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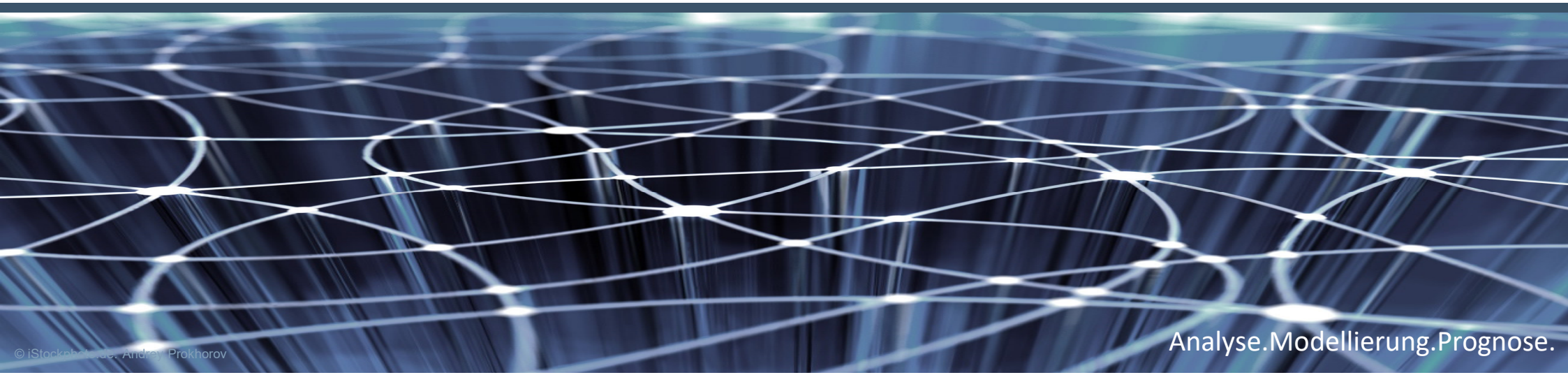
Limits to growth in modelling – implications, impacts and challenges

Günter Haag



One fundamental stimulus of human research

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"Was die Welt im Innersten zusammenhält" (Goethe, Faust I)
"What holds the world together at its core"

Douglas Adams (1979) formulated in his famous book "The Ultimate Hitchhiker´s Guide to the Galaxy" in a simple but realistic way, …where do we come from, where do we go and where do we get the best Wiener Schnitzel?

What is a model?

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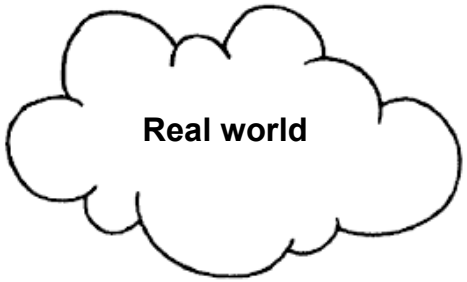
Models are based on rules
Rules are based on experience
John L. Casti



natural system

Models can be formulated and built in different languages.

country sayings and weather proverbs
in a field report

models e.g. for weather forecasting in the
language of physics and mathematics

The model should be kept as simple as possible but not
too simple. Albert Einstein

Picturing the world in mathematics

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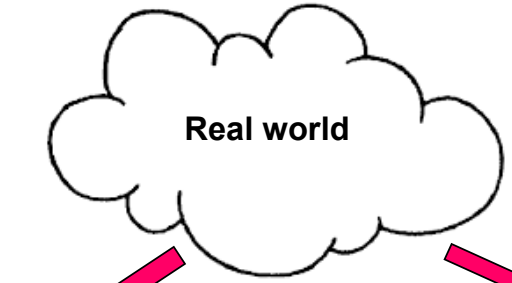
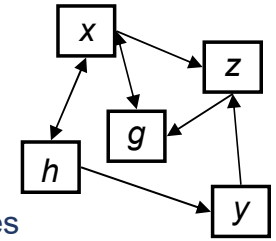
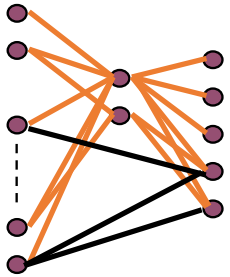


System Theory
(Jay Forrester)



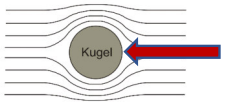
Initial conditions
nonlinearities essential
Phase transitions
cycles, chaotic trajectories
uncertainties of data
scenario technique
simulation of uncertainties
distribution instead of a single value

Neural Networks (AI)
data driven modelling



black box
mass data required
nonlinearities via transfer function
difficult to analyse

Physical Models
Stokes´ law



$$F = 6\pi\eta r v$$

viscosity
velosity
force
radius

A challenge in the 70th

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„Club of Rome (1972)“
MIT System Dynamics
(Jay Forrester)

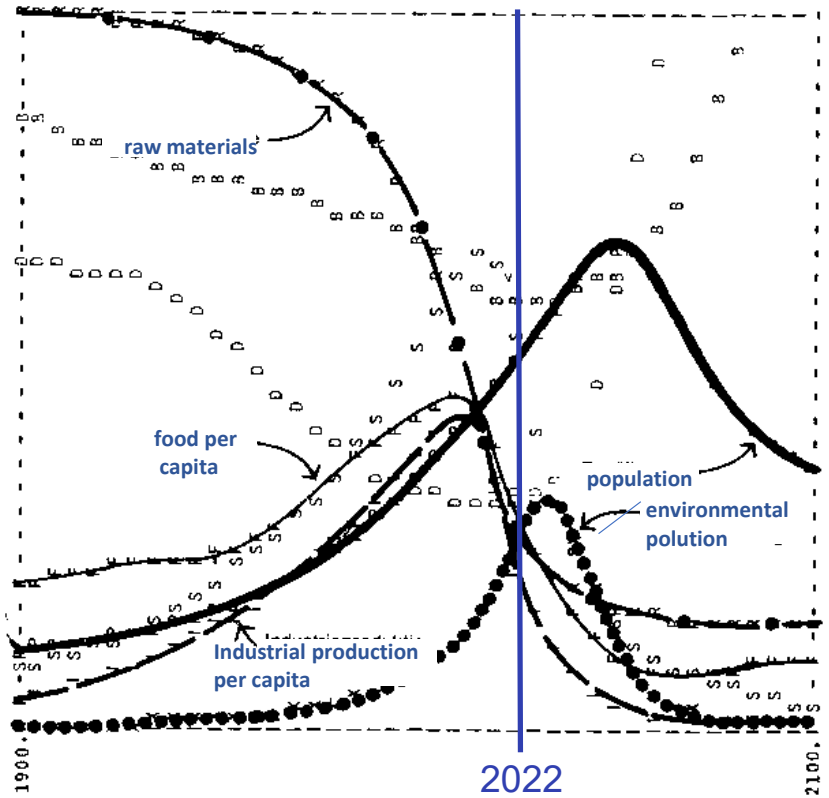
→ Dynamics of Growth in a Finite World (Meadows et. al)

MIT Boston (1990)
World model (about 160.000 equations,
95% of the world economy)

IAB-Inforge (2000) (Meyer, Osnabrück)
Modul of the German economy (MITI (Japan)),
about 30.000 equations. Development of the German economy (NUTS 1, NUTS2)

We need a spatially disaggregated model (Koller, IAB)

IAB-STASA (2002) (Stuttgart, Nürnberg)
Evolutionary model of German economy (NUTS 3), districts (about 1.600 equations)



A few limitations

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Uncertainties

uncertainties and outliners in the data
uncertainties in the initial conditions
uncertainties in the parameter estimation

Complexity

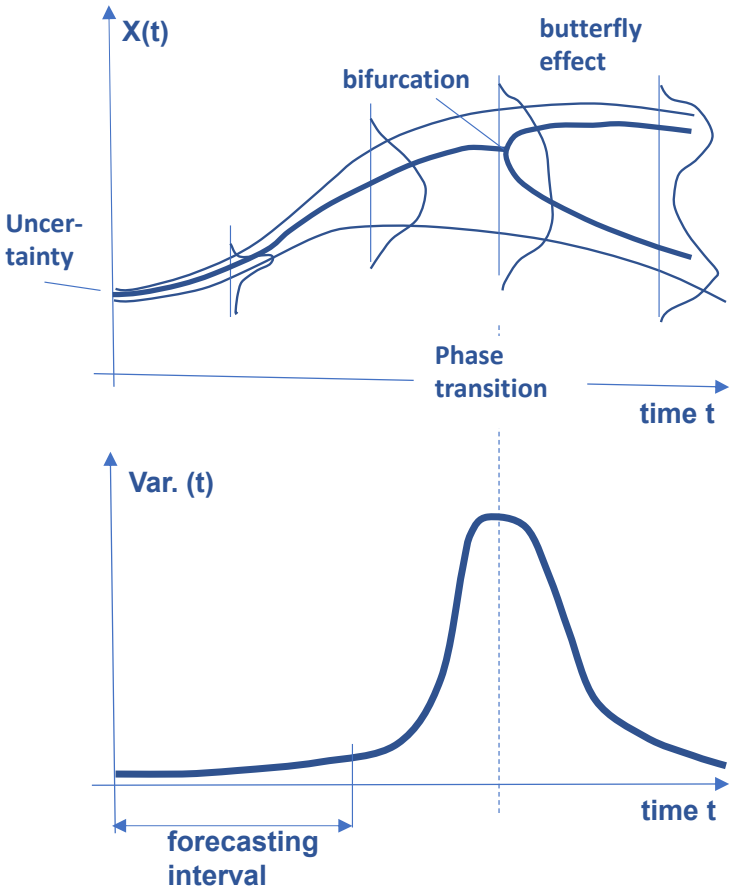
non linearities in the system may create phase transitions
new up to now unknown variables may appear (P. Allen)
social systems are capable of learning
unexpected events (Ukraine war)

What can we do?

scenarios technology - simulation of different possible events (best, expected, worst)
simulation of uncertenties (Monte Carlo procedure)

Conclusion

not only one trajectory but a bundle of trajectories
length of forecasting periode is limited



Towards Interdisciplinarity 50‘s onwards

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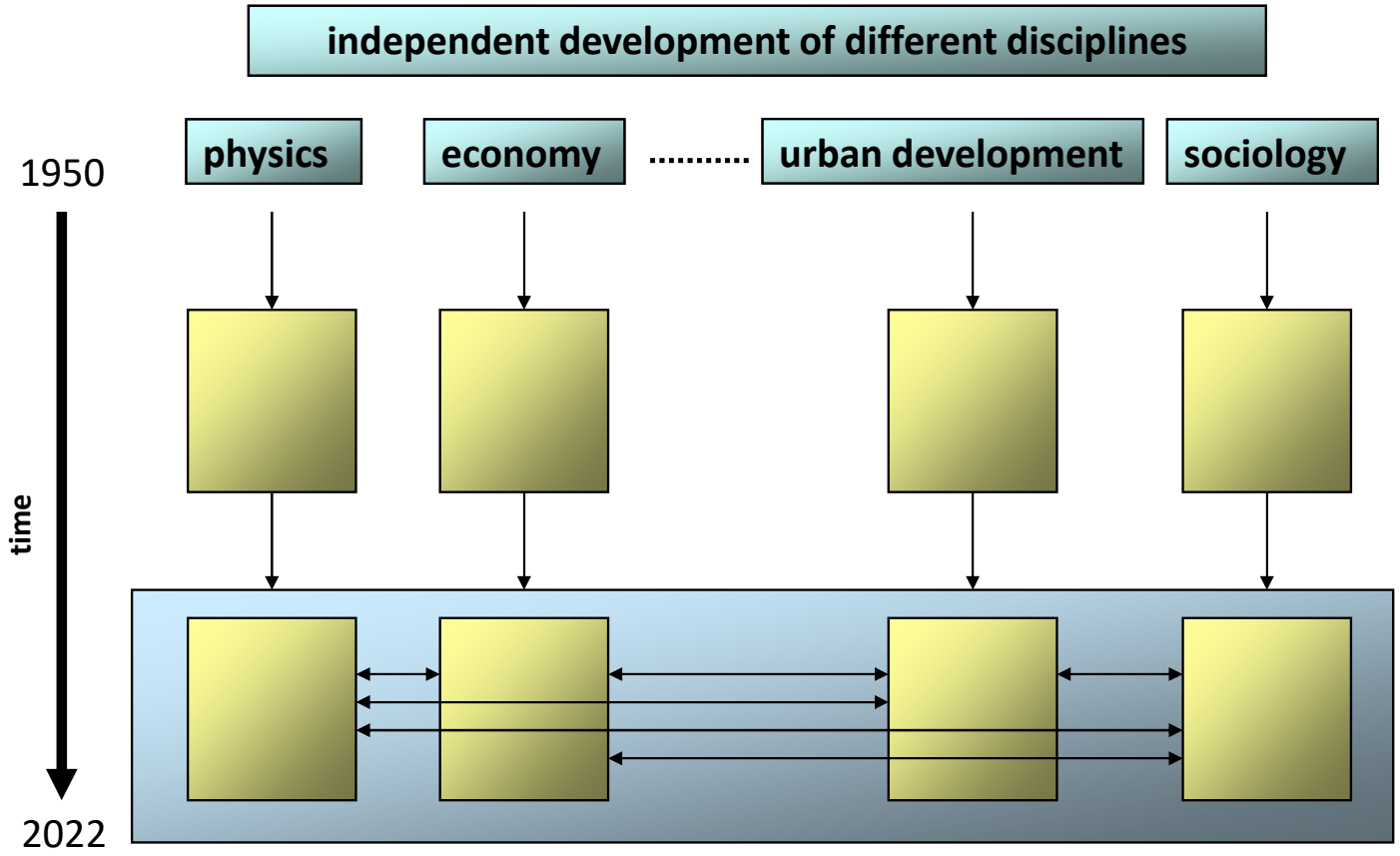

Integration of disciplines, transfer of methods, ideas by pioneers like H.v.Foerster

Appropriate Modelling: Looking for Structural Similarities

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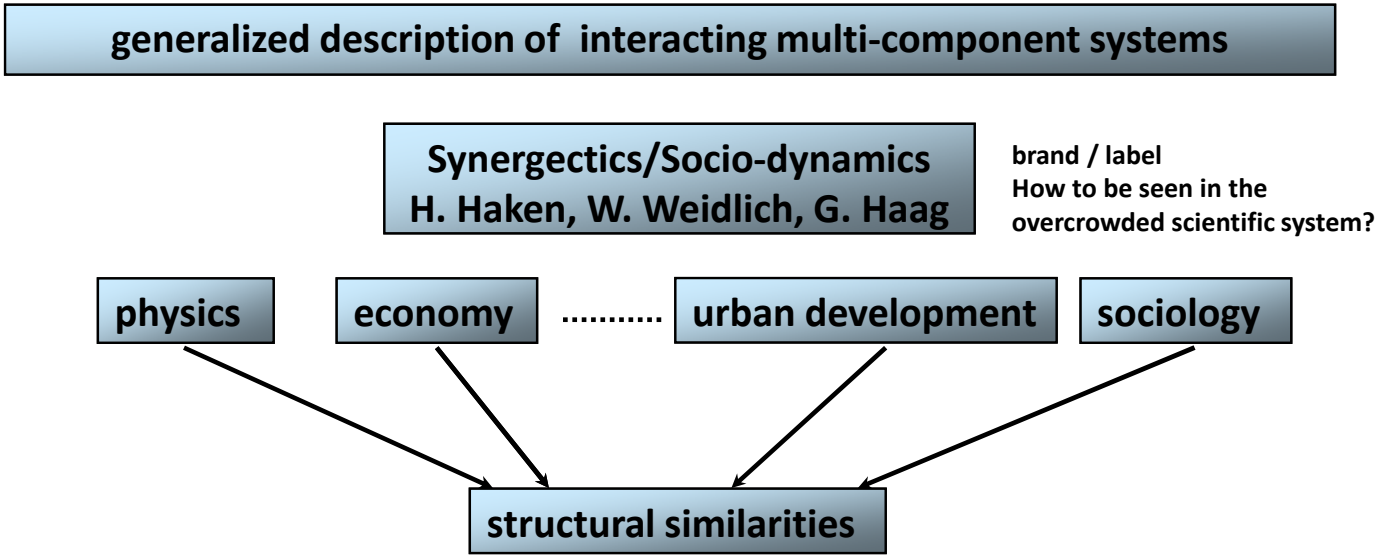

- universality (mathematics of stochastic processes)
- many subsystems
- interactions different on the micro-level beside structural similarities
- non-linearity (self-organisation)
- fluctuations
- space-time features
- open or closed systems

Example: Interregional Migration in Germany

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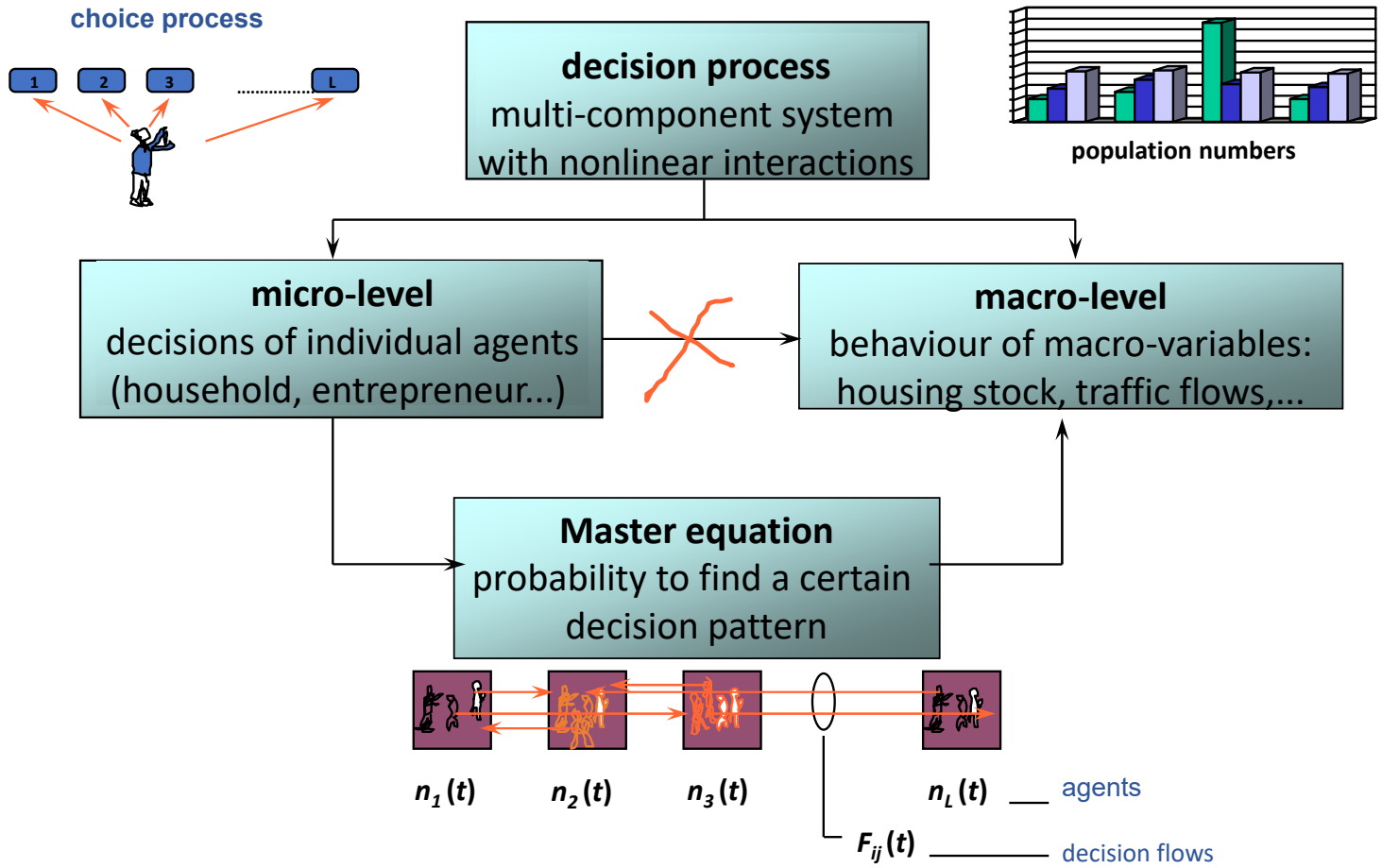
Synergetics/Sociodynamics – The framework



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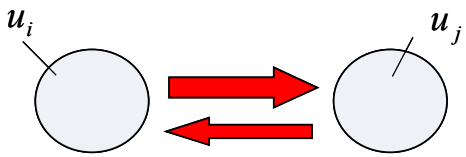
Transition rate: groups of agents



$$W_{ij}(\vec{n},t) = n_i p_{ij}(\vec{n},\vec{\delta}) = n_i \nu_{ij} \exp(\, u_j(\vec{n},\vec{\delta}) - u_i(\vec{n},\vec{\delta})) \geq 0$$

change of residence per time unit *i to j*

population living in region *i*

"individuel" transition rate from *i* to *j*

effect of „distance" (symmetric matrix)

difference in spatial attractiveness or utilities

Regional attractiveness and spatial preferences

$$u_i = \kappa n_i + \delta_i(t)$$

agglomeration effect

$$\delta_i(t) = w_1 XW_i + w_2 XB_i + w_3 XV_i + w_4 XT_i + w_5 XF_i + w_6 XU_i$$

regional preference

housing market indicator

employment indicator

services

accessibility indicator

leisure time Indicator<

environment

Empirical flows versus model flows (total population)

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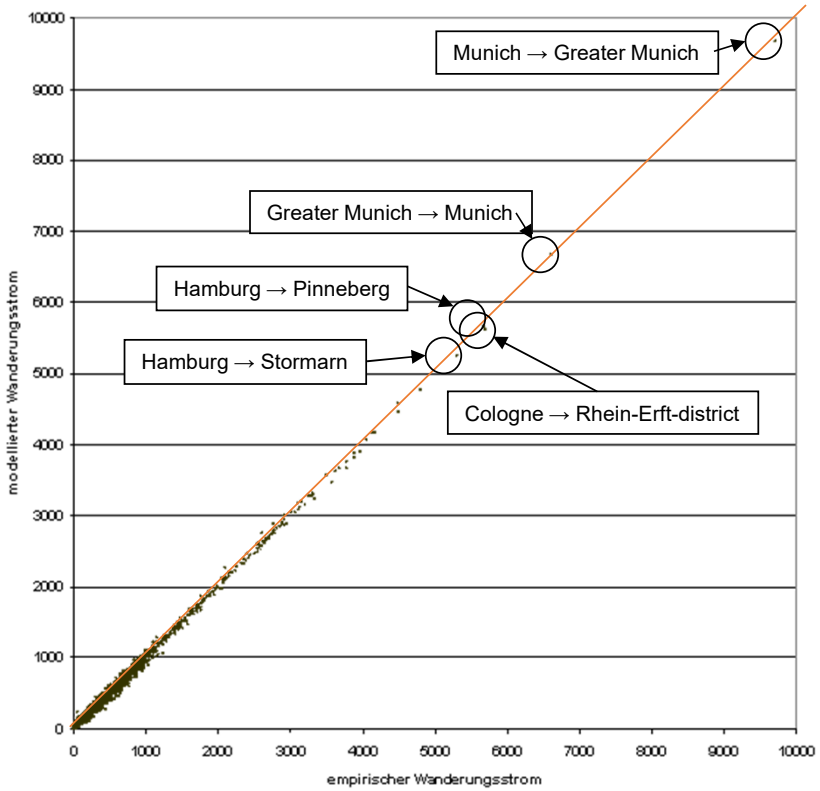
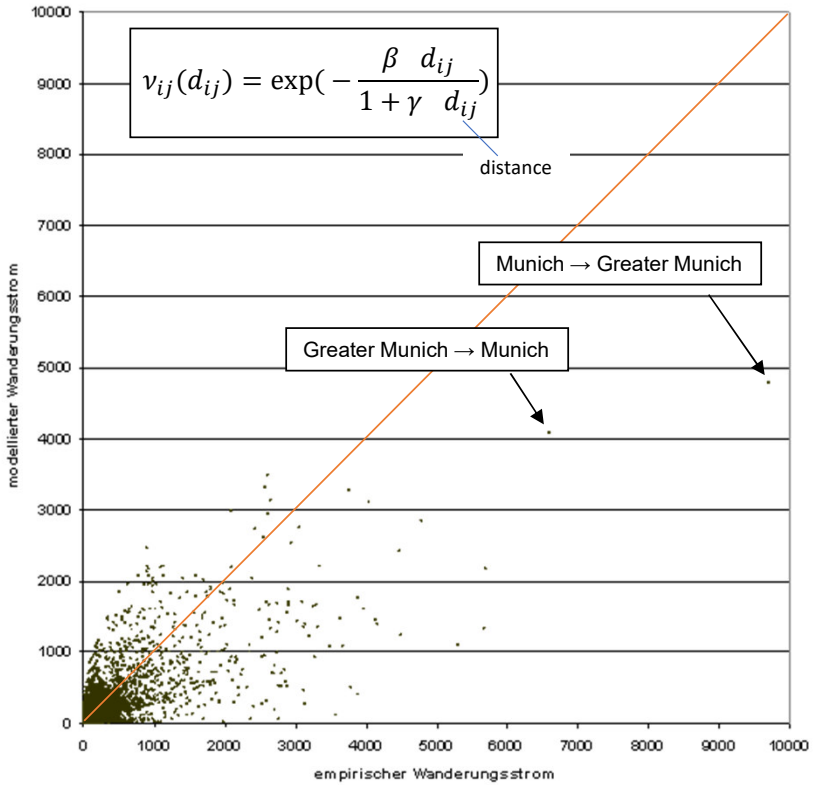
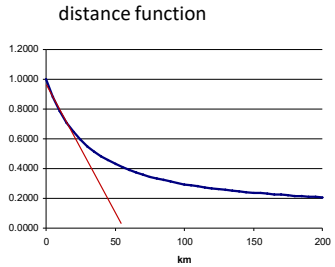
Estimated spatial interaction term



R^2 = 0,98

Assumed distance dependence





β = 0,132; γ = 0,0163; R^2 = 0,600

Spatial preferences (total population): districts (401)

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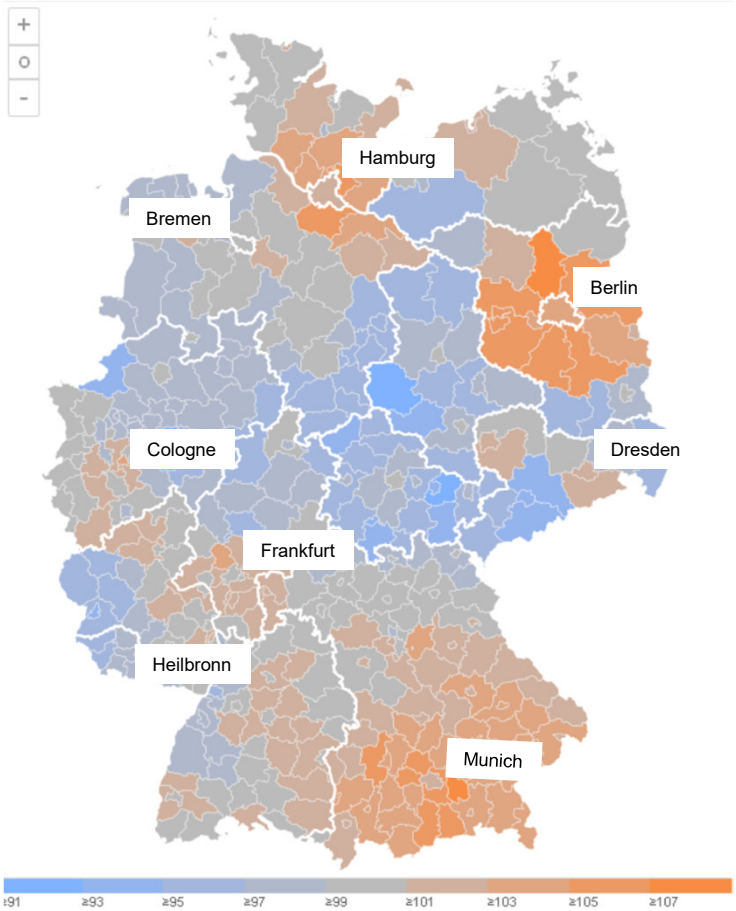

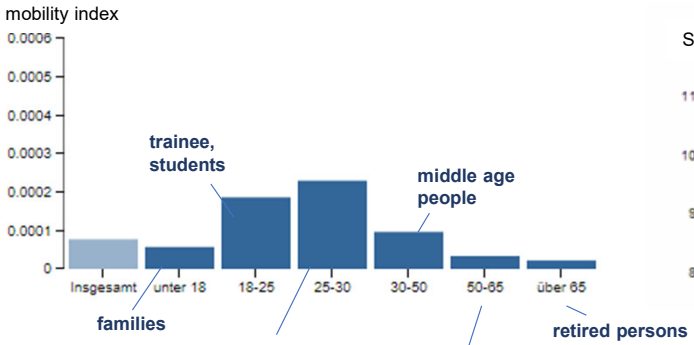

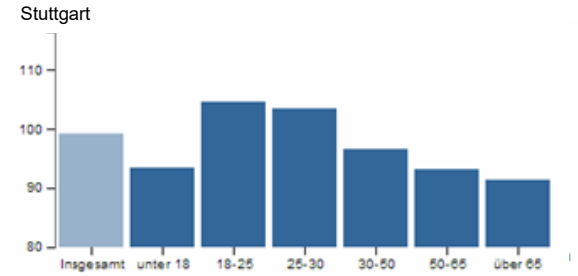

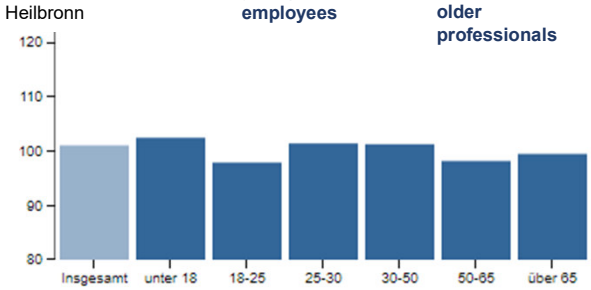

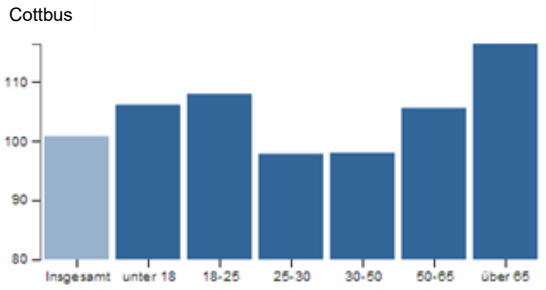

attractiveness
for young people
below average

Preferences: districts (402) and communes (11.418)

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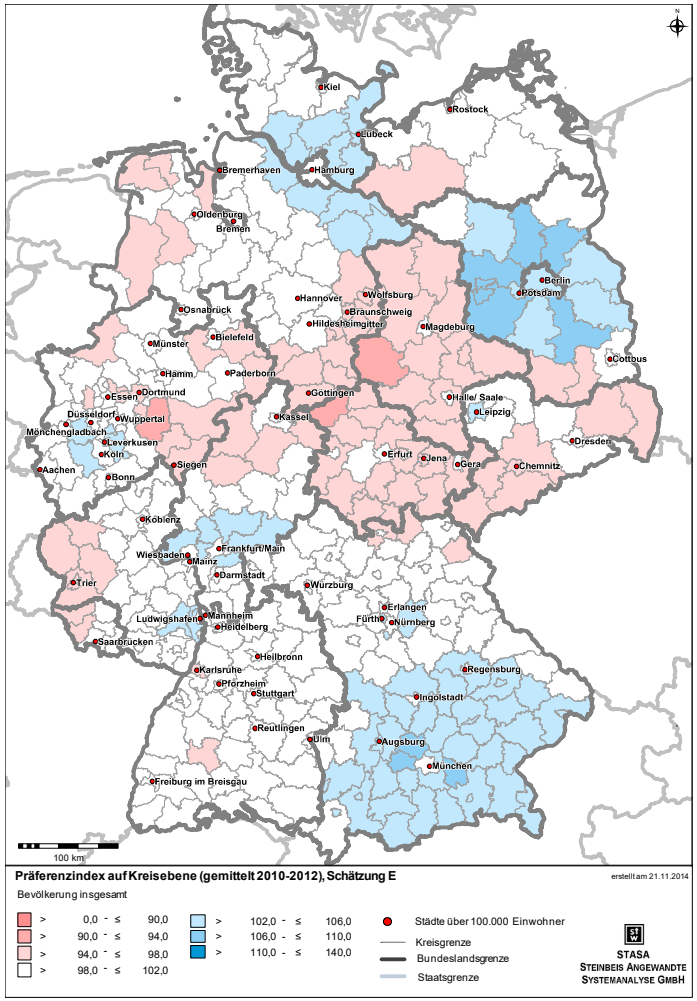

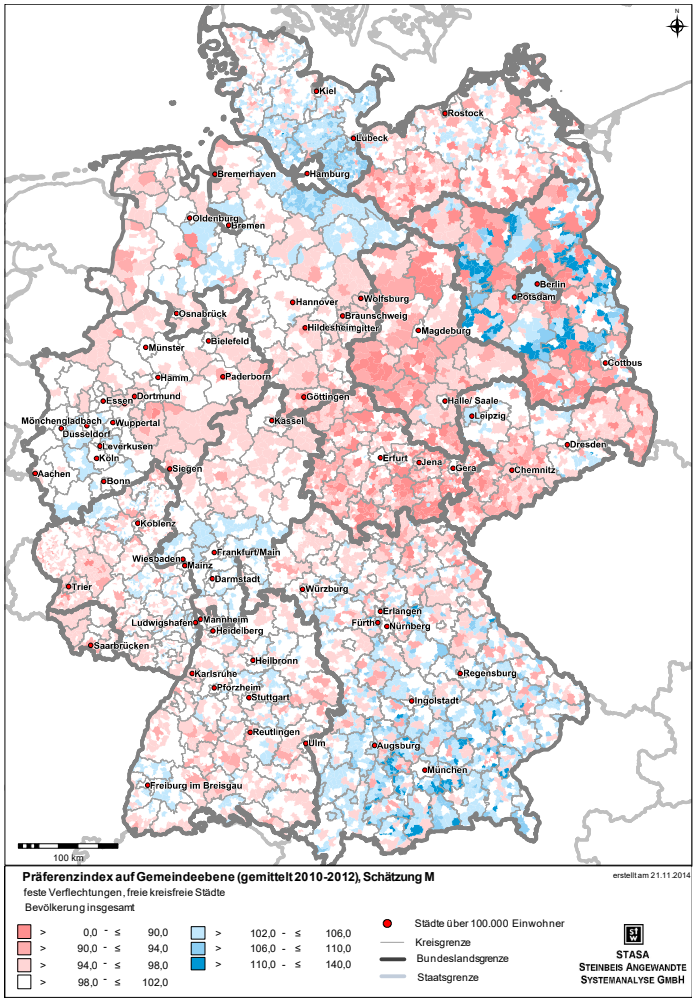

Strength of spatial interaction: Cities of Heilbronn (left) and Stuttgart (right) with other districts

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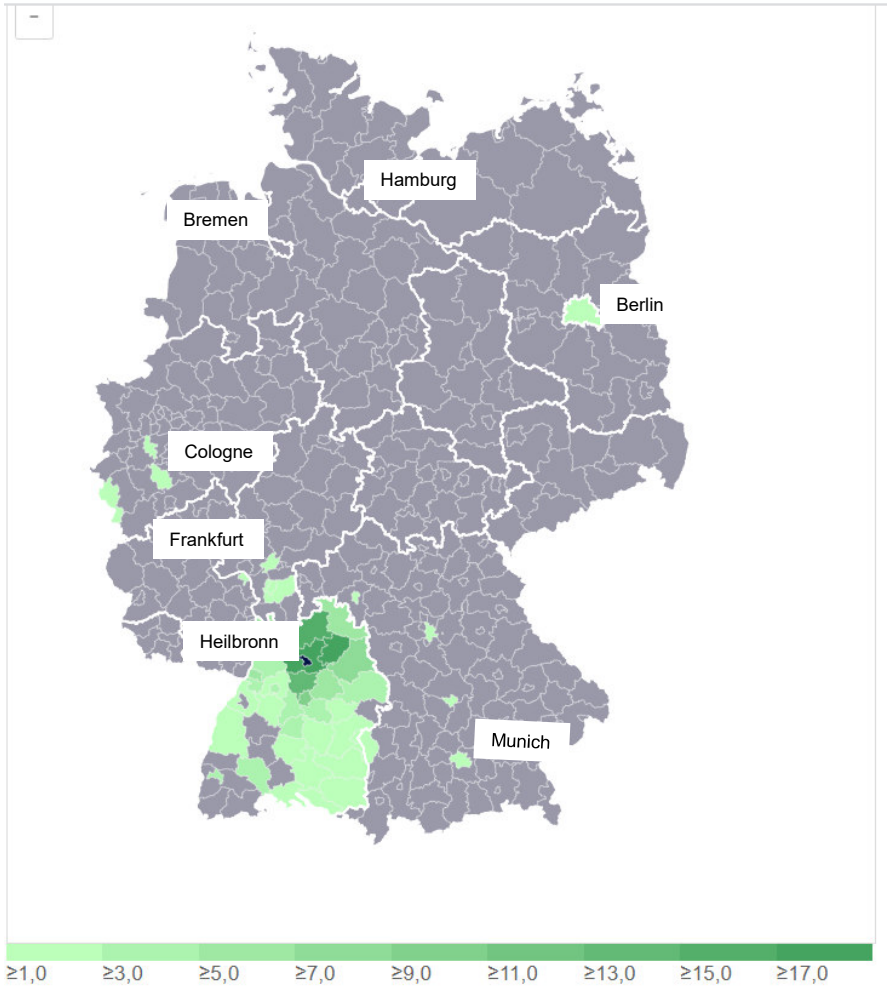

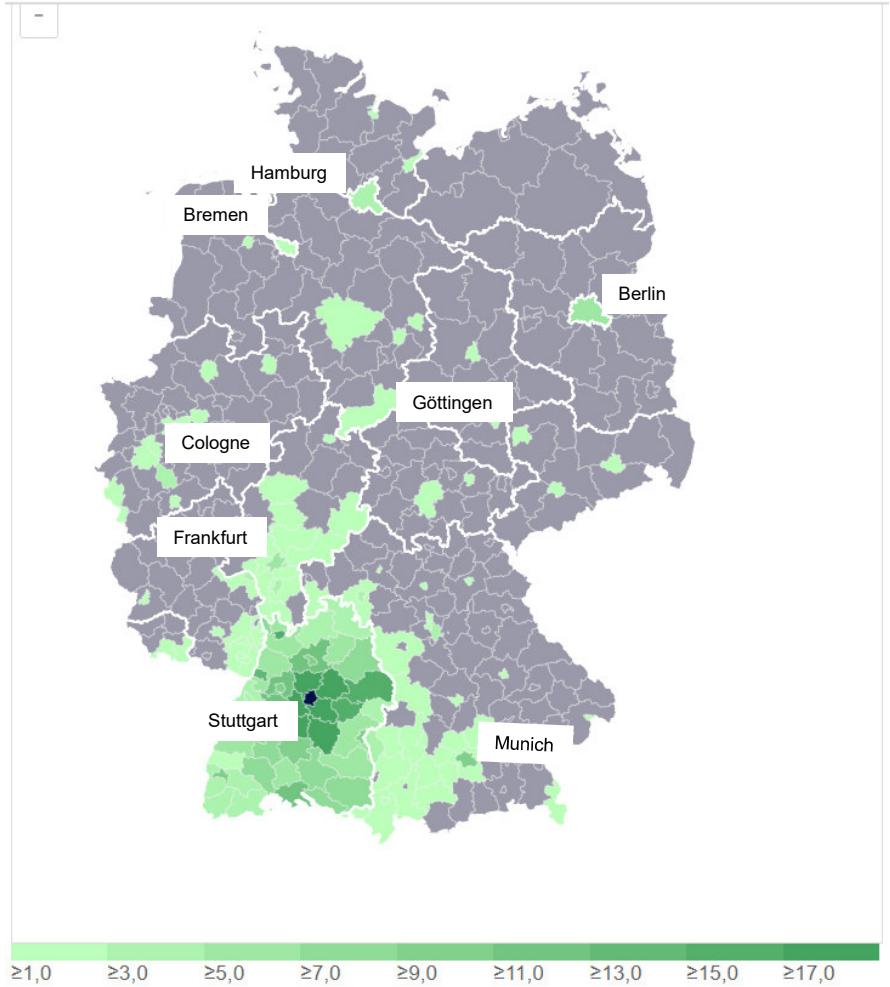

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Theories and tools: Phases of development

Towards Nested Theories

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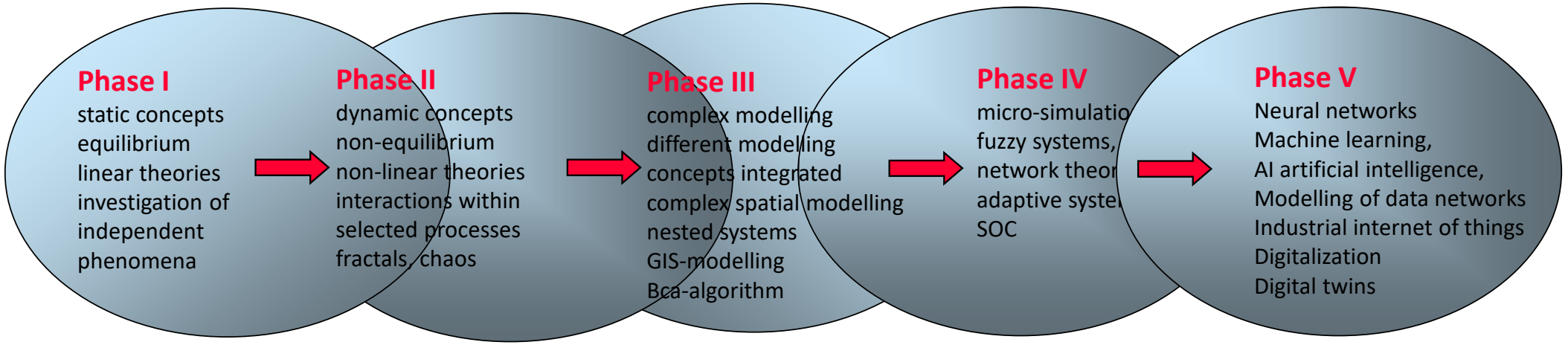

until 1970

1970 - 1990
General Systems Theory
(Forrester, Meadows, Zahn)
Synergetics (Haken)
(H-v.Foerster,...)

1980 – 2000
Nonlinear Systems
Sociodynamics
(Weidlich, Haag,
Nijkamp, Pumain, Pyka)

1990 - 2010
Network Science
(Barabasi, Reggiani, Nijkamp)
Adaptive Systems
(J. Holland,...)
micro-simulations
(R. White,...)

2000- 2020
Tensor Flow
Data cooperatives
(Lasi, Slama,...)

The ideas of H. v. Foerster, H. Haken, W. Weidlich and other pioneers survive and will foster new developments in the scientific society

The theories and tools currently available make research more effective and support interdisciplinary research

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Thank You for your attention