Ex-ante evaluation of research policy

An agent-based model of Austrian biotechnology

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Motivation and objective

- We observe an increased need for legitimization of policy
  - Ex-ante impact assessment of RTI policy initiatives enforced by law, including technological aspects.
  - However, the complexity of the innovation system makes effects of envisaged interventions hard to foresee.
  - Hence, policy makers call for advanced methods and quantitative tools to support ex-ante impact assessment.
- We aim at simulating the long-term influence of different policy options on the knowledge base of a given industry
  - Agent-based models (ABMs) are a way to describe path-dependent evolution of systems considering the underlying micro-dynamics.
  - Strong empirical foundation lends credibility to ABMs to support policymaking.

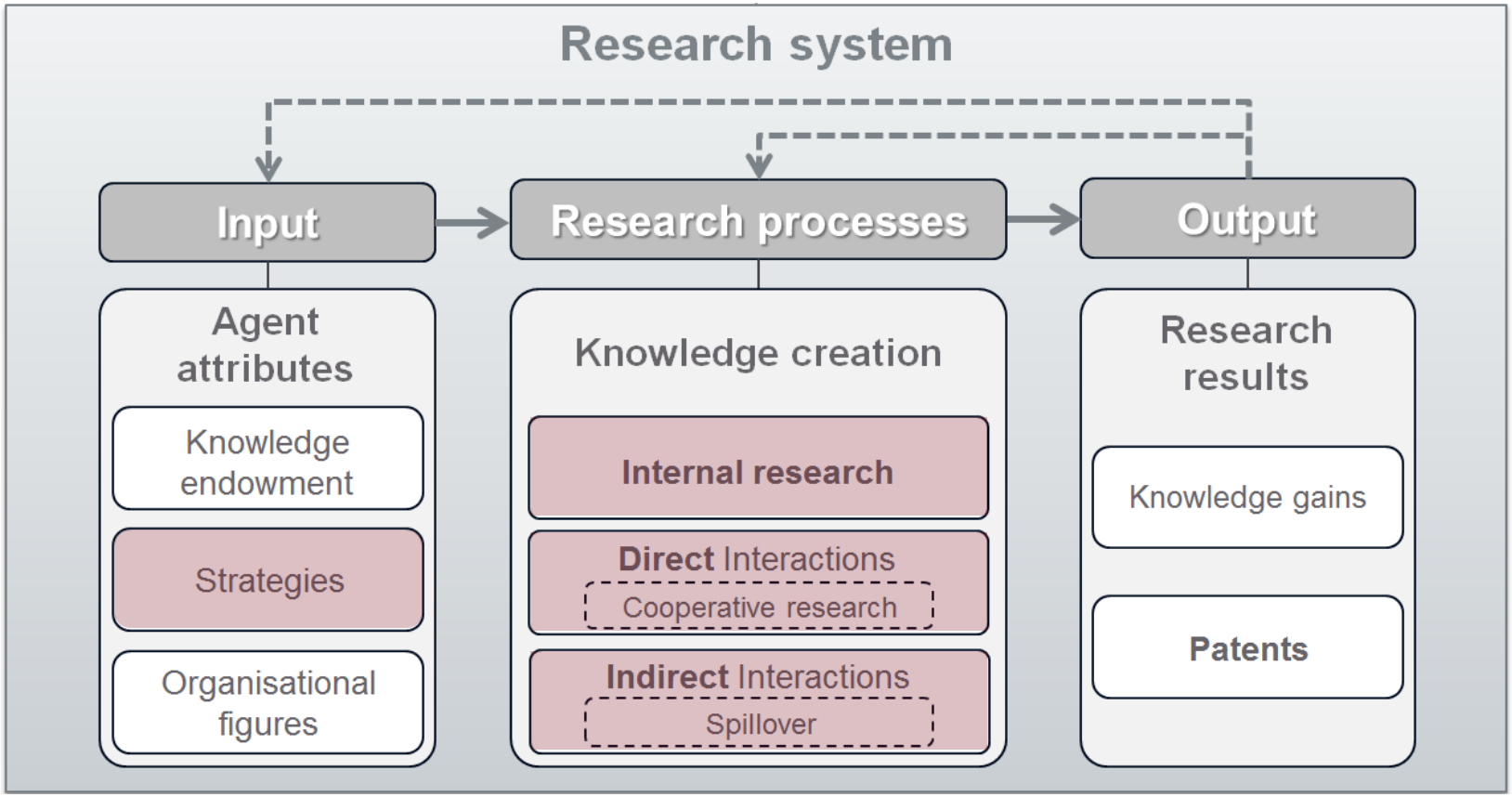
Outline of the presentation

- Agent-based modeling (ABM) – the method
- Model description
  - Conceptual model
  - Empirical input
- Scenario simulation - examples
- Concluding remarks

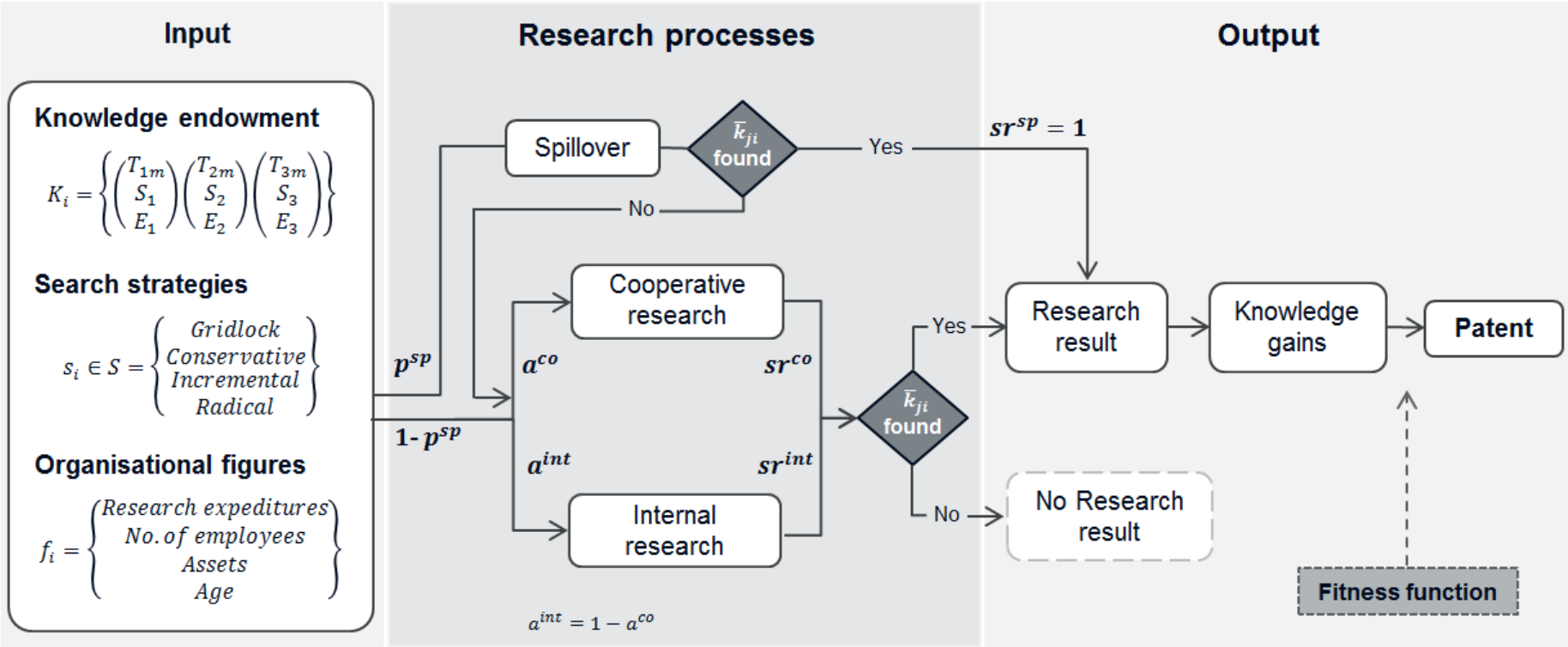
Agent-based Modelling (ABM) – the method

- Three basic elements (Macal and North 2010, p 152)
  - Heterogeneous agents
  - Interaction through mutual relations
  - Embeddedness in a shared environment
- ABM is well-suited to simulate complex real-world systems
  - Increasingly used in social sciences and economics (Gilbert 2008)
  - Not prediction but system understanding and scenario analysis
  - Here: knowledge interaction and innovation as exploratory search (bounded rationality, limited information)
- Model validation is a critical issue (Barreteau et al. 2003, Fagiolo et al. 2007)

Model overview



Model processes



Model output

- The probability p_i of an individual agent to patent its knowledge gain is obtained from a fitness function f using the empirical patenting propensity of Austrian biotechnology firms

$$p_i = p_0 \cdot f(E^{\beta_1}, L^{\beta_2}, I^{\beta_3}, A^{\beta_4})$$

Where

p_0 …system parameter

E …R&D expenditures of agent i

L …number of employees of agent i

I … assets of agent i

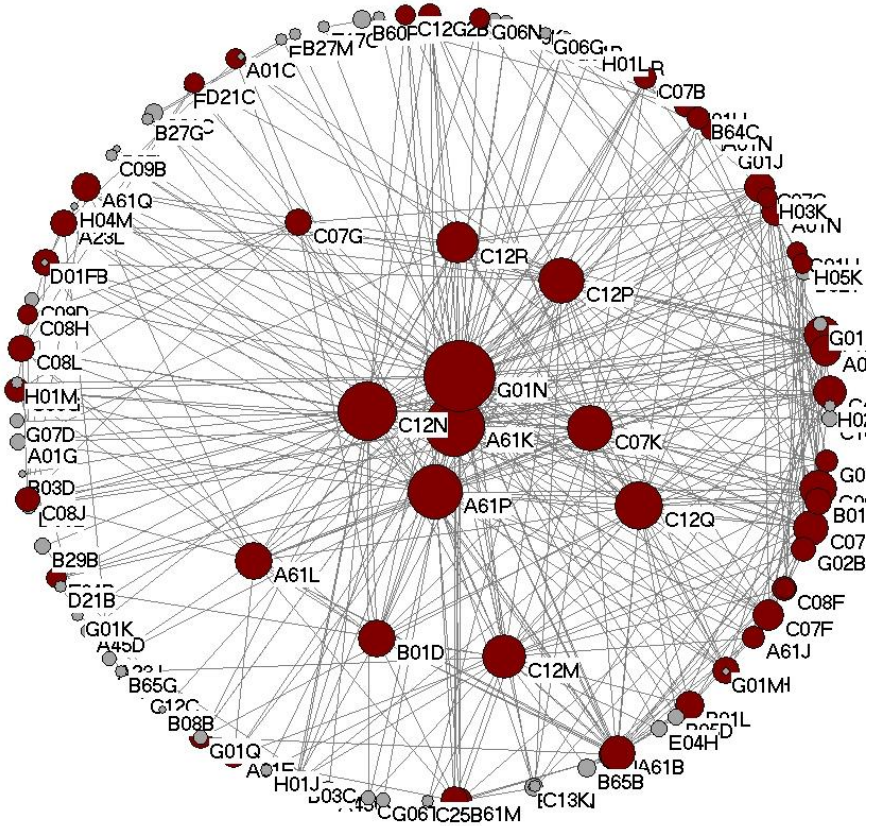
A …age of agent i

- Hereby, the coefficients $\beta_1, \beta_2, \beta_3$ and β_4 are estimated by means of a zero-inflated negative binomial model for a sample of 155 patenting and non-patenting firms. (Paier et al. 2017)

Model population

- Agents represent 61 Austrian private firms holding biotech patents (2000 - 2010)
- Initialization at the agent level
  - Organizational figures from empirical data
  - Research strategies are scenario-specific and assigned to the agents randomly in each step
- Initialization at the system level
  - Empirical „knowledge space“ spanned by the set of patent classes of the firm population
  - Proximity measure: Jaccard-Index based on co-occurrences on patent documents

Technology space



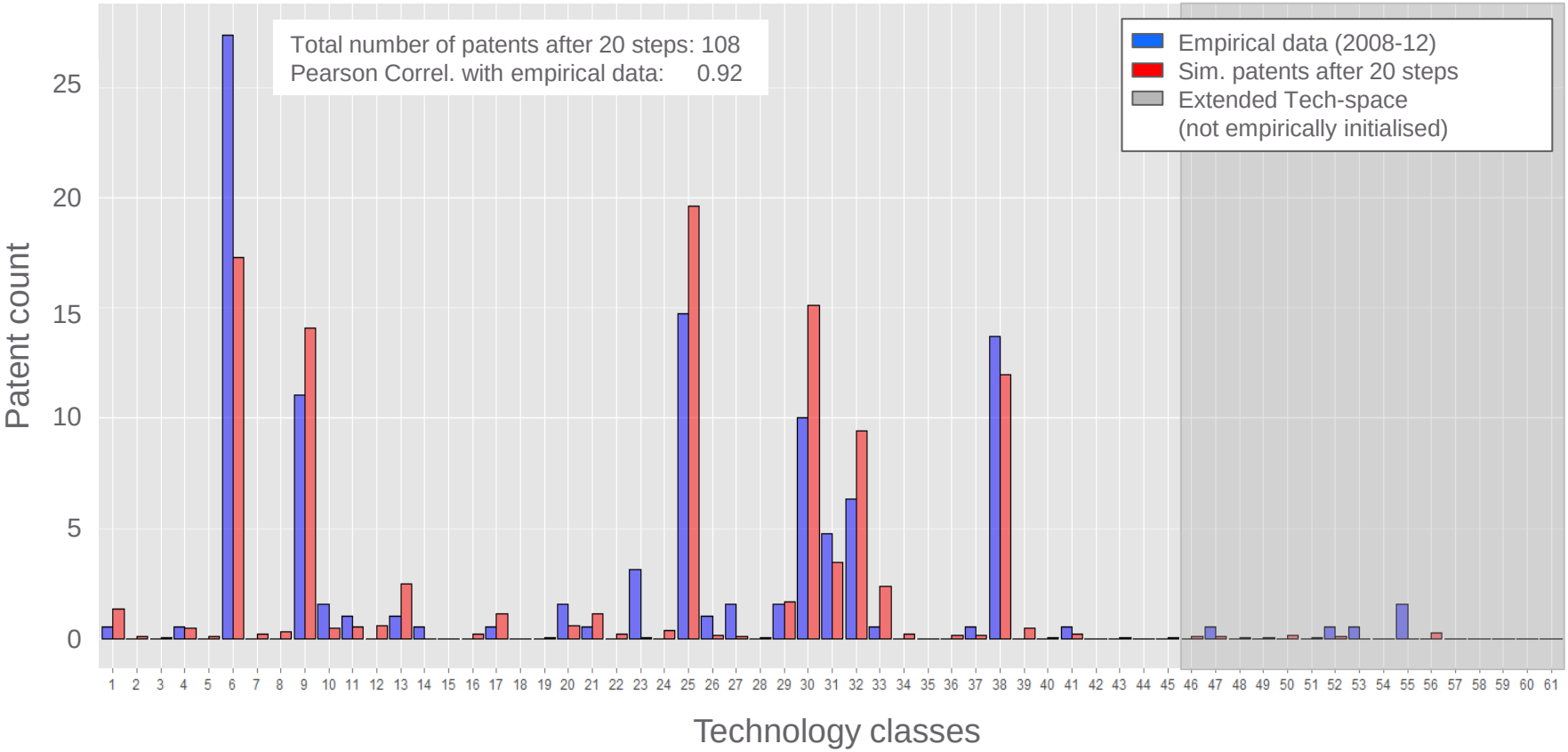
Size: Frequency of patent class during 1990-2012

Colour: Presence during initialization period 2000-2010

- Elements
  - Biotechnology-relevant 3-digit IPC classes
- Proximity measure
  - Jaccard-Index (relative co-frequencies of patent classes)
- Most frequent patent classes of Austrian applicants

A61K	Preparations for medical, dental, or
A61L	Methods or apparatus for sterilising general
A61P	Specific therapeutic activity of chem
B01D	Separation
C07G	Compounds of unknown constitution
C07K	Peptides
C12M	Apparatus for enzymology or microb
C12N	Micro-organisms or enzymes; comp
C12P	Fermentation or enzyme-using proc
C12Q	Measuring or testing processes invo
C12R	Indexing scheme associated with su

Empirically calibrated technology profile



TC (> 10)	Description
6	Preparations for medical, dental, or toilet purposes
9	Specific therapeutic activity of chemical compounds or medicinal preparations
25	Peptides
30/32	Measuring or testing processes involving enzymes or microorganisms; processes of preparing …
38	Investigating or analysing materials by determining their chemical or physical properties

Scenario analysis - overview

- Baseline scenario (using the empirically calibrated parameter set)
  - Implicitly accounts for all policies in place during the calibration period

- Alternative R&D funding scenarios
  I. Stronger focus on individual projects vs. cooperation requirement
  II. Stronger focus on direct vs. indirect government funding
  III. Graduated research premium
  IV. Stronger focus on thematic funding

Scenario comparison II.A ↔ II.B

- **Scenario II.A** „Focus on *direct funding*“
  - **Scenario definition:** government grants for projects, substantial takeover of risk by the state, bottom-up defined research
  - **Model assumptions:** Increased share of researching (=non-gridlock) agents, increased share of agents with radical target setting, wider search horizon

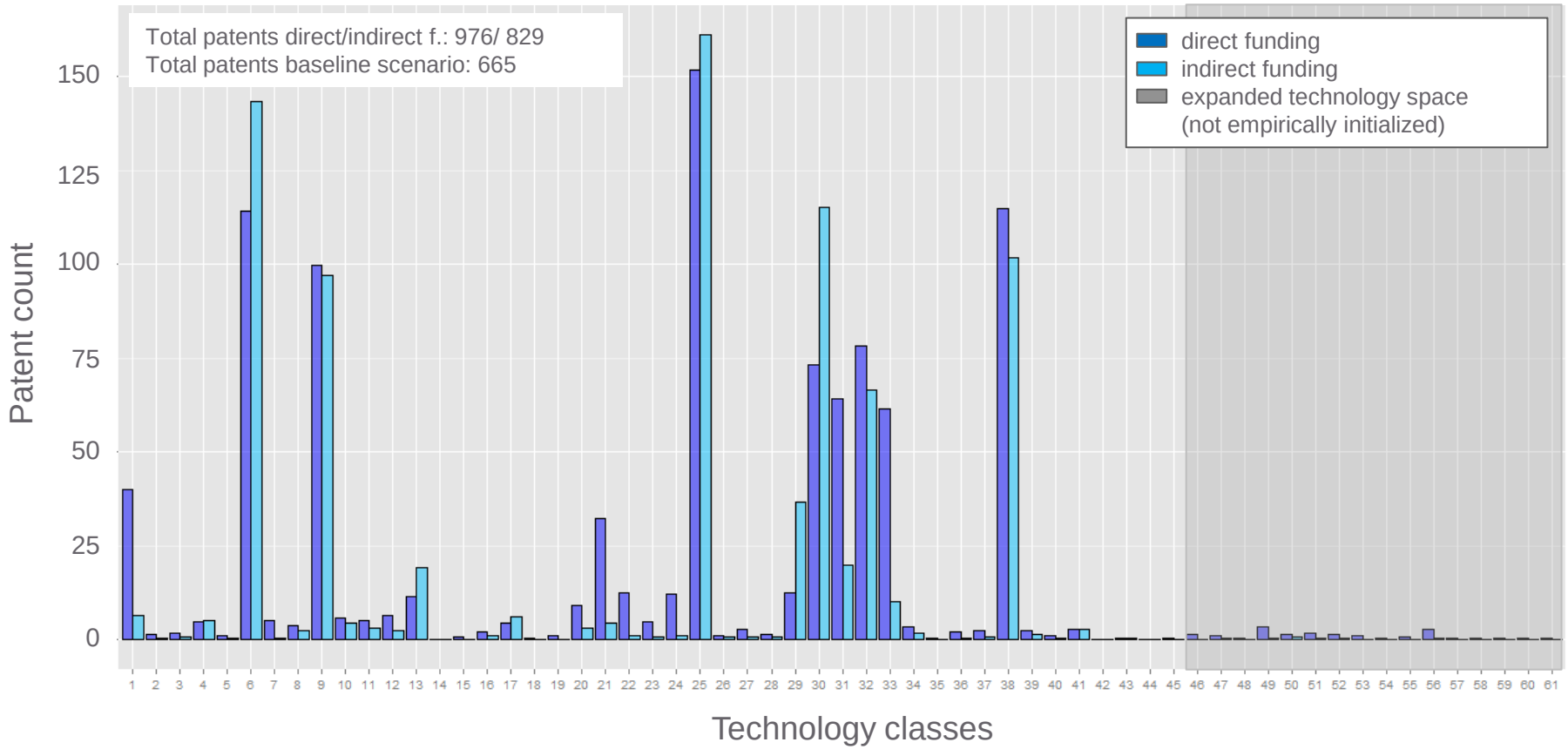
- **Scenario II.B** „Focus on *indirect funding*“
  - **Scenario definition:** bottom-up research, reduced tax burden for private R&D activities, less risk reduction as compared with direct funding
  - **Model assumptions:** Reduced share of agents with radical target setting, increased share of agents with conservative or incremental target setting

System parameters (Baseline ↔ II.A ↔ II.B)

	Parameter	Baseline	Direct funding		Indirect funding	
Input	Inactive	0.5	↓	0.2	→	0.5
	Target – Conservative	0	→	0	↑	0.2
	Target – Incremental	0	→	0	↑	0.2
	Target – Radical	0.5	↑	0.8	↓	0.1
	Search dispersion	0.9	↑	2	→	0.9
F&E-Prozess	R&D-Spillover	0.5	→	0.5	→	0.5
	R&D-Coop	0.6	→	0.6	→	0.6
	R&D-Internal	0.4	→	0.4	→	0.4
	Success rate – Coop	0.6	→	0.6	→	0.6
	Success rate – Internal	0.4	→	0.4	→	0.4
Output	Patenting rate	0.4	→	0.4	→	0.4
	β_1 (R&D expenditures)	0.23	→	0.23	→	0.23
	β_2 (No. employees)	-0.02	→	-0.02	→	-0.02
	β_3 (Assets)	0	→	0	→	0
	β_4 (Age)	0	→	0	→	0

Results (II.A ↔ II.B): : direct vs. indirect funding

Patent profiles of the agent population after 120 time-steps



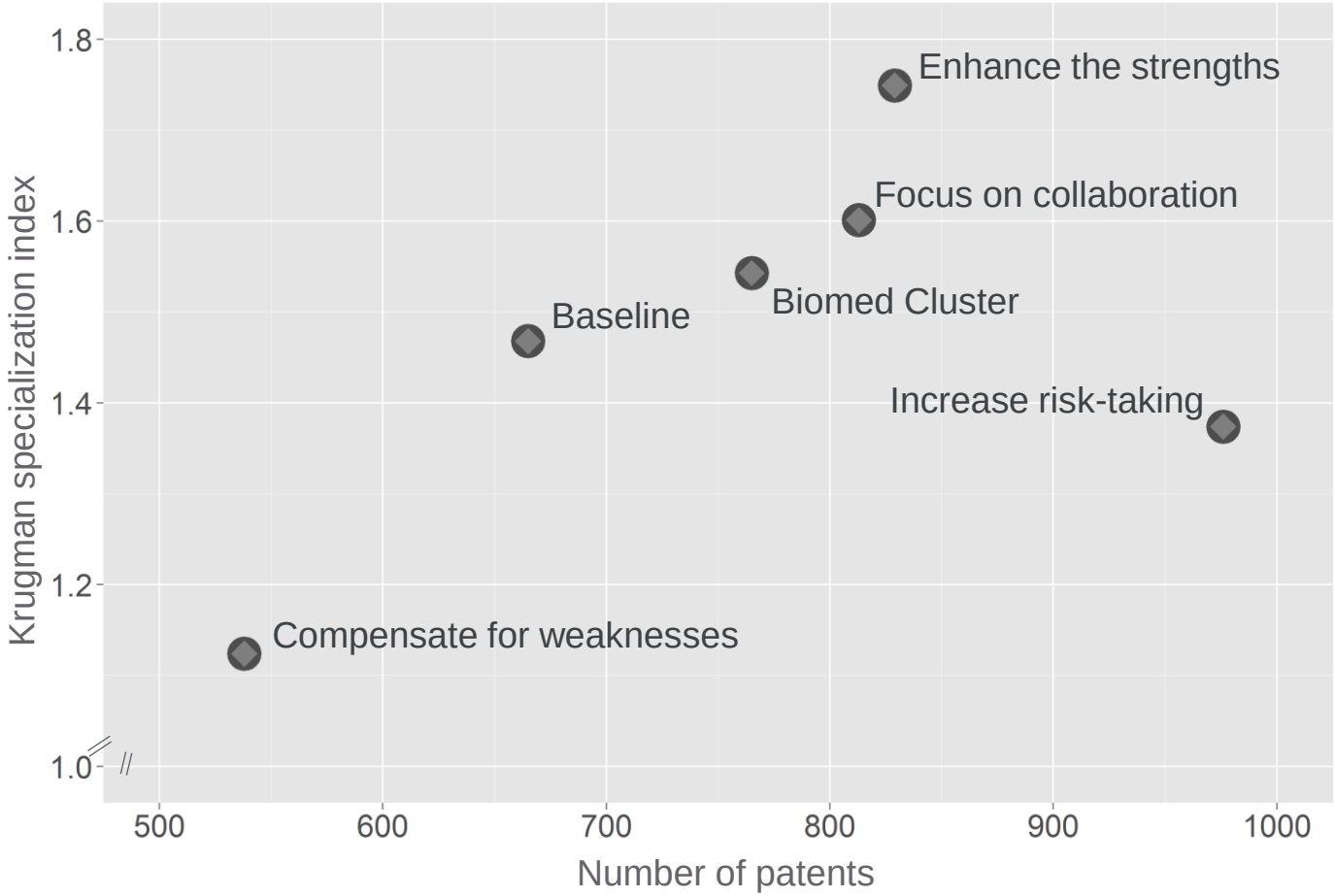
T (> 50)	Description
6	Preperations for medical purposes
9	Therapeutic activity of chemical compounds or medicinal preperations
25	Peptides
30/32	Micro-organisms/enzymes as well as their measuring or testing processes
38	Investigating or analysing materials by determining their chemical or physical properties

Interpretation (II.A ↔ II.B)

- Focus on direct funding leads to
  - Increased overall patenting activity in the innovation system as compared with indirect funding
  - Higher diversity in the technology profile, i.e lower concentration in technology space
  - Emergence of new clusters (of related variety)

- Focus on indirect funding leads to
  - Slightly lower overall patenting activity in the innovation system as compared with direct funding
  - Higher concentration on existing strong technology classes
  - No new clusters

Overview: different specialization effects



The Krugman specialization index (KI) is defined as: $KI = \sum_{m=1}^{M} \left| b_m - \bar{b}_m \right|$, with $b_m = \frac{e_m}{\sum_{m=1}^{M} e_m}$, where e_m denotes the number of patents per research field

Concluding remarks

- Generic model deliberately kept simple, transparent and robust
- Results are novel and relevant for RTI policy
  - Technological concentration and diversification effects of public funding alternatives
  - Comparison of alternative intervention strategies with respect to second-order additionality (Autio et al. 2008)
- Future research includes
  - Adaption to Austrian semiconductor industry, including relevant sectoral characteristics
  - Introduction of additional complexity (e.g. population dynamics, endogenous agent strategies)
  - Embedding into a multiregional setting

Acknowledgement and references

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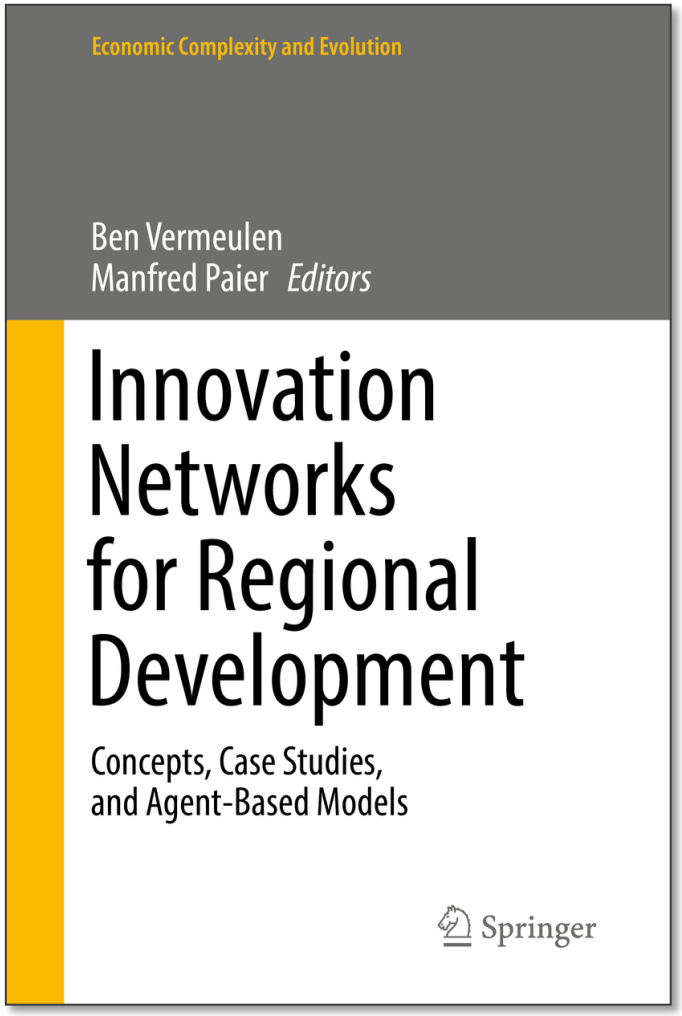

Thank you for your attention!

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