SUBURBANISATION OF JOBS AND COMMUTER TRAFFIC: DOES EMPLOYMENT DECENTRALISATION LEAD TO TRAVEL-REDUCING COMMUTING PATTERNS? EMPIRICAL EVIDENCE FROM GERMANY, 1987-2007.

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1. Introduction

During the last couple of decades metropolitan areas have experienced a considerable change of urban structure due to the spatial deconcentration of economic activities to suburban places. The decentralisation of work places has strengthened the importance of the metropolitan periphery as location for economic activities. Nowadays it is considered to be proved empirically that metropolitan areas are structured multinodally (Aguilera/Mignot 2004; Anderson/Bogart 2001; Gilli 2009; Einig/Guth 2005; Giuliano/Small 1991). It is a widespread position in literature that North American and West European agglomerations are changing into polycentric city regions with a multiple set of suburban centres of economic activity (Anas et al. 1998; Burdack/Hesse 2006; Hesse/Schmitz 1998).

While recent empirical research on the interrelations of employment suburbanisation and urban traffic mostly focuses on US (e.g. Yang 2005), French (e.g. Aguilera/Mignot 2004) and Dutch (e.g. Schwanen et al. 2004) urban regions, there is a striking research gap regarding German literature (exceptions are: Albers/Bahrenberg 1999; Einig/Pütz 2007; Siedentop et al. 2005; Siedentop 2007). A popular – but contested – hypothesis is that the emergence of decentralised urban structures leads to a shortening of commuting distances and therefore to a reduction of traffic flows (Crane/Chatman 2004). Given the existence of suburban residential centres, the decentralisation of employment fosters the locations of living and working coming closer together. According to the proponents of this hypothesis, the spatial convergence of jobs and housing is associated with an increase of intra-suburban commuter flows which are usually shorter in terms of time and/or distance[1] (Albers/Bahrenberg 1999; Crane/Chatman 2003, 2004; Dubin 1991; Gordon et al. 1989, 1991; Gordon/Richardson 1997; Levinson/Kumar 1994; Wabe 1967; Weber/Sultana 2005).

As far as we know, convincing evidence for this hypothesis has not been provided for Germany until now. Despite the fact that some empirical work has been done on the travel-efficiency of decentralised metropolitan areas (Hirschfeld 1999; Holz-Rau/Kutter 1995; Holz-Rau 1997; Motzkus 2002) it remains unclear to which extent the inhabitants of suburbia orientate their spatial actions towards suburban centres and thereby leading to a reduction of radial commuting towards the traditional core cities (Motzkus 2002).

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This paper analyses the dynamics of commuter traffic in German agglomerations from 1987 to 2007. First we show that in the time period under consideration employment suburbanisation took place in all German metropolitan areas. Subsequently we analyse whether or not the deconcentration of economic activities has lead to a decrease of commuting. In order to identify how different urban spatial structures affect commuting, monocentric (Hamburg, Munich) and polycentric regions (Frankfurt a.M., Stuttgart) are compared. For each region two steps are carried out: First we describe the spatial development of work and living locations. We ask for the extent of the jobs housing balance which can be considered as a necessary, but not a sufficient condition for a reduction of commuting. In the second step we analyse the change of both the commuting volume and the distances covered by commuters. Following the hypothesis of a reduction of commuting as an outcome of employment suburbanisation a decrease of commuting could be expected.

2. Data

The empirical analysis is based on data on commuter flows (German Census 1987 and German Social Security Statistics 2007) provided by the Federal Statistical Office and the Federal Employment Agency. Both sources contain data at the individual level (i.e. for single persons). The 1987 Census was conducted as a total population survey in the Western German federal states. Hence, data about the inhabitants of the former German Democratic Republic are not included. In contrast, the Social Security Statistics refers to the population of present-day Germany's area and comprise only employees subject to social insurance contribution. Self-employed and public servants are not registered. Thus about 75 % of the labour force is included (Statistisches Bundesamt 2007).

In both data sources a commuter can be identified by the spatial separation of work and housing locations. All persons who do not work and live in the same municipality are considered to be commuters. There is only in- and out-commuting if an employee crosses at least one municipal boundary on his/her way to work. If no boundary crossing occurs, the person is denoted as "local commuter".

In order to analyse commuting flows, the individual data from both data sources can be aggregated at the community level. By doing so, for each municipality the flows to other municipalities as well as the total number of local commuters, workplaces and employed residents[2] can be identified.

Because of data privacy restrictions commuting flows and stock quantities (total number of workplaces and number of employed residents) which have a low stocking are censored. With regard to the Census data this affects all flows and stock quantities greater than zero and smaller than three. In the German Social Security Statistics all flows between zero and ten and all stock quantities between zero and three are subject to censorship.

The data being censored constitutes a considerable restriction for the analysis of commuting, especially if the group of small municipalities with a small number of inhabitants (and in consequence with a small number of workplaces and employed residents) is in focus of interest. A further data restriction is the lack of information about the employees' actual commuting frequencies. Hence, an analysis with regard to daily and weekly commutes and seasonal commuting trips is not possible.

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In order to assure the comparability of the two data sets, only workers, employees and apprentices were included when aggregating the individual Census data at the community level. Self-employed, public servants and conscientious objectors doing community service were excluded. Besides in the Census data the limit up to which data are censored was set to ten for all commuting flows and thereby adapted to the censorship rule of the Germany Social Security Statistics. Because for 1987 no data for East Germany is available, the following analyses are carried out exclusively for West Germany.

3. Delineation of metropolitan areas and choice of study regions

Delineation of metropolitan areas

In order to delineate metropolitan areas, three steps are carried out:

1. Identification of metropolitan cores: First, metropolitan cores, i.e. municipalities which are highly attractive as locations of working and housing, are defined. As criterion a population above 500.000 (31/12/1986) was chosen.
2. Delineation of catchment areas of the metropolitan cores: Following existing studies by Sinz/Blach (1994), Siedentop et al. (2003, 2005) and Siedentop (2007) the catchment areas are delineated. For this purpose, circles around the centroids of the metropolitan cores are drawn. Their outside radius is 60 km plus the average radius of the metropolitan core[3].
3. Identification of second order core cities: Finally, all cities are identified which have above 100.000 inhabitants (31/12/1986) and are located within the delineated catchment areas. They are referred to as second order core cities. Together with the metropolitan cores they constitute the set of large cities. All other municipalities are denoted as suburban municipalities.

Following this delineation approach, seven West German metropolitan areas are identified. The cores of Cologne, Dortmund, Duisburg, Essen and Düsseldorf are assembled to the Rhine-Ruhr region (cf. figure 1).

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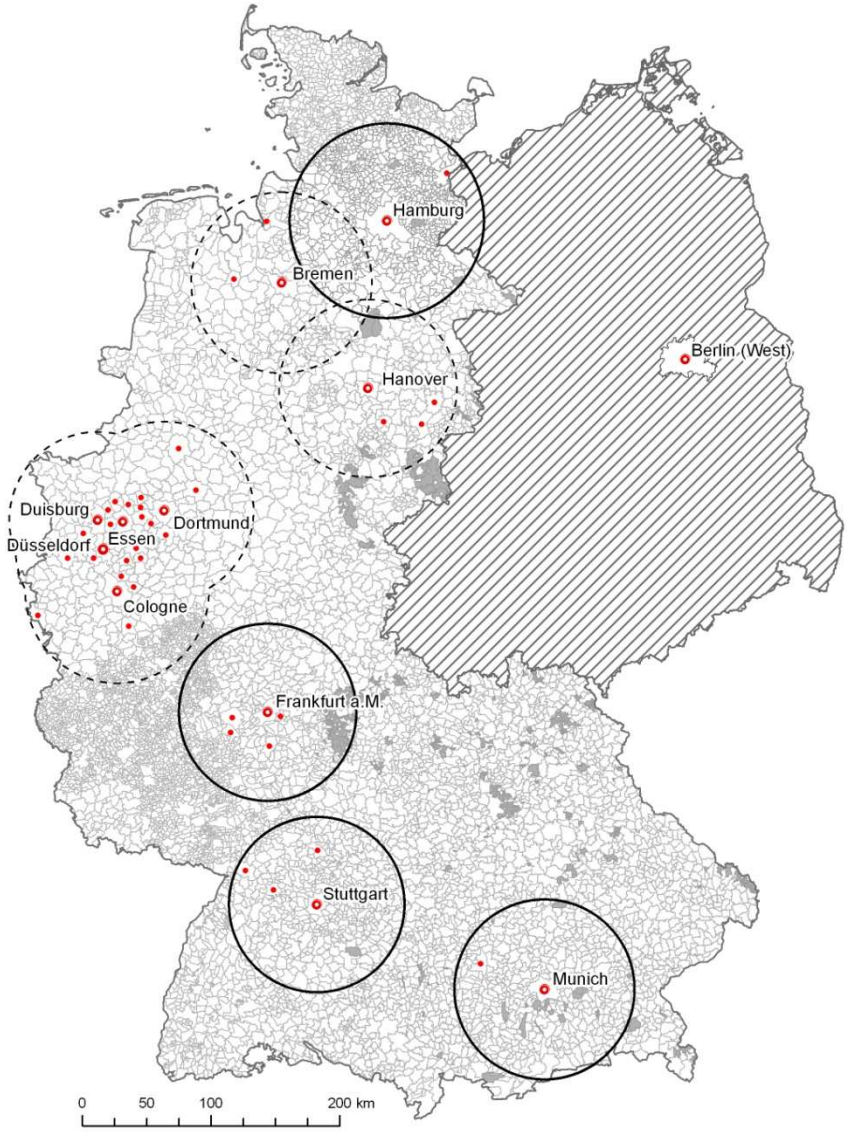
Figure 1: German metropolitan areas



Source: Own illustration based on data from the Federal Agency for Cartography and Geodesy

Cities > 500,000 inhabitants = metropolitan cores

Cities > 100,000 inhabitants = second order core cities

Study regions

Further metropolitan areas

Former national territory of the German Democratic Republic (no data available)

Areas not associated with a municipality (no data available)

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Spatial development of employment

Between 1987 and 2007 suburban municipalities gained importance as locations of employment in all metropolitan areas: The shares of the suburban areas in the regional overall sum of workplaces increased in every single agglomeration (cf. table 1). The process of suburbanisation becomes clearer when comparing the growth rates of the large cities with those of the suburban areas (cf. figure 2): In all cases the values for suburbia exceeds the values for the large cities, i.e. a suburbanisation of employment took place in West German agglomerations in general. The highest growth in suburbia can be observed in the Munich, Hamburg and Bremen regions. The other areas feature significantly lower growth rates (< 10 %). The regions of Hanover, Rhine-Ruhr and Stuttgart are characterised by a definite shrinking of employment in the large cities. Thus the classic type of suburbanisation with growth in the suburban areas at the cost of the traditional centres took place here.

Table 1: Development of employment in German metropolitan areas, distinguished by large cities and suburbia

Region	Workplaces 1987			Workplaces 2007		
	Large Cities	Suburbia	Total	Large Cities	Suburbia	Total
Bremen	346.213	371.148	717.361	344.139	441.389	785.528
	48,3%	*51,7%*	*100,0 %*	*43,8%*	*56,2%*	*100,0 %*
Frankfurt a.M.	802.513	1.130.268	1.932.781	820.137	1.221.091	2.041.228
	41,5%	*58,5%*	*100,0 %*	*40,2%*	*59,8%*	*100,0 %*
Hamburg	790.621	512.320	1.302.941	850.801	593.638	1.444.439
	60,7%	*39,3%*	*100,0 %*	*58,9%*	*41,1%*	*100,0 %*
Hanover	493.331	506.116	999.447	460.613	543.750	1.004.363
	49,4%	*50,6%*	*100,0 %*	*45,9%*	*54,1%*	*100,0 %*
Munich	779.106	693.164	1.472.270	796.919	918.401	1.715.320
	52,9%	*47,1%*	*100,0 %*	*46,5%*	*53,5%*	*100,0 %*
Rhine-Ruhr	2.882.907	1.997.413	4.880.320	2.786.819	2.109.929	4.896.748
	59,1%	*40,9%*	*100,0 %*	*56,9%*	*43,1%*	*100,0 %*
Stuttgart	626.145	1.371.914	1.998.059	600.576	1.478.274	2.078.850
	31,3%	*68,7%*	*100,0 %*	*28,9%*	*71,1%*	*100,0 %*

italics: Share in the regional overall sum of workplaces

Source: Own computations on the basis of data from the 1987 Census and the 2007 German Social Security Statistics

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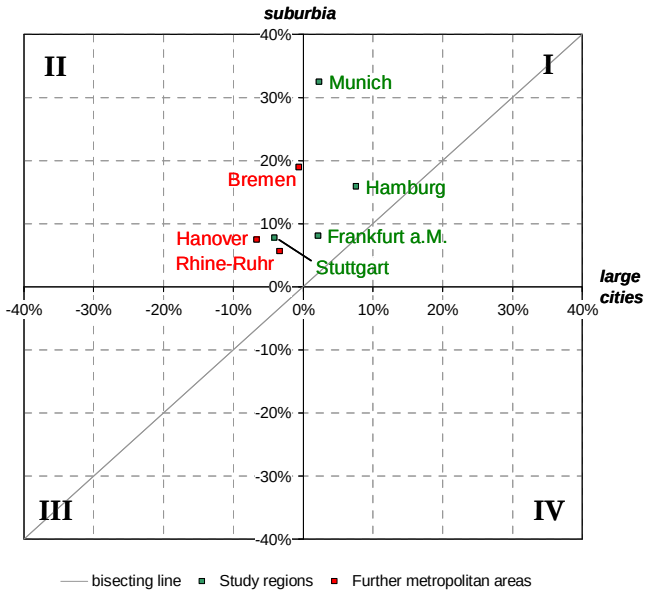
Figure 2: Employment growth rates in the German metropolitan areas, distinguished by large cities and suburban areas



I: growth of employment in large cities and suburbia
above bisecting line: suburbanisation
below bisecting line: (re)urbanisation

II: classical suburbanisation

III: decline of employment in large cities and suburbia
above bisecting line: suburbanisation
below bisecting line: (re)urbanisation

IV: classical (re)urbanisation

Source: Own computations on the basis of data from the 1987 Census and the 2007 German Social Security Statistics

Urban spatial structures of the metropolitan areas and choice of study regions

The agglomerations of Hamburg and Munich are characterised by a rather monocentric structure (up to three large cities; cf. table 2). Frankfurt a.M., Hanover, Rhine-Ruhr and Stuttgart are rather polycentric (more than three larger cities in each region). In order to identify how different urban spatial structures affect commuting, two monocentric (Munich and Hamburg) and two polycentric regions (Stuttgart and Frankfurt a.M.) have been chosen as study regions (cf. figure 1).

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Table 2: Structural data of the German metropolitan areas

	Number of municipalities	Number of metropolitan cores	Number of second order core cities	Number of large cities	Overall area [km²]	Population 2006 [Mio.]
Bremen	297	1	2	3	14.983	2,61
Frankfurt a.M.	669	1	4	5	14.026	5,80
Hamburg	763	1	1	2	16.244	4,34
Hanover	318	1	3	4	14.823	3,46
Munich	471	1	1	2	14.944	4,48
Rhine-Ruhr	632	5	21	26	26.554	15,78
Stuttgart	501	1	3	4	14.606	5,80

Source: Own computations based on data from the Federal Agency for Cartography and Geodesy

4. Dynamics of the jobs housing balance

Many transport researchers argue that the emergence of decentralised urban spatial structures leads to a more balanced spatial mix of work and housing locations in metropolitan regions. In the US-American transportation literature the discussion of this interrelation is associated with the term ”jobs housing balance” (Cervero 1989; Cervero/Landis 1995; Frank/Pivo 1994, Horner 2002; Levinson 1998; Sultana 2002). The following results rely on this hypothesis. The focus is on the change of the jobs housing balance over time.

Indicators

As indicators for working and housing the number of workplaces and the number of employed residents, respectively, are used in the following analyses. In order to measure the spatial mix of these types of land use, for each municipality the balance of the number of workplaces and the number of employed residents is used. A positive balance indicates how many employees have to commute into the municipality to equal the work place surplus which exists because of the spatial distribution of work and housing locations, i.e. determined by the structure of space. Thus a positive balance is a measure for the (spatio-)structural minimum number of in-commuters. Analogously in municipalities with a surplus of employed residents the negative balance indicates the structural minimum number of out-commuters. When aggregating the balances computed at the community level to a total value for the whole region it is necessary to consider that a positive balance in one municipality implies a negative one in another municipality. The consequence is that each commuter crossing municipality boundaries is allocated twice (in both the point of origin and destination). Hence, in order to not overestimate the minimum number of employees who need to commute for spatio-structural reasons, the balance needs to be divided by two. Then the aggregated value for the whole region is:

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Structural Minimum Number of Commuting Activities:

$$SMNC = \sum_{i=1}^{n} \frac{\left| WP_i - ER_i \right|}{2} \qquad (I)$$

WP: Work places; ER: Employed residents
n: Number of municipalities within the region

Analogously to the considerations for the SMNC the minimum number of work places and employed residents indicates the theoretical maximum number of local commuters. The total value for a metropolitan area is computed as follows:

Structural Maximum Number of Local Commuters:

$$SMNLC = \sum_{i=1}^{n} \min\left(WP_i ; ER_i\right) \qquad (II)$$

WP: Work places; ER: Employed residents
n: Number of municipalities within the region

In order to compare the SMNC's of different regions and/or at different points in time, it is standardised by dividing by the number of jobs which equals the mean of the number of work places and the number of employed residents (cf. formula III).

Intensity of the Structural Minimum Number of Commuting Activities:

$$SMNCI = \frac{\sum_{i=1}^{n} \frac{\left| WP_i - ER_i \right|}{2}}{\sum_{i=1}^{n} \frac{WP_i + ER_i}{2}} = \frac{\sum_{i=1}^{n} \left| WP_i - ER_i \right|}{\sum_{i=1}^{n} WP_i + ER_i} \qquad (III)$$

WP: Work places; ER: Employed residents
n: Number of municipalities within the region

The SMNCI can be interpreted as the spatio-structurally determined minimum share of a region's jobs, in which commuting is unavoidable. It can take values from 0 to 1, where 0 implies a total jobs housing balance, 1 a total housing **im**balance.

Results

In 2007 in all regions more employed people had to commute due to spatio-structural reasons than in 1987. For the agglomerations of Munich and Stuttgart the SMNCI values at both points in time amounts to about a fifth (cf. table 3). In the monocentric region of Hamburg there is significantly more balance (SMNCI rises from a sixth in 1987 to just under a fifth in 2007). The polycentric region of Frankfurt a.M. shows a clearly less balanced structure (SMNCI: about 25 %). SMNCI increased in all study areas, i.e., with regard to the spatial dimension jobs and housing became more **im**balanced. This process seems to be somewhat stronger in the two monocentric regions than in the polycentric areas which find its expression in higher SMNCI growth rates.

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Table 3: Development of jobs housing balance measures in the study regions

Region	SMNLC 1987	SMNLC 2007	SMNC 1987	SMNC 2007	SMNCI 1987	SMNCI 2007	Δ SMNCI 1987-2007 [%]
Munich (mc)	1.173.112	1.298.987	277.807	352.707	0,191	0,214	+11,5%
Hamburg (mc)	1.091.363	1.146.693	207.025	261.680	0,159	0,186	+16,5%
Stuttgart (pc)	1.597.679	1.617.035	395.823	434.473	0,199	0,212	+6,7%
Frankfurt a.M. (pc)	1.471.338	1.473.153	467.440	523.913	0,241	0,262	+8,8%

mc: monocentric; pc: polycentric

SMNLC: Structural Maximum Number of Local Commuters

SMNC: Structural Minimum Number of Commuting Activities

SMNCI: Intensity of the Structural Minimum Number of Commuting Activities

Source: Own computations on the basis of data from the 1987 Census and the 2007 German Social Security Statistics

5. Dynamics of commuting

The temporal development of commuter traffic is analysed in two steps: First, the commuting volume is examined. This serves to find out how the share of commuters changed over time. In a second step the analyses focus on the average distances covered by commuters.

5.1 Commuting volumes

Indicators

In order to measure how many employees commute, the number of commuting activities (C; formula IV) and the intensity of the commuting volume (CI; formula V) can be calculated. Analogously to the jobs housing analyses, in- and out-commuters are allocated each half to their locations of origin and half to their destinations. Hence, they can be considered as half jobs and half employees, respectively.

The CI's codomain reaches from 0 – there are no in- and out-commuters, all trips are local commuting activities – to 1 – there are no local commuting trips, all employed residents are out-commuters, all workplaces are occupied by in-commuters.

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Number of commuting activities:

$$C = \sum_{i=1}^{n} \frac{IC_i + OC_i}{2} \qquad \text{(IV)}$$

IC: In-commuters; OC: Out-commuters
n: Number of municipalities within the region

Intensity of the commuting volume (based on Holz-Rau/Kutter 1995):

$$CI = \frac{\sum_{i=1}^{n} IC_i + OC_i}{\sum_{i=1}^{n} WP_i + ER_i} \qquad \text{(V)}$$

IC: In-commuters; OC: Out-commuters
WP: Work places; ER: Employed residents
n: Number of municipalities within the region

Results

The trend of a decreasing number of local commuters – known at the latest since the 1950 German Census – continued between 1987 and 2007 in the four study regions. In contrast the number of commuting activities from one municipality to another rose in the period under consideration. Thus, in all regions the intensity of the commuting volume increased (cf. table 4). The levels observed in Frankfurt a.M. and Stuttgart exceeds the levels of Munich and Hamburg. The CI's[4] growth rates are higher in the monocentric agglomerations, i.e., there seems to be a slight process of convergence between the mono- and the polycentric regions.

Table 4: Dynamics of the commuting volumes in the study regions

Region	Local Com-muters 1987	Local Com-muters 2007	C 1987	C 2007	CI 1987	CI 2007	Δ CI 1987-2007 [%]
Munich (mc)	845.953	666.367	604.966	985.327	0,417	0,597	+43,1%
Hamburg (mc)	865.959	706.682	432.429	701.691	0,333	0,498	+49,6%
Stuttgart (pc)	1.066.212	700.346	927.290	1.351.162	0,465	0,659	+41,6%
Frankfurt a.M. (pc)	960.141	620.014	978.637	1.377.052	0,505	0,690	+36,6%

mc: monocentric; pc: polycentric; C: Number of commuting activities; CI: Intensity of the commuting volume

Source: Own computations on the basis of data from the 1987 Census and the 2007 German Social Security Statistics

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5.2 Commuting distances

Measuring

In this chapter the commuting distances of employees living and working in the respective region are analysed. Because information about the real distances travelled by commuters are missing in the data sets, the distances are – following existing studies – represented by the straight line distances between the centroids of the working and housing municipalities (cf. Einig/Pütz 2007; Siedentop 2007). The distances covered by local commuters are estimated as well. First, for each municipality its area is taken as a circle. Then the average local commuting distance is taken as the product of this circle's radius and a municipality size-specific factor (cf. table 5). Generally, only those employees are included in the following analyses which both live and work within the respective region.

Table 5: Local commuting factors by municipality size classes

Municipality size class [Thousand inhabitants]	Local commuting factor*
up to 2	1,24
2 to 5	1,00
5 to 10	0,66
10 to 20	0,58
20 to 50	0,63
50 to 100	0,63
100 to 200	0,68
200 to 500	0,63
500 to 1000	0,59
1000 and more	0,52

**: estimated from data from the 1989 KONTIV survey; the real distances given by the interviewed persons have been converted into straight line distances*

Source: Own computations based on data from the 1989 KONTIV survey and from the Federal Agency for Cartography and Geodesy

Results

Table 6 shows the changes of the commuting distances estimated as described above: In 1987 the average distances covered by an employee living and working in the respective region were the highest in the agglomerations of Hamburg and Munich. Frankfurt a.M.'s employees commuted somewhat shorter ways than Munich's employees. The Stuttgart region's values differ significantly to the other regions. In 2007, Frankfurt a.M. came somewhat closer to the monocentric regions. The pattern of Stuttgart still was clearly less travel intensive. The relative growth is higher for the two polycentric regions than for Munich. In the Hamburg metropolitan area the relative increase is considerably lower.

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Table 6: Dynamics of the average commuting distances within the study regions (one way)

Region	Average distance 1987 [km]			Average distance 2007 [km]			Δ 1987-2007 Total*	
	Local commuters	Commuters	Total	Local commuters	Commuters	Total	[km]	[%]
Munich (mc)	4,1	17,0	9,0	4,2	19,0	12,0	+2,9	+32,1%
Hamburg (mc)	6,1	18,4	9,9	6,5	20,8	12,4	+2,5	+25,4%
Stuttgart (pc)	3,2	11,9	7,0	3,3	13,5	9,4	+2,5	+35,6%
Frankfurt a.M. (pc)	3,4	14,1	8,5	3,5	16,4	11,7	+3,2	+37,8%

mc: monocentric; pc: polycentric

**: based on unrounded values; thus it does not equal the difference between the given values for the average distances 1987 and 2007 in all regions*

Source: Own computations on the basis of data from the 1987 Census, the 2007 German Social Security Statistics and the Federal Agency for Cartography and Geodesy

6. Summary and outlook

The hypothesis that employment deconcentration leads to a reduction of commuter traffic cannot be verified for the study regions in the period 1987 to 2007. In all agglomerations a process of working and housing locations becoming more (spatially) imbalanced took place. Thus the urban spatial structural pre-conditions for a reduction of commuting deteriorated. Accordingly an increase of cross-municipality commuting volumes as of the commuting distances can be observed. However, this increase is significantly higher than could be expected based only on the development of the jobs housing imbalance.

The comparison between monocentric and polycentric regions shows no unambiguous differences regarding the jobs housing distribution: For Munich and Stuttgart the values are at about the same level. Hamburg is less imbalanced, Frankfurt a.M. considerably more. The process over time is stronger in the monocentric than in polycentric agglomerations.

The polycentric metropolitan areas tend to be more travel-efficient compared to the monocentric ones. Indeed their commuting volumes are substantially higher than in the monocentric regions, but they show slightly (Frankfurt a.M.) and very significantly (Stuttgart) lower commuting distances, respectively. This corresponds to the position widespread in the German spatial science literature that polycentric areas are more travel-efficient (cf. Einig/Pütz 2007; Motzkus 2002; Schmitz 1992; Sinz/Blach 1994;

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Siedentop 2007; Siedentop et al. 2003; Siedentop et al. 2005). Looking at the dynamics over time a contrasting tendency seems to be obvious: The distances rose somewhat more in Frankfurt a.M. and Hamburg than in Munich and Hamburg.

The results for the four study regions presented in this paper give first impressions for the overall situation in Germany. In order to broaden the empirical basis and to allow more universal conclusions, additional analyses on the correlation between spatial development of employment, jobs housing (im)balance and commuting will be necessary. An extension of the used analytical concept to other regions and for an additional point of time (Census data from 1970) will be conducted. Additionally it is intended to use road network distances instead of straight line distances to estimate the distances covered by commuters more precisely.

Acknowledgements

We would like to thank the German Research Foundation (DFG) for the funding of this work. An earlier version of this paper was presented at the mobil.TUM 2009 Conference; a similar version was presented at the Swiss Transport Research Conference 2009.

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Notes

[1]In the literature this position is referred to as “co-location hypothesis“. For a more comprehensive theoretical discussion see Kim (2008) and Schwanen et al. (2001, 2004).

[2]In this paper the terms “workplaces“ and “employed residents“ are used synonymously to „Beschäftigte am Arbeitsort“ and „Beschäftigte am Wohnort“, respectively, the terms from German Social Security Statistics.

[3]In order to take into account the different sizes of the metropolitan cores’ municipality areas, the area of each metropolitan core is assumed to be a circle. Then this circle’s radius is added to the basic 60 km radius resulting in the outside radius of the metropolitan area. Thus for the Hamburg region the additionally added radius is 15,5 km and the overall radius 60 km + 15,5 km = 75,5 km. The outside radiuses for the other areas are: Bremen: 70,2 km; Cologne: 71,4 km; Dortmund: 69,4 km; Düsseldorf: 68,3 km; Duisburg: 68,6 km; Essen: 68,2 km; Frankfurt a.M.: 68,9 km; Hanover: 68,1 km; Munich: 70,0 km; Stuttgart: 68,2 km.

[4]A similar indicator has been suggested by Thomas (1969). His “Independence-Index” equals the ratio of the number of local commuters and the sum of in- and out-commuters (for examples see also Cervero 1995; Cervero 1996; Siedentop 2007). It is usually computed at the community level, but can also be adapted to be used at the regional level. Its values are the higher, the higher the number of local commuters and the lower the sum of in- and out-commuters is. Hence, its theoretical codomain is $[0;\infty[$. As a result the index is not comparable immediately to other commuting indicators – which mostly can take values within the interval [0;1]. This disadvantage is avoided when using the CI.

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