THE SIMULATED CONSUMER – AN AGENT-BASED APPROACH TO SHOPPING BEHAVIOUR

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With 5 figures and 4 tables
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Summary: Recent research on consumption has indicated a growing differentiation of consumption styles and habits, which in turn make the shoppers' decisions increasingly hard to grasp and more complex in general. In particular, it is found that the classic modelling techniques fail to sufficiently represent these decision processes. This paper examines the potentials of an agent-based approach for the locational choices of consumers for their shopping activities on a regional level. The model is applied to two product sectors, groceries and clothing, in two distinct research areas in northern Sweden and southern Germany. While the empirical findings generated for the two case studies resulted in quite different model designs, both are found to be equally applicable for representing the different choice mechanisms and result in forecasts of buying power flows and thus turnovers of individual shops. It is concluded that agent-based approaches provide an elaborate instrument to model consumer locational choices and to forecast consequences of planning decisions, although expanding the empirical basis on qualitative grounds of research may lead to still further advancements.

Zusammenfassung: Die Forschungen der letzten Jahre zeigte, dass Konsumstile und -gewohnheiten sich immer weiter ausdifferenzieren. Dies hat zur Konsequenz, dass Entscheidungen der Verbraucher immer schwerer für die Forschung und Modellierung fassbar werden. Insbesondere ist festzustellen, dass die klassischen Modellierungstechniken bei der Darstellung dieser Entscheidungsprozesse an ihre Grenzen stoßen. Der vorliegende Beitrag untersucht die Potenziale eines agentenbasierten Ansatzes zur Modellierung der Einkaufsstättenwahl auf einer regionalen Ebene. Das Modell wird in zwei verschiedenen Untersuchungsräumen (in Nordschweden und im südlichen Deutschland) auf zwei Produktbereiche, Lebensmittel und Kleidung, angewendet. Obwohl die empirischen Befunde zu den beiden Fallstudien zu verschiedenen Modell-Designs führten, können beide Modelle gleichermaßen eingesetzt werden, um nicht nur die Einkaufsstättenwahl von Individuen darzustellen, sondern auch Abschätzungen von Kaufkraftströmen und Umsatzschätzungen einzelner Geschäfte vorzunehmen. Die Ergebnisse zeigen auch, dass agentenbasierte Ansätze ein sehr gut geeignetes Instrumentarium bieten, um nicht nur das Handeln und Verhalten von Akteuren zu modellieren, sondern auch um Folgen von Planungsentscheidungen zu simulieren. Potenziale bestehen jedoch noch in der Einbindung qualitativer empirischer Ergebnisse in die Modelle.

Keywords: Geography of retailing, agent-based modelling, Sweden, Southern Germany, economic geography

1 Introduction

In the past, estimations of buying power flows between elements of demand and supply have been modelled from aggregate input data characterised by analogies to laws from physical sciences (retail gravitation) or utility maximising assumptions (discrete choice models). This rather inflexible notion of shopping activities has not only recently received fundamental criticism. Multi-optional modes of consumer behaviour seem to become more and more dominant within contemporary consumer cultures. Shopping as a social practice is historically embedded, made and remade through countless acts of repetition, and is governed by routine and habit, but with scope for improvisation and chance within established conventions (Gregson et al. 2002; Jackson et al. 2006, 48). In this context, consumers are considered as knowledgeable and skilful social actors whose modes of shopping are intrinsically tied to currently shared values, norms, conventions, attitudes, preferences, symbols, styles, identities and practices.

Agent-based models are able to integrate such individually differentiated variations of consumer behaviour. They are characterised by a distributed control and organisation of data enabling the representation of complex decision processes with a small number of specifications. With these features, agent-based approaches address many of the objections against analogy and choice models. The strictly individual viewpoint allows for an explicit representation of individual variations of decision processes,

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e.g., regarding tendencies of impulsive and reflexive behaviour (Strack et al. 2006) as well as varying individual interactions with shopping environments based on consumer type specific pre-dispositions. The modelled shopping processes are not standardised, but still follow certain social rules and conventions. From the authors' point of view, it is important to stress that agent-based modelling is the only modelling technique capable of integrating these seemingly conflicting approaches.

In spite of some applications in geographic retailing research (Hesse and Rauh 2002; Arentze and Timmermans 2005; Zhang et al. 2005; Heppenstall et al. 2006; Soboll 2007b), the suitability of agent-based modelling for the support of location decisions and the delimitation of market areas in retailing has not been explored thoroughly up to now. Rather recently, Birkin and Heppenstall (2011) experimented with combining classic spatial interaction models with agent-based models in a retail context. That way, the authors extend market equilibrium models with components for situations of discontinuous evolution of parameters and nonequilibrium dynamics. Zhu and Wang (2011) propose an agent-based market dynamics model of interactions between shopping centres and consumers. While both work with spatially explicit models, they also have in common that they do not include empirical data on consumption styles and shopping preferences.

The work described in this paper aims at filling this gap by illustrating the design of agent simulations of consumer behaviour, unveiling important fields of application including distances covered on shopping trips and traffic flows caused, as well as generating scenarios of purchasing power flows and shapes of market areas under changed supply and demand conditions. Overall aim is to test the suitability of agent-based modelling of consumer behaviour on different scales of functional regions. As an add-on, sales forecasts for single retail locations and retail agglomerations could be useful for practical applications. Of a further special methodical interest is the question about the effects of using different levels of spatial aggregation on the model results.

Two study areas are chosen: The functional region of Umeå, northern Sweden is selected as a showcase for a simulation based on individual data and the sector of food purchasing. Since individual population data is not available publicly in Germany, small aggregate data for the region of Regensburg in south-eastern Germany was used for a simulation of fashion shopping. The two study areas and the two forms of consumption are deliberately chosen to demonstrate that the agent simulation approach is equally applicable for very different data situations and consumer decision logics.

2 Model design and data

There is no general understanding of "the purchase" of groceries or fashion, for they are both often coupled with other activities and can occur in various situations. Both can be characterised by different decision and action mechanisms, different spatial patterns and different intensities of interaction with the social and built-up environment. In spite of these differences, both were initially based on joint simulation logic, and then modified according to the different data situations and the special requirements of the two application areas.

2.1 Model design

In the past, various modes of estimating buying power flows between elements on the demand and the supply side have been widely applied. These include on an aggregate level gravity and entropy maximising models, on the individual level behavioural and utility maximising models (Reilly 1931; Huff 1964; Wilson and Bennett 1985; Güssefeldt 2002). While aggregate models run short of integrating individual decision processes, large scale applications of utility maximising models often exceeded the computational powers of the time.

Because it is not the aim of this work to present a new theoretical understanding of the purchase of groceries or fashion, but rather to explore the possibilities of a new modelling technique (agent-based modelling) using existing theories and assumptions, the model design does resemble previous approaches in assuming a probabilistic decision process of individual consumers choosing a shop for their purchase from a number of available alternatives (eq. 1). It is the great advantage of an agent model that these decisions can be both made and recorded on the level of the individual without further constraints. This opens new perspectives for the analysis of the model results (see below) while keeping the model assumptions relatively basic. So while the modelling technique differs substantially from a purely probabilistic assignment of buying power to shop locations, the underlying decision logic may well be transferred into an agent model. Nevertheless, also a number of other assumptions common in consumption choice theory, mainly differing in the mathematical operations used in combining destination attributes, have been tested in the simulation and their results compared, leading to a preference for the solution above. This process is discussed in more detail in Löffler et al. (2005) and Schenk et al. (2007).

The foundations of the two models are the purchasing preferences of consumers and the attributes of the shops, with their combination resulting in an evaluation of individual shopping locations by the consumers, interpreted as the probability that the respective person may visit the shop (eq. 1, Fig. 1):

$$W_{i,g} = \frac{\sum_{k} P_{i,k} * A_{g,k}}{\sum_{g} \sum_{k} P_{i,k} * A_{g,k}} \qquad \text{(eq.1)}$$

with: $W_{i,g}$: Probability of patronage of individual i to shop g; $P_{i,k}$: preference of individual i for shop attribute k; $A_{g,k}$: attribute value of shop g for attribute k.

2.2 Supply side data

The relevant attributes of the stores were compiled from different sources: For the grocery stores, a number of variables describing their characteristics were obtained from studies conducted by the Swedish Konsumentverket (Office of Consumer Affairs) (1996). They included figures on retail floor space, location coordinates, turnover and partly the staff employed. Additional attributes such as store tidiness and quality of assortment were obtained from an own survey of the 132 shops in the Umeå region (Löffler et al. 2005, 175; Rauh et al. 2007b, 139).

The attributes of the fashion stores in the Regensburg region were investigated by two surveys: One was conducted by the city administration and the University of Regensburg in 2003 containing figures on sales area and format of stores in the city and a number of suburban centres. An own survey of clothes stores supplemented attributes regarded relevant for purchasing decisions in clothing: (1) assortment attributes such as price level, target group, offered clothing styles, assortment depth and width, available garment sizes, offer of branded products; (2) store attributes such as the form of service, size and internal arrangement of the shop, design of the shop's interior and display windows, opening hours, bargain offers and external displays, the presentation of brands, music, and tidiness; (3) attributes of the shops' surroundings such as amenities of the environs, available parking spaces, cafés, bars and restaurants in direct vicinity.

Finally, (4) a number of indicators were identified to reflect atmospheric distinctions between shops: Presence and volume of music played in the store, tidiness, the intensity, variability and flexibility of interior illumination, design and value of floor covers, existence of low-cost product displays, high-quality racks, and the diligence put in the design of manikins, fancy, theme oriented, unified or improvised store design, and the supply with lounges.

2.3 Demand side data

Demand side data needed for the simulation were collected in two steps: While structural (socio-economic) demand data were largely obtained from official statistical sources, consumer surveys served as sources for the specific consumption preferences.

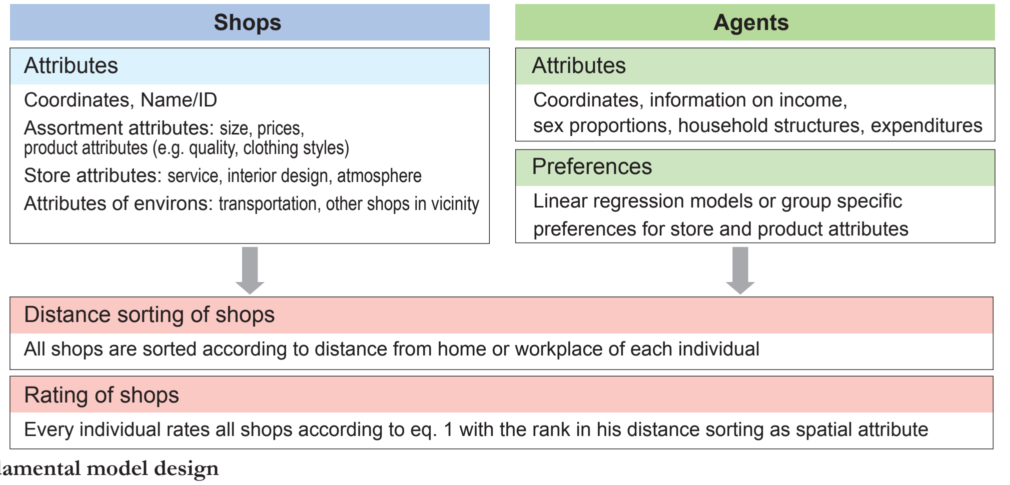

Fig. 1: Fundamental model design

Both phases of data collection were adapted to the different data situations and consumer decision logics in the two case studies.

Demand side data for the **grocery shopping model** in the Swedish study area relied on an extract from the ASTRID data base of all individual inhabitants of the Umeå region above age 15 (n=108,064; compiled yearly by the Dept. of Social and Economic Geography at the University of Umeå, Sweden, in cooperation with the Swedish Statistical Office, SCB), containing coordinates of home and workplace, personalised income, sex and year of birth. Using a common household ID also available in the data base, individuals could be linked to their households. While shopping for groceries is usually an activity at the household level, the decision for a certain store is rather specific to the individual carrying out the shopping trip. To implement this ambivalent process in the model, individual based preferences for shop attributes had to be generated. Following the assumption that these can widely be described by combinations of socio-economic characteristics of the individual customers themselves, a point-of-sale consumer survey (n=1,071) (Löffler and Schrödl 2002) was conducted to obtain consumers' preferences for store attributes. Using their socio-economic characteristics as independent variable, binomial logit regression models for the preferences were calculated. As an example, eq. 2 displays the resulting preference definition for the product quality attribute.

$$Y_Q = -0.269*sex+0.013*age-0.235*h\_size+0.034*h\_inc-0.588,$$
$$P_Q = \exp(Y_Q)/1+\exp(Y_Q) \qquad \text{(eq. 2)}$$

with: *sex*: 1=female, 2=male; *hh_size*: household size; *hh_inc*: household income; *PQ*: Preference for attribute *Q* (=product quality).

In total, approximately 70,000 agents representing randomly selected members of each household in the Umeå region were created.

For the **fashion shopping model** however, small-scale aggregates had to be transformed into individual datasets. For the city of Regensburg, the number of inhabitants, their mean age, sex and mean size of dwelling units on building block level were acquired from the various municipal administrations, for the suburban areas, age distributions and living spaces at the level of the municipalities.

Since data on household income is not accessible in public statistical domains in Germany, an estimation of the social status, as it was assumed to be crucial for attributes such as product quality, service level and entertainment expectations, using dwelling sizes and the proportion of 30 to 64 year-olds as the predominantly economically active part of the population, was calculated as an index. In a second step, about 300,000 artificial individuals were created from the 1,500 spatial units according their socio-economic structures, equipped with individual values for coordinates of their homes, age, sex and their social status.

Since most of this information relies on estimations and spatial aggregates, it was preferred to assign a consumption type to every consumer agent according to its sex, age and social status. The affiliated consumption types have preferences in common, derived from classified data of an own consumer survey with pedestrians in the city centre of Regensburg (n=1,605), which resulted in 43 consumer type groups with at least 15 members in each group (e.g., group 1: men/18-25year/low income; group 2: men/18-25year/average income;...; group 43: women/>65years/high income). Results of the consumer survey in Regensburg have shown that consumers in their decisions for shopping locations show differences arising from e.g., their age, sex, and income (Fig. 2). For the calculation of available buying power, national statistics on average spending depending on age and income groups were used (STATISTISCHES BUNDESAMT 2004).

3 Simulation results

3.1 Simulation of grocery shopping in the region of Umeå

This version of the model was constructed in multiple steps and continuously improved supported by (partly automated) calibrating procedures and plausibility checks (Rauh et al. 2007b).

Experiments with different constellations of shop attributes showed that price, assortment size and quality were the most promising terms for turnover estimations and were therefore chosen for use in eq. 1 for the agents' decisions. Large distances from home and workplace (or the length of a potential detour on the way from home to work via a shop) were assumed to reduce the probability of the shop to be patronised by the agent. The consideration of variables differing among individual consumers such as a relational utility component (distance) and personal preferences significantly increases the complexity of the model and hence complicates the

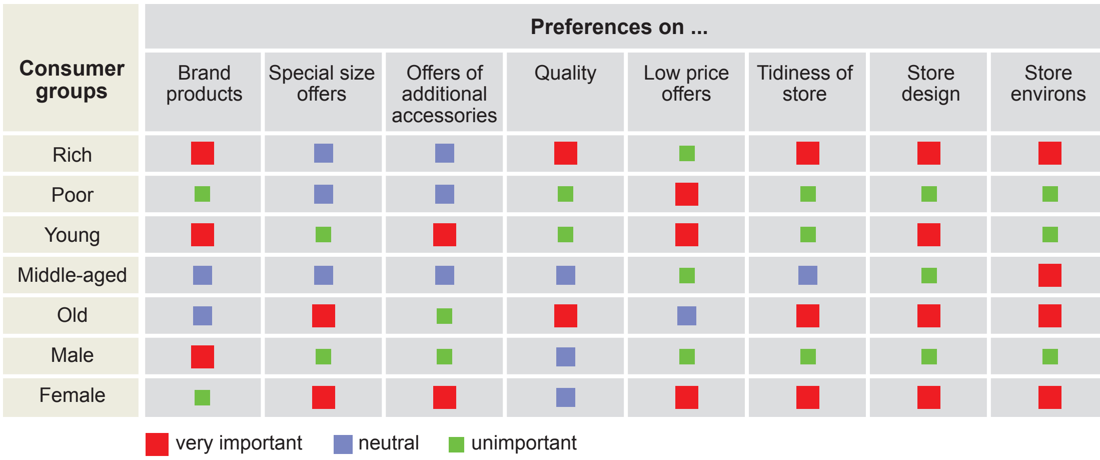

Fig. 2: Attributes and shopping preferences of consumer groups

parameter search. More details on the model design may be found in Löffler et al. (2005) and Schenk et al. (2007). The quality of the turnover estimation for all shops was measured using the relative quadratic deviation of estimated vs. real turnovers (eq. 3).

$$R = 1 - \left[\sum_{s} (T_{est,s} - T_{real,s})^2 / \sum_{s} T_{real,s}^2 \right] \quad \text{(eq. 3)}$$

with: R: goodness-of-fit measure; $T_{est,s}$: turnover of shop s estimated by the model; $T_{real,s}$: turnover of shops measured by public statistics or survey.

The values of the R measure of turnover estimation reached considerably high levels (Tab. 1), which is both due to an extended effort in calibration (Rauh et al. 2007b, 143-145) and more detailed input data. Contrary to most aggregate analogy (gravity) models, explanation (consumer preferences and shop attributes) and the target variable (turnover) were completely independent from each other. Although coming close, this is a reason why the model quality does not reach those values known from gravity models, and also makes a direct comparison of these two very distinct modelling approaches seem inappropriate. Taking a more sophisticated view on the values of R, it can be noticed that the turnovers of the two largest groups of shops, the "Lanthandel" and "Other Supermarkets", together accounting for 66.3% of the total turnover of all shops in the region, are estimated well above the average. It is predominantly the very small kiosks and gas station shops that rate low, together obtaining only 6.7% of the region's buying power. To summarize, it can be stated that the simulation performs well in terms of turnover estimation, in particular for those shops eminent in number and market share.

Apart from the option of an overall estimation quality, agent models bear further possibilities of result evaluation, such as the reckoning of the situation of single shops or the tracing of single individuals on their shopping trips.

Figure 3 illustrates the spending patterns of a 4-person household based in Vännäsby. One household member works in the commercial zone on the north-western edge of Umeå, and is selected to do the shopping trip. As mentioned above, the possible detour on the way to/from work is used as a distance

Tab. 1: Model quality values for groups of shops (eq. 3)

Type of shop (n)	Model quality R	Type of shop (n)	Model quality R
All shops (n=132)	0.721	City Supermarkets (n=3)	0.913
Trafikbutiker (n=22)	0.399	Other Supermarkets (n=25)	0.795
Servicebutiker (n=19)	-0.197	Hypermarket (n=1)	0.597
Lanthandel (n=61)	0.830	Discounter (n=1)	0.987

Explanation of shop groups:
Trafikbutik = gas station shop, Servicebutik = Kiosk, City Super Markets = Super markets and grocery division in department stores with more than 800 sq m sales area in the city centre of Umeå, Other Super Markets from 400 to 800 sq m sales area, Hyper Market and Discounter (low price shop), Lanthandel = other shops below 400 sq m sales area, mostly in rural areas and sub-centres

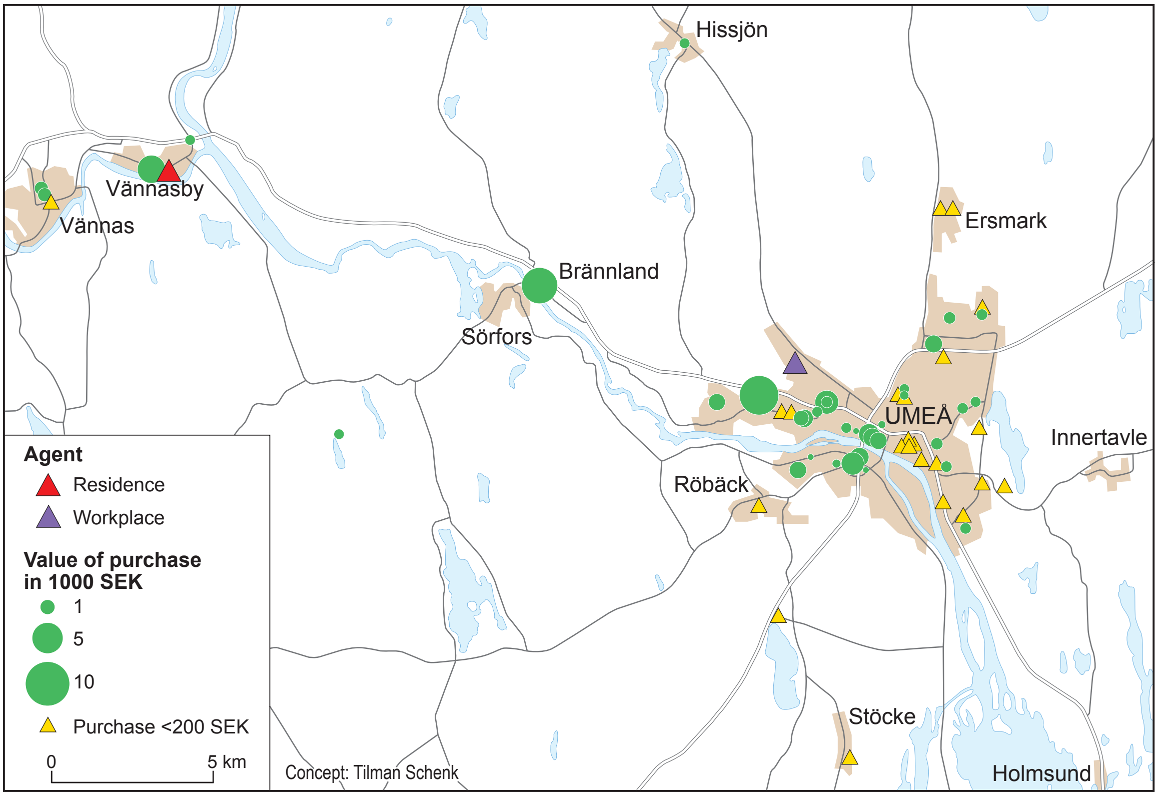

Fig. 3: Tracing of individual shopping agents

measure in this case, which is why predominantly the shops located along the E12 road between Umeå and Vännäs are most likely to be patronised by the agent. City centre shops fall behind, regardless of their relative high rankings in assortment size. This individual perspective opens up a broad range of further possibilities for analysis: Changes of the agents' expenditure orientation over time as some of their preferences are age and household structure dependent; agents' reactions to changing spatial patterns of the shops (closures/start-ups) as well as changes in their attributes (upgrades). Also individual agents or groups of agents could be compared relating to the extent they may be affected by changes on the supply side (age groups, mobility resources). The downside of this analysis is however that an empirical validation of the individual shopping trips is particularly expensive. One alternative would be to conduct qualitative interviews with family members about their shopping habits and compare them to the spatial patronage patterns of the agents. Alternatively, the simulated shopping patterns may be subject to plausibility checks, which was preferred in this case. Further experiments included a sales forecast to demonstrate the potentials of the simulation to support planning decisions. A total survey of the shops from the year 2004 firstly allowed a "retrospective" sales forecast for the situation in 2004 based on the 1997 population data (Fig. 4). A number of shops had already closed within this period of time, and a new shopping centre containing an ICA Maxi hypermarket on the south-eastern edge of the town Umeå had opened. The simulation then traced the redirection of the agents' buying power, resulting in losses mostly for smaller neighbourhood shops ("lanthandel" and "service butik"). Whereas the standard supermarkets seem to benefit at least partly from the closures that had already occurred, and are not so strongly affected by the new hypermarket.

In a second step, a prognosis for a possible scenario for the year 2015 was set up. For several years, the community of Umeå has been planning to develop a site on the western edge of the town for an additional third shopping centre. In order to estimate the future demand, a population projection was derived from the Swedish population forecasting model SVERIGE for the year 2015. One rather surprising result in both scenarios is that the hypermarkets integrated in the peripheral shopping centres are competing harder among each other than

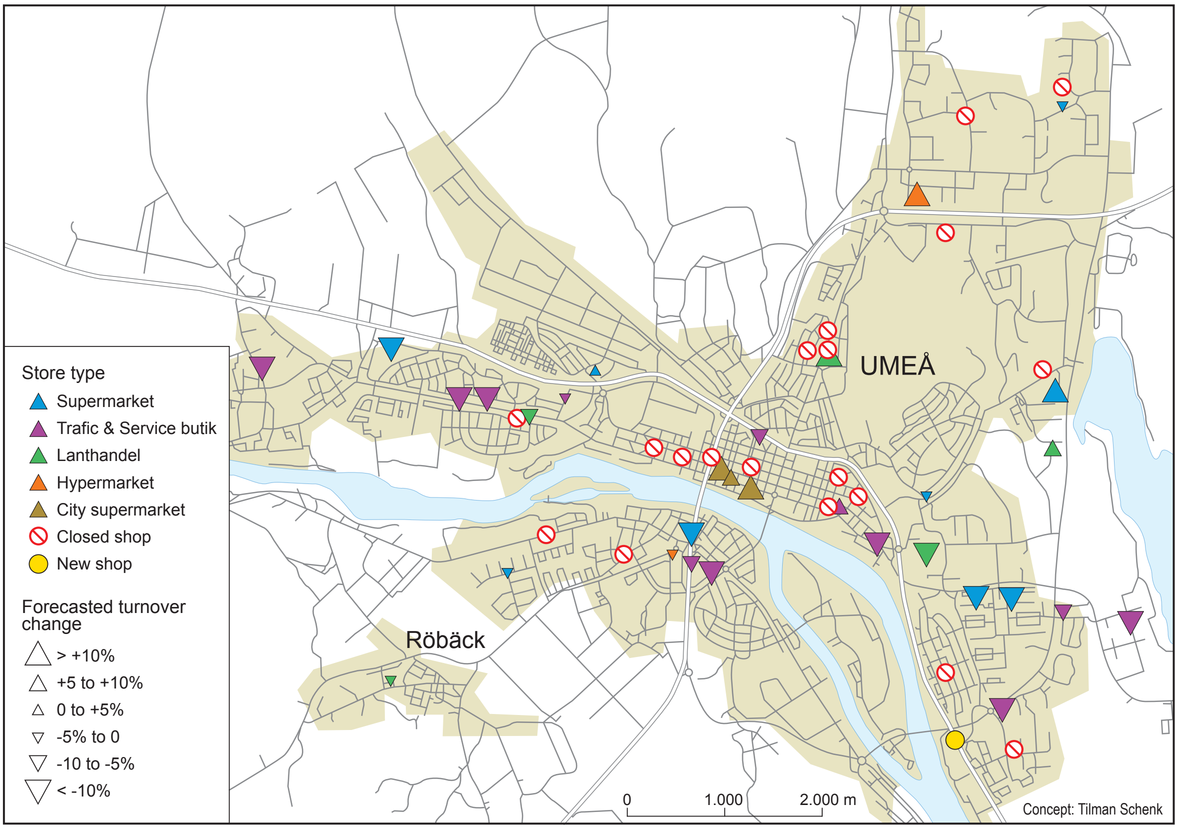

Fig. 4: "Retrospective" turnover prognosis for the retail structures in 2004. "Closed shop" marks outlets that have shut down between 1997 and 2004; the "new shop" is a hypermarket at the south-eastern edge of the town

against inner-city supermarkets or those located in sub-centres or in the rural areas. Still, the number of shops of the latter categories shrank drastically until 2004; due to their low market share, even small losses may jeopardise their existence. Their closures are again to the benefit of larger shop units, which in turn leads to a self-inducing concentration process, found to be retailer and consumer controlled in about equal measures.

Additionally, also the impacts of these alterations on travel patterns were examined. Often spatial concentration processes in retailing are presumed to increase travel distances, due to a decreasing spatial density of shopping opportunities. However, the analysis of the distances covered by the agents drew a far more differentiated picture. Although the overall distances travelled by the agents on their shopping trips increased by 4%, the impacts on individual households are more subtle, as revealed by the analysis of individual shopping trips. Particularly households in the city can rely on a significant reduction of shopping distances, as they replace a large number of trips to nearby sub-centres by smaller numbers of trips to shopping centres further away. In contrast, predominantly the population of the rural hinterland has to accept distances of sometimes more than 25 kilometres to the nearest location of a grocery store (Rauh et al. 2007a).

3.2 Simulation of fashion shopping in the Region of Regensburg

The model for the simulation of fashion shopping was based on the previous grocery version, but was expanded by several fashion specific aspects. In contrast to the grocery model, the purchase expenditures were now assigned to the individual agents instead of households. Consequently, agents perceive only those shops, where clothes for their sex are offered. Furthermore, shops offering distinct areas of products for different age groups are only perceived by the respective agents of that age group, following the argument that age and life cycle phases play an essential role in fashion shopping (Lachance et al. 2003; Studak and Workman

2004; TdW INTERMEDIA 2004). The pre-selected shops are rated individually and by every single agent according to eq. 1. The agents' preferences are determined by the agents' affiliation to one of 43 socio-economic groups. For the shopping activity, every agent is assigned a yearly, age-specific amount of buying power for fashion (based on national statistics; STATISTISCHES BUNDESAMT 2004) that the agent will finally distribute according to the previous store rating.

The quality of the simulation of fashion shopping can be judged in two ways: Interpreting results from the perspective of the supply side, goodness-of-fit values comparing estimated and empirically measured turnovers of shops may be calculated as indicated by eq. 3. Taking the viewpoint of the demand side simulated and empirically surveyed shopping patterns of selected individuals, socio-economic groups or the population of certain districts may be compared in a more qualitative manner.

Table 2 shows that combining different model parameters (all weighted equally) for the decision process of the agents leads to significant impacts on the simulation results. The first three combinations of parameters indicating predominantly the shopping atmosphere (music, tidiness, shop interiors, display windows) or particularly price-conscious shopping ("smart shopper model") lead to best results. Floor space and distance between agent homes and store are important parameters in all model versions, as they proved crucial in previous estimations of both retail turnovers and comprehensible spatial patterns of shopping behaviour (OPPEWAL 1997).

Table 3 displays goodness-of-fit values for different retail locations and store formats. While turnover estimations of fashion stores in the city centre and the two shopping centres Arcaden and DEZ rated best, the results for the remaining districts and the sub-centres are less significant. The turnovers of stores in these areas were systematically over-estimated. This can be traced to their relatively high attribute values concerning e.g., prices, service and available parking spaces, although they seem to be less frequently attended in reality due to their relative isolation and thus a lack of comparing opportunities and an unattractive store surrounding.

The simulation does better at the level of large department stores (more than 2,000 square meters of sales area) with a broad assortment of various styles, price categories, and age-specific offers than it does with small and medium sized shops that are frequently more specialised in certain customer groups.

Turnovers of the stores of large national and international brands such as H&M, New Yorker or Mister & Lady Jeans tend to be under-estimated. While these stores often rank low in some of the attribute values such as service, tidiness or interior design, they obviously benefit from other aspects that are not a directly measured part of the model such as their image, their strong orientation on fashion trends and their central location in highly frequented shopping areas.

Local, traditional fashion shops, often in the sub-centres, as well as those offering specialised products, sportswear, and life style articles are most difficult to grasp in turnover estimations. Traditional shops, though often highly rated in quality, service and interior design attributes, are mostly attended by elder consumers, so their turnovers are often over-estimated. The mentioned specialised stores serve very narrow segments of the market; estimations of their turnovers are particularly hardly tangible.

Apart from tracing individual shopping trips in the simulation, which were conducted in the fashion shopping model in a similar way as in the grocery model, the simulated shopping trips may also be compared to the list of visited stores from the consumer survey. Table 4 exemplarily shows the 10

Tab. 2: Goodness-of-fit values (for store turnovers according to eq. 3) for model variants using different constellations of model parameters

	Model parameters	Overall goodness-of-fit
(1)	Offer of accessories + floor space + distance	0.59
(2)	Prices + special garment sizes + offer of accessories + special clothing styles + floor space + distance	0.64
(3)	Music + tidiness + shop interiors + display window design + floor space + distance	0.66
(4)	"Smart shopper model": special offers + price + external displays + floor space + distance	0.69

Tab. 3: Goodness-of-fit values (store turnovers, eq. 3) for selected groups of garment stores

Locations			
City Centre	0.72	Remaining urban area	0.39
Shopping centre "Arcaden"	0.79	Sub-centres	0.46
Shopping centre DEZ	0.76		
Sales area (fashion only)			
> 2,000 sq m	0.81	250-500 sq m	0.44
1,000-2,000 sq m	0.67	100-250 sq m	0.68
500-1,000 sq m	0.69	< 100 sq m	0.61
Store formats			
Department stores (fashion only and mixed assortments)			0.83
National and international brand stores			0.72
Textile discounters, low price assortment			0.33
Local and traditional garment stores			0.59
Sports gear and life style stores			0.50
Lingerie			0.35

most often visited stores of 40 to 49 year old women of medium income classes, comparing results from the simulation and from the consumer survey. This shows that the simulation is very well capable of reproducing spatial shopping patterns specific to socio-economic groups. There is obviously a strong consistency between simulation and survey which is an indicator for a widely realistic model design.

3.3 Comparison of the grocery and fashion models

The two very distinct application areas (both concerning the shopping modes and the regional contexts) were chosen to demonstrate the suitability of agent-based simulation for each of the situations. While the simulation of grocery shopping relied on very detailed population and store data, the part of the data available for the Regensburg region had to be disaggregated before the simulation. Both models displayed that the simulation of consumer behaviour on an individual scale by multi agent systems is inherently possible. They even lead to feasible results in estimation of retailers' turnovers and in comparison with empirical studies to plausible shopping behaviour of the agents.

The decision processes in grocery and fashion shopping themselves are observed to follow differing rationales: In the grocery model, the structural features price level, assortment size and quality of products are promising variables in the utility function of the agents. Distances to residence and job location performed better using ordinal instead of metric scaled distance measure. This is due to empirical findings about the human perception of spatial structures.

Furthermore, this kind of micro scale modelling enables a view on individual decision making processes by selection of shops. The complex fashion model, which tested different versions of decision logistics (Tab. 2), conveyed the best results if parameters describing the shopping atmosphere (music, tidiness, window display …) or "smart shopping" (bargain, low prices …) were combined. But even in times of individualised, pluralised and hybrid consumers, spatial shopping patterns are not completely diffuse. Distances and floor spaces are still important constraints of consumer behaviour.

Consequently, the results obtained reflect these two approaches: In the grocery model, the turnover estimation was especially highlighted, while in the fashion model results included also more qualitative comparisons of shopping patterns (Tab. 4).

4 Further experiments

Further experiments with the models aimed at demonstrating the potentials of agent simulation in regard to incorporating ongoing theoretical considerations in consumption research, of which only two will be discussed here. The first example applies to the fashion model, the second to the grocery model.

Tab. 4: Comparison of simulation and consumer survey data: the most often visited stores (name, location) by middle-aged and middle-income female agents/consumers

Rank	Simulation	Consumer Survey
1	Kaufhof, city centre	Kaufhof, city centre
2	Kaufhof, DEZ shopping centre	C&A, DEZ shopping centre
3	Peek & Cloppenburg, DEZ shopping centre	Wöhrl, city centre
4	Adler, Neutraubling (sub-centre)	Peek & Cloppenburg, DEZ shopping centre
5	Wöhrl, Arcaden shopping centre	Adler, Neutraubling (sub-centre)
6	C&A, DEZ shopping centre	Kaufhof, DEZ shopping centre
7	Woolworth, DEZ shopping centre	K&L Ruppert, DEZ shopping centre
8	K&L Ruppert, city centre	K&L Ruppert, city centre
9	K&L Ruppert, DEZ shopping centre	H&M, city centre
10	Wöhrl, city centre	Wissmach (trad.), city centre

4.1 Activity coupling and interactions

Consumption research, especially in a modelling context, has long discussed the challenges associated with the consideration of multiple destinations in a single shopping trip (see e.g., Timmermans 1988 or Timmermans and van der Waerden 1992). It was thus the intention of another model version to simulate the procedural character of shopping trips, explicitly representing the combination of activities and the interaction of agents with their social and physical environment (Soboll 2007a). Fashion shopping is frequently combined with leisure activities, such as meeting friends and acquaintances, eating and drinking or cultural activities leading to a number of interactions between the consumers and their environment (Arnolds and Reynolds 2003).

Thus, in this model version, agents combine their shopping activities with the attendance of bars, cafés and restaurants. Agents literally "look about" their environs in 100 m intervals during their shopping trip and re-evaluate their situation. The location of decision making is thus transferred from home or the workplace to the current location of the agent on the shopping trip. The longer a shopping activity lasts and the more shops are frequented, the more probable a desire for a break is triggered. In case a preferred location is too crowded, the agent may avoid it and search for other locations or more fashion shops. After agents have spent some time in a bar, café or restaurant, they continue their shopping trip.

This model shows that a simulation of interactions and communication processes are doubtlessly feasible, when plausible systems of action rules and patterns, and hence data are made available. Due to an increased computing effort however, such models are mostly spatially restricted, in our case to the city centre of Regensburg (Soboll 2007a) or to the interiors of shopping centres (Hesse and Rauh 2002) and to a limited array of activities.

4.2 Communication and learning

So far, the evaluation of shops has relied on individual preferences and store attributes that are both constant over time. However, it seems plausible that repeated visits of a shop accumulate knowledge about the offers, thus implying a learning process. Agent simulation especially allows for integrating such a process due to its orientation on the micro level and its anthropomorphic characteristics. Assuming that at the start of the simulation an agent has no information about the shops (all shops are equal in their attribute values), this image changes while shopping (attributes converge towards their empirical values). This can be formalised as follows:

$$B'_{i,g,k} = B_{i,g,k} + P_{i,k} * (A_{g,k} - B_{i,g,k}) * W_{i,g} \quad \text{(eg. 4)}$$

with: $B'_{I,g,k}$ ($B_{I,g,k}$): New (previous) perceived attribute value (belief) of criterion k of shop g in the view of individual i; $P_{i,k}$: preference of individual i for criterion k; $A_{g,k}$: attribute value of shop g in criterion k; $W_{i,g}$: previous rating function value (eq. 1; probability, and thus share of visits) for shop g and individual i.

This learning process is repeated until the perceived attribute values have sufficiently approached their empirical counterparts. Simulating this in the grocery shopping model, the goodness-of-fit value for turnover estimation of the original model version is reached after 40 iterations.

5 Conclusions and outlook

The experience gained from the simulations, modifications and extensions of the models can be used to re-evaluate some of the fundamental assumptions the research started out with (Fig. 5):

Agent-based modelling should embrace results from qualitative empirical methods in the formulation of activity rules for the agents. Techniques are to be developed to integrate such information without the detour via operationalising preference values. Both approaches, qualitative methods and agent simulation, share a common ground accepting a complex view of humans and the uniqueness of human decisions. Qualitative social science, as it is directed on understanding the motivations of action patterns, forms an excellent basis for agent simulations.

Previous discussions of consumption have so far either relied on an objectivist (constant consumer preferences and store attributes, constant decision mechanisms, complete information of customers) or a constructivist view (consumption as a crucial aspect in the construction of identity, relevance of semiotics, consumption discourses). However, both have failed to integrate the materiality of consumption as well as interactions of consumers with their social and designed physical environment in a distinct decision situation (Gregson et al. 2002; Jackson et al. 2006). Modelling and simulation of individual shopping activities and hence the emergence of retail landscapes however requires precisely the integration of such interactions. Consumption as such is contingent, context specific and path dependent, not directed towards equilibrium as postulated in neoclassical assumptions, but develops dynamically, non-linear and open-ended. Only agent simulation is able to grasp these complex processes in a formal way. Linking to existing discussions on geographical complexity theory (Byrne 1998; Ratter 2006), it becomes clear that future consumption research should be directed towards more evolutionary and time geographical approaches.

To summarise, it can be stated that the simulation of grocery shopping in the region of Umeå and fashion shopping in the region of Regensburg proved to be successful on both methodological and theoretical grounds in geographical consumption research. Technical and theoretical resources were joined to model and simulate individual consumption decisions at a regional level resulting in turnover estimations for all shops in the study areas. However, the effort needed for the collection and arrangement of individual data also became evident. Agent-based simulation is obviously suitable to generate scenarios and prognoses with their consequences for both the supply (changing competitive situations and agglomeration effects) and demand sides (changing transport efforts and opportunity spaces). Finally, agent-based models will pave the way to a methodological restructuring of human geography towards an action oriented social science (Deiters 2006, 303).

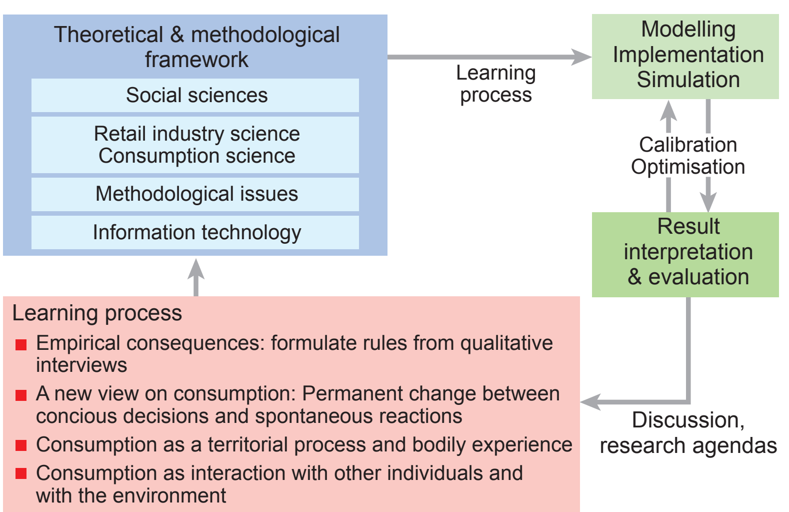

Fig. 5: Lessons learned for social geography

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