SIMULATION OF FIRMS TO DISCOVER PLANNING POLICIES REDUCING URBAN SPRAWL OF JOBS

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Abstract: This paper presents a simulation model that analyses alternative strategies for limiting the suburbanization of employment. It applies microsimulation by representing every business individually. The model was implemented in the urban region of Dortmund in Germany. Zoning, transportation and tax-related policies are tested and compared to estimate their likely success in fostering a sustainable land use development. The analyses reveal that a regionally coordinated approach would be the most successful policy option for reducing the urban sprawl of employment. Benefits and drawback of using microsimulation for business modelling are discussed.

Keywords: Businesses, firms, employment, microsimulation, micro data, integrated modelling

1. INTRODUCTION

Whereas urban sprawl of housing is a common topic among urban planners, the shift of employment from central cities to the suburbs receives much less attention. Every year, 8 percent of all employment is relocated, either because one firm goes out of business and a new firm is established elsewhere or because an existing business decides to relocate (Birch 1984). In many regions, this fluctuation leads to a continual employment shift from central cities to the suburbs. The impacts on urban development are substantial. Commonly, greenfield development in promoted in the suburbs coincidently with growth of derelict sites in central cities. Since it is more expensive to reactivate a brownfield because of real or perceived contamination a lot of non-residential floorspace is rather built on greenfield than on brownfield sites (Bowman and Pagano 2004: 143-145). Loss of tax revenue may be another impact of employment sprawl for selected cities. Employment shift towards suburban location generally increases the car dependency of employees for their daily commute.

However, this notable fluctuation of 8 percent of all jobs has a great potential for designing urban and regional development. If this job turnover is steered towards urban development goals more sustainable cities and regions may be created. As location decisions cannot and should not be enforced by governmental institutions, a sophisticated combination of incentives and restrictions is required to influence entrepreneur's location decisions. Urban and regional planning constantly strives to develop successful strategies to reduce this urban sprawl of employment, so far with little success.

A simulation model serves to test alternative policies and to estimate their likely impact before these policies are realized. For this reason, a model has been developed that simulates location decisions and development of firms. It is designed as a microsimulation, i.e. every business establishment is modelled individually. Furthermore, the business simulation is integrated in the land-use/transport model ILUMASS to represent the interactions between employment, population and transport.

2. MODEL INTEGRATION

The ILUMASS (Integrated Land-Use Modelling And Transportation System Simulation) was a joint research effort in cooperation of five Institutes at German Universities under coordination of the Transport Research Institute of the German Aerospace Centre (DLR). The Institute of Spatial Planning at University of Dortmund was in charge of developing the land use simulation. One part of this task was to simulate location decisions of firms, which is described in this paper.

The ILUMASS model approached every step from land use to activities to transport to environment by microsimulation. This resulted in long run times reducing the number of model runs to exploratory work. Even though this was an important scientific achievement, this model could not be used for policy advice. To reduce the complexity significantly, the research group in Dortmund headed by Michael Wegener decided after completion of the ILUMASS model to replace the microscopic transport simulation with an aggregate transport model. This simplification allowed running the model within approximately one hour. Due to this short execution time it became

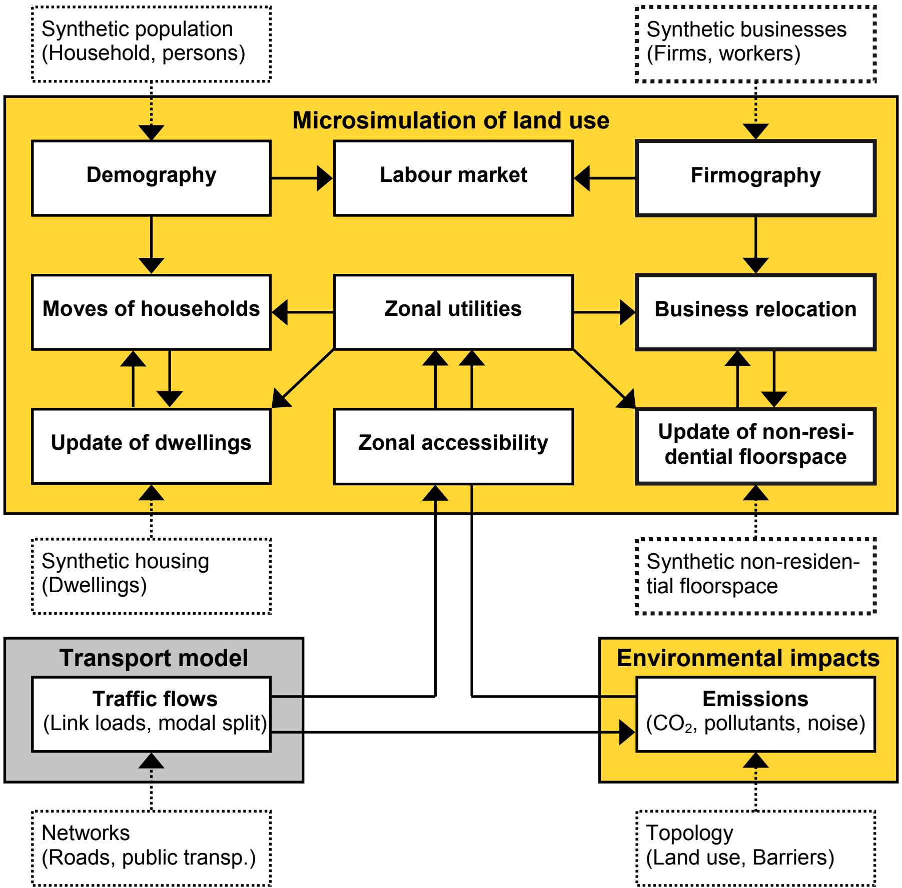


Figure 1: Model overview

possible to perform hundreds of model runs for testing, calibration, and validation. Figure 1 shows a flowchart of this approach.

The larger box in the middle represents the entire microscopic land use model. Every box with a dotted line shows microscopic input data. The left part of the land use model shows the simulation of population and dwellings. Demography simulates demographic changes, such as aging, marriage/cohabitation, birth of children, divorce/separation, children leaving the parental household or death. The module moves of households simulates spatial changes of the population. Update dwellings serves to build, modernize or demolish dwellings. On the right side of the land use model the business simulation is shown in bold boxes. Similarly as for population, the firmography module simulates the demography of firms, i.e. birth, growth, decline and closure. The business relocation module simulates spatial changes of firms, and the module Update of non-residential floorspace represents developers who build new floorspace. The labour market connects persons and firms by hiring or releasing employees. All location decisions heavily depend on zonal utilities. These are calculated among others by accessibilities provides by the transport model and environmental quality provided by the module called environmental impacts. A complete description of this model is presented and published at this CUPUM conference by Moeckel et al. (2007).

The model has been applied to the urban region of Dortmund in Western Germany. Figure 2 shows the study area of the land use model. This region covers the city of Dortmund and 25 surrounding municipalities. The area has a population of 2.6 million and approximately 1.0 million jobs. The region is subdivided into 246 zones. This zonal system is too coarse to represent spatial interactions at the micro level (Spiekermann and Wegener 2000). Therefore, raster cells of 100 by 100 metres are used to represent micro locations. The total area is covered by approximately 207,000 such raster cells.

Fig. 2: The Dortmund study area

Important work on microsimulation of firms has been done in particular by de Bok (2007, De Bok and Sanders 2005), Kahn et al. (2002), Landis and Zhang (1998a, 1998b), Maoh and Kanaroglou (2005), Waddell and Ulfarsson (2003) and van Wissen (2000, 2004). A comprehensive overview of these models can be found in Wegener (2004) and Timmermans (2003).

3. SIMULATION MODULES

The simulation of business is designed as a microsimulation of single business establishments and therefore requires micro data. Section 3.1 describes the applied methods to synthesize firms and non-residential floorspace. Every year, the firmography module and the business location search module are run to update the employment. These modules are described in sections 3.2 and 3.3, respectively. Firmographic events are simulated by Markov models using transition probabilities to simulate the outcome of events. Business relocation, in contrast, is simulated by Logit models (Domencich and McFadden 1975: 53-69). Specifically, Markov models are used if the reasoning of the business for a certain event is not of further interest for policy analysis. As no policies are tested that try to influence business growth or decline these firmographic events are simulated by Markov models. Logit models, instead, allow representing a behaviourally rich decision processes that are influenced by habits, uncertainty, or prejudices. Since policies aiming at influencing location decision are tested, business relocation is simulated by Logit models.

All events that can happen to a firm, namely business relocation, birth, growth, decline and closure, are simulated in random order for all firms. Thus, it is possible that one firm grows and relocates in the same simulation period. Other firms may relocate and be closed in the same year.

3.1 Micro data

Microsimulation models require micro data about the single individuals represented by the model. This micro data generally is unavailable from public registers. As the privacy of individuals needs to be respected, only aggregate data are available, commonly. To be able to run a microsimulation synthetic micro data have to be generated from the available aggregate data. Basically, there are two methods called Iterative Proportional Fitting and Monte-Carlo Sampling that are used to synthesize micro data.

Iterative Proportional Fitting is a simple method that generates multi-dimensional data from one-dimensional data. For instance, if there are data available about number of firms by size and data about number of firms by industry Iterative Proportional Fitting can be used to generate a two-dimensional table of number of firms by size and by industry. Not all industries have the same size distribution. For example, the average architect’s office is likely to be smaller than the average firm in heavy industry. To take into account this differentiation it is advisable to use a seed either based on theory or micro data of another region to direct the Iterative Proportional Fitting to a more likely distribution. This method was used extensively to prepare multi-dimensional data for Monte-Carlo Sampling.

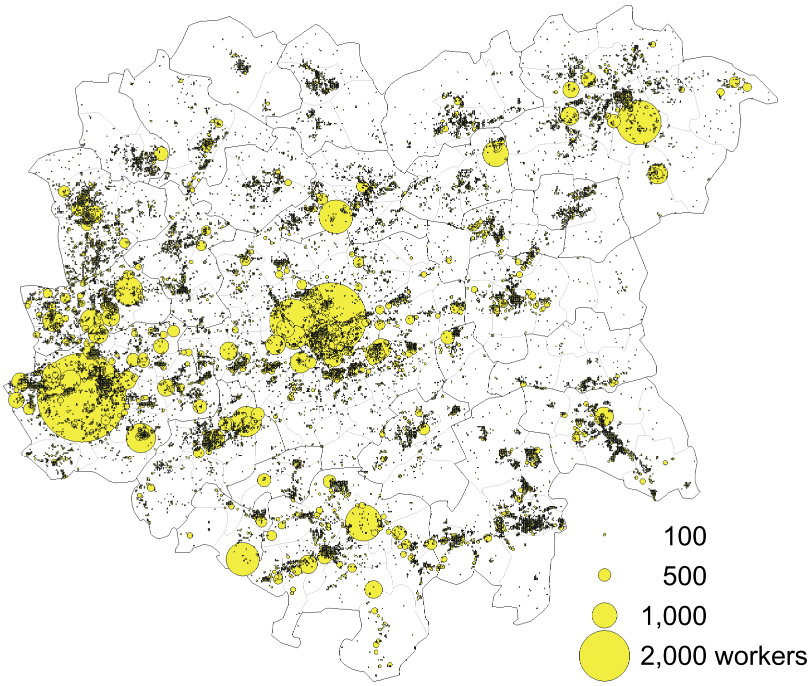


Fig. 3: Firms by size

The Monte-Carlo Sampling is used to select features for each business. Based on the probabilities provided by Iterative Proportional Fitting, every business is selected separately and enriched with individual characteristics. The following details are generated for every synthetic firm in the study area: business type (out of 44 types), number of employees by qualification (distinguishing half-time, full-time and telework employees), number of vacant job positions by qualification, size of site in square metres, raster cell coordinates of occupied floorspace, type of occupied floorspace (out of 4 types), and number of parking spots. Figure 3 shows all firms by size within the study area. The micro data represents single business establishments. Dependencies to remote headquarters or interaction with different branches of the same chain are not represented. This simplification was necessary due to lack of both theory and data and is assumed to be an insignificant shortcoming in this context.

Businesses need to be located in non-residential floorspace. Likewise, no micro data is available from public registers. Instead, synthetic non-residential floorspace is generated based on digitised land use, office parks, retail concentrations, and land prices. The generated floorspace stock distinguishes the four types agriculture area, industrial, retail, and office floorspace. Both occupied and vacant floorspace is stored by micro location on raster cells. The rent per floorspace type and raster cell is estimated based on digitised land values that have been interpolated to raster cells by inverse distance weighting.

3.2 Firmography

The firmography module deals with non-spatial changes a firm may experience. These events include birth (i.e. new establishment), growth, decline and closing. Businesses that are newly established are created in this module and then handed over to the location search module, which is described in section 3.3 in more detail.

Firmographic changes happen based on two main factors, namely economic restructuring and economic cycles. Economic restructuring describes the general trend of declining and growing business types. This development is given exogenously and set to a general decline in most manufacturing business types and growth of most service industries. Economic cycles, in contrast, influence all business types in the same direction, though some are more responsive to economic cycles than others. This overall development of the economy is given exogenously, too, by a sinuous curve with peaks every five years.

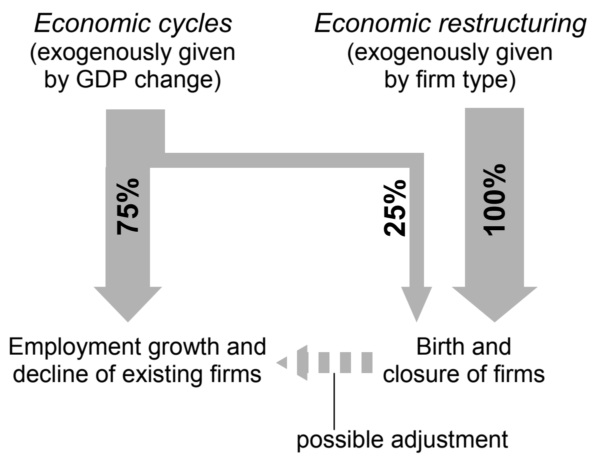


Fig. 4: Rationale of simulating firmography

On the other hand there are two event groups that react on changes of the economy, namely growth/decline and birth/closure. Figure 4 shows the rationale how economic restructuring and economic cycles affect growth/decline and birth/closure. Whereas economic cycles influence both growth/decline and birth/closure, economic restructuring pushes births and closures only. Economic restructuring is not assumed to influence business size directly. It is not plausible that growing business types result in larger business sizes, and that declining business types would result in smaller businesses sizes. Instead, economic restructuring is reproduced in the model by influencing the number of businesses born and closed. The percent values shown in figure 4 are based on literature review (in particular Birch (1983: 25-26)) and set exogenously.

The dashed arrow in figure 4 indicates that some adjustment is possible. This is necessary as sometimes employers misjudge the current economic conditions. Although the number of firms that have to be born and that have to close can be calculated exactly at the beginning of each simulation period, the actual firm closing or opening with a specific firm size is selected by Monte-Carlo simulation. Hence, sometimes birth and closure result into too many employees lost or too many employees gained. In reality, this adjustment happens constantly. For instance, if too many retail facilities open, the turnover of each will decrease and employees have to be laid off. This is the concept of carrying capacity explaining that the economy is able to sustain a certain workforce per business type in its current condition (Hannan and Freeman 1989, Hannan and Carroll 1992: 29-30). The model reproduces this adjustment by influencing growth and decline of existing firms positively or negatively to reach the given regional control totals set by economic restructuring and economic cycles.

Growth and Decline

Every simulation period, each business is checked if it increases or reduces the number of employees, affected by economic cycles and economic restructuring. The size of the site is not changed if the number of employees changes, the firm stays at the same site. However, if the change of employment is large the firm is likely to decide to move either the same simulation period or in the near future. The actual growth and decline of a single business is determined by a normal distribution as shown in figure 5. Depending on economic restructuring and economic cycles the overall employment change is calculated by business type. The grey line shown in figure 5 assumes that there is no overall change of employment. Single firms may grow or decline nevertheless. The probability distribution in figure 5 shows that most firms do not change or change a little bit only, whereas a few firms are selected to grow or decline a lot. If economic restructuring and economic cycles lead to an overall strong employment growth the normal distribution is shifted to the right as shown by the red line in figure 5. A few firms may decline regardless of this overall growth, but the majority of firms is likely to grow. The blue line in figure 5 shows the normal distribution shifted to the left to represent an overall employment decline.

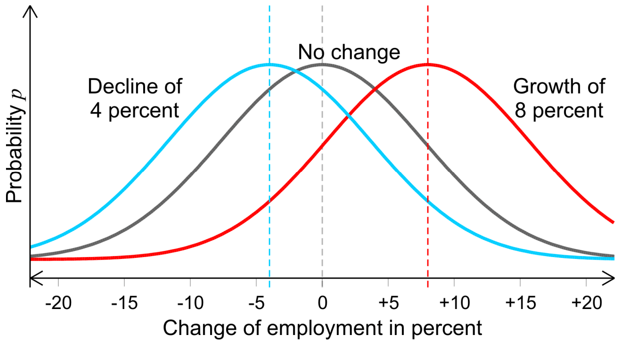


Fig. 5: Probability for growth and decline

To ensure that the overall employment change is reached the centre of the normal distribution shown in figure 5 is adjusted constantly depending on actual growth and decline of other firms:

$$p_{bn} = \exp\left(-\beta \cdot \left(n - \frac{\Delta E_k''}{B_{k_b}} \right)^2 \right) \tag{1}$$

p_{bn} probability for business *b* to grow or decline by *n* percent

$\Delta E_k''$ remaining net change of employees in firms of type *k* of firm *b* due to growth and decline (updated constantly)

B_{k_b} remaining number of businesses of type *k* of firm *b* to simulate (updated constantly)

β parameter (currently set to 0.05)

As no appropriate data was available, the parameter was set heuristically after several trial runs. The current setting seems to represent the fluctuation of growing and declining firms plausibly.

Birth and Death

Within a given business type the employment gain or loss through birth and closure of businesses is given by economic restructuring and economic cycles. The net employment change has to be translated into number of births and number of closures. Industry-specific birth and death rates are applied to receive a real-world fluctuation. The maximum number of workers in firms born or closed is set to 100. If birth or closure of very large firms were simulated endogenously, the impact of policies would be overshadowed by these large born or closed firms as they are simulated stochastically. To exclude such historic events the maximum size for firms born or closed endogenously is set to 100 workers. If desired, establishments or closures of larger firms can be set exogenously to ensure that the larger firm locates or dies in the same zone in every scenario.

The number of employees of new firms and firms that are selected to close is estimated by an exponential function. For birth the size is multiplied with the existing size distribution per business type to keep the initial share of different sizes of business type *k* approximately stable.

$$p_{ks} = \exp(-\beta \cdot (s - \gamma)) \cdot B_{ks} \qquad (2)$$

p_{ks} probability for a new business of type *k* to have size *s* (with $0.5 \leq s \leq 100$)
B_{ks} number of existing businesses of type *k* with size *s*
β coefficient (currently set to 0.1)
γ coefficient (currently set to 20)

The number of births calculated for the entire study area is distributed to zones based on the number of existing firms per zone and number of highly educated persons per zone. This resembles the incubator hypothesis (where there are many businesses many new firms are founded) and the education hypothesis (persons with some degree of higher education are more likely to establish a new business). The zone a business birth is assigned to is not binding (except for those firm births that are set exogenously as historic events). Instead, a zone assigned to a business birth is the zone from where the new business starts looking for a location. For instance, a business that is born downtown may find its first location in the suburb due to more attractive site utilities, such as lower rents in the suburb. This appears to be close to real business development. Spin-offs of universities, for instance, do not locate exclusively in the university neighbourhood; however, some nearness to the starting location is given. In section 3.3 the location decision of new firms is described.

The number of businesses to be closed is calculated by multiplying the number of business in zone *i* of business type *k* with the closing probability based on economic restructuring and economic cycles. In contrast to business births where the zone is only the starting point for location search, the number of closures by zone has to be executed in the given zone. To calculate the probability for a firm to be closed equation 2 is used without the multiplier B_{ks}. Based on this probability the correct number of firms to be closed is selected in every zone. Only firms with 100 workers or less are considered for closing. Larger firms to be closed can be set exogenously to make sure that the same historic events appear in every scenario. Workers of closed firms are set unemployed and become available to be hired by other firms. The non-residential floorspace the closing firm occupied is made vacant immediately and added to the floorspace market.

3.3 Business relocation

Businesses that are newly established require finding a location. Other firms that are unsatisfied with their current location, which commonly happens if the firm has grown or declined a lot, search for alternative locations to relocate (Pieper 1994: 86-87). The business relocation module applies a Logit model to find a location within the available floorspace market.

In general, firms hesitate to relocate. The costs are high, and the risks connected with relocation are substantial in terms of losing the link to customers, employees, collaborating partners, etc. Thus, a firm is unlikely to move only because alternative locations are more attractive. In fact, most businesses will not consider relocating at all unless the firm is notably unsatisfied with its current location. This assumption is supported among others by Bade (1983: 283-286). Hence, in the model only those firms that are unsatisfied with their current location are considered for relocation.

Figure 6 shows that the first step of business relocation is finding a threshold value. This value serves to estimate if a business considers moving at all. In line with the hypothesis that firms hesitate to move only those firms are treated for relocation that actually are unsatisfied with their current location. This threshold value is calculated separately for every business type and stands for an average minimum location utility. The current location satisfaction of every business is checked and the threshold value is set to a level that ensures that the exogenously given number of firms moves every year.

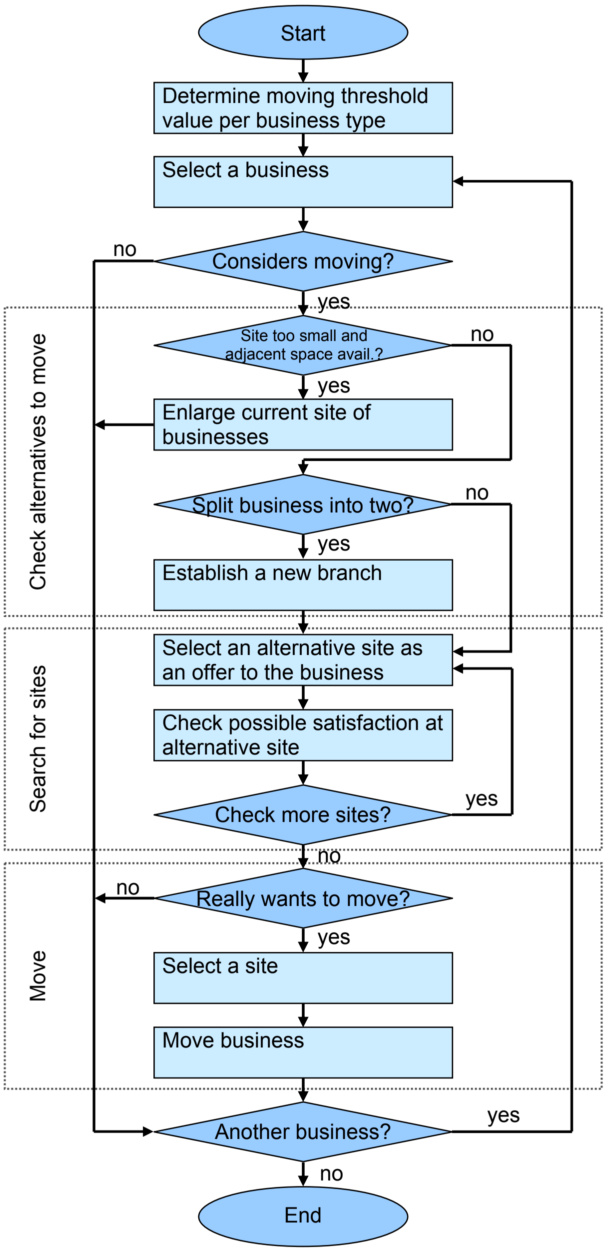


Fig. 6: Overview of the procedure to simulate businesses relocation

The relevant location factors include aspects such as rent, accessibility of customers, closeness to competitors, image or available floorspace. Since businesses tend to move over small distances only (Birch 1984) closeness to the previous location is another important location factor. According to a study of German manufacturing firms, the evaluation of a site distinguishes limitational, i.e. non-replaceable, and substitutional, i.e. replaceable, location factors (Lüder and Küpper 1983: 192-193). Therefore, location factors are divided into essential and desirable ones, or non-replaceable and replaceable ones. Whereas all non-replaceable location factors have to be fulfilled to a certain degree, replaceable location factors may substitute each other. This distinction is achieved mathematically by aggregating non-replaceable location factors by a Cobb-Douglas-Function. As the factors are multiplied each factor has to be greater than 0 to assign a utility greater than 0 to a site. Replaceable location factors are aggregated by simple weighted addition, so that one location factor with a higher utility can outweight those with lower utility. Some factors, such as accessiblity or image, are evaluated at the zonal level, as local differences are small. Other factor, such as price or local agglomeration effects, are analysed at the level of a single site as even close locations may differ noteworthy.

Next, all businesses are selected in random order and every business is asked if it considers to move. A binomial logit model is used to determine if a firm moves or not, depending on the current location satisfaction and the satisfaction at the above-mentioned threshold value.

$$p_b = \frac{1}{1 + \exp(\beta \cdot u_{lb} - \beta \cdot u'_{k_b})} \qquad (3)$$

p_b probability to consider moving for business *b*
u_{lib} utility of business *b* at current site *l*
u'_{k_b} critical utility for business type *k* of business *b*
β coefficient (currently set to 15)

If the firm decides to search for an alternative location it is checked first if the size of the current location is the major driver for relocation. In that case it is searched for vacant floorspace adjacent to the current location. If there is vacancy, the firm will not start the location search process but rather expands its current site on adjacent vacant floorspace. As another alternative, firms with lack of space will consider to establish a branch, thus moving only part of the firm and keeping the current location for the rest. This is in line with the hypothesis that firms are likely to avoid any relocation if the current location is acceptable or can be improved somehow.

The next phase deals with the analysis of possible alternative sites. Firms that are newly established (as described in section 3.2) start their location search at this position. Very small new firms in the service sector have the alternative to locate their new business in the home of the entrepreneur. Firms that search for a new location are unable to analyse hundreds of vacant sites. Instead, some preselection has to be made. In the model, first a zone and then a site is selected to be evaluated by the firm. A zone is selected based on zonal utilities of every zone for the according business type and on the closeness to the current location. The utility of closeness is calculated by an exponential function with a negative coefficient representing decreasing utility with increasing distance. The zone is selected by a multinomial logit model.

$$p_{jb} = \frac{F_j \cdot \exp\left(\beta \cdot u'_{jb}\right)}{\sum_j F_j \cdot \exp\left(\beta \cdot u'_{jb}\right)} \qquad (4)$$

p_{jb} probability for business *b* to select zone *j*
F_j available vacant non-residential floorspace of appropriate type in zone *j*
β coefficient (currently set to 2)

u'_{jb} total utility of zone j for business b (including utility of zone and utility of distance to current location)

After selecting a zone a site is chosen to be analysed. In reality, only those sites are considered that have the appropriate size. As most sites can be split into several smaller sites, the business may analyse a site that is actually too big. The model solves this with a gamma function, which excludes sites that are too small, gives the highest probability to sites that have the right size and gives some probability to larger sites, too.

$$u_{S_l b} = \frac{1}{\exp\left(\frac{-\lambda}{\mu}\right)} \cdot s_{lb}^{\lambda-1} \exp\left(\frac{-\lambda s_{lb}}{\mu}\right) \tag{5}$$

$u_{S_l b}$ utility of the size of site l for business b

λ coefficient (currently set to 2)

μ coefficient (currently set to 2)

s_{lb} Size of site l in relation to the ideal size for firm b

Every site selected is analyzed in terms of its potential location utility for the firm that is searching for a new location. A business may search up to 10 different sites. The actual number of sites analyzed is simulated dynamically, i.e. firms that have a successful search strategy and find attractive sites will search fewer sites, whereas firms with a less successful search strategy are likely to search the maximum number of ten sites.

Next, the business is asked if it wants to move at all. This decision is based on the current location utility and on the utility of the alternative sites the firm has found.

$$\Delta\hat{u}_b = \frac{\sum_L \exp\left(\beta \cdot u_{ljb} - \beta \cdot u_{lib}\right)}{L} \tag{6}$$

$\Delta\hat{u}_b$ average expected improvement the alternative sites offer to business b

β coefficient (currently set to 1)

u_{ljb} utility of alternative site l in zone j for business b

u_{lib} utility of current location of business b

L number of alternative sites offered to business b ($1 \leq L \leq 10$)

A binomial logit model is used to select if the firm moves at all.

$$p_b = \frac{1}{1 + \exp\left(\beta \cdot \Delta\hat{u}_b - \beta \cdot 1\right)} \tag{7}$$

p_b probability that business b decides to move

β coefficient (currently set to 5)

If the alternatives found are relatively poor compared to the current location, the firm is likely to decide to stay. It may reconsider to move the next simulation period, when different sites are available or the firm's characteristics and hence location preferences might have changed. Those firms that decide to move select a new site by a multinomial logit model.

$$p_l = \frac{\exp(\beta \cdot u_{ljb})}{\sum_l \exp(\beta \cdot u_{ljb})} \tag{8}$$

p_l probability to select site l

β coefficient (currently set to 2)

u_{ljb} utility of site l in zone j for business b

If a firm moves the previous location is made available for other businesses to move immediately. Hence, the floorspace stock is updated constantly.

4. SIMULATION RESULTS

The presented business simulation model is able to represent major economic changes of urban employment and business location. Validation, sensitivity tests, and policy scenarios indicate that the model is capable to simulate the likely effects of future urban development under different policy assumptions.

The model has been calibrated extensively. As high importance was given to efficient run times, hundreds of model runs where possible to improve the model performance. The validation analysis was fairly limited. As the model starts in the year 2000 and employment data for the years 2000 to 2005 was available only, validation could be done for a very small time period only. It is not very meaningful to evaluate a model after five years only. Employment numbers become blurred by unpredictable location decisions of single larger firms. It would have been desirable to start the model in the past, for instance in 1980, and evaluate the model results in 2000. As this was not achieved here a rather qualitative validation has to be made.

The results show that the *Base Scenario* is able to continue the employment development that has been observed in the past. Figure 7 shows the employment development simulated in the Base Scenario as a difference map between employment in 2000 and 2030. A kernel estimation has been applied and visualized with a technique developed by Michael Wegener (unpublished). A kernel estimation is a smooth histogram of spatial data and represents the density of jobs by interpolating between raster cell values with a normal function (Bailey and Gatrell 1995: 84-88). Red hills show areas that gained employment, whereas blue valleys lost jobs. The scale represented by λ cannot be translated in absolute numbers of workers. The interpolation only allows to compare different parts of the study area. However, all three-dimensional maps in this section are plotted in the same scale so that different scenarios are comparable.

Figure 7 shows that the centre of the study area, which is the Central Business District of Dortmund, has lost employment. This area does not necessarily lose em-

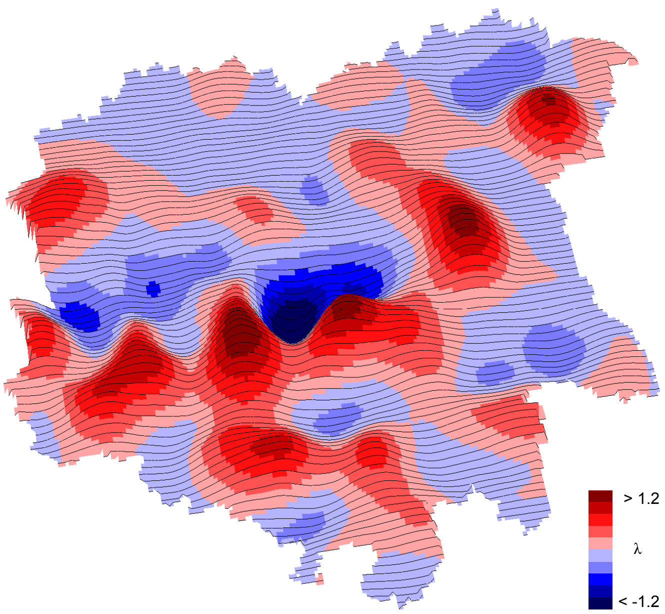


Fig. 7: Base Scenario: Employment change from 2000 to 2030 as kernel estimation

ployment because it is unattractive, but rather because the average amount of floorspace used per employee is growing over time. As almost no new floorspace can be built in the centre, where no developable land is left, employment density of the city centre declines over time. The two adjacent red hills southeast and southwest of the Dortmund city centre are subcentres that gain significantly. Several suburban locations further to the east and to the southeast gain, too. The total study area gains 3.0 percent employment over 30 years in accordance to exogenously given regional control totals. Whereas Dortmund gains 0.6 percent only, suburban towns gain 4.5 percent on average. The simulation indicates that the trend of suburbanisation of jobs observed in the past will continue in the future.

Following, the results of five policy scenarios are presented. They cover land use, transport and fiscal policies. The Base Scenario presented the employment difference between 2000 and 2030. In contrast, the policy scenarios are presented by showing the difference between the policy scenario and the Base Scenario in the year 2030. This way the influence of a certain policy can by interpreted.

Figure 8 shows the impact on employment development in the *Compact City Scenario*. In this scenario every new floorspace development outside of Dortmund has been prohibited. As the red hill in the middle of the study area indicates, Dortmund gains a lot of employment through this draconic land use restriction. Most of the areas where no floorspace is developed lose employment. However, a few areas outside of Dortmund are able to take advantage of this policy even though they added no floorspace. The reduced competition of other more attractive regions makes this counter intuitive employment shift possible.

A scenario that is more likely to be realised is the *Decentralized concentration scenario* shown in figure 9. All larger cities and subcentres are allowed to add floorspace, whereas growth in suburban regions is prohibited. Most of the centres and subcentres appear as a little hill, and the suburban regions form blue valleys.

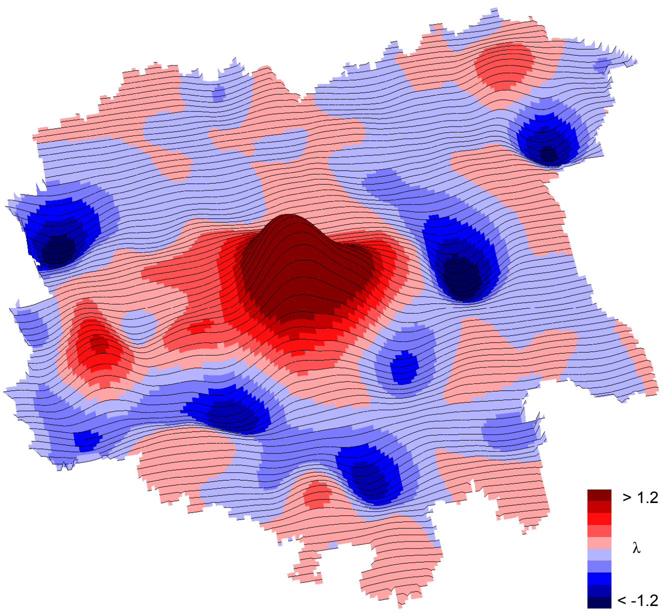


Fig. 8: Compact City Scenario vs. Base Scenario: Differences in employment development as kernel estimation

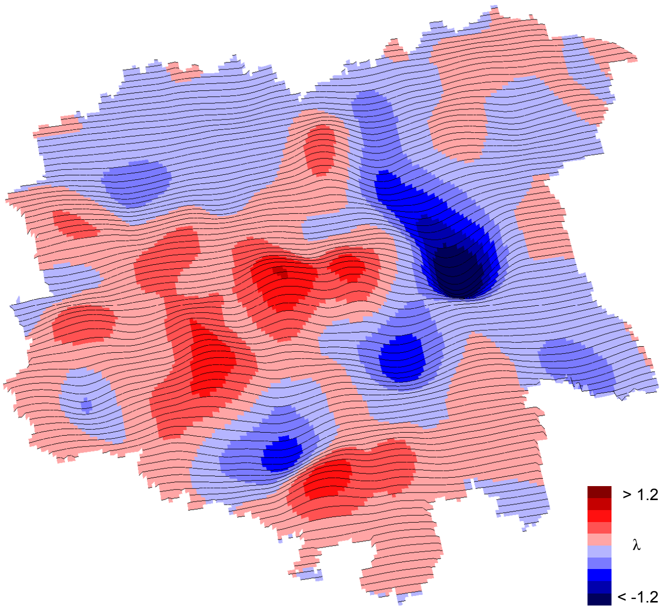


Fig. 9: Decentralized concentration scenario vs. Base Scenario: Differences in employment

The difference between the *Everything goes scenario* and the base scenario is shown in figure 10. To contrast the two previous restrictive scenarios this scenario abolishes any land development restrictions. Investors may build new floorspace on any open space where they expect demand. Two subcentres within Dortmund are able to increase employment. However, due to the increased competition the city centre of Dortmund looses even more employment. In total, the city of Dortmund (DO) is able to increase employment by 4.3 percentage points. At the same time, however, floorspace construction is increased immensely. Whereas the base scenario covers 400 hectares with additional non-residential floorspace in Dortmund, the Everything goes scenario covers additional 719 hectares, which is an increase by 80 percent. The price for a small employment growth is high, as a large amount of urban forests and farmland are lost. This scenario was developed to test the likely impacts of an oversupply with developable land. It could be shown that developers take advantage of additionally available land, and that firms partly react by changing location behaviour. However, the employment shift by extensive floorspace supply results comparatively small. The results call for ensuring that land use planning is not further undermined.

In the *Regional cooperation scenario* the floorspace construction that is needed in the entire study area is distributed to every zone according to their current employment, i.e. the actual floorspace demand is met but cities are not allowed to build up a large floorspace stock. In figure 11 this scenario is compared to the base scenario. In particular Dortmund is able to reduce the employment loss. Overall, this scenario leads to the most balanced employment development. The employment shift from central locations to the suburbs is halted and even slightly reversed. The total floorspace demand is reduced, thus, less additional soil is covered. However, this scenario appears unlikely to be realised under current political conditions. There is no incentive for suburban cities to cooperate with central cities. As they lose employment without receiving any other compensation they would most likely impede this collaboration between cities and suburbs. Exclusively, a regional authority could implement such a zoning restriction.

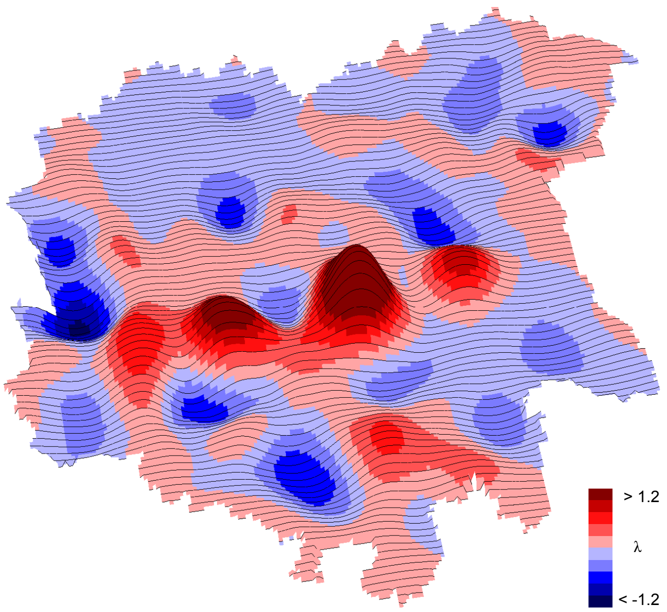


Fig. 10: Everything goes scenario vs. Base Scenario: Differences in employment

To show the interaction of land use change and transport policies a *fuel price scenario* was tested. This scenario shows the likely effects if fuel prices increase threefold from 2000 to 2030 (real prices, adjusted to inflation). The base scenario assumed a price increase of a factor of 1.3 only. Figure 9-12 shows that the impact is small. The city centre of Dortmund gains some employment. Compared to other regions the accessibility of the city centre improves relatively, thus makes it more attraktive for firms to locate. Some firms in manufacturing tend to move closer to highways to reduce transport costs. Overall, the effect of increased fuel prices is quite small on this local scheme.

The last scenario discussed here tests the impact of fiscal policies. The *Subsidy scenario* assumes that business tax in the city of Dortmund is reduced to the lowest value that is possible under German legislation. All other cities keep the tax rate ap-

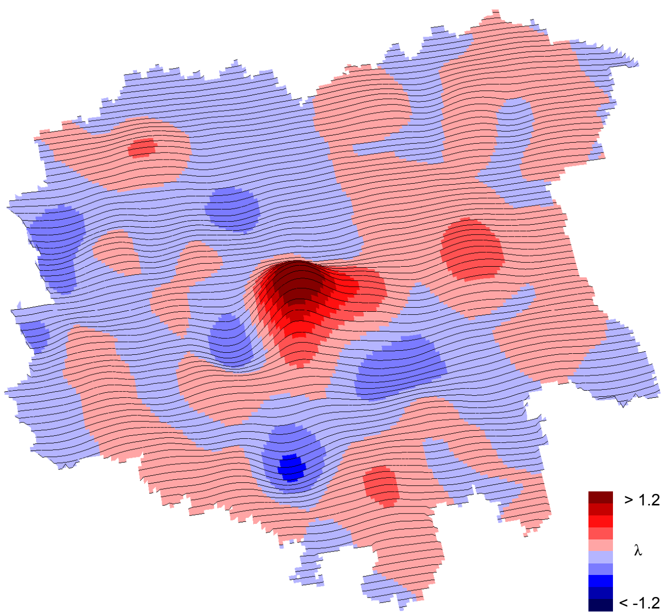


Fig. 11: Regional cooperation scenario vs. Base Scenario: Differences in employment

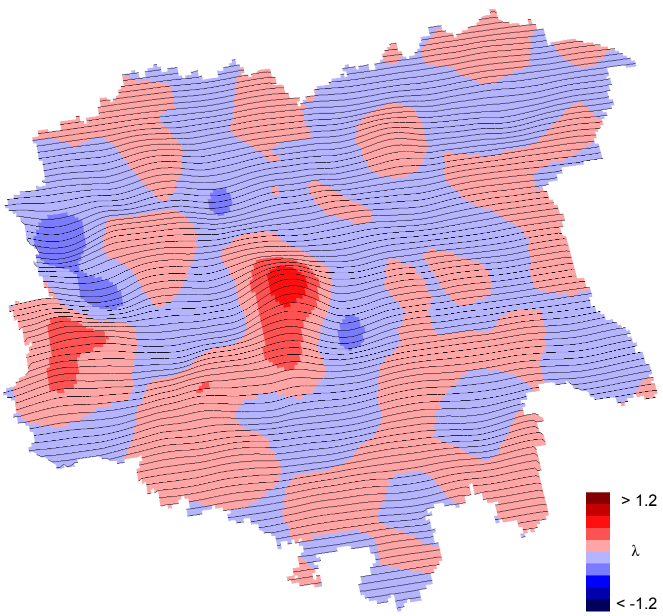


Fig. 12: Fuel price scenario vs. Base Scenario: Differences in employment

plied in the base scenario. Figure 13 visualizes the comparatively small impact. Dortmund is able to gain employment outside the city centre. However, this growth is mostly due to employment loss in other larger cities. Suburban areas barely receive less employment. Dortmund is able to receive 2.0 percentage points more employment than in the base scenario. On the other hand the costs for this scenario due to tax deficits are significant. The subsidy scenario would generate costs of approximately 53 Million Euros per year (including additional business taxes received by employment growth in Dortmund), an unaffordable sum for a city like Dortmund that struggles with a financial crisis since years.

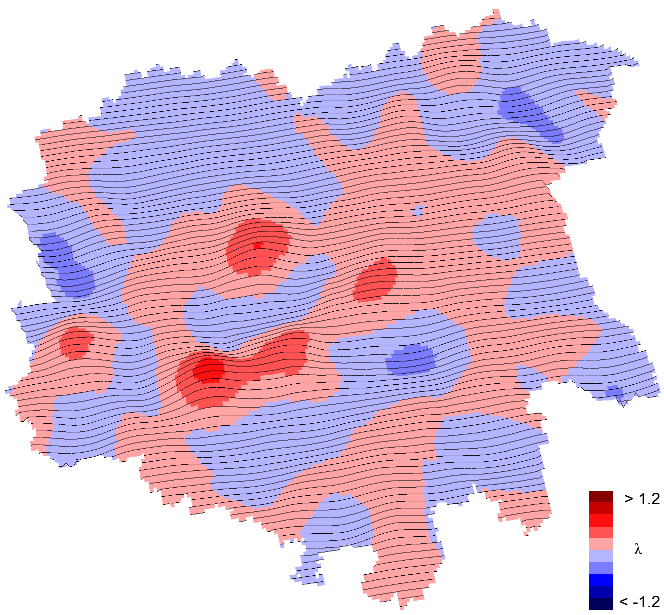


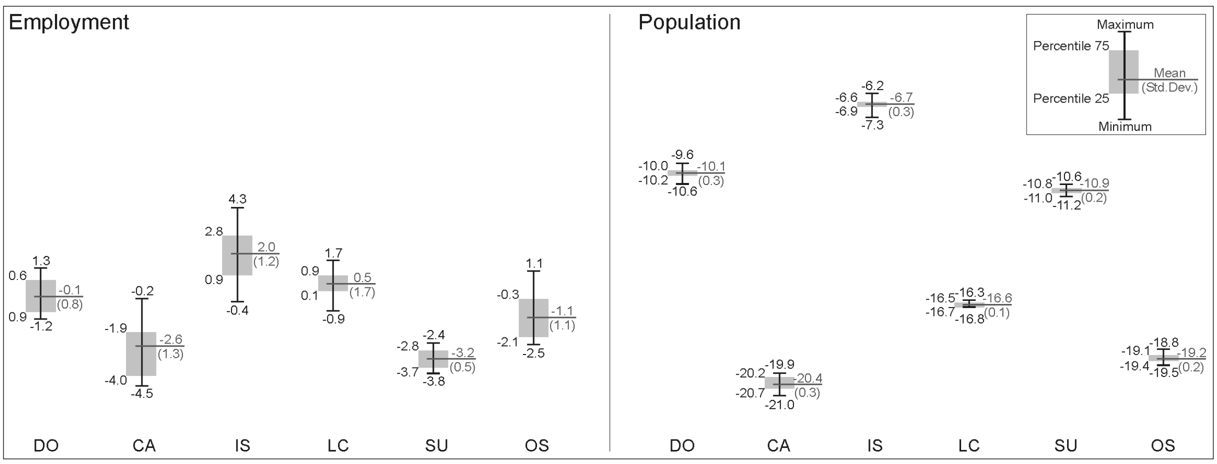
Fig. 13: Subsidy scenario vs. Base Scenario: Differences in employment

5. CONCLUSIONS OR HOW MUCH MICROSIMULATION IS NEEDED

The ILUMASS model started with the idea to develop an integrated land-use transport model that builds entirely on microsimulation. A lot of scientific progress has been made on solving simulation tasks at the microscopic level. Nevertheless, a research group at University of Dortmund decided to step back and replace parts of the microsimulation with simpler and fast-running aggregate simulation modules. The result is a microscopic land use model integrated with an aggregate transport model and an environmental impacts module working on the raster cell level. This model had to simplify in some respects but it makes it possible to execute many fast model runs that allow calibrating the results and improving the model performance. This leads to the question how much microsimulation is actually needed. Following, the experience made with the business simulation module is used to explore pro and contra of a microscopic approach.

Modelling firms by microsimulation was chosen for at least three reasons. First, it was aimed at accounting for the decision-taking unit when simulating firmographic events or relocation. Second, the impact from firmographic events on business relocation should be represented in the model; a business that grows is more likely to move as the current site may have become too small. And third, a relocating business should be constrained by available floorspace. If jobs are treated individually, each job simply has to find floorspace to locate itself; if firms are treated explicitly, enough floorspace has to be found to accommodate all jobs of this firm on one continuous site. In fact, a couple of micro interactions were included, such as agglomeration effects on the neighbourhood scale, path dependent events (e.g. a firm grows and relocates subsequently), or the inclusion of site-specific features (such as size, local price or quality) to estimate the business' satisfaction. These aspects cannot be simulated in an aggregate model that summarizes jobs into groups.

In some cases, however, microsimulation might lead to a level of detail that cannot be handled by the model. Figure 14 shows an analysis of the stochastic variation of 15 model runs. Even though input data and scenario settings where equal, the results show some deviations due to randomness of the Monte-Carlo choice approach. As the initial seed of the random number generator was set different in every model run, choices in each model run differ. For comparison reasons, the employment data



DO: Dortmund CA: Central area IS: Inner suburbs LC: Larger cities SU: Subcentres OS: Outer suburbs

Fig. 14: Deviations of results of 15 model runs due to randomness

on the left is shown with the population on the right side of figure 14. Each box plot represents one subregion in the study area that has been analysed. The deviations in different runs are much larger for employment than for population. Due to a higher number of individuals (2.6 million persons, 1.1 million households) the number of stochastically selected choices is much bigger for population than for firms (1 million workers, 80,000 firms). Accordingly, larger subregions, such as Dortmund (DO), Larger cities (LC), or Subcentres (SU) show a smaller stochastic deviation as more simulated choices level out random deviation. As smaller the subregion becomes, the more uncertainty is included in the model results. Luckily, most results analysed in the comparison of scenarios show larger differences than the deviations of figure 14. Thus, for the evaluation of model results it can be assumed that the influence of policy scenarios is greater than random deviation. The results show, that no smaller zones may be selected to analyse model runs.

The model distinguishes 44 business types, which in retrospective appears to be too detailed. For instance, business types with less than hundred firms in the study area, such as mining and quarrying or treatment of sewage, may not be analysed separately at all. A single location decisions or firmographic event alters the employment distribution in one of these business types a lot. Subsequently, the intended randomness provided by Monte Carlo simulation makes scenarios incomparable for these business types. They may be presented exclusively in aggregation with other business types. If business types with few firms would exclusively add randomness it should be preferred to merge these businesses with another business type, since added randomness does not improve model results.

One reason for applying microsimulation for employment development was the idea to distinguish single firms instead of jobs. As location decisions are done by firms rather then by employees, it appeared to be behaviourally richer to represent single

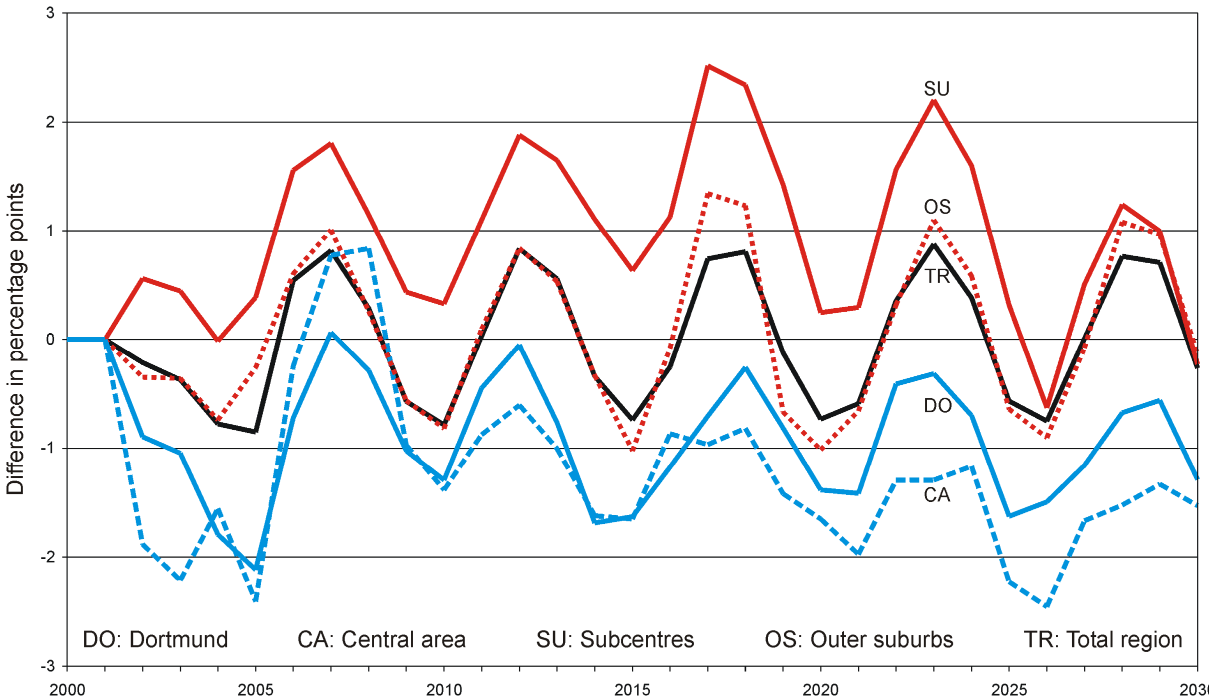


Fig. 15: Base scenario with economic cycles vs. base scenario without economic cycles: Employment difference in percentage points

firms in a model. The Base scenario assumes economic cycles of upswings and recession phases. Figure 15 shows the comparison of the Base scenario with an artificial scenario in which the economic cycles where switched off. Obviously, this artificial scenario may not be considered as a policy scenario, as in reality economic cycles cannot be switched off. The model, however, returns an interesting result. The black line in figure 15 shows the employment development in the total study region. This line shows the difference of the waves of economic cycles in one scenario and the non-existent cycles in the other scenario. In the long run, the total employment development is identical in both scenarios. The employment distribution within the study area, however, differs in the two scenarios. The blue lines show the employment development in the entire city of Dortmund (DO) and in the Central area of Dortmund (CA). The lines show that the employment in DO and CA declines over time. On the other hand, the employment growth in suburban Subcentres (SU) and in the Outer Suburbs (OS) increases due to economic cycles over time. In other words, if there were no economic cycles Dortmund would lose less employment; or due to economic cycles the urban sprawl of employment is increased. An increased suburbanisation of employment due to economic cycles has been proven empirically by Howland and Peterson (1988) and Manson et al. (1984).

In the model this effect is realized simply by the treatment of firms instead of jobs. During upswing phases many firms grow. If the current site gets too small the entire firm is forced to look for a new location, unless a branch is established. An aggregate model would shift the fraction of employment that cannot be located in one zone to other zones. For instance, if a zone with 1,000 employees that has no vacancy grows in employment by 10 percent an aggregate model would shift 100 employees to other zones. A microscopic model, instead, simulates single firms that grow. Those that grow and don't fit into their current location anymore will leave this zone or establish a branch. In a microsimulation, thus, a zone growing from 1,000 to 1,100 employees loses several firms that don't fit into their current location. Most likely the sum of employees in all firms that have to leave the zone due to having grown is larger than 100 employees. Therefore, the microscopic treatment of firms instead of jobs allows to represent an increased urban sprawl in economic upswing phases.

The examples show that there is a fine balance between details that improve simulation results and factors that only increase uncertainty. Given the model experience so far, it appears likely that the advantages of microsimulating businesses exceed the uncertainties added by employment simulation. Compared to aggregate methods, microscopic modelling improves results if historic events are not simulated endogenously and the number of businesses in every analyses subset is high. Microsimulation of firms seems to be a promising way to represent urban employment development more reliably.

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