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Quod Erat Expectandum
The Modus Operandi of Models and Quantifications

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Geographies of Uneven Development

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Abstract

This paper is a plea for a computational social geography (CSG). It argues that neglecting quantitative approaches in social geography leaves empirical socio-spatial facts incomplete. Numbers and their emergence through quantitative methods are indeed one possibility to raise a kind of uniqueness to facts, phenomena, and events which cannot be realized by other approaches. CSG makes relations visible and comparable. It does so by applying the model approach adequately, i.e., to not equate models with reality and to explicate the model purpose. As is the case with all other scientific approaches, computational or analytical social geography is inherently bounded by reductionism. Scale, entity, and context are the inextricable reductionist ingredients of modeling relationships between the social and the spatial. Recently, significant efforts have been put towards a critical quantitative geography that takes past weaknesses seriously into account and delineates its strengths as a progressive social science.

Keywords: quantitative approaches in social geography, modeling and simulating socio-spatial processes, epistemology of models, critical quantitative geography

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1. Introduction

"Impossible is something that does contradict to be. Possible is something that does not contradict to be. Accidental is something that does not contradict not to be. Necessary is something that does contradict not to be" (Kamper 1996: 109; translation A.K.). This interplay suitably frames the intention of this paper. The circularity of semantic associations is a presupposition in order to comprehend coherently each sentence and the relationship of all four sentences. Be it theories or methods, descriptions or explanations, texts or maps – relationships always create, explicitly or implicitly, these nexuses with which particularities are being contextualized. Contextualization generates meaning. However, neither the creation of relationships nor the creation of meaning is grounded on objective criteria, not in science and not in everyday life. They are, on the other hand, not completely arbitrary, but depend on particular social-cultural, temporal (historical) and spatial (geographical) contexts.

The referential contexts emphasize in addition that, how, and why complementarities are fundamental for comprehensive reasoning. Complementarities can be dialectic; the decisive point is that they are simultaneously expressing a mutual excluding *and* complementing relationship, as it the case of the dualism between wave and particle or of impulse and location in physics. One characteristic of complementarity is that the so far unconnected (or differently connected) components do already exist. Every social construction of space, for instance, presupposes spatial rules, patterns, and conventions which are independent properties compared with the social rules, patterns, and conventions being applied when taking possession of social space. Among others, it is geometry, topology, or algorithmic computation. This is equally true for every statistical analysis. The result of a model run or a statistical analysis presumes the selected technique(s) which itself is based on concrete procedural rules (e.g. that interactions among agents and between agents and their environment is taken into consideration). The process of computing a number is usually not reflected in the result, except it is made explicit. In this respect, a mathematical emergence of reality does not differ from a textual or (carto-)graphical emergence of reality, in all cases we refer to a priori objectives, reflections, etc. What makes a difference is the nature of translation.

For modeling geographical phenomena from a social scientific perspective an understanding of relations and complementarities is crucial, because both spatial and social facts do rely heavily on their inner-temporal dynamics and develop in time differently (see also Schäfer and Schnelle 2012: xxf). Social spatial segregation processes may obey common rules of homogenization, the quality of the process, however, together with its concrete manifestations of social, cultural, architectural upgrading (gentrification) is influenced by the idiosyncratic peculiarity of their local, temporal, and community compositions.

These introductory remarks aim at highlighting the relevance of relationship, reference, and complementarity in understanding our world scientifically as well as from a Lebenswelt perspective. In the remainder this world comprehension will be discussed from a model theoretical and quantitative

methodological perspective by focusing exemplarily on social geographical phenomena of regional disparities and processes of segregation.

2. Some peculiarities of the quantitative approach

According to Lewin (1931) three approaches of accessing reality can be distinguished: the *Homeric* mode of narration which gives priority to moral judgments; the *Aristotelian* mode of classified descriptions which focuses on differentiation (e.g. dark-bright); and the *Galileian* approach of measuring which stresses exactness. In addition to these three approaches one could refer to the *Ortelian* approach of cartography which offers a synchronous representation to recognition (the English word recognition includes cognition and recognition, thus the complementary referencing mentioned above). From a practical perspective it is important to recognize that both the four different approaches and the mutual transition between them are crucial when reasoning about reality. No access to reality is exclusively restricted to one single approach.

In contrast to the common understanding of quantities which are assumed to devaluate the individual as an abstract number and negate its qualities, it is Lewin (1931: 150) who appreciates the peculiarity of quantification: "It is the increased desire, and also the increased ability, to comprehend *concrete particular cases*, and to comprehend them fully, which, together with the idea of the *homogeneity* of the physical world and that of the *continuity* of the properties of its objects, constituted the main impulse to the increasing quantification of physics". Numbers, quantifications, and their emergence through quantitative methods are one possibility to raise a kind of uniqueness to facts, phenomena, and events which cannot be realized by the other approaches. "There is nothing more abstract and singular than numbers. Beyond numbers no further abstraction is thinkable, because abstracting from numbers would mean to disregard singularity. This in turn would mean to give up the Self, because the Self is only possible in contradiction to 'Another'" (Weiss 2010: 4; translation A.K.). Weiss also points out that quantity (the single part) and quality (the whole) conflate; they can be distinguished analytically, but need to be mutually related in order to understand both sides of the coin – and the coin.

3. Implications of applying methods, numbers, and models

As a preliminary conclusion we can say that quantitative approaches in social-spatial investigations are relevant as well, because they specifically make relations visible and comparable. By referring to scalable domains they move beyond material and metaphorical characteristics of space and society. Attempts to define regional disparities may here be a good example of dealing with quantities qualitatively. Maretzke (2006: 473) proposes a definition of regional disparities as "[…] deviations of particular indicators which are assumed to be relevant, from an imagined reference distribution […] which is being referred to a particular spatial scale, depending on the subject matter" (translation A.K.). Measuring deviations depends fundamentally on available instruments and data, crucial, however, is the problem at hand. The problem in turn is interrelated with theoretical, empirical, normative, and experimental issues, and should not primarily be determined by questions of data acquisition.

Commonly, a pragmatic compromise of theoretical, methodological, and applied justifications must be realized in scientific and political praxis. This, however, shall not induce an attitude that provides the compromise with a law-like status, nor to adapt the problem to the methodological "needs".

Transparency and reproducibility of the research process give numbers and models their value. Belina and Miggelbrink (2010: 14) require with regard to spatially referenced comparisons "[…] to unfold the reasons for the creation of entities and references of comparisons. Neglecting this implies a production or confirmation of ideologies by corroborating comparisons with seemingly objective statements about seemingly self-evident entities" (translation A.K.). These are reasonable requirements, because experience, familiarity, and persuasion for or against a method, technique, or model are natural characteristics of a research process. What may grow as an independent force can be termed "voiceless knowledge" according to Rheinberger (2001: 80).

Measurements, quantifications, and models bring out a concrete single case, as argued above. What they bear must be contextualized; from an epistemological perspective it is the well-known threefold "context of discovery", "context of justification", and "context of utilization". Contextualization, in addition, must refer to other measurements and models in order to validate model results, but also to utilize them comparatively in connection with other approaches (see Christie et al. 2011: 5). In so doing, it is not a competition between outcomes and paradigmatic settings but an abductive approaching to the explicit problem(s) at hand.

This may sound trivial. Indeed, the claim of *trans*formability (of methodological approaches, of modeling aims and types, etc.) among and between modeling paradigms, scientific and epistemological explanations has been uttered many times over the past six or so decades. One of them, except of Thomas Kuhn, was Ludwik Fleck, a Polish physician who refused to accept an "absolute truth" as an epistemological counterpart of scientific exploration. He insisted on three social factors which inherently determine scientific reasoning (Schäfer and Schnelle (2012: xxii) in their introduction of life and work of Ludwik Fleck):

(1) The "weigh of education": knowledge foremost consists of learnt items, being then subtly transformed by learning and communication, however.
(2) The "burden of tradition": new recognition is primarily coined by already existing recognition.
(3) The "effect of the recognition sequence": what has been once conceptualized theoretically and/or methodologically restricts the spaces of new concepts.

Incorporating these social factors into the evaluation of research results may help to relax from unobtainable truths and to focus more strictly on the processes and purposes of model production.

4. Model purpose and circularity within the quantitative approach

Measuring and modeling regional disparities becomes more important if they coherently unfold the selection of "indicators which are assumed to be relevant" which implies to integrate the quality of the indicators, complementary to their quantitative manifestation. Qualities too need a referencing of the spatial, temporal, and social scale. The qualitative experience with inequality feeds mainly on very subjective and local living conditions; it is, however, simultaneously an amalgamation of aggregated knowledge as "socialized subjectivity" (see Bourdieu and Wacquant 1996: 159). This kind of knowledge which refers to local and subjective-social living conditions can be termed "local knowledge". Though deriving from a different epistemology and perspective (ethnography and natives in developing countries) (see Geertz 1993), local knowledge can be transferred to contemporary (post)modern, globalized *and* localized living conditions as well. Local knowledge of people living in impoverished or wealthy regions is, apart from scaling, important for disparity research, because it

incorporates another mode of observation. While knowledge about poverty, inequality, or disparate living conditions in scientific and political contexts is mostly a perspective of people who are not affected by the these disparities (a second order observation), local knowledge of poor and excluded people offers a first order observation which, at least partly, can be derived through participatory fieldwork and interviews (Koch 2013).

In addition to mutual relationships between different modes of recognition, ordering, and understanding it is important to account for the relationships within the quantitative methodology. It can be confirmed that "calculating is existing equality of opportunity" (Lotter 2011: 43), because inequality can be – and must be – made comparable through exact differentiation and objectivation which can then be used for opinion-forming in the political arena. Regionally varying allocation patterns are usually approached by economic indicators like business sectors, public infrastructures and economic innovation. They provide a reference for evaluating the legal mission of creating and/or preserving equivalent living conditions. As long as statistical analyses are considered as an instrument among others I would agree with Lotter. If not, the "equality of opportunity" turns out to be misused as ideology, representing an interest- and power-driven inequality of opportunity, since there is no longer an explicit advice of reductionism of complexity. This is why Strubelt (2006: 307) claims: "Thus, equivalence [of living conditions; A.K.] nowadays has changed its meaning. As an abstract aim, and independent from difficulties of measuring and illustrating disparities […], it became a conceptual and political idea which is hard to operationalize. Attempts to solve this by applying very different indicators and by creating rankings of regions […] encounter high public interest, but are methodologically very problematic. They often represent a trivial reduction of complexity […]" (translation A.K.).

Another problem of the internal confirmatory referencing of quantitative methods is the danger of not only making the measured values absolute but also the models and techniques applied. The mathematician Ortlieb phrases this "to explain the real through the impossible" and exemplifies it for economics: "Economics creates mathematical models which never could be rebuilt in reality but are used nevertheless to compute and reduce complex economic processes to a few numbers. Here too, the try to describe the real through the impossible. […] Neoclassical economics assumes a kind of market harmony. If markets are left to their own resources then everything develops best. Dummy arguments are used to confirm this opinion by misusing mathematics in order to circulate ideology" (Link 2001: 112f. This quotation is based on an interview with Ortlieb, translation A.K). The critical point is not that quantitative methods are dealing with artificial experimental settings or models, but that they equate models with reality. In addition, the methodological and technological progress must be thought of explicitly too. Batty (1995: 16) emphasized this with respect to the development of Geographical Information Systems (GIS) at that time: "[…] the current generation of GIS are systems which are not well adapted to their context, contain little of the theories and methods which have been developed over the last two decades in subject areas embracing the spatial perspective, and rarely focus upon the particular characteristics of the problems to which they are being addressed".

5. Reductionism and scaled circularity

For an appropriate appreciation of quantification and modeling a different kind of concluding translation between method and epistemology seems to be necessary. Statistics often assumes an absence of ideologies and normative values which is not true when considering the modes of acquiring, pro-

ducing, and publishing data and results, respectively. The basic instrument with which we observe, describe, explain, and interpret the world are models – there is no immediate access to our spatial and social environment.

This must be briefly explained. I agree with Schurz (2008: 56f) who claims for a hypothetical-constructivist realism approach. According to this realism, our perception and imagination of reality is not a priori given, but constructed and conditioned through active cognition (which is referred to as "epistemic" constructivism). Contrary to an ontological constructivism which conclusively claims that reality too is not a priori given, the hypothetical-constructivist realism does not link perception and reality as tightly. Instead, it assumes a structural correspondence which transforms information between perception and reality, which is neither complete nor unambiguous. Taking such a corresponding linkage into consideration, leads to an understanding of models that does not claim a straightforward coincidence of models with *the* reality, *the* nature, or *the* world. Models are not simply simplified representations of reality; they are images (imaginations) which we make from our environment. We constantly construct and reconstruct our environmental entry by using many and different instruments and tools proactively and interactively. And these instruments and tools in turn influence our ways of (re-)construction. This making-of is not always an act of creation, we also (and may be mainly) are using images (imaginations) made by others, be it maps, news articles, social network blogs, novels, theatre plays, and alike. The application of images differs with respect to experience, social roles and positions, and many more contexts.

If this assumption of how reality can be accessed is true then the role and meaning of models changes significantly. Models, then, are created, developed, and applied to generate reality, not to represent it (although representation remains one, but only one important characteristic). In so doing, they untie from an assumed objective, true or total reality which has to be imitated by applying certain sets of rules. They establish a kind of independence. Models, moreover, do reduce complexity in order to make the subject matter concretely tangible. Hence, it is not the unimaginable, opaque complexity addressed theoretically to "reality" which is under investigation in models and computationally translated to quantities. Complexity of reality is a metaphor which shall act as a counterpart to models, theories, quantifications. To compare it with system theory: we can conceive characteristics of systems, because they emerge as distinct objects structurally and functionally. Initially, we are not able to talk about a system's environment – it is just the not assigned other side of the system.

If the aim of a model is not to represent or imitate the complexity of an unknown reality (see, for instance, Nipper (2011: 141), who claims that models shall "represent reality as best as possible") then a model inhabits inherently its own justification by explicitly expressing its purpose, assumptions, and ways of reducing complexity. This is quite similar to map-making by applying rules of generalization, or to statistical analysis by deliberately selecting variables and techniques in order to achieve a certain result.

Models are thus a distinctive way of creating an experimental system to make "epistemic objects" visible and tractable (see Rheinberger 2001: 8). He defines "epistemic objects" as "[…] things which embody notions" (ibid.: 15; translation A.K.). From a social geographical perspective "objects" as injustice, inequality, poverty, or segregation may be perceived as epistemic when associated with a spatial fixing (see Dorling 2011). Dorling (2012) and Hennig (2013) provide impressive examples of making social-spatial injustice visible by applying cartograms and other quantitative tools. Rheinberger's intention is to avoid theory as the primary angle in research and putting experimental systems to the foreground. My aim is to avoid absolute external reality as a reference in modeling, but

putting the inherent purposes, assumptions, framing conditions, parameter settings, etc. to the foreground. In so doing, it is a realization of a modeling epistemology that has been claimed by several researchers, among others Epstein (2006), by arguing for a "generative social science" which accounts for letting the phenomenon of interest grow in a simulation model of interacting agents, or Küppers et al. (2006) who equate simulation models epistemologically with a "pragmatic construction of reality", whereby reality is emerging inside the models.

It would therefore be more appropriate to refer to "originals" instead of "reality" which are being generated and represented by models. Originals refer to other originals and in doing so there is no need to refer to an absolute truth/reality. This is in line with Stachowiak's (1973) General Model Theory, whereby models are defined through three characteristics: (1) a model always is a representation of a natural or artificial original, and the original can itself be an original; (2) a model does not encompass all attributes of an original, but only those which seem to be relevant for the model purpose; (3) a model does not conflate with the original inherently, but depends on the purpose, thus on the questions 'whereto', 'for what and whom', 'when', and 'where'.

For example, the model creating and model representing character manifests impressively in the well-known "modifiable areal unit problem" (MAUP) of a scale- and zonal-dependent variation of statistical results. It is a common methodological and theoretical problem with both scientific and practical meaning which calls for an insertion of modifiable "temporal units" and "social units" (Koch and Carson 2012). MAUP is for long a well-known problem in the geographical methodological research (see, e.g., Openshaw 1981) with established solutions or suggestions like, for example, Geographically Weighted Regression (Fotheringham et al. 2002; Ward and Gleditsch 2008). The discursive and hermeneutical implications seem to be less obvious. As the variation of a statistical technique – for example, applying different measures of similarity and cluster creation procedures of a cluster analysis investigation leads to different results with the same input data – it is likely with MAUP that the results depend crucially on the selected scale and the different size and shape of (mostly territorial) polygons; although the data set and the spatial analysis remains the same. A common phenomenon is an increase in homogenization through aggregation. "This leads to some ambiguity. During the conversion of individuals to spatial units aggregation transforms the observed phenomenon completely. Though it is not always obvious one should be aware that all kinds of aggregation are a transformation in the quality of information, even if it is a small step from one spatial scale to the next" (Madelin et al. 2009: 647 (translation A.K.); see also Belina and Miggelbrink 2010: 23). Hermann (2009: 703f) in his study of correlations between "individualization" and "social status" in Switzerland concludes that there is a positive correlation at canton level, but dissolves at the municipal level. Csillag and Agnew (1995: 104) draw a similar conclusion in their investigation of election results in Italy with varying approaches of regionalization: "Perhaps the most important conclusion of this comparison of electoral regionalizations is that there is no clear 'winner'. Geographical regionalization is a complex task involving the weighting of different criteria of 'goodness'. If internal homogeneity and boundary contrast are given equal weight then we can reach a certain outcome, but if another weighting is desired then the choice might be different".

A similar problem arises with boundary effects (zoning) when changing the shape of areas (and keeping the scale unaltered). While there are justified political reasons for adapting borders, e.g. in spatial planning and the constitution of electoral constituencies, the choice of a concrete spatial bordering concept because of restricted data availability remains a problem with respect of result interpretation and must be made transparent and explicit. It occasionally implies an uncritical dealing with spatial multilevel models. "One of the criticisms of multilevel models, however, is that context is of-

ten unquestionably defined by the hierarchical structure of the available data" (Zolnik 2009: 342). It is the model purpose that should determine the choice of an adequate spatial bordering concept which in turn prevents an objective and unbiased interpretation of spatial-statistical results. Focusing on the relationship between the EU-funding policy and the NUTS-based spatial ordering of EU member states, Madelin et al (2009: 651) concludes: "The selection of the spatial reference unit is not an unbiased fact, and one can assume that some states have chosen greater or smaller area units for the selection of their NUTS-ordering in a deliberate manner" (translation A.K.).

6. An example: modeling social-spatial segregation

Three references have been outlined so far: (1) a diversity of accessing and perceiving our environment; (2) a model driven approach in reasoning about our environment, (3) a scale-dependent variation of results. Through translations and transformations we can mutually link all three domains and try to develop models which incorporate these. One well-known phenomenon in this respect is the idea of emergence which, applied in social geography, can be observed when linking individual motives at a local level with social-spatial behavior at a global level (global is used here as a relative term and refers to the model purpose). Based on investigations by Schelling (1971, 1969) about patterns of segregation in highly abstract conceptual spaces it can be stated that processes of emergence can be reproduced by using simple local neighborhood rules that affect the distribution of individual agents at the macro level in an unexpected way. In other words, the macro pattern result cannot be derived straightforwardly out of the local neighborhood rules (see, e.g., Crooks 2008; Ioannides 2013: 115ff; Pancs and Vriend 2009; with respect to complexity theory Manson et al. 2012: 125ff). Figure 1 illustrates the result of a simulation run with two populations, characterized by one variable (red and green), who evaluate their immediate neighborhood with respect to a preference for their own social group. If a neighborhood ratio of red and green agents falls below a certain threshold value then the respective agents are dissatisfied and move to another place, repeating the evaluation at this new place. It is remarkable that, contrary to the individual aim of 30% identical neighbors (in this simulation case of Fig. 1) the actual segregation is much higher in most areas which has not been intended by any single agent.

This approach of accessing and reflecting scale linkages is based on inductive modeling without an explicit segregation theory. Though there are theories which may help understanding the basic principles of growing social homogeneity – among others, theories of social interactions which focus on strong thus similar ties (Granovetter 1973; Squazzoni 2012; Metcalf 2014), theories based on endogenous, exogenous, and correlated effects (Ioannides 2013), theories referring to hedonic behavior of households and rent seeking housing markets (Waddell 1997), or econometric theories of land prices and land uses (Filatova et al. 2009), and, last but not least, planning theories like central-place theory (Christaller 1933) or social housing policies (Dangschat 1998) – the Schelling-type segregation model and its contemporary derivations are foremost hypothesis-driven empirical models, taking observations from (large) cities around the world into account. Its explanatory character makes this model type attractive for applied research in this field.

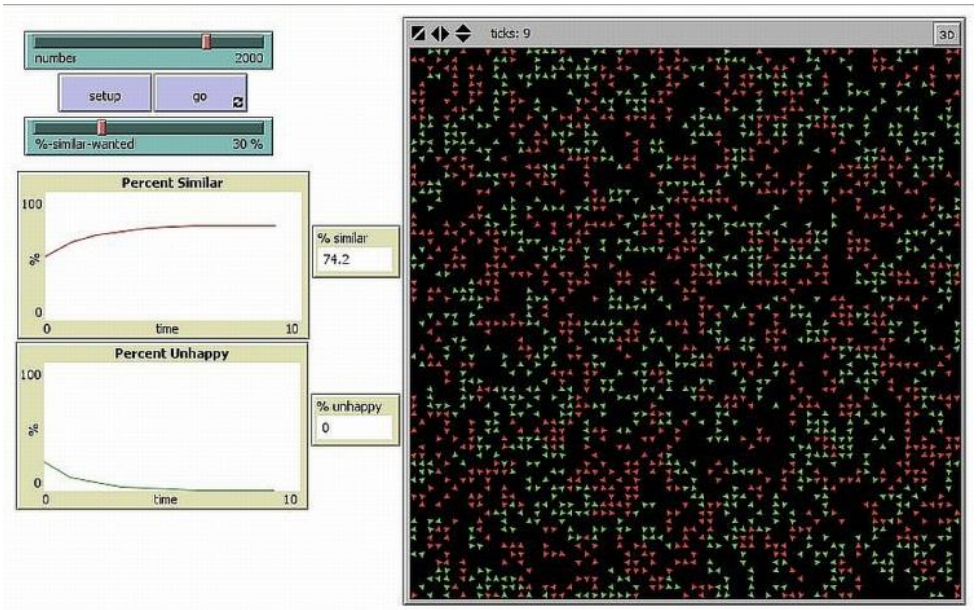

Figure 1: Simulation run of a Schelling-type segregation model in NetLogo (source: Wilensky 1999)

Models inevitably imply a reduction of complexity of an imagined original. All scientific efforts of reasoning, explanation, and comprehension are thus constructive, selective, and perspective. The relationship between independence and interdependence is in constant transformation: "Many individuals determine market events, and markets determine what happens in the heads and hearts of many individuals. It is, however, an individualistic ideology to belief that many individuals would be able to determine the "nature" of markets, societies or civilization exclusively by their will. The problem of this thinking is grounded in the statement "we all as many individuals". How does a "we" emerge from many "I's" which generates completely different effects than a set of single actions" (Hampe 2011: 278; translation A.K.). On the other hand a subjective assessing is continuously influenced by a social "we", because "[…] individuals are repeatedly exposed to socially biased sets of stimuli […]" (Eagles 1995: 10).

7. Models as instruments and the risk of instrumentalization

The relationships between contexts, presuppositions, multi-methodological approaches, reductionism, and transformational perspectives exhibit quite often frictions, because they were neglected and/or not explicitly applied. If this happens then models, numbers or analytical results tend to be used as ideology. The model becomes a fetish, an independent and self-referred object. Belina and Miggelbrink (2010: 13) point to this problem for space-based comparisons: "The compared subjects, […], rights and discourses, cities, regions, or territories are going to be cut off from the process of their creation through the comparisons – and thus cut off from all conflicts, struggles, and contradictions which trigger them" (translation A.K.). If the premises of a model cannot be derived from the results then the risk of blind generalization and over-simplification is likely happening.

Without relationships and associations models and numbers tend to be used as ideology or sheer instruments. They become stylized facts, and the images (imaginations) they produce induce a kind of necessity, i.e., something that does contradict not to be. A regional disparity, a poverty threshold, or a correlation between voter turnout and social status is set equal with reality even none of the parameters would represent a single case accidentally. A related problem is given with the use of the

notion of “optimization” – model optimization often is equalized with empirical optimization, embezzling purpose and premise of the model.

Complementary to the ideologization *of* models we have to take the ideologization *through* models into account. Members of a social community or milieu potentially identify with scientific and political model results or analyses, be it confirmatory or deprecatory or something in between. Mechanisms of self- and external exclusion are one of the most negative and sustainable effects of stigmatized identification. Quantifications of social life may, at specific scales, result in an image of social-spatial homogeneity. Gentrification can be seen as a good example for this. Theoretically understood as a repeated process of invasion and succession (whomever the term invasion actually is used for) which commonly implies displacement of less affluent people and thus a growing social similarity of a local neighborhood, gentrification is empirically evident in many large cities worldwide. It is, however and simultaneously, a socially and spatially rather diverse phenomenon with many different manifestations. “Setting ethnic minorities equal with other pioneers is misleading, because the latter (students, artists, trainees) are at much higher degrees equipped with legitimate social capital, according to Bourdieu […], as, for example, migrants or members of the working class” (Baumgärtner 2009: 66; translation A.K.).

8. The problem is not to model the world, but how to deal with it

Transparency and a more definite explication of the model purpose and its premises offer scopes of freedom of analysis and conclusion. Comparisons, the creation of hypotheses and scenarios, and the conduction of experiments or the recognition of patterns – they all cannot avoid specification and concreteness which is provided with quantification. The problem is not to model the world, but how to deal with it. To be honest, ideology and instrumentalization does not necessarily disappear with transparency and explication of intention. Specification and concreteness conflates with contingency and compromise.

It would also be naïve and shortsighted to believe that the other scientific accesses – qualitative-interpretative or narrative techniques – would not be threatened by ideology or instrumentalization as it can be stated for discourse theories (see, e.g., Foucault 2011; Habermas 1995; Lyotard 2006) or neo-pragmatism (see, e.g., Putnam 2007; Rorty 1981). The construction and reconstruction of regional disparities and social stigmatization, as mentioned above, may serve as pithy examples.

9. A plea for a critical quantitative geography and quantitative critical theory

In the light of quantitative and critical geography two special issues of the *Professional Geographer* of the Association of American Geographers (AAG) have been published with the programmatic title “Quantitative Revolution 2: The Critical (Re)Turn” (Kwan and Schwanen 2009). The strengths of a critical quantitative geography have been stressed by several authors by hinting at the context and the limitations of this kind of doing geography. “Quantitative geography is a powerful tool for challenging social and global injustice, and can play an important role in progressive social and political change” (ibid: 289). It can play this role because it acknowledges new epistemological knowledge methodologically. “It now aligns more closely with certain premises of critical geographies than the kind of quantitative geography conceived during the quantitative revolution – for instance, its emphasis on local context and local relationships instead of global generalizations about spatial pro-

cesses, its increased sensitivity to multiple axes of difference (e.g. gender, race, ethnicity, sexuality, and age), and its attention to processes through which individual spatial knowledge is constituted" (ibid: 284). In addition, the development of (geo-)statistical analytical techniques like geographically weighted regression (GWR, see above) or of simulation models like agent-based models or system dynamics approaches is progressively proceeding towards the postulated topics.

This development might be influenced by the fact that a translation of model purpose and premises into a software tool (e.g. a Geographical Information System (GIS) or a simulation software tool) requires an a priori fixation of the modeling steps and with it a decision about scales and the nature of reduction. Moreover, translations of commonly used notions within quantitative and critical geography have to be mutually proved with respect to adequacy and reliability. "[I]mportant notions central to both critical and quantitative geography can be used to reconnect critical and quantitative geographies. The notions of difference and context, for instance, are two such connective constructs that can stimulate dialogue and enhance mutual understanding, even though – or perhaps exactly because – their conceptualizations in critical theory and spatial analysis differ in various ways […]" (ibid: 288).

Models and quantities generate and specify context by its inherent nature of concreteness. This allows for visualization of spatial structures, functions, and processes across multiple spatio-temporal scales, as Ellis (2009: 305) emphasizes too, without denying the difficulties of such an endeavor: "With no census and other survey data on race, the material stratification of society by race would not fade, but it would become much harder to see at a structural, systemic level. […] The act of collecting data by these fixed categories [of racial classification; A.K.], of counting and estimating populations in them, reifies race and misleads with respect to the porosity of group boundaries and the variability of group experience". The character of modeling in descriptive and narrative representations of originals is also not immune against reification, it is a general part of the methodological denominator: "'Fact' became fact became law became reality" (Wyly 2009: 312).

A derived problem is data-driven reasoning, not because of its pragmatic relation between data availability and model adaptation, but because of an interchange of means and purpose – data justify the model purpose and thus the claim of representing the truth. Context remains important too in methodological reasoning, and there is always a mutuality between empiricism and theory, between induction and deduction. "Properly specified statistical models do nothing more than account for a quantity of the variance in an outcome of interest. In so doing, they are a representation […] of a priori theorized causal relationships; they are never a substitute for this theorizing" (Ellis 2009: 306). And theory targets to some degree empirical and experimental research.

All kinds of contextualization increase differentiation and the complexities of research settings, epistemological perspectives, and aspirations of valid interpretations. This leads to higher degrees of specialization and a narrowed claim of explanation. In quantitative spatial analysis the sophistication of statistical tools is continuously growing (Kwan and Schwanen 2009: 284) which enables tailored models and tailored foci. Precisely this awards quantitative techniques for approaching complexity. This has been appreciated by a couple of critical female geographers: "All statistics are social constructions, but when critical geographers abandon statistics, we give up the opportunity to shape and mobilize these constructions for progressive purposes. Our unilateral disarmament allows the socially constructed world of measurement to become more conservative, more ignorant of geography, and usually both. We give up the chance to construct certain things of facts – certain *things done*" (Wyly 2009: 316). And Peake (2008: 9) endorses: "I believe we are in danger of producing a whole genera-

tion of feminist geographers – and not just feminist geographers – who not only have no interest in quantitative techniques, but also have no training in how and when (or not) to use them, cutting off from enquiry and analysis a wide swathe of policy-based and applied research".

10. Conclusion

The basic idea of this paper was to establish an understanding of models and quantitative approaches which stress their adequateness in social scientific reasoning due to their characteristics in dealing with the subjects that matter. It has been argued that numbers, quantifications, and models do not refer to an absolute truth or reality; that they do not represent or imitate reality, but create their own reality and impact by its application within scientific communities. Or as Ihde (2006: 84) argues with respect to imaginative techniques: "[…] imaging in the context of simulation and modeling is more analogous to a critical, interpretative *instrument*, through which we see and read. […]. *There is no original from which to copy*. Yet the end result *is* image-like; it is a gestalted pattern which is recognizable, although it is a *constructed* image".

Instead, models and numbers attempt to make phenomena we observe or deduce theoretically tractable, graspable, and visible. Since many social processes designed by models cannot be perceived straightforwardly or are unobservable in principle, it is the (communicative) relationship between model builders and model users that awards their use, which is more important than looking for and looking at an intangible truth. "Occam's razor may still be the ultimate quest, but in many social systems, evident complexity is so great that plausibility rather than validity may be the real quest" (Batty 2012: 48).

Statistical spatial analysis, modeling, simulation – they all do play a crucial role in helping us to structure our world, to orientate and navigate through the complexities that surround us (a comprehensive confirmation of this appraisal can be found in Heppenstall et al. 2012). Though models are not synonymous with theories for a couple of reasons, they are not as different as Derman (2011) makes us believe. While it may be plausible to refer theory to "stated facts" and models to "assumed facts", the "[…] role of theory is to make evident what is hidden" (ibid: 60) can be ascribed to models as well. Moreover, models and theories merge in the process of uncovering invisible principles. Models and theories do simplify (which is contrary to Derman's position, who states: "A theory does not simplify" (ibid.)), both are inherently partial, scaled, temporal, selective, and translated (see Nagel 2012). Models, numbers, and quantitative methods are thus necessary – thus something that does contradict not to be.

References

Batty M. (2012): A Generic Framework for Computational Spatial Modelling. Heppenstall A. J., Crooks A. T., See L. M., Batty M. (eds.) (2012): Agent-Based Models of Geographical Systems. Dordrecht, Heidelberg, London, New York, p. 19-50.

Batty M. (1995): Geographic information systems in the social and policy sciences. Eagles, M. (ed.): Spatial and Contextual Models in Political Research, London, S. 15-40.

Baumgärtner E. (2009): Lokalität und kulturelle Heterogenität. Selbstverortung und Identität in der multi-ethnischen Stadt. Bielefeld.

Belina B., Miggelbrink J. (2010): Hier so, dort anders. Zum Vergleich von Raumeinheiten in der Wissenschaft und anderswo – Einleitung zum Sammelband. B. Belina/J. Miggelbrink (Hrsg.) (2010):

Hier so, dort anders. Zum Vergleich von Raumeinheiten in der Wissenschaft und anderswo. Münster. S. 7-39.
Bourdieu P., Wacquant L. (1996): Reflexive Anthropologie. Frankfurt a.M.
Christaller W. (1933): Die zentralen Orte in Süddeutschland. Eine ökonomisch-geographische Untersuchung über die Gesetzmäßigkeit der Verbreitung und Entwicklung der Siedlungen mit städtischer Funktion. Darmstadt 1980, (Repr. d. Ausg. Jena 1933).
Christie M., Cliffe A., Dawid P., Senn S. (2011): Simplicity, Complexity and Modelling. Chichester.
Crooks A. (2008): Constructing and Implementing an Agent-Based Model of Residential Segregation through Vector GIS. UCL Working Papers Series, Paper 133.
Csillag F., Agnew J. (1995): How many Italies? A strategy for spatial analysis of regionalizations of Italian election results, 1953-87. Eagles, M. (ed.): Spatial and Contextual Models in Political Research, London, S. 85-105.
Dangschat J. (1998): Warum ziehen sich Gegensätze nicht an? Zu einer Mikro-Meso-Makro-Theorie ethnischer und rassistischer Konflikte im städtischen Raum. Zitiert in: May M., Alisch M. (Hrsg.) (2012): Formen sozialräumlicher Segregation. Opladen, Berlin, Toronto, S. 23-50.
Derman E. (2011): Models.Behaving.Badly. Free Press.
Dorling D. (2012): The Visualization of Spatial Social Structure. Chichester.
Dorling D. (2011): Injustice. Why Social Inequality Persists. Bristol.
Eagles M. (1995): Spatial and contextual models in political research: an introduction. Eagles M. (ed.): Spatial and Contextual Models in Political Research, London, S. 3-14.
Ellis M. (2009): Vital Statistics. The Professional Geographer, 61(3), S. 301-309.
Epstein J. M. (2006): Generative Social Science. Studies in Agent-Based Computational Modeling. Princeton and Oxford.
Filatova T., Parker D., van der Veen A. (2009): Agent-Based Urban Land Markets: Agent's Pricing Behavior, Land Prices and Urban Land Use Change. Journal of Artificial Societies and Social Simulation, Vol. 12, No. 1, http://jasss.soc.surrey.ac.uk/12/1/3.html (2014-01-30).
Fotheringham A.S., Charlton M., Brunsdon C. (2002): Geographically weighted regression: The analysis of spatially varying relationships. New York.
Foucault M. (2011): Die Ordnung des Diskurses, 11. Auflage, Frankfurt a.M.
Geertz C. (1993): Local Knowledge. London.
Granovetter M. S. (1973): The Strength of Weak Ties. American Journal of Sociology, Vol. 78, Issue 6, p. 1360-1380.
Habermas J. (1995): Theorie des kommunikativen Handelns (2 Bände), 8. Auflage, Frankfurt a.M.
Hampe M. (2011): Tunguska oder Das Ende der Natur. München.
Hennig B. (2013): Rediscovering the World. Map Transformations of Human and Physical Space. Dordrecht, Heidelberg, London, New York.
Hermann M. (2009): Kartographie sozialräumlicher Zusammenhänge. Informationen zur Raumentwicklung, Heft 10/11, S. 701-709.
Heppenstall A. J., Crooks A. T., See L. M., Batty M. (eds.) (2012): Agent-Based Models of Geographical Systems. Dordrecht, Heidelberg, London, New York.
Ihde D. (2006): Models, Models Everywhere. Lenhard J., Küppers G., Shinn T. (eds.): Simulation. Pragmatic Construction of Reality. Dordrecht, p. 79-86.
Ioannides Y. (2013): From Neighborhoods to Nations. The Economics of Social Interaction. Princeton.
Kamper D. (1996): Je mehr Zufall, desto mehr Spiel. E. Hammel (Hrsg.): Synthetische Welten. Kunst, Künstlichkeit und Kommunikationsmedien. Essen. S. 109-117.
Koch A. (2013): Lokales Armutswissen und regionale Disparitäten. Gaisbauer H., Kapferer E., Koch A., Sedmak C. (Hrsg.): Armut und Wissen. Reproduktion und Linderung von Armut in Schule und Wissenschaft. Bielefeld, S. 225-246.
Koch A., Carson D. (2012): Spatial, Temporal and Social Scaling in Sparsely Populated Areas - geospatial mapping and simulation techniques to investigate social diversity. Car A., Griesebner G., Strobl J. (Hrsg.): Geospatial Crossroads @ GI_Forum '12, Proceedings of the Geoinformatics Forum Salzburg, Offenbach, p. 44-53.

Küppers G., Lenhard J., Shinn T. (2006): Computer Simulation: Practice, Epistemology, and Social Dynamics. Lenhard J., Küppers G., Shinn T. (eds.): Simulation. Pragmatic Construction of Reality. Dordrecht, p. 3-22.
Kwan M.-P., Schwanen T. (2009): Quantitative Revolution 2: The Critical (Re)Turn. The Professional Geographer, 61(3), S. 281-291.
Lewin K. (1931): The Conflict between Aristotelian and Galileian Modes of Thought in Contemporary Psychology. In: Journal of General Psychology, 5, p. 141-177.
Link O. (2011): „Die Welt lässt sich nicht berechnen". brand eins, 13. Jg., Heft 11, S. 110-115.
Lotter W. (2011): Wir rechnen mit allem. brand eins, 13. Jg., Heft 11, S. 40-54.
Lyotard F. (2006): Das postmoderne Wissen. 5. Auflage, Wien.
Madelin M., Grasland C., Mathian H., Sanders L., Vincent J.-M. (2009): Das "MAUP": Modifiable Areal Unit – Problem oder Fortschritt? Informationen zur Raumentwicklung, Heft 10/11, S. 645-660.
Manson S. M., Sun S., Bonsal D. (2012): Agent-Based Modeling and Complexity. Heppenstall A. J., Crooks A. T., See L. M., Batty M. (eds.) (2012): Agent-Based Models of Geographical Systems. Dordrecht, Heidelber, London, New York, p. 125-139.
Maretzke S. (2006): Regionale Disparitäten – eine bleibende Herausforderung. Informationen zur Raumentwicklung, Heft 9, S. 473-484.
Metcalf S.S. (2014): Modeling Social Ties and Household Mobility. Annals of the Association of American Geographers, Vol. 104, Number 1, p. 40-59.
Nagel T. (2012): Mind and Cosmos: Why the Materialist Neo-Darwinian Conception of Nature is Almost Certainly False. Oxford.
Nipper J. (2011): Rechnen und Mathematikmachen: quantitative Analyseverfahren in der Geographie. Gebhardt H., Glaser R., Radtke U., Reuber P. (Hrsg.): Geographie. 2. Auflage. Heidelberg.
Openshaw S. (1981): The modifiable areal unit problem. Wrigley N., Bennet R.J. (eds.): Quantitative Geography: A British View. p. 60-69.
Pancs R., Vriend N. J. (2007): Schelling's spatial proximity model of segregation revisited. Journal of Public Economics 91, p. 1-24.
Peake L. (2008): Moving on up. Gender, Place, and Culture 15(1), p. 7-10.
Putnam H. (2007): Pragmatism and Realism. London.
Rheinberger H.-J. (2001): Experimentalsysteme und epistemische Dinge. Eine Geschichte der Proteinsynthese im Reagenzglas. Göttingen.
Rorty R. (1981): Der Spiegel der Natur. Frankfurt a. M.
Schäfer L., Schnelle T. (Hrsg.) (2012): Ludwik Fleck. Entstehung und Entwicklung einer wissenschaftlichen Tatsache. 9. Auflage. Frankfurt a.M.
Schelling T. C. (1971): Dynamic models of segregation. Journal of Mathematical Sociology 1 (2), p. 143-186.
Schelling T. C. (1969): Models of segregation. American Economic Review, Papers and Proceedings 59, p. 488-493.
Schurz G. (2008): Einführung in die Wissenschaftstheorie. Darmstadt.
Squazzoni F. (2012): Agent-Based Computational Sociology. Chichester.
Stachowiak (1973): Allgemeine Modelltheorie. Wien New York (Reprint).
Strubelt W. (2006): Auf der Suche nach der Gleichwertigkeit der Lebensverhältnisse – oder: Die Suche nach verloren gegangenem Sinn der Zeit? Informationen zur Raumentwicklung, Heft 9, S. 305-308.
Waddell P. A. (1997): Household Choice and Urban Structure. Aldershot.
Ward M. D., Gleditsch K. S. (2008): Spatial Regression Models. Los Angeles, London, New Delhi, Singapore.
Weiss W. (2010): Gödels Unvollständigkeitssatz, die Vernunft, Metawahrheit(en) und Everetts Vielweltentheorie. Wissenschaftliche Nachrichten des Bundesministeriums für Unterricht, Kunst und Kultur, p. 3-12.
Wilensky U. (1999): NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.
Zolnik E. J. (2009): Context in Human Geography: A Multilevel Approach to Study Human-Environment Interactions. The Professional Geographer, Vol. 61, No. 3, p. 336-349.