.0%
Brussels	1981 - 2001	6	0.2%	-0.4%	0.3%	0.2%	0.4%	0.2%
Stuttgart	1976 - 2000	15	0.5%	-0.5%	-0.1%	0.4%	0.8%	0.2%
Bristol	1971 - 1991	*3*	*0.1%*	*-0.8%*	*0.8%*	*0.4%*	*0.9%*	*0.7%*
Helsinki	1990 - 1999	*4*	*1.2%*	*-0.5%*	*0.5%*	*-0.4%*	*0.4%*	*-0.7%*
Rennes	1962 - 1999	6	1.5%	-0.7%	1.8%	-0.2%	1.6%	-0.3%

Source: STASA[10]

Table 4 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for jobs and/or employees registered at the workplace

case study	years	time steps	smoothed λ	smoothed γ			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Milan [2])	1961 - 2001	6	0.7%	-1.0%	1.3%	1.0%	2.5%	1.2%
Brussels [1])	1984 - 1999	5	1.2%	-0.9%	1.7%	0.6%	2.1%	0.7%
Stuttgart [2])	1976 - 1999	9	0.4%	-0.7%	0.4%	0.3%	0.6%	0.1%
Bristol [3])	1971 - 1991	*3*	*0.4%*	*-1.1%*	*1.2%*	*0.6%*	*1.5%*	*0.9%*
Helsinki [1])	1990 - 1999	*4*	*0.3%*	*-1.1%*	*1.5%*	*-0.6%*	*-0.7%*	*-0.9%*
Rennes [1])	1982 - 1999	*3*	*1.3%*	*-0.7%*	*1.6%*	*-0.6%*	*0.8%*	*-0.5%*

[1]) jobs and/or workplaces

[2]) employees registered at the workplace

[3]) employees (population resident)

Source: STASA[10]

[10] If less than 5 time steps are available the data is written cursive.

Table 5 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for income per capita

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Brussels [1])	1984 - 1999	5	2.2%	-1.3%	-0.1%	0.3%	3.0%	0.3%
Helsinki [2])	1990 - 1999	*4*	*3.2%*	*0.9%*	*-0.0%*	*-0.1%*	*3.4%*	*-0.2%*

[1]) income per inhabitant (constant prices of 1990)

[2]) income per inhabitant

Source: STASA[10]

Table 6 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for commuters

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Milan	1981 - 1991	*2*	*-6.4%*	*-1.7%*	*0.6%*	*1.3%*	*-4.1%*	*1.1%*
Bristol	1981 - 1991	*2*	*0.1%*	*-0.6%*	*1.0%*	*0.1%*	*0.5%*	*0.4%*
Helsinki	1993 - 1999	*3*	*3.8%*	*-1.1%*	*1.7%*	*-0.9%*	*2.9%*	*-1.1%*
Rennes	1975 - 1999	*4*	*4.2%*	*-1.2%*	*-0.1%*	*0.8%*	*8.7%*	*0.6%*

Source: STASA[10]

Table 7 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for the commuter trip length

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Milan	1981 - 1991	*2*	*0.0%*	*-0.3%*	*0.3%*	*0.0%*	*-0.1%*	*-0.1%*
Bristol	1981 - 1991	*2*	*1.2%*	*1.0%*	*0.0%*	*-1.0%*	*0.3%*	*-0.9%*
Helsinki	1993 - 1999	*3*	*2.8%*	*-1.0%*	*-1.2%*	*0.6%*	*4.2%*	*1.0%*
Rennes	1975 - 1999	*4*	*0.5%*	*-0.0%*	*0.3%*	*-0.3%*	*0.4%*	*-0.1%*

Source: STASA[10]

Table 8 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for house prices

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Milan	1993 - 2001	8	2.6%	--	-0.9%	0.4%	3.6%	0.5%
Helsinki	1992 - 2000	*4*	*5.1%*	*2.9%*	*0.5%*	*-2.0%*	*0.6%*	*-3.8%*

Source: STASA[10]

Table 9 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for dwellings

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Milan	1971 - 2001	*4*	*0.7%*	*-1.0%*	*0.7%*	*0.9%*	*2.1%*	*1.0%*
Stuttgart	1976 - 2000	7	1.2%	-0.5%	0.0%	0.3%	1.6%	0.1%
Rennes	1968 - 1999	5	2.3%	-0.5%	1.7%	-0.4%	2.6%	-0.4%

Source: STASA[10]

Table 10 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for residential buildings

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Stuttgart	1976 - 2000	7	1.2%	-0.7%	-0.1%	0.2%	2.7%	0.2%

Source: STASA[10]

Table 11 : Temporal mean value of $\tilde{l}$, $\tilde{g}$, $\hat{H}$ and $\hat{H}^{rel}$ for jobs directly induced by the population[11]

case study	years	time steps	smoothed l	smoothed g			$\hat{H}$	$\hat{H}^{rel}$
			whole study area	urban centre	outer urban ring	hinterland	temporal mean value	temporal mean value
Brussels	1984 - 1999	5	1.2%	-1.4%	0.8%	1.4%	3.0%	1.4%

Source: STASA[10]

[11] Jobs directly induced by the population: retail trade and local private and public services.

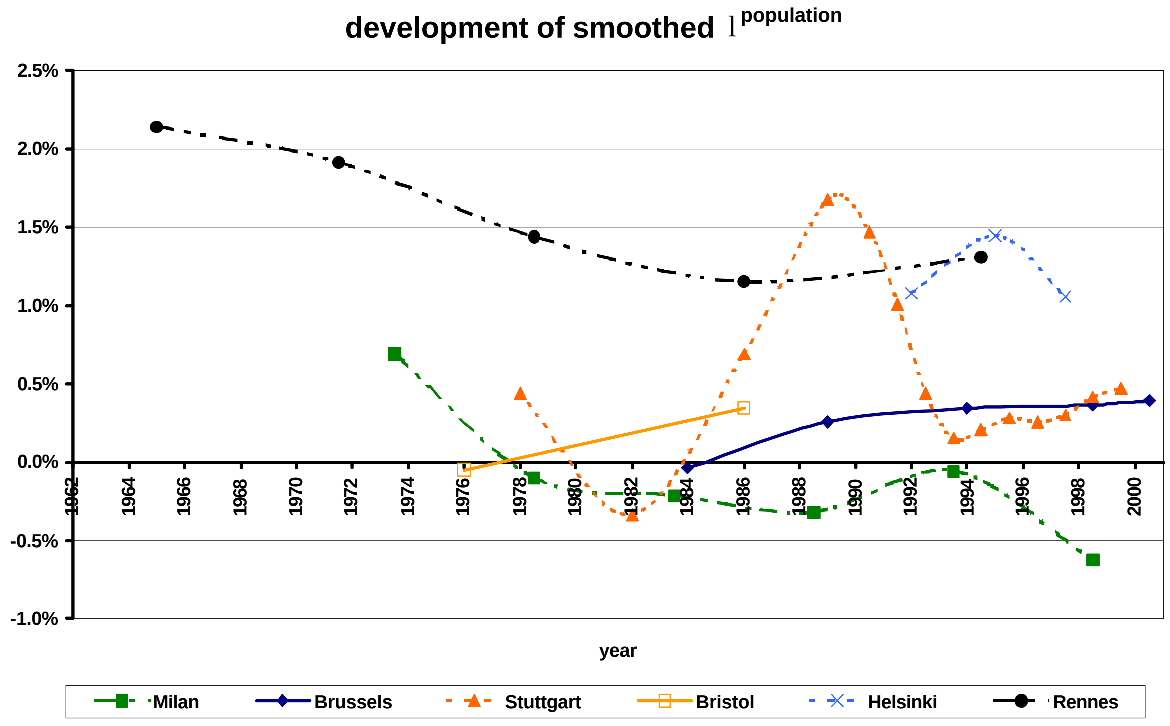


Figure 14 : Smoothed l for population for all case studies

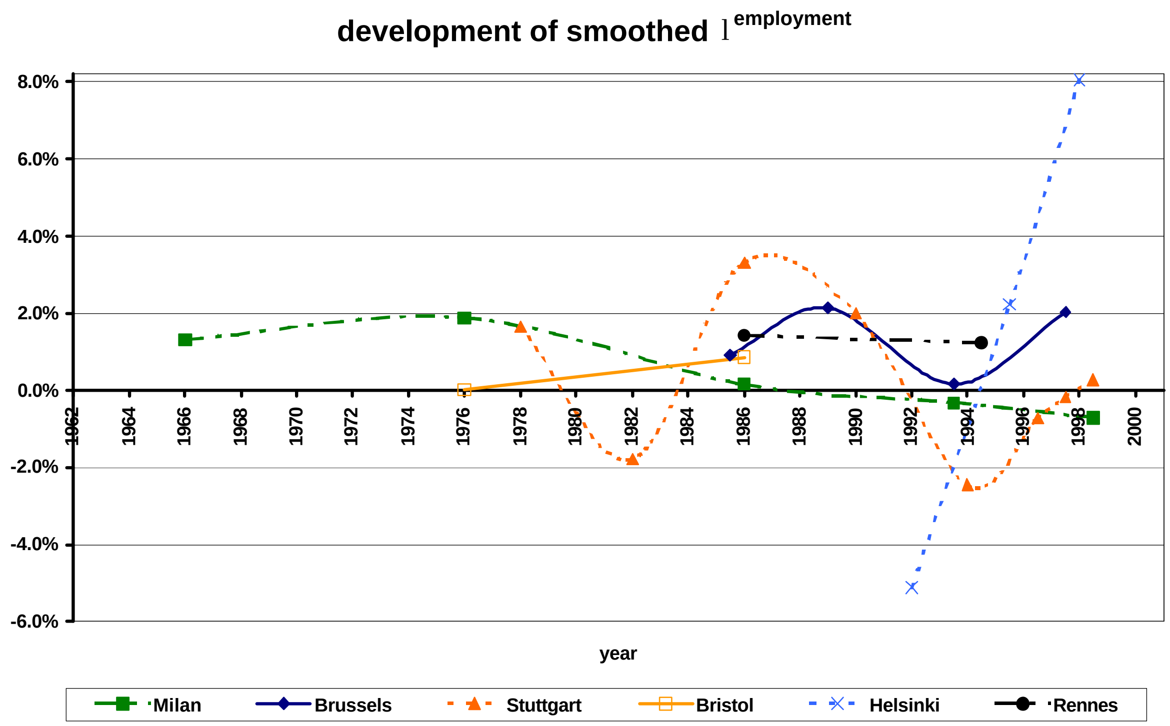


Figure 15 : Smoothed l for employment for all case studies

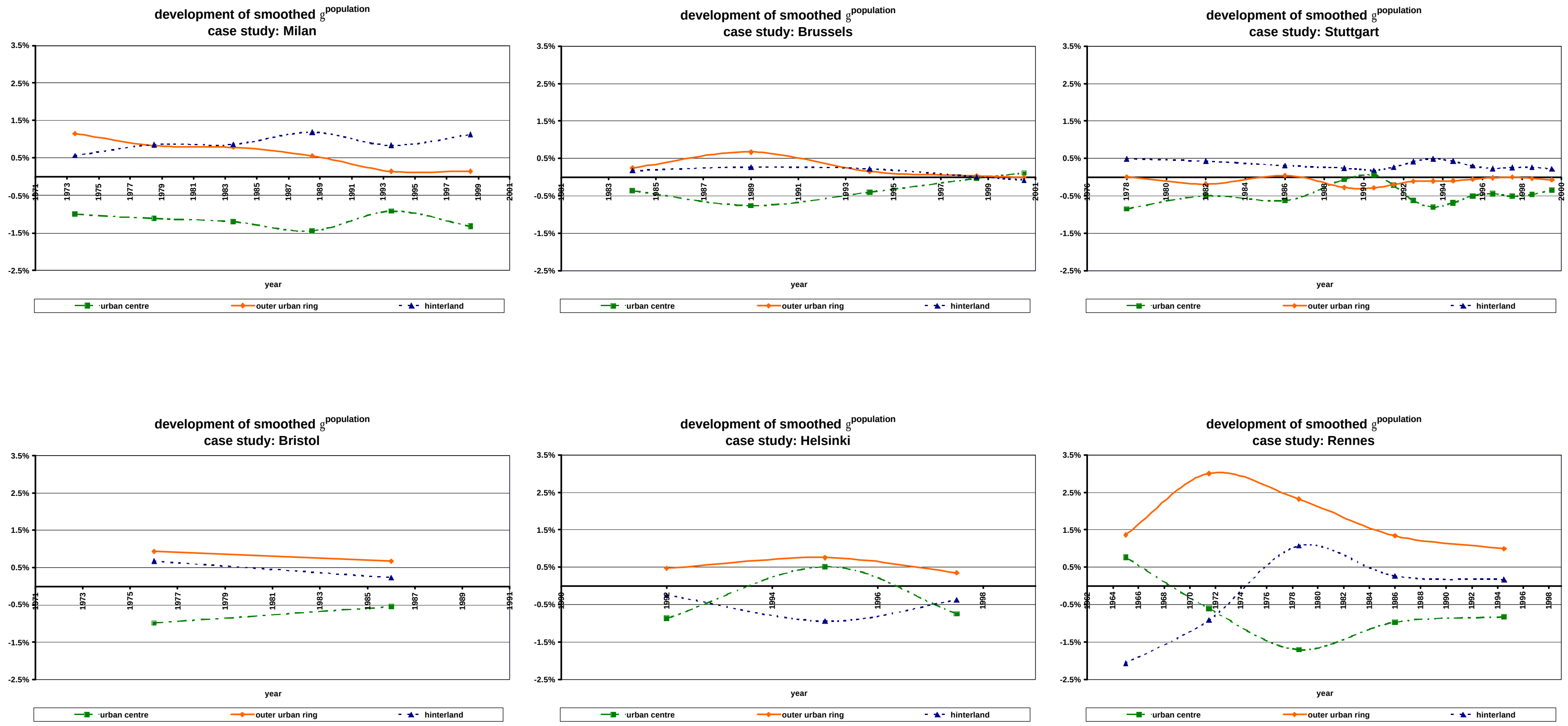


Figure 16 : Deviation of the average growth path of $\tilde{g}^{\text{population}}$

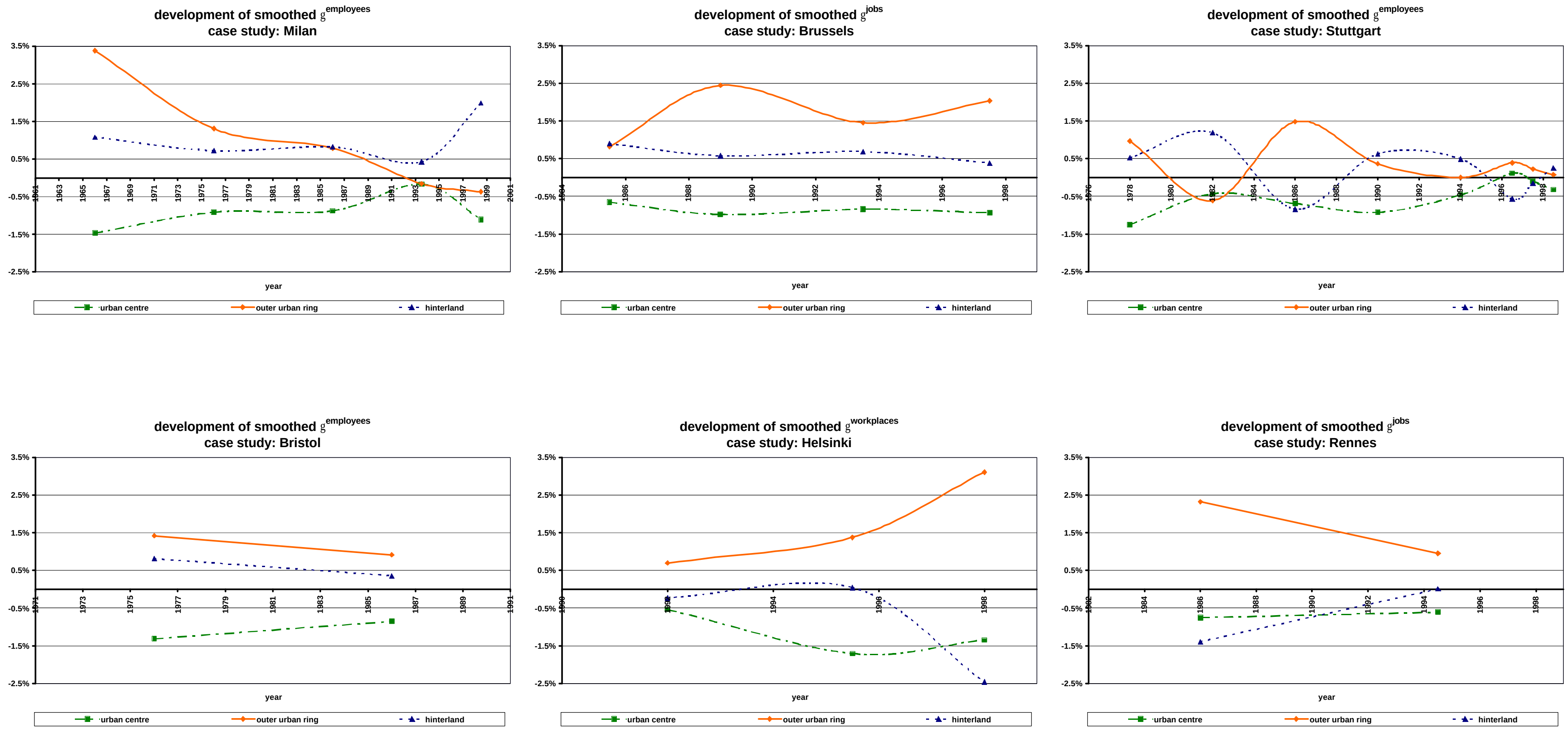


Figure 17 : Deviation of the average growth path of $\tilde{g}^{\text{employment}}$

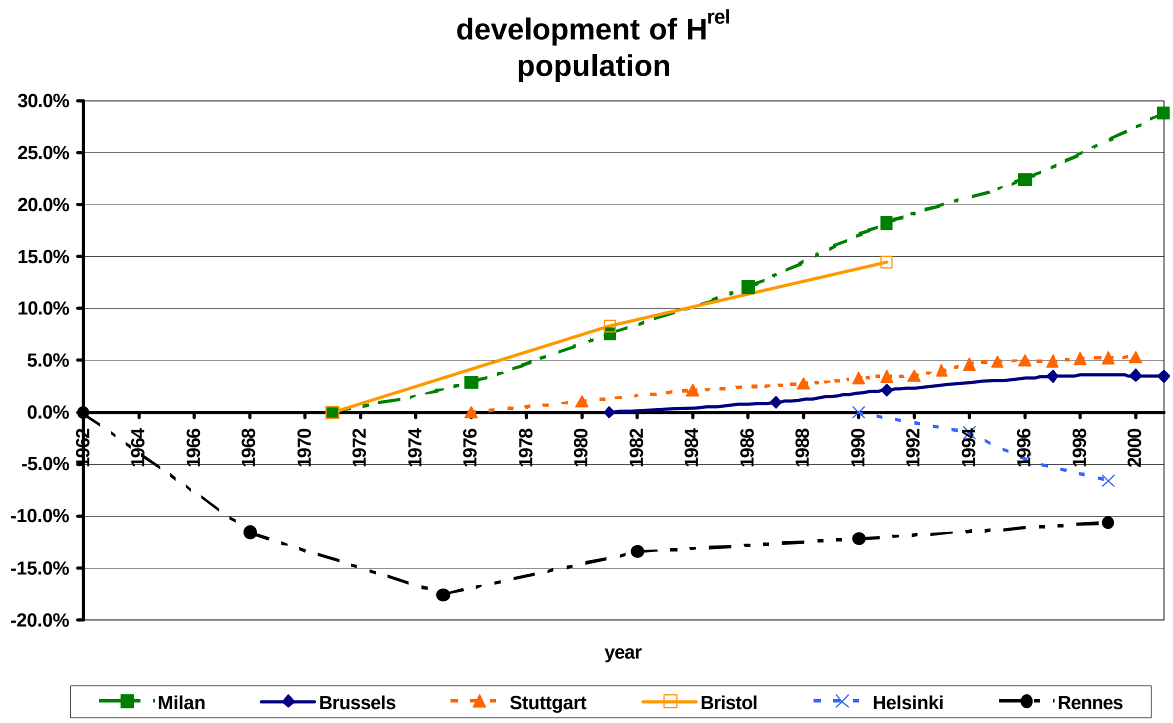


Figure 18 : Concentration measure H^{rel} for population for all case studies

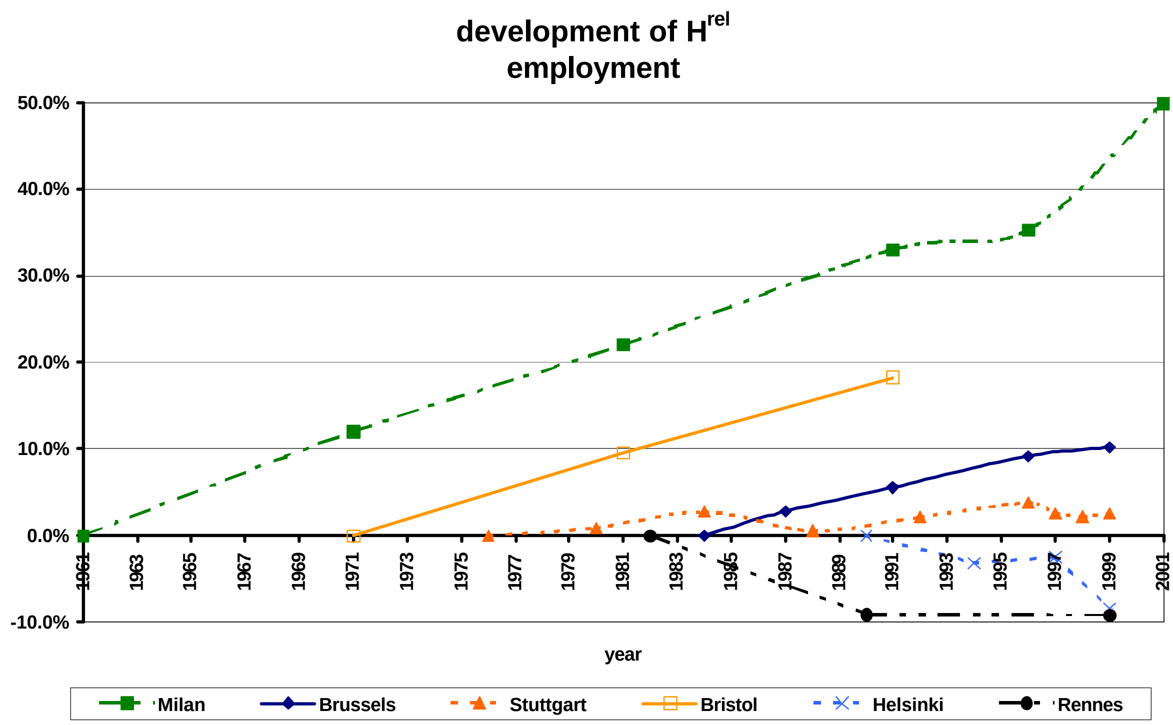


Figure 19 : Concentration measure H^{rel} for employment for all case studies

4.3.3 Spatial Distribution of Growth Rate Deviations of the six Case Cities

The spatial distribution of the temporal mean growth rates ($\tilde{g}^{\text{population}}$ and $\tilde{g}^{\text{employment}}$) are shown in Figure 20 and Figure 21, respectively. The spatial de-concentration of population and employment in Milan is reflected in big above average growth rates of zones mainly located in the southern part of Milan.

Bristol shows a more scattered polycentric pattern with a horse-shoe like structure of growing zones belonging mainly to the outer urban ring.

Brussels and Stuttgart are not so much affected by topographical constraints. Therefore population and employment can expand from the city centre towards the more rural areas. In both case studies, the mean population growth rates are more homogeneously distributed in the study area in a ring like structure. However, in case of employment, specific growth zones can be identified close to the main transport axes.

The main population and employment growth centres of the case studies Helsinki and Rennes are mainly concentrated within the outer urban ring and near the border between the outer urban ring and hinterland. The growth centres are closer to the city centre located in Rennes compared with Stuttgart and Brussels.

The extension of the Helsinki study area is quite large compared with the other case studies. Considering an area comparable with the other case studies a high concentration of population and employment in the city centre and a decreasing concentration with distance must be stated. However, spot like zones with high and low growth rates are distributed over space.

All case cities show a more or less scattered spatial distribution of the temporal mean growth rate of $\tilde{g}^{\text{population}}$ and especially of $\tilde{g}^{\text{employment}}$.

In order to obtain an additional quantitative hint of urban sprawl, measures of local spatial statistics are summarised in the next section.

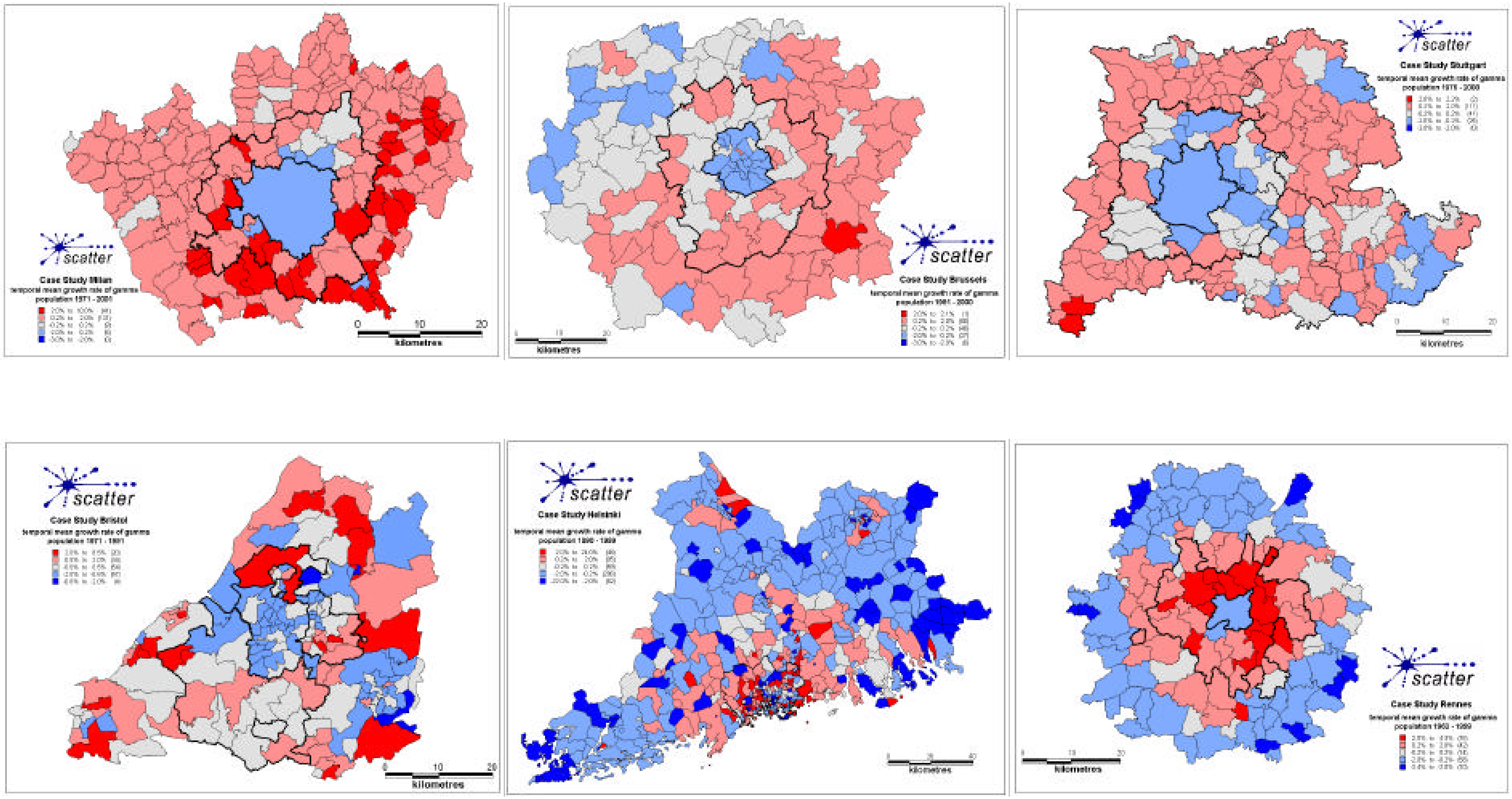


Figure 20 : Spatial distribution of the temporal mean growth rate of $\tilde{g}^{\text{population}}$

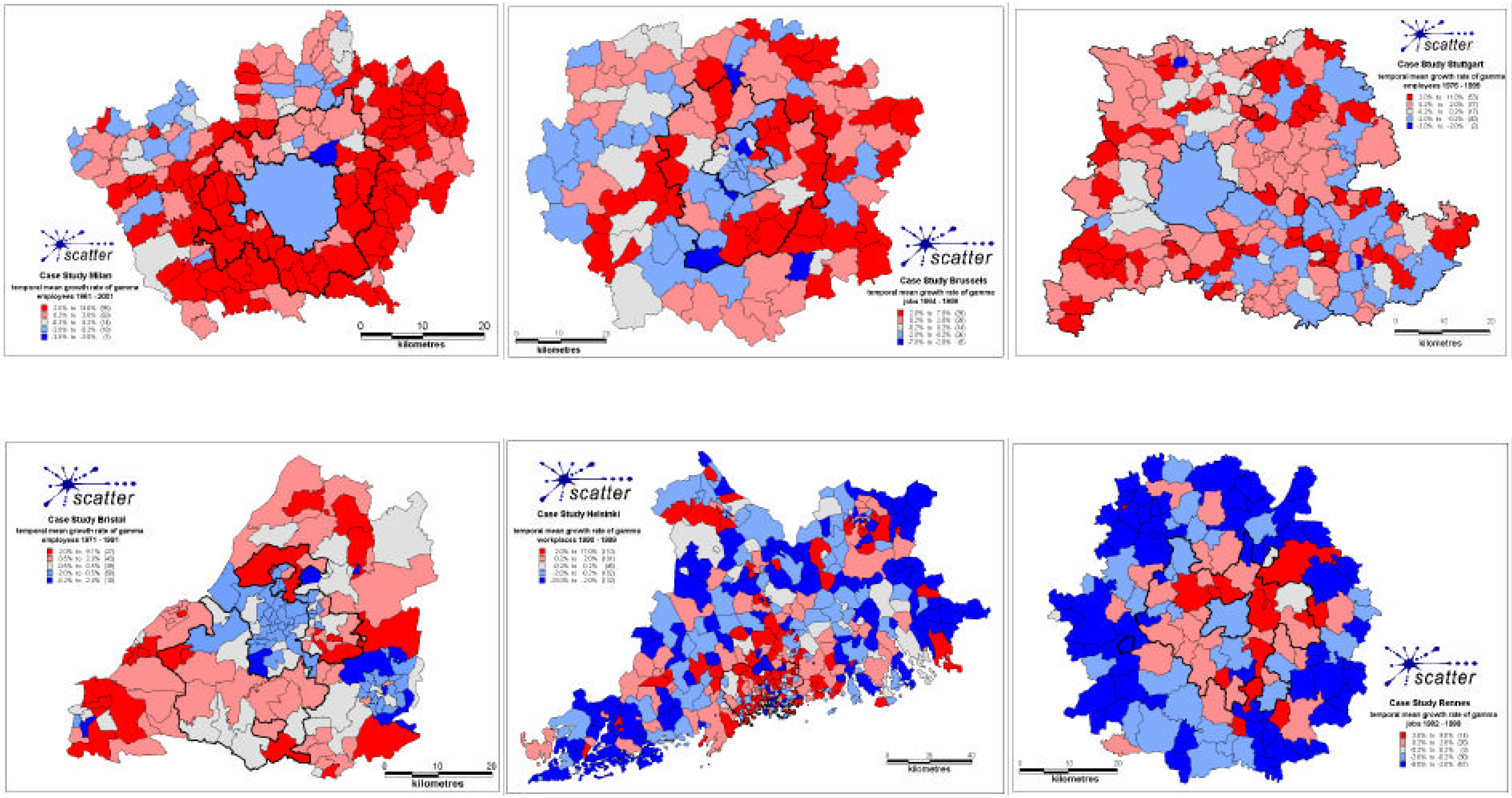


Figure 21 : Spatial distribution of the temporal mean growth rate of $\tilde{g}^{\text{employment}}$

4.3.4 Indicators of Spatial Autocorrelation

For all case studies, the spatial distributions of Local Moran's *I* of population and employment density are depicted in Figures 22 and 23. The development of global Moran's *I* is shown in the Figures 24 and 25.

Local Moran's *I* indicates areas of high or low spatial autocorrelation or without any correlation. A high value does not indicate that the evolution in a certain area is worse or better than in an other area. It only shows, for example, areas with similar behaviour or with similar development. For example, communes belonging to rural areas are spatially correlated, or communes showing the same behaviour in close neighbourhood of a city are expected to be highly correlated. In contrary those communes which are located at the transition region between growing and declining or stagnating zones may have quite different growth rates and are therefore only marginally or not spatially correlated with its neighbourhood.

In Milan the population density of the city centre and northern communes are highly correlated, also population and employment of communes belonging to the west-southern part of the study area. The development of communes located in the south of the city centre seem to be spatially uncorrelated showing quite different rather scattered behaviour.

If, as in the Stuttgart case study, the urban centre is highly correlated with some neighbouring communities (Figure 22, 23), it can be stated, that the "field of influence" of the urban centre is growing. This can be seen not only in the Stuttgart and Milan case study very clearly, but also in the other case studies on a less high level. The spatial pattern of the study areas of Milan and Stuttgart look quite similar. Both study areas must be considered as metropolitan areas showing rather high values of densification over space and widely scattered activities.

It can be seen that rural areas also develop very similar. Therefore, rural areas within the conurbation field also exhibit rather high values of spatial autocorrelation. Here, the case studies of Brussels and Helsinki provides a good example. The urban centres of Brussels and Helsinki and some neighbouring communities show strong spatial autocorrelation in population density and density of workplaces. The hinterland, on the other hand provides a very homogeneous and spatially medium high correlated area. The outer urban ring in-between, however, exhibits very low spatial autocorrelation, since in this active area the transition between urban and rural spatial and economic structure appears. Strong zonal and socio-economic differences are typical and determine this transition area.

The "transition area" in the case studies Milan, Stuttgart and Rennes are not so much extended as in case of Brussels, Helsinki and Bristol. In addition those transition areas are not showing a full undistorted ring like structure, rather a scattered pattern.

Almost the same spatial structure can be identified for Rennes and Bristol. In this area of transition all indicators of the shift-share analysis have shown, that an increase in the different growth rates occurred during the last decades and must be expected, at least in the near future. A strong and scattered densification process has already started and must be expected to continue.

The development of the global Moran's *I* for the different case study areas (Figure 24 and Figure 25) give some indication of the spatial autocorrelation within the whole study area. In so far, it is obvious that the communes belonging to the Brussels study area are much more similar in population density and workplace density than communes of Rennes and Bristol. Milan, Helsinki and Stuttgart are in-between. With the exception of Bristol, all other study areas develop towards more homogeneous spatial structures.

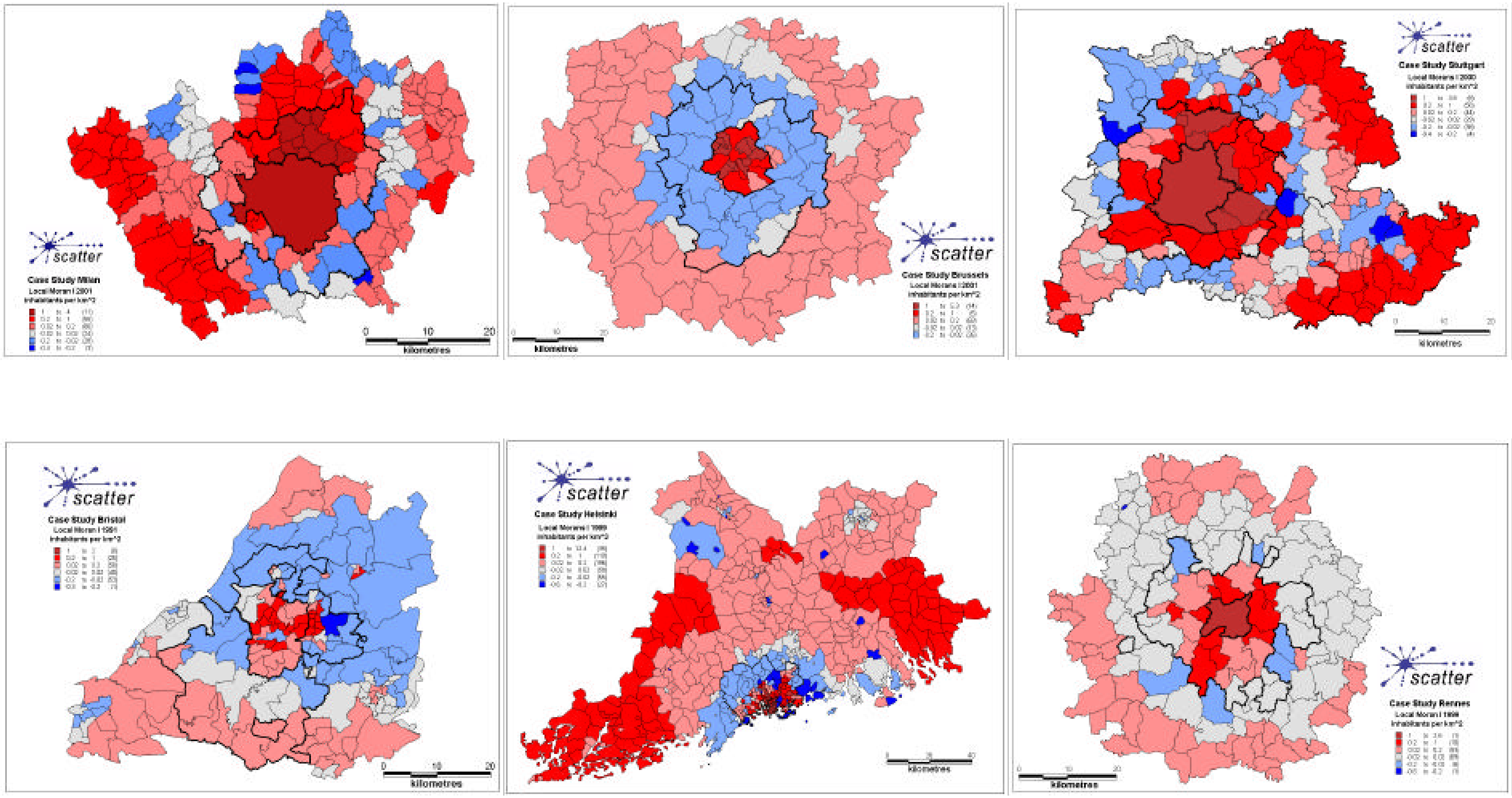


Figure 22 : Spatial distribution of Local Moran *I* for inhabitants per km^2

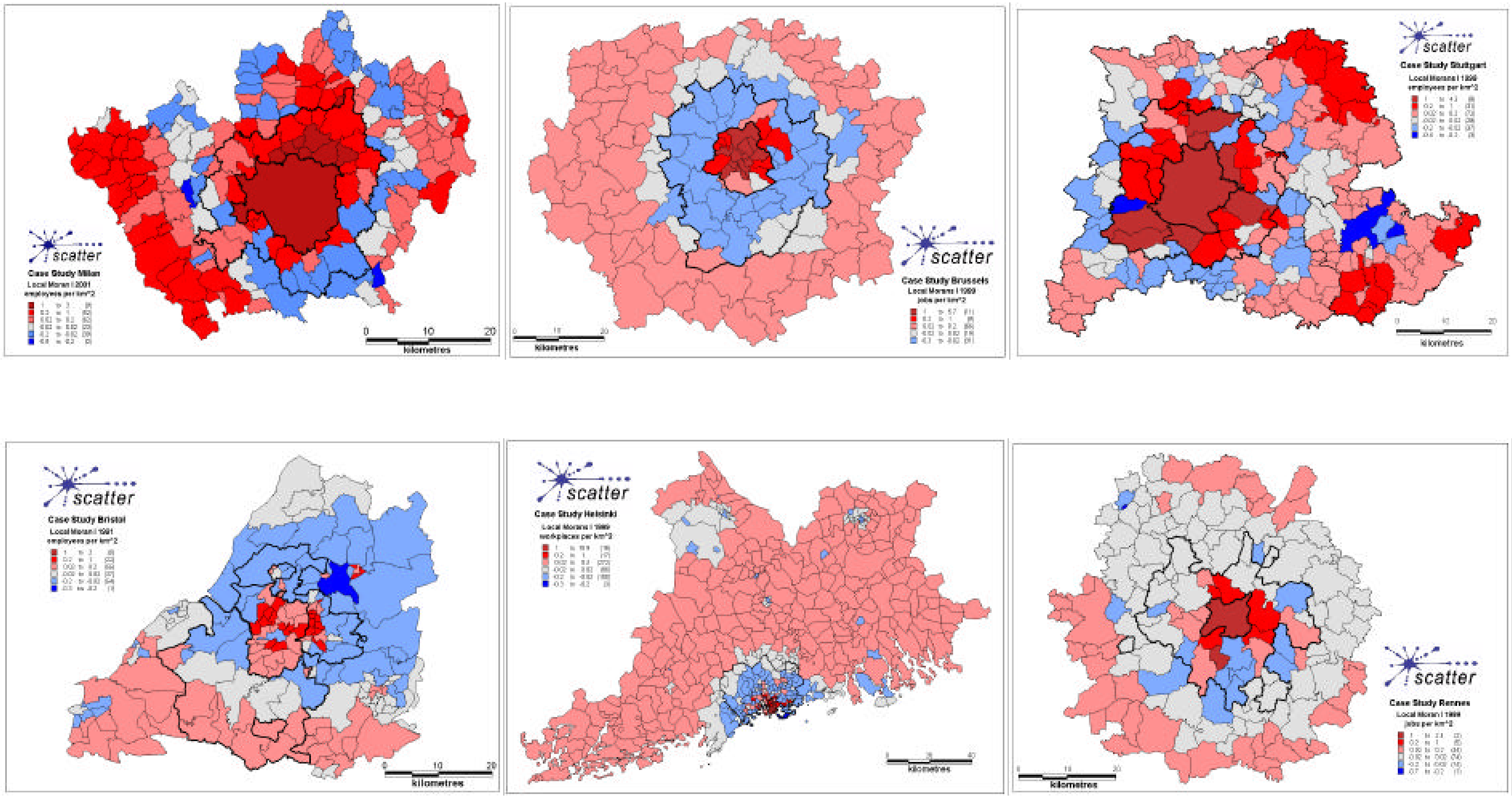


Figure 23 : Spatial distribution of Local Moran *I* for workplaces, jobs and/or employees registered at the place of work per km^2

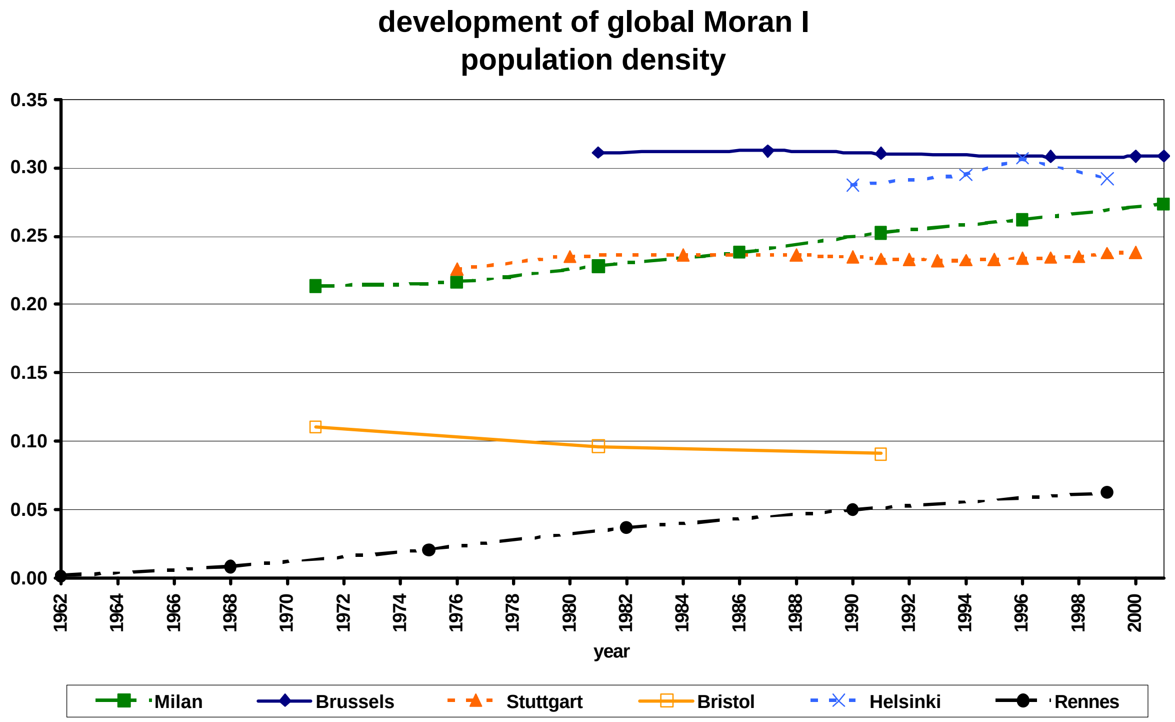


Figure 24 : Global Moran's *I* for inhabitants per km² for all case studies

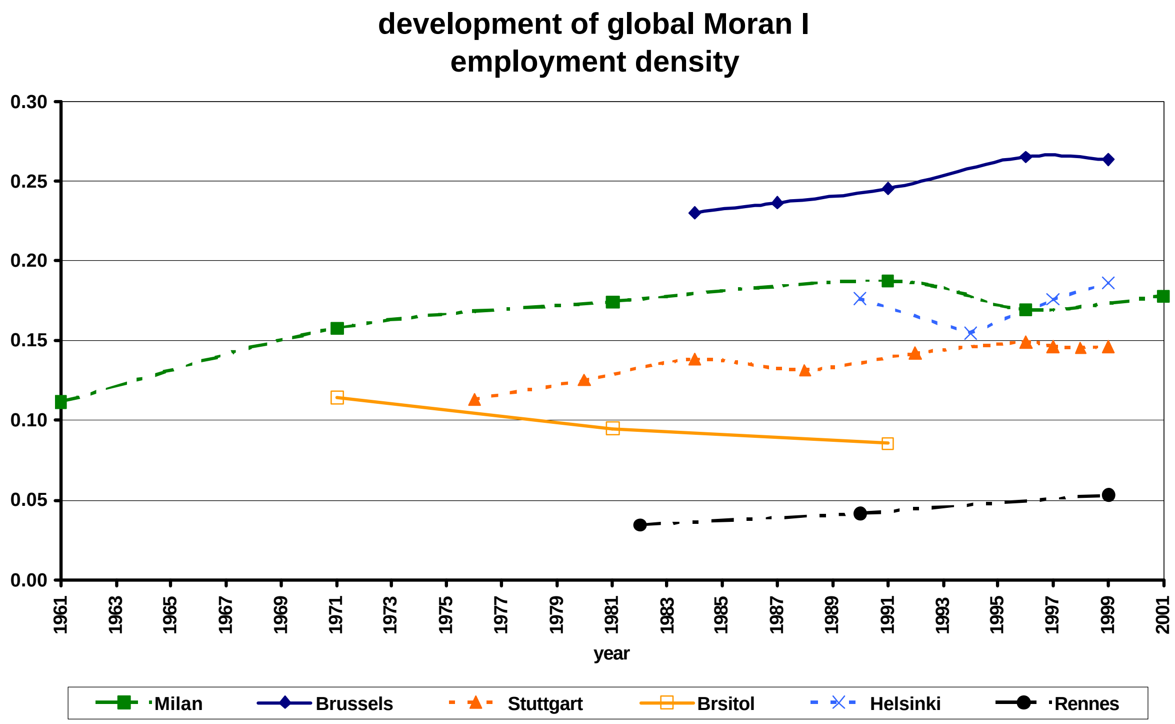


Figure 25 : Global Moran's *I* for workplaces, jobs and/or employees registered at the place of work per km² for all case studies

5 SUMMARY AND CONCLUSIONS

5.1 Summary of the Statistical Analysis of the Case Studies

The monographic reports on the statistical analysis of the six case cities are collected in the common Annex to D2 and D3. In this section for each case city the results are briefly summarised. Comparing the results of the statistical analysis some general conclusions will be drawn in section 4.4.2.

5.1.1 BRISTOL

The Bristol city region did not grow very much in terms of population and employment between 1971 and 1991. In fact from 1971 to 1981, the population fell by some 0.5% while it grew modestly from 1981 to 1991 by some 3%. In fact during this period employment grew much faster reflecting, an increase in participation in the labour market as well as an increase in long distance commuting from outside the city region.

These trends are explicable in terms of macro-economic and demographic factors. First, the decade of the 1970s in the UK was a period where there was massive loss of manufacturing jobs and declining birth rates and this probably accounts for the slight fall in population during this period. The macro economy was depressed in the 1970s as the 1960s boom turned to recession, which only began to correct itself in the mid 1980s. The early 1990s was also a period of recession. Although we do not have finalised figures for the overall population and employment growth from 1991 to 2001 – these will be available in 2003 from the 2001 Census of Population – it is already clear that population has grown at a much faster rates in this region during the last 10 years.

The growth rate in population is increasing but at a slower rate than employment. We only have one growth rate for commuting but this is higher in terms of percentage annual growth than population and employment.

The deviations from the average growth rates in both population and employment reflect fairly classic changes in the spatial structure of the Bristol region. In essence, the urban centre shows negative growth and this is reflected in the rates while the outer urban ring shows the greatest growth and the hinterland which is furthest away from the centre of the region in downtown Bristol has positive growth but less than the outer ring. What is slightly surprising is that for both population and employment, these rates converge over the period. This means that the rate of decline of the urban centre gets less during this period while the rates of growth of the outer ring and the hinterland also get less.

In terms of the detailed spatial pattern of these deviations from the average growth rate, what can be seen in Bristol for population and employment is a pattern which reflects these broad observations about positive growth in the suburbs and negative in the urban cores. One key issue in this region is that it is not strictly speaking mono-centric. The town of Bath which merges in to Bristol on the eastern side is a strong centre which is, in fact, much longer established historically than Bristol, going back to Roman times. The town is on the western border of the region although is contained within the hinterland of the region. The same is true of the town of Western Super Mare on the south west of the region. Both these towns complicate our analysis. Moreover the region to the south of Bristol is rural and has suffered from a drop in population and employment through restructuring of agriculture; this area is within the outer ring.

Basically what can be observed is a decline in the urban core of Bristol but also decline in the urban core of Bath for employment and population, with employment declining faster. In addition growth in the outer ring and in the hinterland in the Western Super Mare area but also in the north and the east and south east must be stated. But this is extremely patchy. There is not the perfect radial concentric pattern. Thus the interpretation of the deviations in the growth rates from these overall averages is that the patterns are complicated by the urban morphology of the region, which is based on a central core and two competing smaller cores in the hinterland.

The H measure is a measure which reflects the centre of gravity of the variable in question within the region. What these measures for population, employment, commuter and commuting length show is that the centre of gravity of the region is shifting outwards during these time periods. In the case of population the shift is some 20 per cent over 20 years whereas this is greater for employment which is up to 30 percent and increasing. This is consistent with what can be observed casually in the Bristol region with rapid employment growth in the outer ring and hinterland and declining population in Bristol centre. The shift in commuting reinforces this for the one date shown although the shift in commuter length is in the negative direction. The measure does reveal an increasing suburbanisation around the core of the city region which is substantial. This is consistent with the patterns of growth and also indicates that even in the face of very low growth in this city region, there is substantial restructuring taking place.

The Moran statistic is a measure of spatial autocorrelation. It essentially measures the extent to which the space in question is homogeneous structured or heterogeneous. In a sense, it might be interpreted as a measure of scatter but at the level of analysis which is used in our approach to sprawl, it cannot be used to imply scatter in the sense of broken-up urban morphology.

For Bristol, the Moran’s *I* statistics shows that the degree of autocorrelation changes very little over the 20 year period for the population and employment. In short, there is not much restructuring in terms of the way populations and employment relate to each other overall, although these is a slight drop in value showing that the measure of similarity between adjacent population is getting less. This could be taken as the fact that the region is beginning to concentrate in clusters a little more but the change is too small to be significant.

In terms of the spatial pattern, then these statistics show that the pattern of employment and population for 1991 show high autocorrelation in the core area and high on the eastern edge of the region with lower values in the outer ring. As expected, given the complex morphology of the region, these patterns are not very clear. The shift from 1971 to 1991 however does show that the inner core is getting more clustered while the outer ring and hinterland is becoming more homogenous, more evenly spread.

5.1.2 BRUSSELS

The statistical analysis gave a possibility of recognising different temporal phases and spatial phenomena on the 1981 – 2001 period in Brussels. The shift-and-share analysis of the growth rates, the H indicators, the Moran *I* indicators appeared to be adequate and relevant tools and indicators to measure urban sprawl. The evolution of the Brussels urban area shows that the sprawl phenomenon of population and jobs seems to be strongly linked with economic cycles: in a period of high economic growth, new jobs are created, income rises and the households, having gained confidence in the future, move towards the urban periphery probably to have more space and comfort, inducing there service jobs. On the contrary, in a period of low economic growth or economic recession, the sprawl of population tends to slow down or even stop. Measures to tackle urban sprawl should take into account this mechanism. Three distinct phases were identified:

The first phase (1985-1989) is characterized by a sprawl of population and of jobs, essentially towards outer urban ring, which seems to be at least partly due to the economic growth. Higher income are more frequent out of the city, induced jobs are created essentially in the outer urban ring. This sprawl phase is in some way confirmed by figures giving the number of active people living in zones of different urban hierarchical level, and working in Brussels, in 1981 and in 1991, as well as the variation 1981-1991. The total absolute variation of people working in Brussels is negative, due to the decrease of people living and working in Brussels (- 13,07%). But the number of people living out of Brussels and working in the city has mainly increased (11,17%), confirming in a way the sprawl of population. This growth of commuters is essentially composed by commuters coming from the 4 level I cities (Antwerp, Gent, Liège and Charleroi). Links between Brussels and these cities are reinforced, such as with cities of level II.

The second phase (1989-1993) is characterized by a low economic growth or even economic recession, and in the same time, by a slow down of the sprawl observed before.

The growth of jobs is very much reduced in the outer urban ring, and is increasing slightly in the urban centre: the sprawl of jobs seems to reduce. An additional increase of jobs in the urban centre is to be mentioned, which is not apparent in these data: the European institutions locate in Brussels in this period, providing 15.000 jobs in 1991. This likely induces an increase of population, of attractiveness and of induced jobs in the urban centre.

This might explain the slow down phenomenon of sprawl: $?^{population}$ of the urban centre increases, the decrease of population in urban centre is lower (with a lower increase in the outer urban ring); and with regard to the jobs, $?^{jobs}$ of the urban centre does no more decrease, while $?^{jobs}$ of the outer urban ring is well decreasing.

The third phase (1993-2001) presents a totally reversed trend compared to the sprawl of the first phase, except for jobs location. Again, the higher economic growth starting from 1993, induces an increase of jobs, mostly in the outer urban ring. But this time, the income is not only rising in the periphery, but also in the centre. This can be a consequence of a change in the type of jobs offered in the centre, but also of the development of the European Commission in Brussels offering high-income jobs (those incomes are not included in this income data, nor in the jobs data – it represents 16.400 jobs in 1994), inducing more consumption and a certain increase of income. The variation of income in the urban centre is much more dynamic compared to the outer rings. The centre is gaining in jobs, in income and in population. Starting from 1997, inhabitants start to increase in the urban centre, meanwhile its growth is attenuated in the outer urban area: it seems that, from 1999, the sprawl of population is stopped and that a reverse trend is starting. Induced jobs follow clearly this trend.

In terms of impacts, the analysis highlighted that the sprawl of population induces an increase of the market share of car, presenting major negative environmental impacts. The outer urban ring seems to be strongly linked to the city centre evolutions, whereas the hinterland is less linked: evolutions in the hinterland may also depend on distinct evolutions of secondary cities, or on the evolution of other surrounding cities not included in the study area, such as Antwerp or Charleroi.

The global spatial structure of the Brussels urban area is concentric in terms of the studied variables, with a East-West dissymmetry. Several poles exist in Brussels' periphery. A sprawl phenomenon of jobs and population has thus occurred but has been reduced by some event(s), which seem(s) to have increased the attractiveness of the city centre. The development of the European Commission in Brussels, essentially since 1992 (Treaty of Maastricht) has to be kept in mind in this analysis: it has probably increased the attractiveness of the urban centre, has induced jobs and indirectly has probably increased the incomes in the centre. It could be one of the reasons – if not the most important one – of the reverse of trend observed since 1997. This illustrates thus that in some cases, like in the case of Brussels, an exogenous factor is able to increase the attractiveness of the urban centre and can contribute to reducing sprawl.

In conclusion, this statistical analysis confirms that a sprawl phenomenon of jobs and population has appeared, but has been reduced by some event. These evolutions of the sprawl phenomenon seem to be strongly linked to economic cycles.

5.1.3 HELSINKI

The population growth has been stronger within the capital region than in surrounding areas. With hardly anymore space in the city core for new housing, the growth in the centre (5,7% during the study period) has been slower than in other areas. Real earnings in the entire study area have grown during the 1990s. The growth, however, has been slower in the capital region's outer areas than close to the centre. The metropolitan area's commuter-shed has shaped itself in such a manner that the high-income areas are close to the centre while the lower income areas are situated in the outer areas. The housing prices are also higher in the vicinity of the centre and decrease, with a few exceptions, as one moves further away from the centre. The region is also typified by the fact in that housing in the central area retains its value while in the outlying area prices are highly volatile. During the 1990s the Helsinki Metropolitan Area, excluding the city core, has proved to be a significantly growing employment area. The growth in the outlying areas has been slower. The length of commuter trips has increased but the fastest growing area has been the city centre. The volume of work trips once again has grown relatively more in the outer urban ring. The average length of work trips originated from this area has, however, grown the least.

The largest population and employment growth areas have concentrated mainly within the capital region but growth can be clearly seen up to a distance of about 70 km from the centre. Rail lines also play a part in attracting jobs to the region. Many of the fasted growing areas are, in fact, those emphasising railway station surroundings. The spatial pattern indicates that the above average growing zones (communities) are scattered mainly over the capital region and on the border to the hinterland. The population in the capital region during the 1990s is relatively more compact: growth has concentrated mainly within the capital region and nearby. Consequently, the population density in the outskirts has decreased as well as the relative H-measure.

At the end of the 1990s the spread in income levels has inflated such that incomes in the capital region's east and northern areas have decreased; as has been the case in the outer areas of the region. This can be also seen by the employees, workplaces and commuters. In the early 90s all and the employees/commuters show an increase of the relative H-measure and therefore a de-concentration of the urban area. The less educated, whose opportunities for improving their economic livelihood are more restricted, reside in these areas. Workplaces and house prices show only in the mid of the 90s an increase of H^{rel}. Only the commuter length seems to increase over the last decade.

The negative concentration measures H^{rel} can be found in case of Helsinki for nearly all variables. This is pointing to an increase of concentration of activities in the inner regions of the study areas (urban centre and urban ring). The main growth centres of the case city Helsinki are situated in the outer urban ring.

The income per inhabitant and the house prices show a high positive level, the workplace per km^2 and commuter ad low positive level and the other variables a medium level of spatial autocorrelation. A high level of global autocorrelation indicates that the characteristics of the areas situated close to one another are similar while a low level of global autocorrelation indicates that there are some clustering regions but the most areas are uncorrelated (unsimilar) in the Helsinki area. The global Moran *I* of the house prices shows a steadily increasing spatial autocorrelation. The increase of the spatial auto-correlation during the last ten years indicates, that within the Helsinki Region the economic interactions between the certain communities have spread out and slightly increased. The whole area has become more homogeneous, since the sprawling effect of the house prices statistically diminish the differences between rather rural and urban communities. The opposite development of the global Moran's *I* can be seen by the income per capita.

5.1.4 MILAN

The average growth rate does not reveal the presence of evident economic cycles at this scale, but indeed there is evidence of a common general tendency in the decrease of the growing rate of employees and, less relevant, of population from mid '70. A decrease in absolute numbers of inhabitants can be stated since the late '70 and for the employees since the late '80 (negative annual growth rate).

The growth trends for dwellings and for residential floor prices seem to be not directly correlated to these variables. Considering the whole study area both have a positive tendency despite the null or negative trend of population. This can be attributed to the decrease in the average number of persons per households (that leads to a higher consume pro-capita of dwellings) and to an increasing number of city-users. Moreover it can be seen that the average increase of floor price, despite a small decrease in the growth rate in the late '90, is very significant. In this case is to notice that floor space values are very influenced by the variance of the profitability of alternative investment forms.

The deviations from the general annual growth path of population show that the central municipality has been loosing population in a quite constant way from mid '70, and that such a population has been moving first in both outer urban ring and hinterland, and then, in the last decade, essentially in the hinterland. Population seems to prefer shifting location preferences in more and more external rings. The same consideration, about ten years later with a more visible trend, can be noticed in the development of employees at the place of work. From ’60 to ’80, when the employees growth rate (1% < $\tilde{l}^{employees}(t)$ < 2%) was positive, the development was located mainly in the outer urban ring, and partially in the hinterland, where the deviations are between 1 and 3% above the annual growth, and in the main city. In the last decade, when a decrease in the total number of employees is detected, such decrease is located in the main municipality and in the outer urban ring, while the hinterland, that increases the total number of employees, presents a more and more high growth rate of employees.

These observations make evident the entity of the decentralization process (of population and employees), which have been occurred in the Milan study area since the last decades, and are still going on.

Although a general positive growth rate in the total number of dwellings can be observed, the city centre has had in ’70 and ’80 negative/null growth rates with a peak in mid ’80 (sum of annual deviation and annual growth rate), probably due to the change in land use destinations in the core of the study area. In the same years, outer urban ring and hinterland have had an almost constant and relevant increase of the available dwellings. In the last decade these developments are still visible, but at a lower level: Milan Municipality is now gaining dwellings also in absolute terms, the outer urban ring is now quite near to the average growth rate and the growth rates of the hinterland are lower than in the past.

Deviations from mean values in the case of residential floor spaces show that in the last decade the values in the outer areas was increasing much faster than in the areas surrounding the city centre. But it is interesting to note that in the last years this trend seems to be inverted. The fact that residential floor values rise faster in the hinterland means that the demand of such housing location, leading to sprawl, was high. The inversion of the observed phenomenon in the last years is interesting and can, partially, be explained with the renewed interest in more central housing locations.

The spatial pattern indicates that the average growing zones (municipalities) are scattered over the outer urban ring and the hinterland of the Milan region. However, the urban centre and some adjacent communes are developing below average. In the case of employees the development of the growth rates are more “scattered” over the study area and the influence of transport axes on the zonal attraction is more evident.

5.1.5 RENNES

The Rennes Region is well known in France as a dynamic urban area. All indicators (population, number of jobs, number of dwellings, income per family, commuters and commuter length) have had a positive growth rate over the last decades. The annual growth rate of the commuters decline from 5.5% to 3% during the last two decades. Indeed, local authorities are faced to migration of households from the city center. People live in theses communes but were still working in the city center. Therefore the growth rate of the commuter length increased.

The average annual growth rates of population and dwellings show the same development. They decline in the 70s and 80s and increase again in the late 80s and 90s. The absence of delays between population development and dwellings evolution, could be a consequence of urban planning tradition by elected politicians. The annual average growth rate of jobs is slowly declining in the second part of eighties, but is still positive and greater then 1%.

The annual deviations from the average growth rate of population indicates that the annual population growth rate of the outer urban ring and hinterland are mainly above the average growth path, while the deviation of the urban center are below the average growth path. Rennes keeps a green belt around the city where the urban area has a very low density. Any more, an effort about new dwellings has been accomplished since twenty years in this area. Several housing plans have been implemented to increase production of new buildings in the city center neighboring communes. The annual deviations from the average growth path of the number of commuters follow the trend in the outer urban ring during the whole period. The development of commuters in the hinterland areas is always above average annual growth.

The City of Rennes wasn't affected by an economic recession and the number of jobs is still growing. More and more employments seem to be located in hinterland areas. For example, several firms working in close link with Citroën settled around the outer urban ring areas because the level of taxes was more attractive. Nevertheless, the urban centre and the outer urban ring still represent most of the jobs in the Rennes urban area. It shows residential specialisation of this zones, jobs are polarised in the urban centre and outer urban ring areas. The spatial differences in the growth rate of the income per family in real prices show, that the urban centre and outer urban ring are strongly influenced by the economic cycle, not so much the hinterland.

The spatial pattern of the average annual deviations from the mean growth rate of population between 1962 and 1999 indicates that the above average growing zones (communities) are scattered mainly over the outer urban ring and zones near the border between outer urban ring and hinterland. This municipalities are really attractive because of the quality of life (no industrial zones) and a new highway has been created which increases their accessibility. The average annual deviations from the mean growth rate of jobs on the level of communes indicates that the communes with an above average growth are less numerous and more scattered than those in the case of the growth rates of population.

The relative H-measure of jobs decreased in the 80s and is nearly constant in the 90s, accompanied by a spatial concentration of business activities towards the urban centre in the 80s and a more homogeneous development since the 90s. The relative concentration-measure *H* of commuters and income per family show a stable effect of de-concentration. The commuter length exhibit a period of increase in the 70s and 80s and a period of decrease in the 90s of the relative H-measure. This means that the travel distance of the commuters increased, especially in the inner communes of the urban area of Rennes in the last decade.

The increase of spatial autocorrelation (global Moran's *I*) of all considered variables during the last decades indicates, that within the Rennes region the economic and social interactions between the «communes» have increased. Socio-economic differences between rather rural and urban areas has decreased.

5.1.6 STUTTGART

The development of growth rate of employment (employees registered at the workplace) reflects the economic business cycle of the Stuttgart Region with its strong dependence on the export activities. The growth rate in population development shows a similar temporal behaviour as the growth rate of employment, but with a time delay of about 2 years.

However, since the growth rate of population remains positive, even after the year 1992, the population number of the Stuttgart Region started to increase in 1984 for almost one decade. However, one has to take into account, that the increase in the growth rate of population between 1984 and 1994 is partially caused by huge migration flows starting in 1989 from the former East Germany (GDR) to West Germany (FRG) and in so far also to the Stuttgart Region, after the reunification of Germany.

The deviations from the mean development of population $\tilde{g}^{\text{population}}(t)$ shows, that especially the hinterland areas are growing faster than the average over the Stuttgart Region, whereas the outer urban ring follows more or less the average population development and the urban centre lost population in relative as well as in absolute values. Only during the population boom between 1989 and 1992 (reunification boom) the population of the urban centre was increasing. With respect to employment a strong competition between the hinterland and the outer urban ring must be stated. It is also obvious, that the number of workplaces of the urban centre was decreasing during the whole period under investigation.

The hinterland was less effected, by the recession of the early 80th and with a time delay, compared with the outer urban ring. In the following upswing of the economy the outer urban ring has profited at most. The temporal development $\tilde{g}^{\text{employees}}(t)$ of the hinterland behaves anti-cyclical to the average growth rate $\tilde{l}^{\text{employees}}(t)$ in contrast to the outer urban ring. This indicates that employment of the outer urban ring increases during an economic boom. During a recession phase the employment development of the hinterland behaves much more stable than in the urban centre and neighbouring communes. Residential building activities of the urban centre are during the whole time period below average, follow the trend in the outer urban ring and are above average in the hinterland of Stuttgart.

In the Stuttgart Region the temporal development of the relative *H*-measure of population $H^{\text{population}}(t)$ indicates an increasing de-concentration over the whole investigation period. The relative concentration-measure *H* of employees $H^{\text{employees}}(t)$ indicates a growing tendency of concentration of employees in the outer urban ring and the hinterland between 1978 - 1984 and 1988 – 1996. Nevertheless a concentration of employees in the urban centre must be stated between 1984 – 1988 and for a short period of time between 1996 and 1998. However, in the long-run the de-concentration effect of work places dominates. It is worthwhile that the effect of population de-concentration is rather strong compared with the de-concentration effect of employees. The conclusion is that the urban centre is keeping its labour force unlike its population. As a consequence commuting and transport related emissions have increased and are still increasing. The conclusion is, that a spatial de-concentration effect of all variables (indicators) under investigation in the Stuttgart Region exists.

The global Moran *I* of the workplace density shows a lower but a steadily increasing spatial autocorrelation. The increase of the spatial autocorrelation during the last twenty years indicates, that within the Stuttgart Region the economic interactions between the certain communities have spread out and slightly increased. The whole area of the Stuttgart Region has become more homogeneous, since the sprawling effect of the workplaces statistically diminish the differences between rather rural and urban communities. An increase of spatial autocorrelation for the population can be stated in the northern and southern part of the outer urban ring and in the eastern part of the hinterland. Nearly all communes of the urban centre and outer urban ring show an increase in its spatial autocorrelation. Therefore, an assembly of correlated and uncorrelated communities within the Stuttgart Region can be identified for the different socio-economic variables under consideration.

The temporal development of all indicators have shown, that the development of the urban centre lacks behind the average growth path, while the outer urban ring and the hinterland are mostly above the average growth path. The conclusion is, that a spatial de-concentration effect of all variables (indicators) under investigation in the Stuttgart Region exist. Especially the spatial patterns of the temporal mean growth rates of employment and population over the last two decades are very scattered and show the main growth centres of the region. Furthermore, the analysis of spatial autocorrelation also identifies an assembly of correlated and uncorrelated communities within the Stuttgart Region for the different socio-economic variables.

5.1.7 General Conclusions of the Statistical Analysis

The statistical analysis shows so far, using shift-share analysis and the *H*-measure, as well as more traditional indicators like density, that the six case study areas can be clustered according to its (de-)concentration behaviour into three groups:

- Milan, Bristol: ***continuing and rather strong spatial de-concentration of activities*** (activities include population and employment), with local specificities such as:
  - Milan: population and employment are out-migrating to areas which are more and more distant from the centre;
  - Bristol: it exhibits a more polycentric pattern, with 2 other urban poles included in the hinterland;
- Stuttgart, Brussels: ***moderate spatial de-concentration of activities, tending towards a stagnation of the pattern***; in the case of
  - Brussels: it seems that the sprawl, as regards population, has slowed down these last years, and even stopped very recently;
  - Stuttgart: sprawl can be stated for population on a low level but in case of employment sprawling seems to stagnate.
- Rennes, Helsinki: ***continuing spatial concentration of activities***: these two metropolitan areas do not exhibit all conditions of urban sprawl, but the growth of the population and of the employment is nevertheless scattered to a certain extent. In both areas, there is in the same time an out-migration of the rural population towards the urban centre and especially the outer urban ring, and a scattered growth pattern, but at a lower level than in the 4 other cities.

With the exception of Bristol, which has a more or less constant spatial autocorrelation, all other study areas develop towards more homogeneous spatial structures.

The pattern of local Moran's *I* indicates that the urban centres of Brussels and Helsinki and some neighbouring communities show strong spatial autocorrelation in population density and density of workplaces. The hinterland, on the other hand provides a very homogeneous and spatially medium high correlated area, whilst the outer urban ring in-between, exhibits very low spatial autocorrelation, since in this active area the transition between urban and rural spatial and economic structure appears. Strong zonal and socio-economic differences are typical and determine this transition area.

The “transition area” in the case studies Milan, Stuttgart and Rennes are not so much extended as in case of Brussels, Helsinki and Bristol. In addition those transition areas are not showing a full undistorted ring like structure, rather a scattered pattern.

In Milan the population density of the city centre and northern communes are highly correlated, also population and employment of communes belonging to the west-southern part of the study area. The development of communes located in the south of the city centre seem to be spatially uncorrelated showing quite different rather scattered behaviour.

As an outcome of the shift-share analysis the average growth rates of the different case study areas as well as its local spatial deviations of the average path are determined. The average growth rates of e.g. population and employment are beside regional effects determined by the national and international socio-economic development.

Comparing the yearly growth rates of population on the national level with the average growth rates of the study areas within the last decade shows, that Rennes and Helsinki are growing 3 times larger than their national level (France and Finland). With respect to population, Helsinki (1.2%) and Rennes (1.4%) show the strongest stable growth rates. In relation to this evolution, these two cities show an over-proportional increase in its commuter flows, but also an increase in its corresponding trip length. In addition, the growth rate of the average income per capita in the study areas of Rennes and Helsinki were above 3% over the last ten years. The growth rate of the Stuttgart Region is also clearly above its national average, but follows rather strictly the national up- and downs of the population growth. The yearly growth rate of population of the Brussels case study is comparable with its national level. Between 1990 and 2000 a small population growth (0,2% per year) in Italy must be stated. Contrary to this development the study area of Milan has lost population (average growth rate per year –0,1%).

The average growth rate of employment and the growth of the GDP on the national level shows that for Rennes the growth of employment is on the same level as the growth rate of the GDP of France. In Brussels the growth of employment follows more or less directly the development of the growth rate of the GDP of Belgium. The annual growth rates in employment (workplaces) are 1.2% and 1.3% in Brussels and Rennes, at least double as high as in the other case cities. A strong increase in the growth of employment in Helsinki and the GDP of Finland must also be stated. The development of the growth rate of employment in the Stuttgart Region exhibits a clear cyclical movement, much more enhanced as the growth rate of the GDP in Germany, which lags behind the EU-15 average. This shows the strong dependence of the Stuttgart Region on export activities. The average growth rate of employment in Milan in the long run is about 0,7%, since 1986 it about 0% and lags behind the GDP growth rate of about 2% of Italy.

Moreover, the results of the shift-share analysis for the urban centre, outer urban ring and hinterland for all case studies are summarised. All case studies show, that the development of the urban centres of all six case studies Milan, Brussels, Stuttgart, Bristol, Helsinki and Rennes are behind the average growth paths over the last decades. This applies for population growth and employment growth. Beside the smaller average growth rates in the urban centres of the six case cities, their corresponding outer urban ring and hinterland are above the average growth rate of the whole region and also in general of the national level. Only Helsinki shows a different development. In the study area of Helsinki the outer urban ring is gaining population and also the urban centre for some years, whereas the hinterland is losing population during the whole time period 1992 – 1998. This means, that a population redistribution towards the outer urban ring must be stated. In case of employment, Helsinki behaves more similar as the other case cities. In case of Stuttgart a strong competition between its hinterland and its outer urban ring with respect to employment must be stated, and between its urban centre and its hinterland in case of population. The outer urban ring of Rennes is growing with a growth rate at least twice as high as in the other case studies, but also the urban centre lags far behind the average growth path. In so far within the study area of Rennes a strong reorganisation of the urban system is under way.

The shift-share analysis indicates that in all case studies the main growth poles of population and employment are situated in the outer urban ring or the hinterland or in both. This leads to an increase of the investigated stock variables (population, employment, commuters, dwellings, residential buildings and directly induced jobs) mainly in the outer urban ring accompanied by an increase of the investigated density variables (income per capita, commuter trip length and house prices) in some not all zones belonging to the outer urban ring and the hinterland. Milan is in so far an exceptional case, since total population and commuters are decreasing (stagnating). However, this could be related to the fact that the conurbation area for Milan is too small.

Urban sprawl can be identified per definition, if the growth of the investigated indicators are more or less scattered over the whole region, with the urban centre of the region as source.

Combining the statistical results of the shift-share analysis and the statistics of the spatial autocorrelation for all the six case studies, together with the more general statements contained in the classical maps, a significant improvement in the quantitative determination of urban sprawl can be given. Essential for this statement is the combination of different statistical methods and the growth of a new innovative measures such as the improved shift-share analysis and the *H*-measure.

Most of the investigated variables in the six case studies show a scattered spatial behaviour on the level of zones (communes) and exhibit spatially scattered growth rates which manifest themselves in growing specialisation of zones, since the pattern of distribution of the growth rates of different activity pattern and variables are often not spatially identical. In other words, the observed development leads to a spatial diversification, to a spatial concentration of activities, e.g. concentration of population, dwellings, residential buildings in several zones (communities), other communes are specialised in working activities (production and services).

The detailed statistical analysis of the six case studies indicates that in the case studies of Milan and Bristol in addition the necessary condition for urban sprawl, namely a strong de-concentration effect must be stated. As one conclusion of the statistical analysis Milan and Bristol are considered as strongly affected by urban sprawl.

In the case studies of Stuttgart and Brussels only a moderate to stagnating de-concentration is observed. The scattered growth rates of all indicators of Stuttgart and the spatial autocorrelation pattern exhibits that urban sprawl in the Stuttgart Region exists but is rather moderate. The spatial re-orientation of Brussels follows more a diffusion pattern (“normal” growth phenomenon of a city) with some implemented scattered structures. Several poles exist in Brussels’ periphery. A sprawl phenomenon of jobs and population can be identified.

In contrary, Helsinki and Rennes still tend to concentrate its activities close to their city centres. In so far both case studies do not exhibit all conditions of urban sprawl. Nevertheless, Rennes and Helsinki show some typical aspects of urban sprawl, e.g. scattered spatial growth of population and of workplaces. However, the spatial autocorrelation analysis and the shift-share analysis shows that for both variables only around the rather small urban centre a high spatial correlation can be found, despite the unbalanced and widely spread growth of population and workplaces in the outer urban ring of Rennes and Helsinki. The whole process gives hints to suppose a superposition of different effects. On the one hand an out-migration of rural population towards the urban centre, and especially the outer urban ring. This process can be better described by a centripetal force. On the other hand Rennes and Helsinki show first typical scattered pattern with a centrifugal part in its driving force, but on a low level compared with the other case studies. The superposition of these two “forces” constitute the spatial pattern of Rennes and Helsinki.

The understanding of the mechanisms behind urban sprawl are of central importance for the whole SCATTER project. The developed statistical framework, tested and applied to the statistical analysis of all six case studies, provides fundamental insights into the nested structure of the interlinked urban and regional system.

ANNEXE: DEFINITIONS OF THE ZONING SYSTEM AND DATA SOURCES

The objective of this annex is to provide a clear definition of the zoning system used in WP3, for the 6 case cities, and secondly, to specify the data sources which were used in the statistical analysis. The precise explanation of the zoning system in the 6 case cities is a necessary condition to be able to make relevant comparisons.

The theoretical zoning system defined for WP3 (urban centre, outer urban ring, hinterland) has been adjusted in the 6 case cities to fit as far as possible the local realities and the local interests as it can be seen in the Table 12

Table 12a : The SCATTER zoning of the six case cities – the urban area or urban region

The urban area or urban region		
SCATTER definition:	**a functional urban area at a large scale or an urban region**	
Local definitions and raw description		
Bristol	Previous County of Avon which is the regional administrative and planning unit	168 municipalities 933,000 inhabitants 1,348 km^2
Brussels	Functional urban area. It contains the city center, the morphological agglomeration, the suburbs and a wider hinterland with secondary cities, like Leuven and Mechelen. It roughly corresponds to the set of communes which are in relation with the central urban area with regard to home-work commuting. It also corresponds to the area which will be served by the future Regional Express Railway. (RER)	135 communes 2,945,000 inhabitants 4,331 squares kilometres
Helsinki	The study area covers postal zones of the Helsinki Metropolitan Area (about 930.000 inhabitants and 520.000 jobs) and other postal zones at its sphere of influence (at the Helsinki region).	489 postal zones 1,624,000 inhabitants 15,236 km^2
Milan	Urban region constituted by the urban pole of Milan, with about 1.200.000 inhabitants and 680.000 jobs, by the suburban ring with mostly industrial districts, in part dismissed, in the north and rural/residential districts in the south, and the rest of the province (except one municipality that is outside study area)	187 municipalities 3,607,000 inhabitants 1,967 km^2
Rennes	Functional urban area. (“aire urbaine” INSEE 99) Group of ”communes” of a single upholder and without enclave, constituted by an urban pole of more than 5000 jobs, and by a suburban ring formed with rural districts or with urban units of which at least 40 % of the resident having a job works in the pole or in the municipalities attracted by this one.	140 basic administrative units (communes) 521,000 inhabitants 2,551 km^2
Stuttgart	The study area should cover an area of about 50km x 80km. The region acquired its own political organisation in 1994, namely the “Verband Region Stuttgart”, consisting of a directly elected regional assembly. Its competences cover regional, infrastructure, landscape and transport planning as well as economic development, local public transport, waste management, and tourism. The central goal of the “Verband Region Stuttgart” is the co-ordination of policies among the 179 independent	179 administrative districts (communes) (NUTS 5) 2,613,000 inhabitants 3,654 km^2

	communities.

Table 12b : The SCATTER zoning of the six case cities – the urban center

The urban centre		
SCATTER definition:	**the central city of the urban area**	
Local definitions and raw description		
Bristol	City of Bristol	27 zones (93 km^2)
Brussels	Brussels-Capital Region (note that the morphological agglomeration spreads beyond the limits of the Region)	19 communes (161 km^2)
Helsinki	City centre of Helsinki	40 zones (40 km^2)
Milan	City of Milan	1 municipality(180 km^2)
Rennes	City of Rennes	1 commune (50 km^2)
Stuttgart	City of Stuttgart	1 commune (202 km^2)

Table 12c : The SCATTER zoning of the six case cities – the outer urban ring

The outer urban ring		
SCATTER definition:	**an outer suburb defined from the daily commuter trips or a political area**	
Local definitions and raw description		
Bristol	All wards of the previous County of Avon with > 40% of workers commuting to the urban center (Guerois and Pumain, 2002)	46 zones (386 km^2)
Brussels	Corresponds to the urban-suburban ring which was included in the study area, in the first Regional Mobility Plan (Plan IRIS) which was set up by the Region in 1991-96	33 zones (919 km^2)
Helsinki	A political area:"Helsinki Metropolitan area" except the central city. This area consists of four municipalities Helsinki, Espoo, Vantaa and Kauniainen.	126 zones (767 km^2)
Milan	A functional area formed by the municipalities that have a high level of relationship with Milan. Such area is defined as "homogeneous" in relation with the environmental critical issues (traffic bans) and is considered in several institutional researches on transport and environment.	38 municipalities (450 km^2)
Rennes	A political area: la "communauté d'agglomération", except the central city.	35 communes (559 km^2)
Stuttgart	The outer urban ring included all communes which are less than 17 km (average commuter length of the Stuttgart Region) away from the central city.	36 communes (759 km^2)

Table 12d : The SCATTER zoning of the six case cities – the hinterland

The hinterland		
SCATTER definition:	**all other communes/municipalities of the urban region**	
Local definitions and raw description		
Bristol	All wards of the previous County of Avon with <40% of workers commuting to the urban center (Guerois and Pumain, 2002)	95 zones (870 km^2)
Brussels	Rest of the functional urban area (excluding the urban centre and the outer urban ring)	83 communes (3,252 km^2)
Helsinki	Rest of the Helsinki urban region (excluding the urban centre and the outer urban ring)	334 zones (14,329 km^2)
Milan	Rest of the Milan Province (excluding the urban centre and the outer urban ring)	148 municipalities (1,336 km^2)
Rennes	Test of the functional urban area (excluding the “communauté d’agglomération”)	104 communes (1,942 km^2)
Stuttgart	Rest of the Stuttgart urban region (excluding the urban centre and the outer urban ring)	148 communes (2,688 km^2)

Data and sources:

Table 13a : The SCATTER data an sources – population by zone

Local definitions & elements			
City	***definition***	***Source***	***Years of the data***
Bristol	100% census count	UK Census	1971, 1981, 1991
Brussels	Total population by commune	INS, census and demographic statistics	1981, 1987, 1991, 1997, 2000 and 2001
Helsinki	Resident population	Population Register Centre, Statistics Finland	1990, 1994, 1996, 1999
Milan	Resident population	Census and Registry data	1971, 1976, 1981, 1986, 1991, 1996, 2001
Rennes	Population without double account (for example, student are only taken into account at one place)	INSEE, census	1962, 1968, 1975, 1982, 1990 and 1999
Stuttgart	Registered population on its first habitation (normally the place where the people live when they are working)	STALA Baden-Württemberg	1976, 1980, 1884, 1888, 1990 - 2000

Table 13b : The SCATTER data an sources – employees at the place of work and/or workplaces by zone

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol	100% census count. employees by place of residence	UK Census	1971, 1981, 1991
Brussels	Total jobs per commune (counted at work place) – excluding self-employees, and people working in the EU institutions Jobs directly induced by the population: include detail trade and services to persons (jobs are counted at the work place)	ONSS (National Social Security Office)	1984, 1987, 1991, 1993, 1996 and 1999
Helsinki	Employed persons registered at the place of work.	Statistics Finland	1990, 1994, 1997, 1999
Milan	Employed persons registered at the place of work: it includes all private and public jobs except 1996 data (only private sectors but agriculture).	Census	1961, 1971, 1981, 1991, 1996, 2001
Rennes	Number of jobs: it includes all private (work for its personal account also) and public jobs	INSEE, census	1982, 1990 and 1999
Stuttgart	Employees liable on social insurance and registered at the workplace	STALA Baden-Württemberg	1976, 1980, 1884, 1888, 1992, 1996, 1997, 1998, 1999

Table 13c : The SCATTER data an sources – number of commuters by zone

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Brussels	Not available	none	
Bristol	10% sample count, multiplied by 10	UK Census	1981, 1991
Helsinki	Commuters from other postal zones (in Finland in general) to certain postal zone.	Statistics Finland	1990, 1993, 1995, 1999
Milan	Employees and students who daily commute to workplaces/schools locate outside the municipality where they have residence. Not used in shift-share analysis because only two data points were available	Census	1981, 1991
Rennes	commuters: employees, who are living in the commune but who are working in an other one in the urban area + commuters living everywhere and who are coming to a commune of the urban area for work have not been considered.	INSEE, census	1975, 1982, 1990 and 1999
Stuttgart	Employees who are living and working in different communes Not used in shift-share analysis because time series are short	Verband Region Stuttgart	1997 - 1999

Table 13d : The SCATTER data an sources – length in km and/or time of commuter trips by zone

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Brussels	Not available	none	
Bristol	10% census count, multiplied by 10	UK Census	1981, 1991
Helsinki	Length of a commuter trip is the shortest distance (between coordinates) between the building in the start point and building in the end point of the trip	Statistics Finland	1993, 1995, 1999
Milan	Travel time needed to reach workplaces/schools. Not used in shift-share analysis because only two data points were available	Census	1981, 1991
Rennes	From the centre of the commune of living to the commune of the working in the urban area.	INSEE, census	1975, 1982, 1990 and 1999
Stuttgart	Not used in shift-share analysis because time series are short	Verband Region Stuttgart	1997 - 1999

Table 13e : The SCATTER data an sources – total number of dwellings

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol, Brussels, Helsinki	Not available	none	
Milan	Stock of dwellings	Census	1971, 1981, 1991, 2001
Rennes	Stock of dwellings per year. Note that the new dwellings are calculated by the difference between number of houses at two dates. It doesn't exactly correspond to new dwellings because it includes some other types of new dwellings like those who were used previously as work place.	INSEE, census	1968, 1975, 1982, 1990 and 1999
Stuttgart	Stock of dwellings	STALA Baden-Württemberg	1976, 1980, 1984, 1988, 1992, 1996, 2000

Table 13f : The SCATTER data an sources – total number of residential buildings

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol, Brussels, Helsinki, Milan, Rennes	Not available	none	
Stuttgart	Stock of residential buildings	STALA Baden-Württemberg	1976, 1980, 1984, 1988, 1992, 1996, 2000

Table 13g : The SCATTER data an sources – average income by capita and by zone

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol, Milan	Not available	none	
Brussels	Yearly income per inhabitant, per commune, in constant prices of 1990. The average income only takes into account the taxable income.	INS – Federal Income Statistics	1984, 1987, 1991, 1996 and 1999
Helsinki	Average income/capita in real prices (changes in the purchasing power has not been taken into account).	Statistics Finland	1990, 1993, 1996, 1999
Rennes	Average level of income by family in the commune	Fiscal sources	1986, 1989, 1992, 1995 and 1998
Stuttgart	Not used in shift-share analysis because data is only on NUTS3 available	Institute of Labour market and Employment Research, IAB, Nürnberg	

Table 13h : The SCATTER data an sources – average residential land price and/or house price by zone

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol, Brussels, Rennes	Not available	none	
Helsinki	Average price paid of one square meter of residential dwellings by zone. In some zones the data was not available because of low number of sales (to protect privacy)	Statistics Finland	1992, 1994, 1996, 2000
Milan	Average price paid in the considered year to purchase one square meter of residential dwellings by zone (in some zones such data was not available because the number of the sales of real estate wasn't relevant).	Borsino Immobilare (CCIAA Milan)	1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001
Stuttgart	Average price paid in the considered year to purchase one square meter of residential dwellings by zone. Not used in shift-share analysis because only one year were available:	Verband Region Stuttgart	1994

Table 13i : The SCATTER data an sources – total area (km^2)

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol	Area for each ward is given as an attribute of the digital boundary file	UKBorders digital boundary file for County of Avon by ward	1981
Brussels	Area by commune	INS	1991
Helsinki	Area of each postal zone calculated from the digital coordinate data	Genimap Oy, digital data	2000
Milan	Area by municipality	Census	1991
Rennes	Area of each "commune" of the urban area	INSEE	1999
Stuttgart	Area by commune	STALA Baden-Württemberg	2000

Table 13j : The SCATTER data an sources – residential area, company and industrial area, traffic, airport, harbour area, revival area and rural area in km^2

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol, Brussels, Helsinki, Milan	Not available	none	
Rennes	Not used in shift-share analysis because only one data point were available	IGN – CORINE-LandCOVER	1994
Stuttgart	Not used in shift-share analysis because only two data points were available	STALA Baden-Württemberg	1996, 2000

Table 13k : The SCATTER data an sources – distance between each zone (from the centre of a zone to the centre of another one)

Local definitions & elements			
City	***Definition***	***Source***	***Years of the data***
Bristol	Matrix indicates distances between centres of wards. Derived using ArcView 3.3 scripts Real Centroid Generator by O. de la Pommeraye and Distance Matrix by Hannah Maoh. Available http://arcscripts.esri.com/	UK Borders digital boundary file for county of Avon by ward	1981
Brussels	Distance as the crow flies between the centres of communes.	Centres of communes from the integrated land-use/transport model (gravity centres with regard to population and economic activities)	1991
Helsinki	The shortest distance between centre coordinates of each postal zone (MAPINFO, centre of gravity method)	Genimap Oy, digital data	2000
Milano	A matrix indicates the distances between barycentres of the municipalities.	Calculation from GIS data	1991
Rennes	A matrix indicates distances between centres of commune	IGN-MAPINFO	1994
Stuttgart	A matrix indicates distances between centres of commune	MAPINFO (Map base: Verband Region Stuttgart)	2000

BIBLIOGRAPHY AND REFERENCES

Anselin, L. (1995). *Local Indicators of Spatial Association – LISA*, Geographical Analysis 27, 93-115

Bahrenberg, G. (1997). *Suburbanisierung – Aufloesung der Stadt in die Region?*, In: Kraemer-Badoni, T., Petrowsky, W. (Hrsg.). *Das Verschwinden der Staedte* (to be printed)

Bahrenberg G., Priebs, A. (1995). *Bremen und sein Umland – eine schwierige Beziehung*, ZWE Arbeit und Region, Arbeitspapier 20/7

Barf, R.A., and Prentice L. Knight III.(1988). *Dynamic Shift-Share Analysis*. Growth and Change 19(2):1-9

Batty, M. (1970). *Models and Projections of the Space Economy: A Subregional Study in Northwest England*, Town Planning Review, 41, 121-148

Batty, M., Longley, P. (1994). *Fractal Cities*, Academic Press, London

Bao S. (1998). *Literature Review of Spatial Data Analysis*, Working Paper, China Data Center, University of Michigan, Ann Arbor, MI

Bao, S., Mark S. H. (1996). *Heterogeneity issues in local measurements of spatial association*, Geographical Systems, Vol. 3: 1-13

Bertuglia, C.S., Clark, G.P., Wilson, A.G. (1994). *Modelling the City*, *Performance, Policy and Planning*, Routledge (London)

Berzeg, K. (1978). *The Empirical Content of Shift-Share Analysis*, Journal of Regional Science 1/38, 463 - 469

Berzeg, K. (1984). *A Note on Statistical Approaches to Shift-Share Analysis*, Journal of Regional Science 24/2, 277 - 285

Birg, H., Filip, D., Hilge, K. (1983). *Verflechtungsanalyse der Bevoelkerungsmobilitaet zwischen den Bundeslaendern von 1950-1980*, IBS-Materialien, 8, Universitaet Bielefeld

Blair, J. P. (1995). *Local Economic Development: Analysis and Practice,*. Thousand Oaks, CA: Sage Publications

Blien U., Wolf K. (2001). *Regional Development of Employment and Deconcentration Processes in Eastern Germany: An Analysis with an Econometric Analogue to Shift-Share Techniques*, in Uddevalla Symposium 2001, *Regional Economies in Transition*, Research Report 02:1, University of Trollhättan/Uddevalla, Sweden

Boekemann D (1982). *Effects of Transportation Investments on Regional Growth: A Theoretical and Empirical Investigation*, Papers of the Regional Science Association, 49, 169-184

Boots B., Tiefelsdorf M. (2000). *Global and local spatial autocorrelation in bounded regular tessellations*, Journal of Geographical Systems 2: 319-348

Bucher, H., Koks, M. (1987). *Die Suburbanisierung in der ersten Haelfte der 80er Jahre,* In: Bundesforschungsanstalt fuer Landeskunde und Raumordnung, 689-707

Christaller, W. (1933). *Die zentralen Orte Süddeutschlands. Eine ökonomisch-geographische Untersuchung über die Gesetzmäßigkeiten der Verbreitung und Entwicklung von Siedlungen mit städtischen Funktionen* (Jena)

Clarke G.P., Wilson A.G. (1987). *Performance indicators and model-based planning 1: the indicator movement and the possibilities for urban planning*, Sistemi Urbani 1: 79-127

Clarke G.P., Wilson A.G. (1987). *Performance indicators and model-based planning 2: model-based approaches*, Sistemi Urbani 2/3: 137-165

Cliff A., Ord, J.K. (1973). *Spatial Autocorrelation*, Pion, London

Cliff, A. D., Ord, J. K. (1981). *Spatial Processes: Models and Applications*, Pion, London

Cressie, N. A. (1993). Chapter 2-3, In *Statistics for Spatial Data*, NY: John Wiley & Sons, Inc.

Cressie, N. A., Hawkins, D.M. (1980). *Robust estimation of the variogram*, I. Journal of the International Association for Mathematical Geology, 12, 115-125

Fotheringham A.S., Charlton M., Brunsdon Ch. (1997). *Two techniques for exploring non-stationarity in geographical data*, Geographical Systems 4: 59-82

Gaschet F. (2002). *The new intra-urban dynamics: Suburbanisation and functional specialisation in French cities*, Papers Reg. Sci. 81, 63-81

Getis, A., Ord, J. K. (1992). *The Analysis of Spatial Association By the Use of Distance Statistics*, Geographical Analysis, 24:189-206

Getis, A., Ord, J. K. (1995). *The Use of a Local statistic to Study the Diffusion of AIDS from San Franciso*, Paper presented at the 42nd North American Meetings of the Regional Science Association International in Cincinnati, November, 1995

Getis, A., Ord, J. K. (1996). *Local Spatial Statistics: An Overview*, In P. Longley and M. Batty (eds.). *Spatial Analysis: Modeling in a GIS Environment*, Cambridge, UK: Geoinformation International

Goodchild, M. F., Haining, R. P., Wise, S. (1992). *Integrating GIS and spatial data analysis: problems and possibilities,* In International Journal of Geographical Information Systems 6(5):407-423

Haag G. (1989). *Dynamic Decision Theory. Applications to Urban and Regional Topics* (Kluwer)

Haag, G. (2002). *Sprawling Cities in Germany*, FrancoAngeli, Milano

Haisken, J. (1996). *Migration and the Inter-Industry Wage-Structure in Germany* (Springer)

Haken, H. (1972). *Synergetics, An Introduction,* Springer, Stuttgart

Hauer, J., Timmermans, H., Wrigley, N. (Eds) (1989). *Urban Dynamics and Spatial Choice Behaviour,* Kluwer

Hayter, R. (1997). *The Dynamics of Industrial Location*. Wiley, 1997/8. pp.435-9

Houston, D. B. (1967). *The shift and share analysis of regional growth: a critique,* Southern Economic Journal. 33(4): 577-581

Kitanidis, P.K. (1997). Chapter 2-5, In *Introduction to Geostatistics*, NY: Cambridge University Press

Koller M., Schwengler, B. (1999). *Revisal and Selection of German Regions for Structural Subsidies* (Arbeitsmarkt- und Einkommensindikatoren). Expert Report presented to the National Commission in March 1999. IAB, Nürnberg

Loveridge, S., Selting, A.C. (1998). *A Review and Comparison of Shift Share Identities*

Lösch, A. (1962). *Die räumliche Ordnung der Wirtschaft*, 3. Auflage (Stuttgart)

Matheron, G. (1963). *Principles of Geostatistics*, Economic Geology, 58, 1246-66

Ord, J. K., Getis, A. (1994). *Distributional Issues Concerning Distance Statistics,* Working Paper, The Pennsylvania State University and San Diego State University.

Perloff H.S., Dunn E.S., Lampard E.E., Muth R. (1960). *Regions, Resources and Economic Growth. Resources for the Future*, Inc., Washington D.C. Lincoln: University of Nebraska Press

Pumain D., Haag G. (1991). *Urban and Regional Dynamics - Towards an Integrated Approach*, Environment and Planning A, 23: 1301-1313

Scherer, F.M.; Perlman, M. (Eds) (1992). *Entrepreneurship, Technological Innovation, and Economic Growth,* The University of Michigan Press

STASA (2001) *Modellgestützte Analyse zur regionalen Entwicklung von Beschäftigungs-volumen, Lohnsummen und Beitragseinnahmen*, study in order of Institute of Labour and Employment Research (IAB), Nürnberg

Stevens, B. H., Moore C.L.. (1980). *A critical review of the literature on shift-share as a forecasting technique,* Journal of Regional Science. 20(4): 419-437

TRANSECON (2002). EC-Project, Contract No GMA1-2000-27049

Weidlich W., Haag G. (1983). *Concepts and Models of a Quantitative Sociology, The Dynamics of Interaction Populations*, Springer Series of Synergetics, Vol.14, Springer

Weidlich W., Haag G. (Eds.) (1988). *Interregional Migration, Dynamic Theory and Comparative Analysis*" (Springer)

Weidlich W., Haag G. (1999). *An Integrated Model of Transport and Urban Evolution,* Springer