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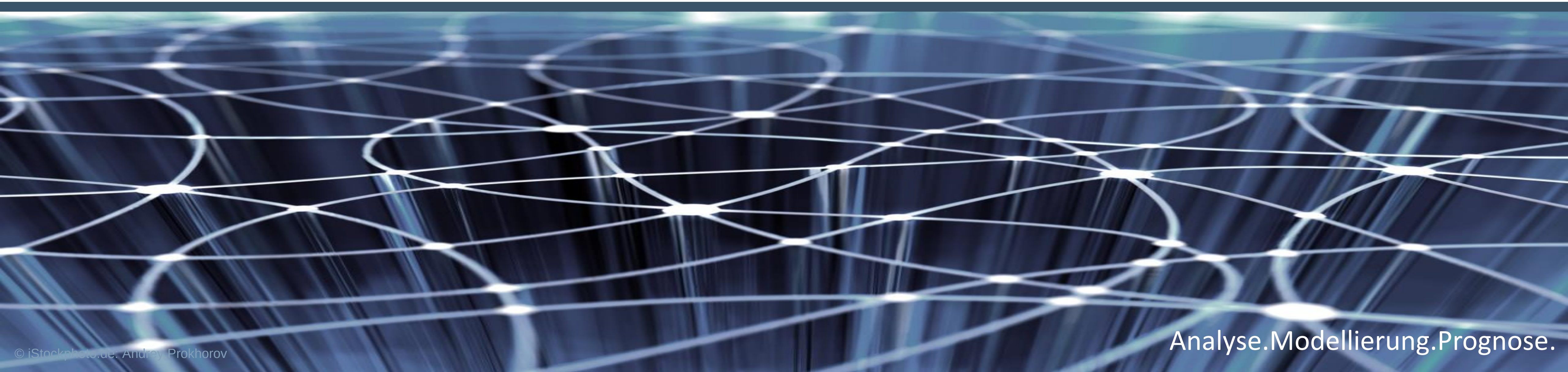
Systemanalyse GmbH

Universität Stuttgart
II. Institut für Theoretische Physik

Individual Decisions, Innovations and Sustainable Economics

Günter Haag



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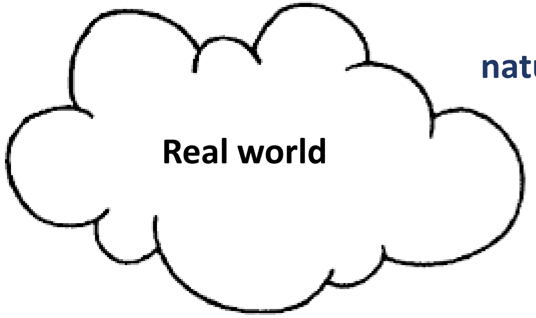
One fundamental stimulus of human research



natural system

“Dass ich nicht mehr mit saurem Schweiß
rede von dem was ich nicht weiß

(sondern)

Dass ich erkenne, 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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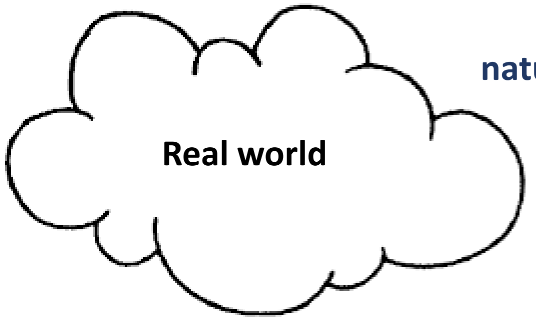

natural system

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

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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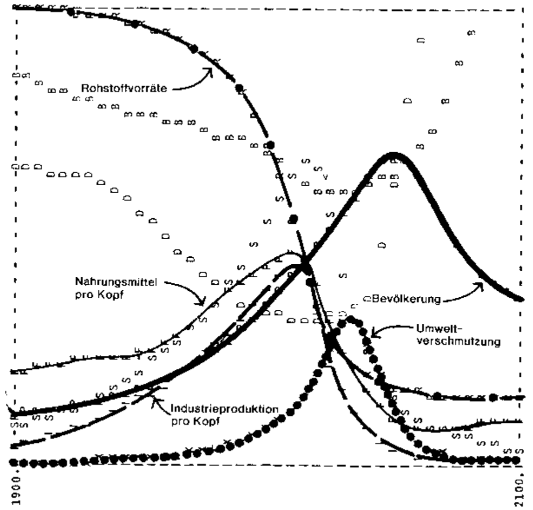
Real world

Deterministic Models

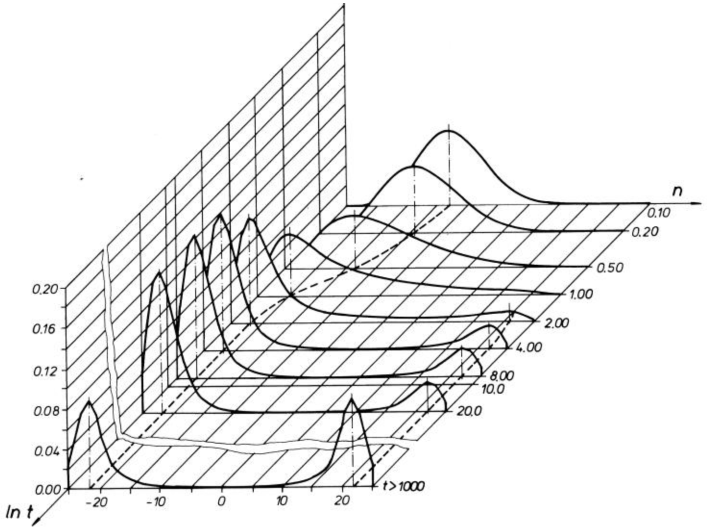


Club of Rome (1972)
System Dynamics (Jay Forrester)

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

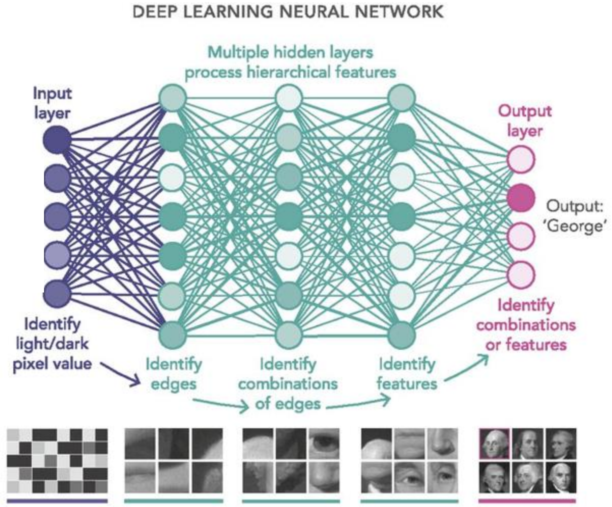
Statistical Models

models with uncertainties

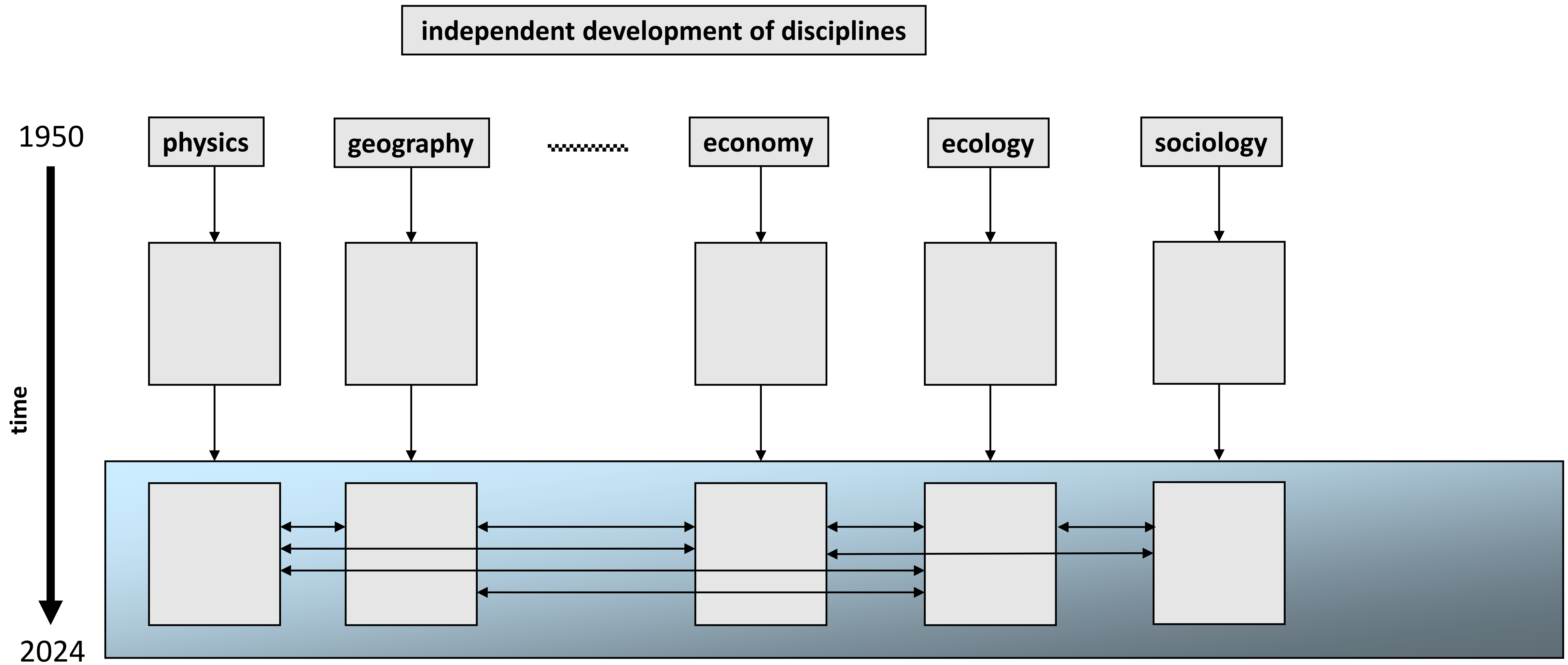


Neural Networks (AI)

data driven modelling

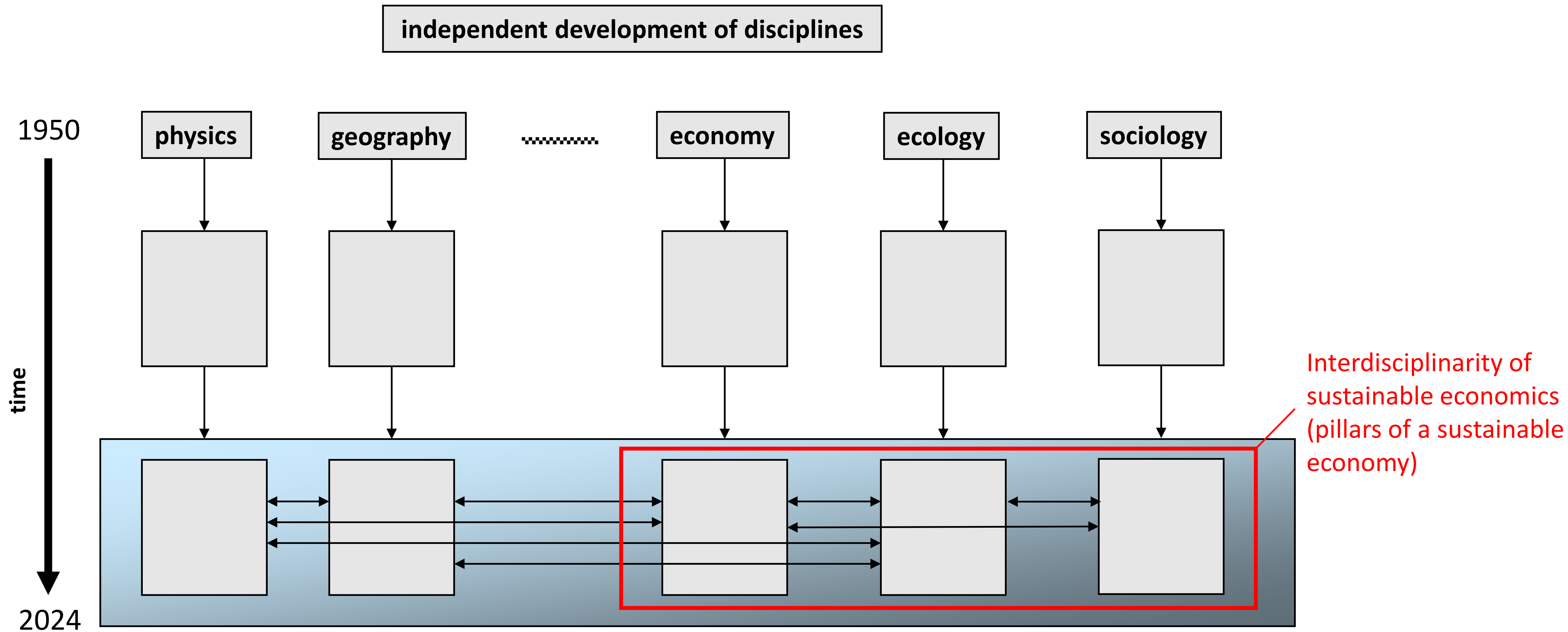


Towards Interdisciplinarity 50‘s onwards



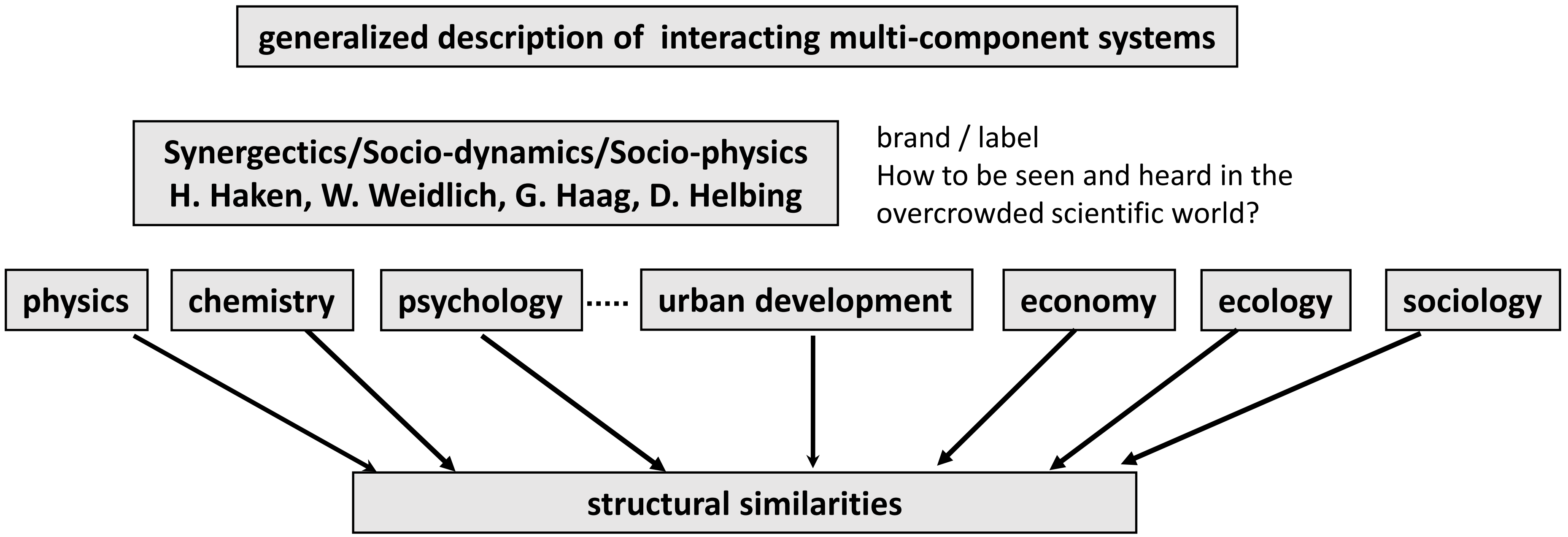
Integration of disciplines, transfer of methods, ideas by pioneers like H.v.Foerster, Haken, Weidlich, Prigogine, Haag,…

Towards Interdisciplinarity 50's onwards



Integration of disciplines, transfer of methods, ideas by pioneers like H.v.Foerster, Haken, Weidlich, Prigogine, Haag,...

Appropriate Modelling: Looking for Structural Similarities



- universality (mathematics of stochastic processes)
- many subsystems
- interactions different on the micro-level beside structural similarities
- non-linearities (self-organisation)
- fluctuations
- space-time features, path dependence, SOC, multiple equilibria, chaos,…
- open or closed systems

Appropriate Modelling: Looking for Structural Similarities

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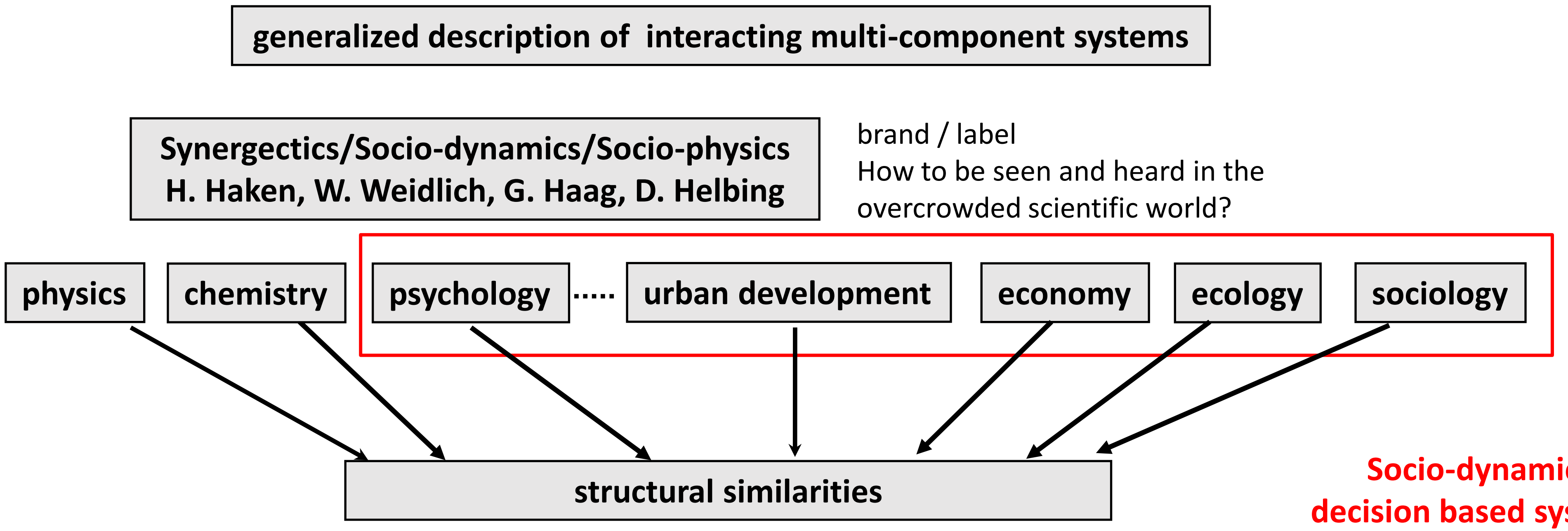

- universality (mathematics of stochastic processes)
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Socio-dynamics
decision based systems

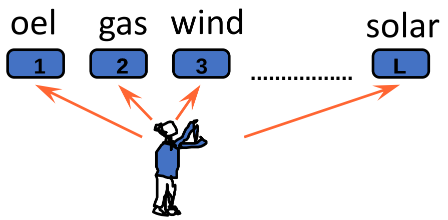
- highly nested system
- uncertainties constantly present
- decisions influenced by the society
- political guidelines
- highly dynamical environment
- nonlinear interactions

⇓

sustainable economics

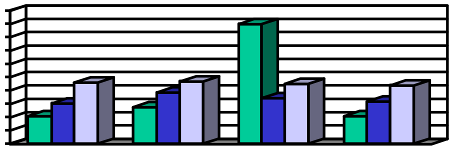
How to model Decision Processes – The Framework

Individual choice
selection of alternative technologies



Individual attitudes
cost
longevity
value for money
regionality
conserving resources

decision process
multi-component system
with nonlinear interactions



number of users of an alternative

micro-level
decisions of individual agents
(household, entrepreneur...)

feedback

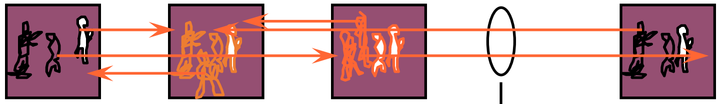
macro-level
behaviour of macro-variables
(share of market pentration,
housing stock, population,...)

socio-economic environment
global climate
policy
number of user of
different technologies

Master equation
probability to find a certain
decision pattern

$$P(\vec{n})=P(n_1, n_2, \dots n_L)$$

probability



$n_1(t)$ $n_2(t)$ $n_3(t)$ $n_L(t)$ — number of decision maker

$W_{ij}(t)$ — number of changes between alternatives

Master equation framework

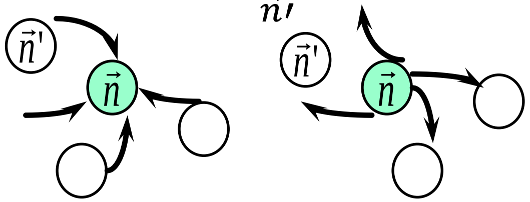
Pauli Master equation

input: transition rates

trend parameter

$$\frac{dP(\vec{n},t)}{dt} = \sum_{\vec{n}'} w_t(\vec{n},\vec{n}';\vec{\kappa})P(\vec{n}',t) - \sum_{\vec{n}'} w_t(\vec{n}',\vec{n};\vec{\kappa})P(\vec{n},t)$$

output: change of probability



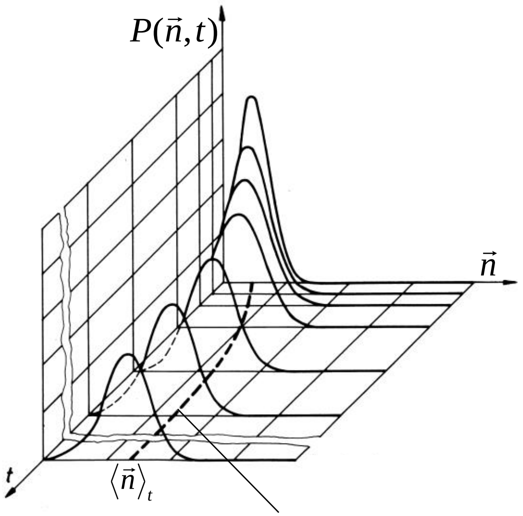
$\vec{n}=(n_1, n_2, \dots n_L)$

different alternatives

Equations of motion

mean value

$$\frac{d\overline{n(t)}}{dt} = \sum_{\vec{n}} \vec{n}\,\frac{dP(\vec{n},t)}{dt} = \frac{d}{dt}\sum_{\vec{n}} \vec{n}P(\vec{n},t)$$

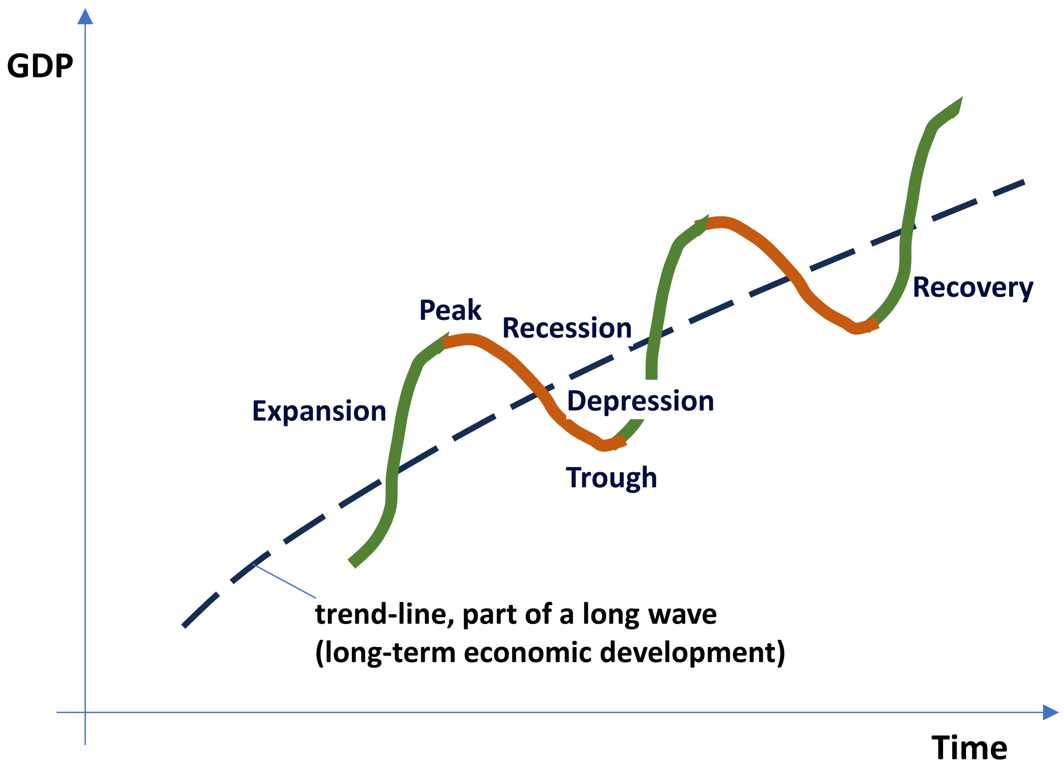


mean value

Some properties

- The transition rates define the process – all we need
- dynamic equation for probability to find a certain configuration
  → Mean value equation, variance equation
- balance equation for probability fluxes
- irreversable dynamics → unique stationary state
- Markoff assumption → socio-dynamics: system parameters change over time
- Master equation → Agent-Based-Modelling, Fokker-Planck-Equation

1. Example: Business Cycles – Theory of Investments



Business cycle (4 to 6 years)

cycle of fluctuations in the Gross Domestic Product (GDP) around its long-term natural development

- Expansion
- Peak
- Recession
- Depression
- Trough
- Recovery

Observation at trade fairs:

years nothing new – years all have new

coordination of firms activities (information exchange)

→ collective behaviour

How can we eliminate business cycles (Tinbergen, 1983)?

Business cycles and fluctuations around the trend line are natural – we have to anticipate its development (Haag)

Schumpeter Clock – Theory of strategic investments

choice process
strategic investment

$I(t) = E(t) + R(t)$

$E(t)$ $R(t)$

expansionary investment

rationalizing investment

Investor entrepreneur

Transition rate E → R

$$w_{RE}(n) = n_R p_{RE}(n) = n_R \nu \exp(u(n_E) - u(n_R)) = n_R \nu \exp((\delta(t) + \kappa(n_R - n_R))$$

rate of change preference from $E \rightarrow R$

frequency of switch

utility difference

alternator

coordinator

investors configuration

$$\frac{d\bar{x}(t)}{dt} = 2\nu[\sinh(\delta(t) + \kappa\bar{x}(t)) - \bar{x}(t)\cosh(\delta(t) + \kappa\bar{x}(t))]$$

alternator dynamics

$$\frac{d\delta(t)}{dt} = -2\mu[\delta_0 \sinh(\beta\bar{x}(t)) + (\delta(t) - \delta_1)\cosh(\beta\bar{x}(t))]$$

Schumpeter Clock (Mensch, Weidlich, Haag, 1981)

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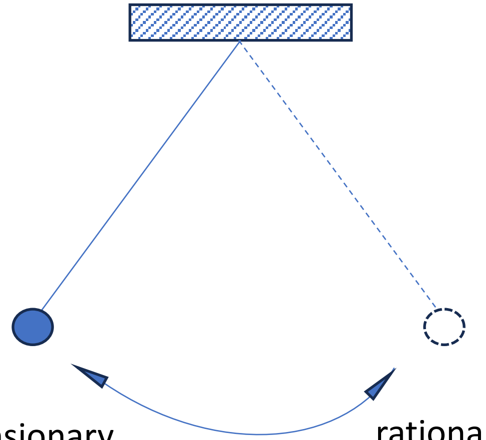
strategic investment
searching of profits
$I(t) = E(t) + R(t)$



expansionary
investment E(t)

rationalizing
investment R(t)

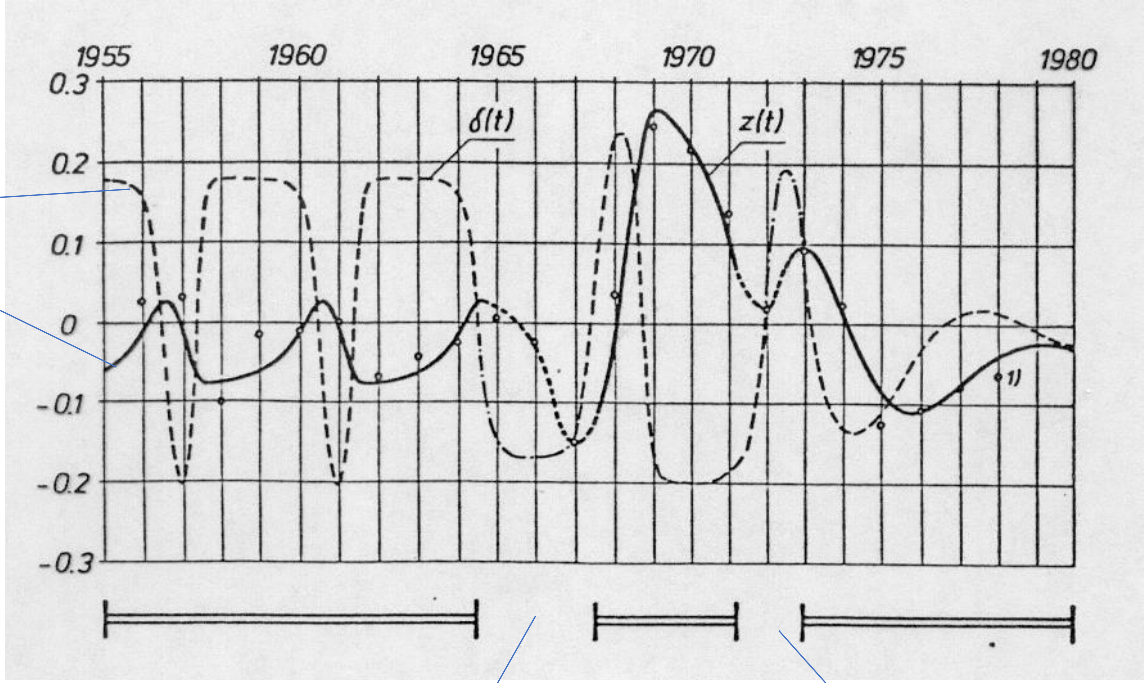
Data Base: IfO-Data about firms investment
of about 6.000 firms

expansionary investments

alternator dynamics

investment structure index
Z=(E-R)/(E+R)

rationalizing investments



How much do I want to invest (next period)

How much did I invest (last period)

hyperboom
„Schiller“ effect
Keynesian economist
Grand coalition
CDU+SPD

two oil shocks caused
slumpflation
(M. Freedman)

Some limitations in economic modelling

Uncertainties

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

Complexity

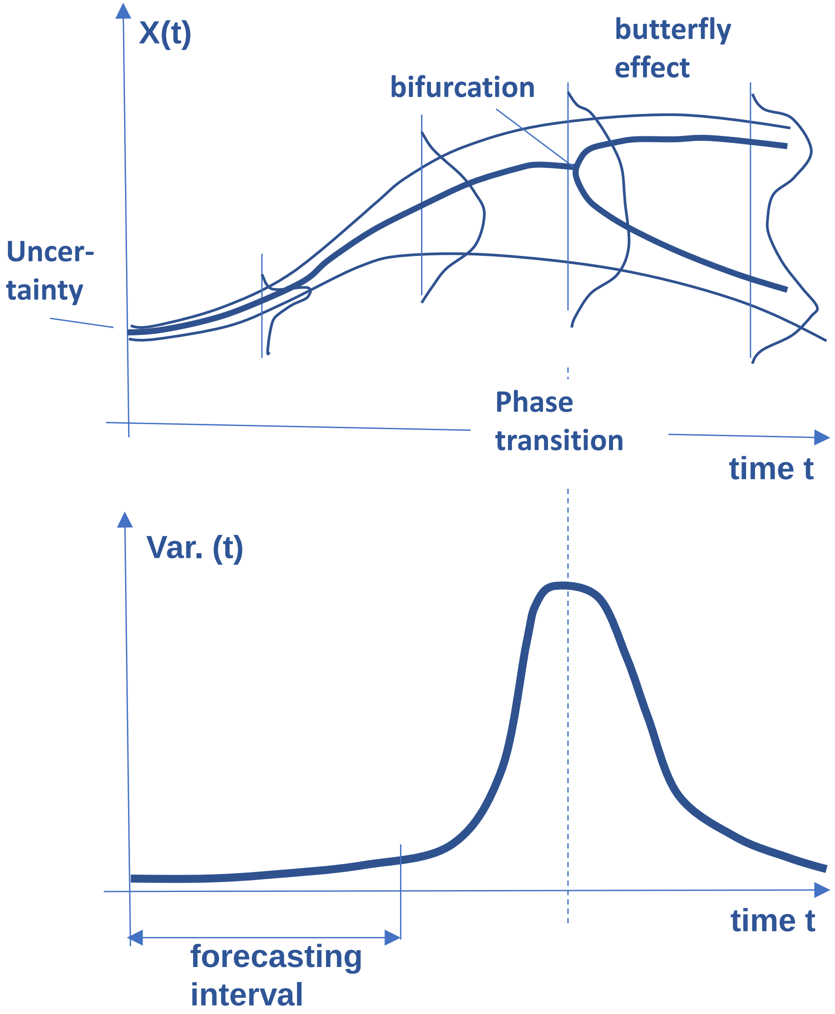
non linearities in the system may create phase transitions
new up to now unknown variables may appear (P. Allen)
social systems are capable of learning
unexpected events (Ukraine war)

What can we do?

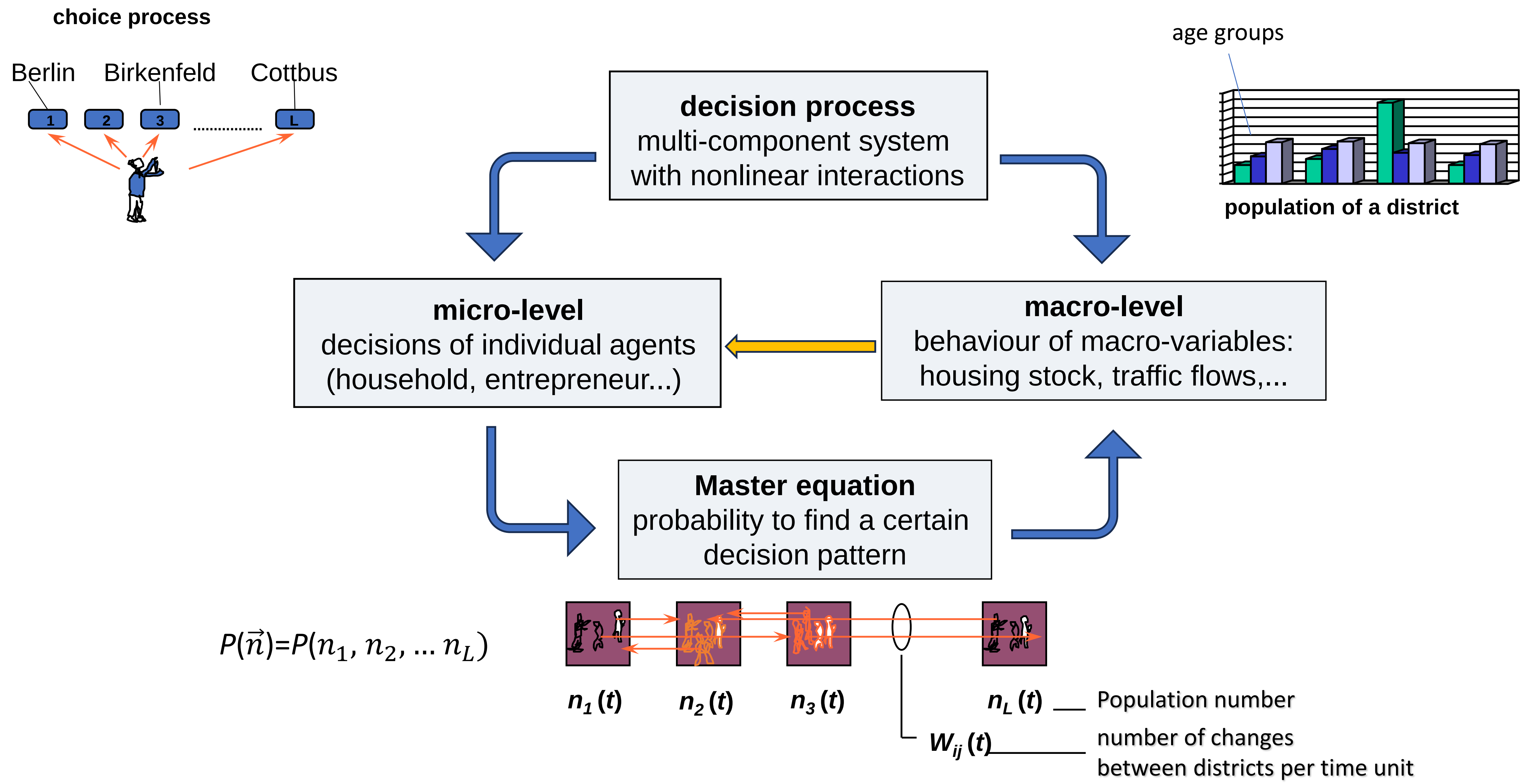
scenarios technology - simulation of different possible events (best, expected, worst)
simulation of uncertenties (Monte Carlo procedure, agent based modelling)

Conclusion

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



2. Example: Interregional Migration (German Districts and Communities)



Weidlich-Haag Migration model (1981/1988)

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transition rate: changes of residence per year

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

change of residence per time unit *i to j*

population living in region *i*

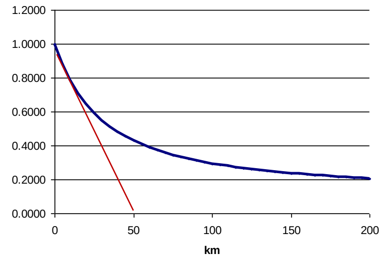
"individuel" transition rate from *i* to *j*

effect of „distance“ (symmetric matrix)

$$\nu_{ij} = \nu_{ji}$$

difference in spatial attractiveness or utilities

distance function



concentration of information

regional attractiveness and spatial preferences

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

regional attractive-ness

Spatial agglomeration effect

regional preference

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

regional preference

housing market indicator

employment indicator

services

accessibility indicator

leisure time Indicator

environment

Empirical flows versus model flows / parameter estimation

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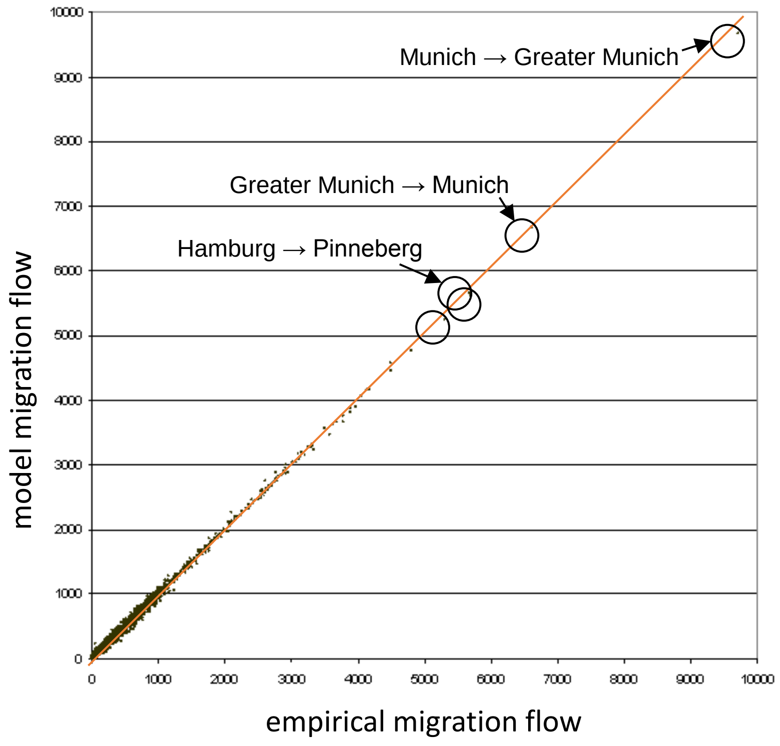
parameter estimation via cost function*

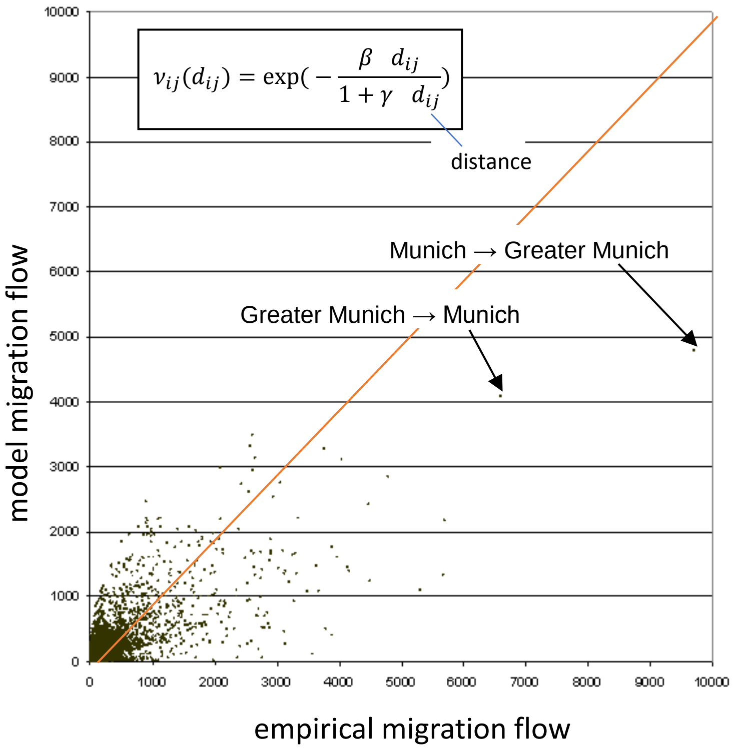
$$F[\nu,\vec{u}] = \sum_{i,j}(w_{ij}^{e} - w_{ij}^{m}(\nu,\vec{u}))^2 \quad = \min$$ → all trend parameters

estimated spatial interaction term

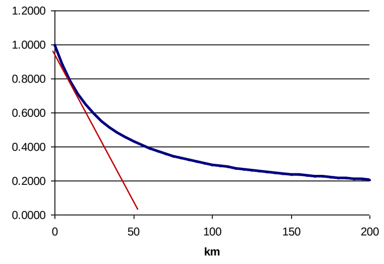


$R^2 = 0{,}98$

assumed distance dependence



$\beta = 0{,}132$; $\gamma = 0{,}0163$; $R^2 = 0{,}600$



Spatial preferences (total population): districts (400)

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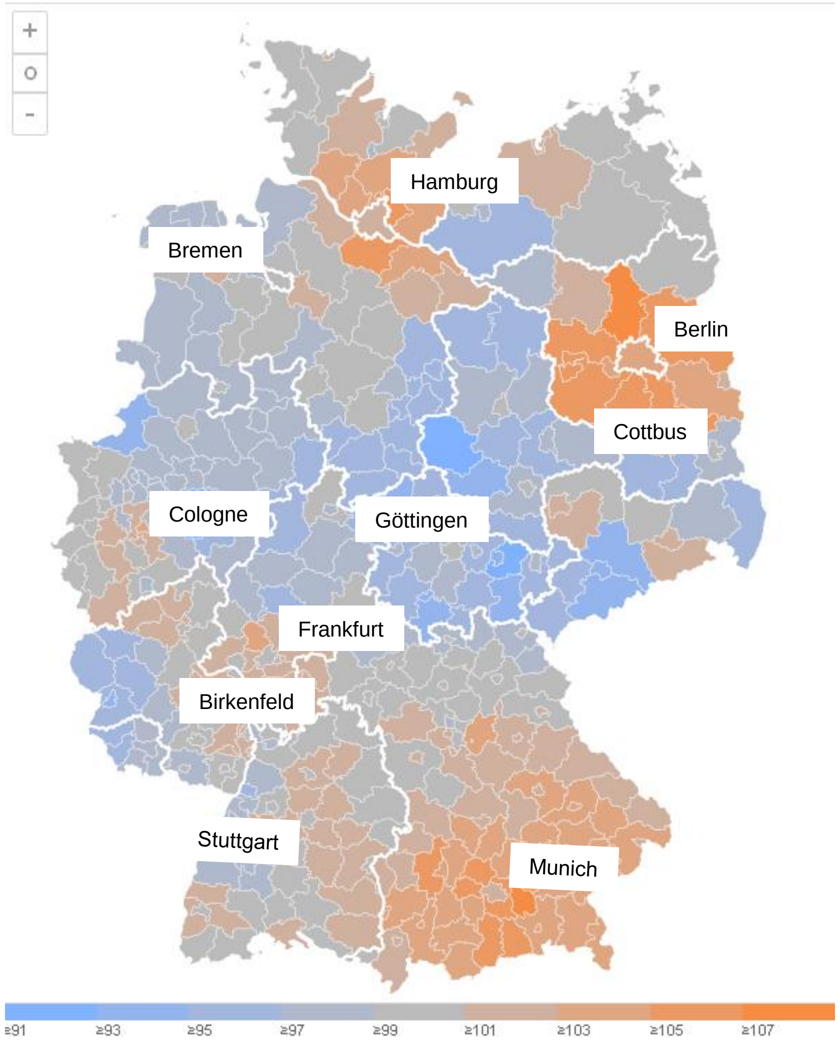
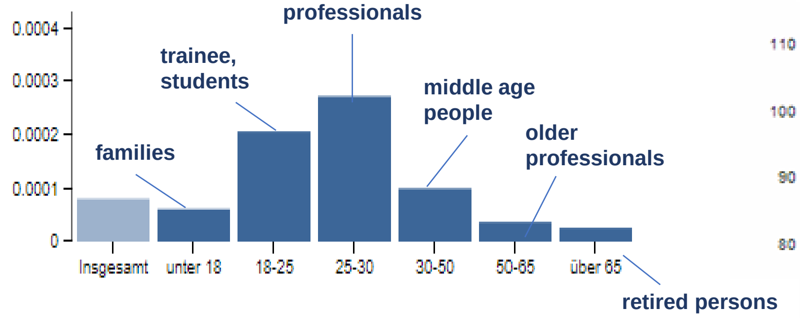
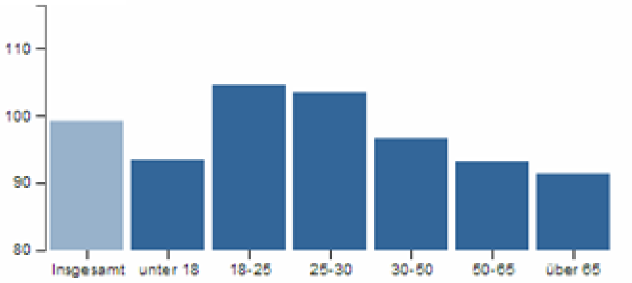


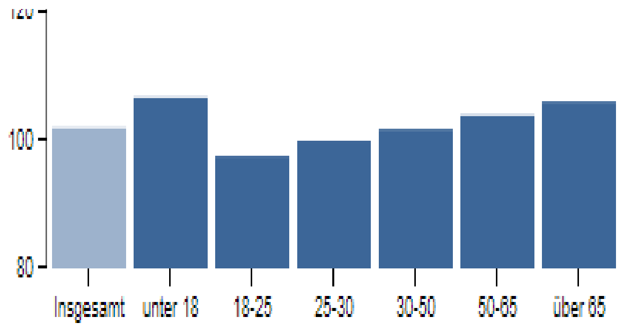
mobility index



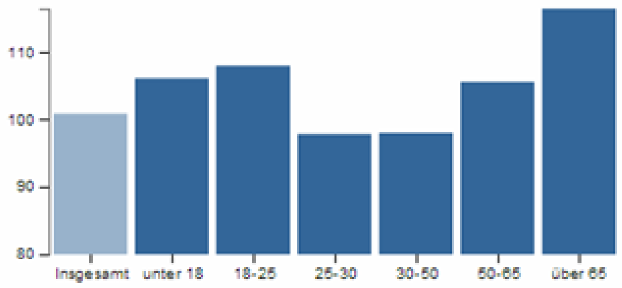
Stuttgart



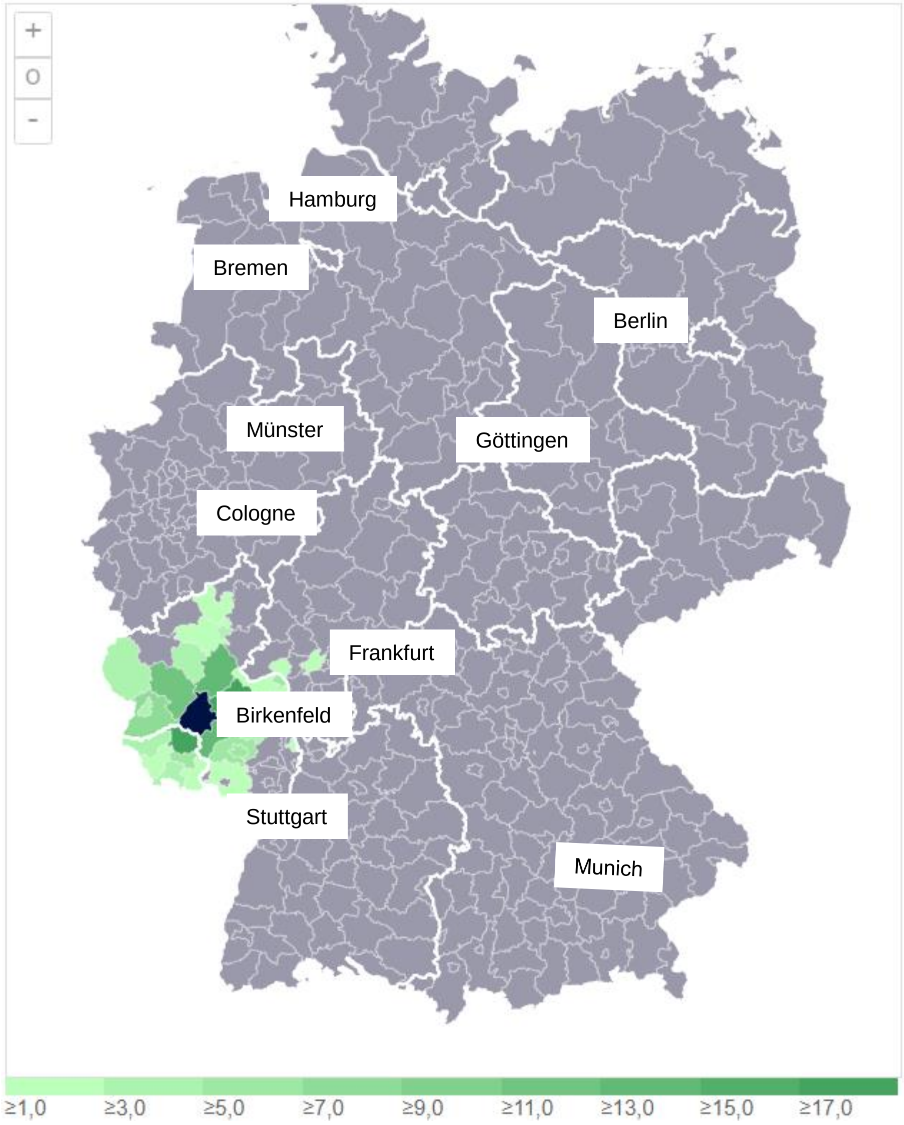
Birkenfeld

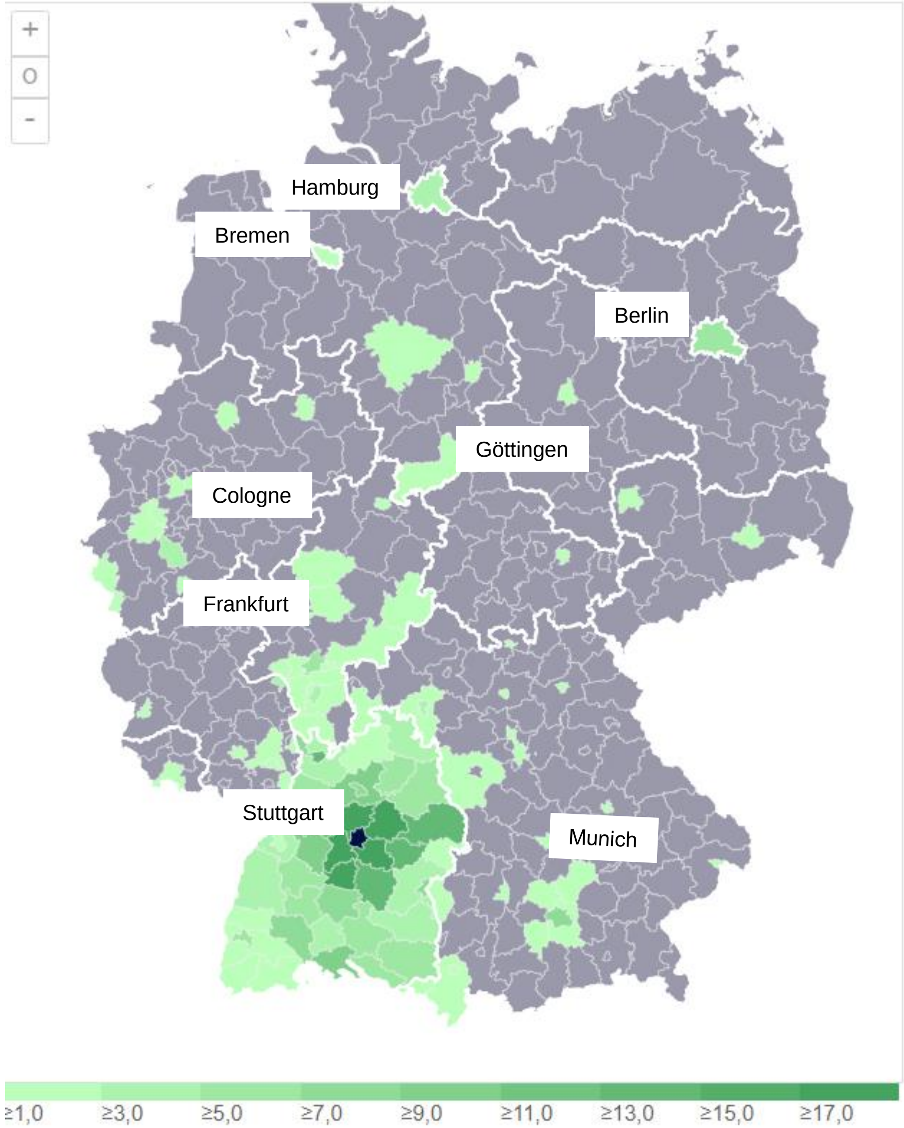


Cottbus

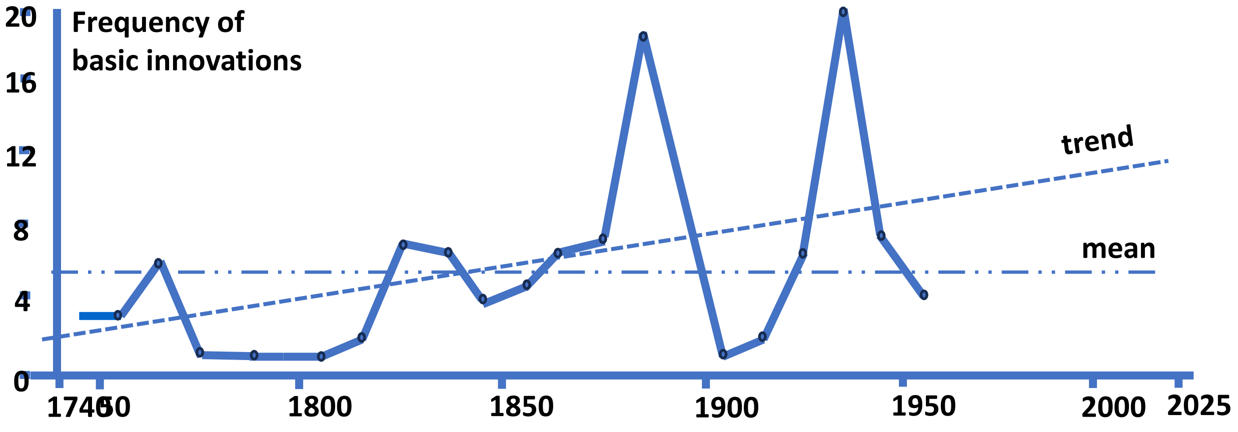


Strength of spatial interaction: City of Birkenfeld (left) and Stuttgart (right) with other districts



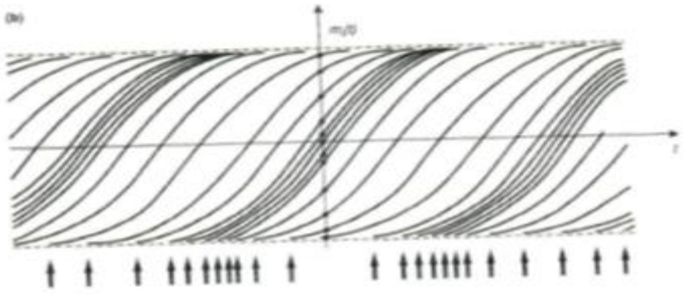


3. Example: Long-Term Economic Cycles



G. Mensch (1979): Stalemate in Technology, Frequency of basic innovations, 1740 – 1960.
The numbers of basic innovtions reported here are given in 10 years bunches.

fraction of market penetration



Basic innovtions

- Clustering of Innovations, G. Mensch
- Basic innovations give rise to a new industry

Long-term economic cycles

- Cycle time 40 to 60 years, Cesare Marchetti (54 years, energy sector)
- Logistic growth curve of technologies
- If a technology enters ist peak → chance for a new technological breakthrough (e.g. coal → oil → gas → nuclear → green

Basic Innovations and Long Waves

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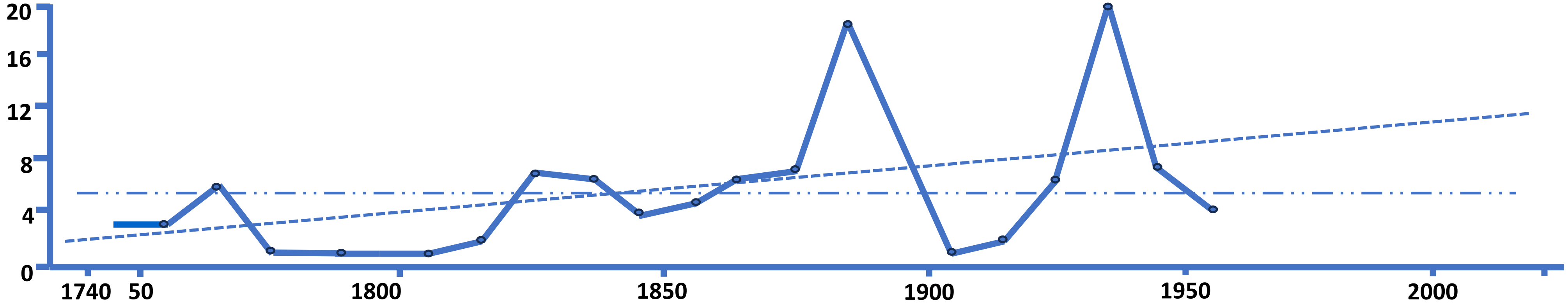

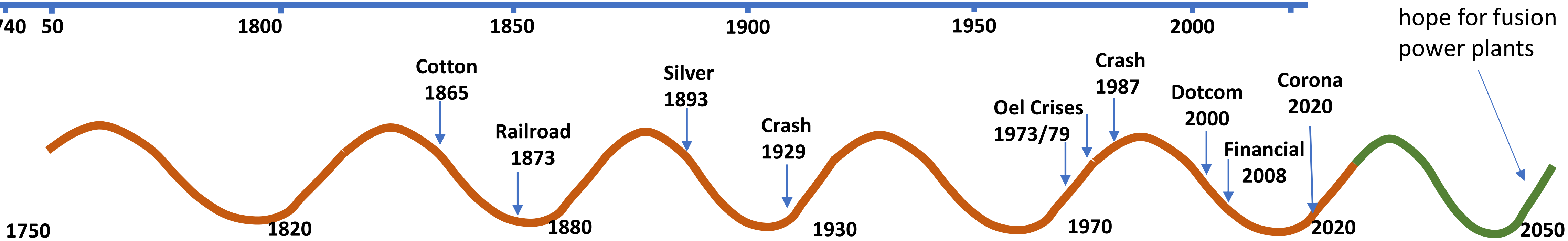

	Kondratieff 1	Kondratieff 2	Kondratieff 3	Kondratieff 4	Kondratieff 5	Kondratieff 6
	Dampfmaschine, Textilindustrie, Eisenproduktion, Mechanisierung der Produktion	Eisenbahn, Stahl, Schwer-industrie, Dampfschiffe, Brücken- und Bahnhöfe, Vernetzung über die Schiene	Chemie, Elektroindustrie, Elektrizität, Elektrogeräte, Röhrentechnik	Automobil, Petrochemie Kerntechnik, Transistor, Radio, Fernseher, Kühlschrank, PC-Computer, Zuse Z3	Computertechnik, PCs,Informationstech. Halbleitertechnik, Internet, Smartphone, GPS, integrierte Bau-teile,	Grüne Energie, KI, Elektrofahrzeuge, Biotechnologie, vegane Ernährung, Blockchain, ChatGPT, Wasserstoff, Sustainable products
	1. Industrielle Revolution		2. Industrielle Revolution		3. Ind. Revol.	4. Ind. Rev., 5. Rev.

Towards Nested Theories

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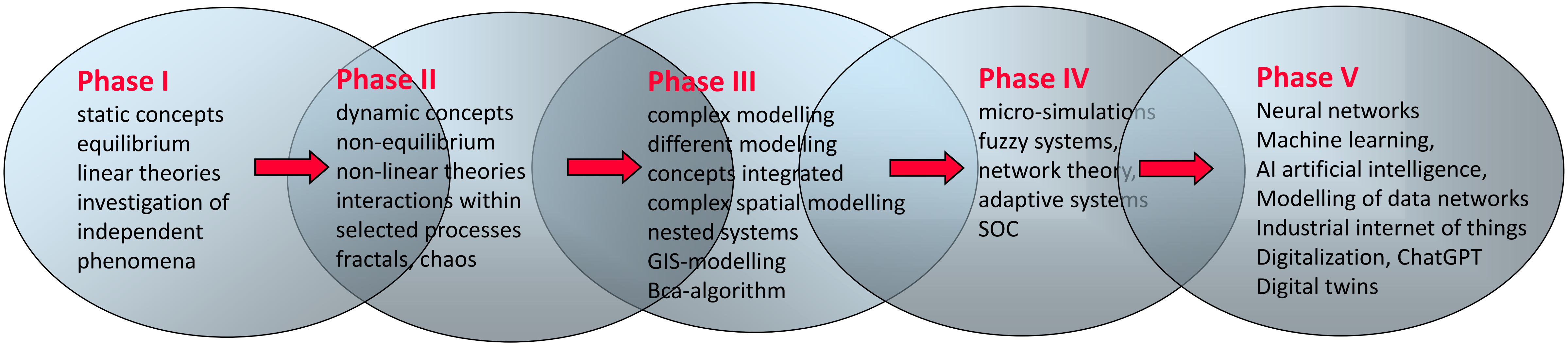

until 1970

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

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

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

2000- 2020
Deep Learning,...
Self-generating networks
(Ash, Fahlman, Haag)
Data cooperatives
(Lasi, Slama,...)

The ideas of H. v. Foerster, H. Haken, W. Weidlich, Prigogine 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

Thank You for your attention