Technology-life-cycle assessment through patent data as a governance tool for evaluating innovation processes – The case of German renewable energies

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Workshop I – The Use of Knowledge for Sustainability Transitions

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Agenda

1.) Introduction

2.) The use of patents for evaluating renewable energy policies

3.) Technology-Life-Cycle Assessment as alternative method

4.) Preliminary conclusions

5.) References

work in progress

The regulatory debate on the use of feed-in tariffs for renewables in Germany is still ongoing…

	Role of the state	*Rationale*	*Feed-in tariffs?!*	*References*
Hayekian Evolutionary Economics	Minimal, favouring free individual market forces and decentralised spontaneous order.	No intervention: knowledge problem Impossibility Theorem	**No**	*Hayek (1945), Schmidt (2018)*
State-sceptical Neoclassical Economics	State capacities limited by government failures and rent-seeking	Only market failures, but government failures impede its correction.	**No,** because of too vast discretionary policy space	*EFI (2013), Schmidt (2018)*
Ordoliberalism	Limited to economic framework policies, no active, technology-specific process policies	Market failures, societal preferences	**No,** because of neutrality violation	*Oberender and Rüter (1987), Müller (2008, 2013)*
State-confident Neoclassical Economics	Benevolent planner, able to pareto optimal market corrections	Only market failures	**Yes,** if innovation impact exists!	*Lehmann and Gawel (2013), Gawel et al. (2014)*
Neo-Schumpeterian Economics	Part of complex innovation system, state gives funding, regulation, directional guidance and takes risks	Market failures, system failures, transitional failures → Normative turn!	**Yes,** for overcoming barriers for the innovations	*Fraunhofer ISI (2014), del Río and Bleda (2012)*

... and measuring the innovation impact of feed-in tariffs plays a crucial role in it!

Market failures	*Innovation policy objective*	*Research question for evaluation*
Negative externalities on environment	CO_2 reduction via innovation diffusion or consumption cut	***Does diffusion reduce CO_2 emissions?***
Positive network externalities of diffusion	Word-of-mouth effect	***Does diffusion attract higher demand?***
Positive externalities of knowledge	More codifiable and tacit knowledge development and diffusion	***Does an innovation impact exist?***
Indivisibilities/ Subadditivity	Cost reductions using economies of scale	***Does an innovation impact exist?***
Risk, uncertainty and asymmetric information		***Does an innovation impact exist?*** Not predictable how strong it is and how long it takes

Gustafsson and Autio (2011), Chaminade and Edquist (2010), Jaffe et al. (2005), Bleda and del Río (2013), Gawel et al. (2017)

Research question: Did feed-in tariffs have an impact on innovation for renewable energies?

"Our goal in this paper is to test the effect of various renewable energy policies on **innovation**."

(Johnstone et al., 2010: 136)

"In this paper we ask how **technological innovations**, represented as increases in a global technology stock, affect the use of renewable energy technologies." *(Popp et al., 2011: 649)*

"Renewables and innovation: did policy induced structural change in the energy sector effect **innovation** in green technologies?" *(Wangler, 2013: title, 211)*

"As the argument of climate protection fails, protagonists of renewable energy promotion strive after additional reasons (e.g., increasing **innovation activities**) to justify green subsidies. One prominent justification roots in a **market failure caused by knowledge externalities**." *(Böhringer et al., 2017: 546)*

Innovation indicator: patent statistics

Innovation indicators: Patent statistics only give a narrow view on the innovation impact.

Input indicators

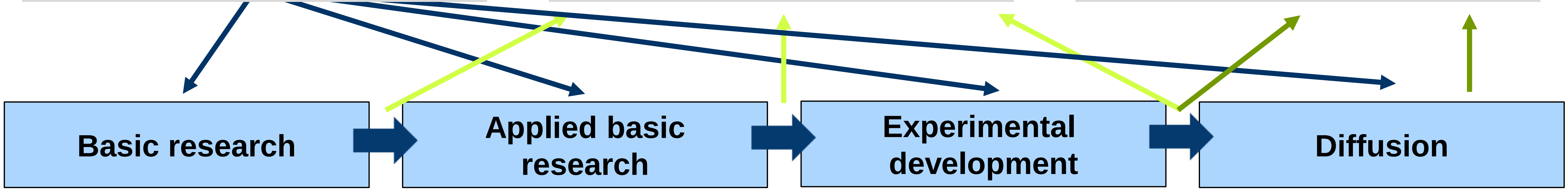
- R&D expenditures
- R&D employees
- Innovation expenditures
- Venture capital

Throughput indicators

- Scientific publications
- Patent statistics

Output indicators

- Innovation counts
- Cost development
- Technometrics
- Production growth
- Market penetration
- Employment
- Macroeconomic effects



Grupp (1998)

	Johnstone et al. (2010)	*Popp et al. (2011)*	*Wangler (2013)*	*Böhringer et al. (2017)*
Evaluated instruments	• RE feed-in tariffs, targets • Inv. and tax incentives, price control, obligations,	Measuring the effects of policy-induced innovative activity	• Public R&D for RE • RE feed-in tariffs: 1990-99 SEG/2000-05 EEG	• RE feed-in tariffs: • 1990-99 SEG/ 2000-05 EEG
Covered RE technologies	Wind, solar, ocean, biomass & waste	Wind, solar, biomass, geothermal, waste	Wind, solar, water, geothermal	Solar, wind on/offshore, hydro, biomass, biogas, geothermal
Innovation indicator	*Dependent variable:* patent applications (appl. date)	*Dependent variable:* RE capacity investments *Explanatory variables:* patent applications,…	*Dependent variable:* Patent counts of granted patents using application date	*Dependent variable:* patent applications (appl. date), patent families of Germans (priority date)
Data basis	25 industrialised countries	26 OECD countries	Germany	Germany
Time period	1978-2003	1990-2004	1990-2005	1990-2014
Time lag	No	Not for patent variable	2-3 years for expl. variables	1 year for all expl. variables
Innovation impact?	Feed-in tariffs with positive effect on solar patents, other effects not robust	Feed-in tariffs only increased biomass investments	Yes, for public R&D No structural break to EEG, need larger time period	Yes, but low and impact of technology-specific feed-in tariffs smaller than on average
Central conclusion	Public policy (rather than prices) with very significant influence on patent activities.	Small effect of a rise in the knowledge stock on capacity investments	Market size/increase play a crucial role for innovation, evidence for instruments only robust for wind energy	Positive effect of feed-in tariffs, but no difference between costly EEG and SEG; no EEG appraisal on innovation grounds

Frontiers of econometric modelling approaches with patent indicators so far:

1. Patents do not consider all innovation activities. *(Böhringer et al. 2017, Grupp 1998)*
   - Influence of policies notable on input, throughput and output indicators.
   - Feed-in tariffs mainly aim at innovation by market diffusion → cost reductions as main indicator.
2. Patent quality difficult to measure – limited power of patents as innovation indicator *(Schmoch and Khan 2017)*
   - Patents not necessarily innovation success, knowledge production not necessarily patentable.
   - The value of a patents for research and innovation is not predictable and might change.
3. Functional interrelationship not existing because of fundamental uncertainty in patentable knowledge creation *(Schmoch and Khan 2017)*
   - Shrinking feed-in tariffs and rising patent counts do not mean, that feed-in tariffs are not the trigger of the innovation impact.

Which alternative methodological approaches can consider these inconveniences?

Technology-Life-Cycle-Assessment more realist alternative for patent analyses.

By expanding the argument of Wangler (2013) on emphasizing the significance of policy induced structural breaks and considering the shortcomings of patent indicators for econometric modelling, the general research question is reformulated:

Did feed-in tariffs have an impact on innovation for renewable energies?

→

Do patent statistics indicate a higher state of maturity for RE technologies following the EEG feed-in tariffs introduction?

Patent data for answering this research question:

- Covered RE technologies: Solar, wind on/offshore, hydro, biomass, biogas, geothermal
- Data basis: Germany
- Data period: as broad as possible in order to cover the whole life cycle
- Innovation indicator:
    - Patent applications, application date → aiming at covering patenting activities, in general
    - Patent grants, application date → aiming at covering patent successes

“Patent Indicators for Technology-Life-Cycle Development” (Haupt et al. 2007)

- Preparation: “The measurement of patent applications (in general of patent activity) requires the **complete statistical survey of all patent applications** and applicants of the considered technological field.” (p. 388) → challenge for the patent data collection

- Analysis: “A patent index is an appropriate life cycle indicator only if its **mean value differs significantly between the life cycle stages**. It cannot be an indicator candidate if it shows presumably stagnation or non-significant change of the mean value in the evolution of the life cycle stages.” (p. 389)

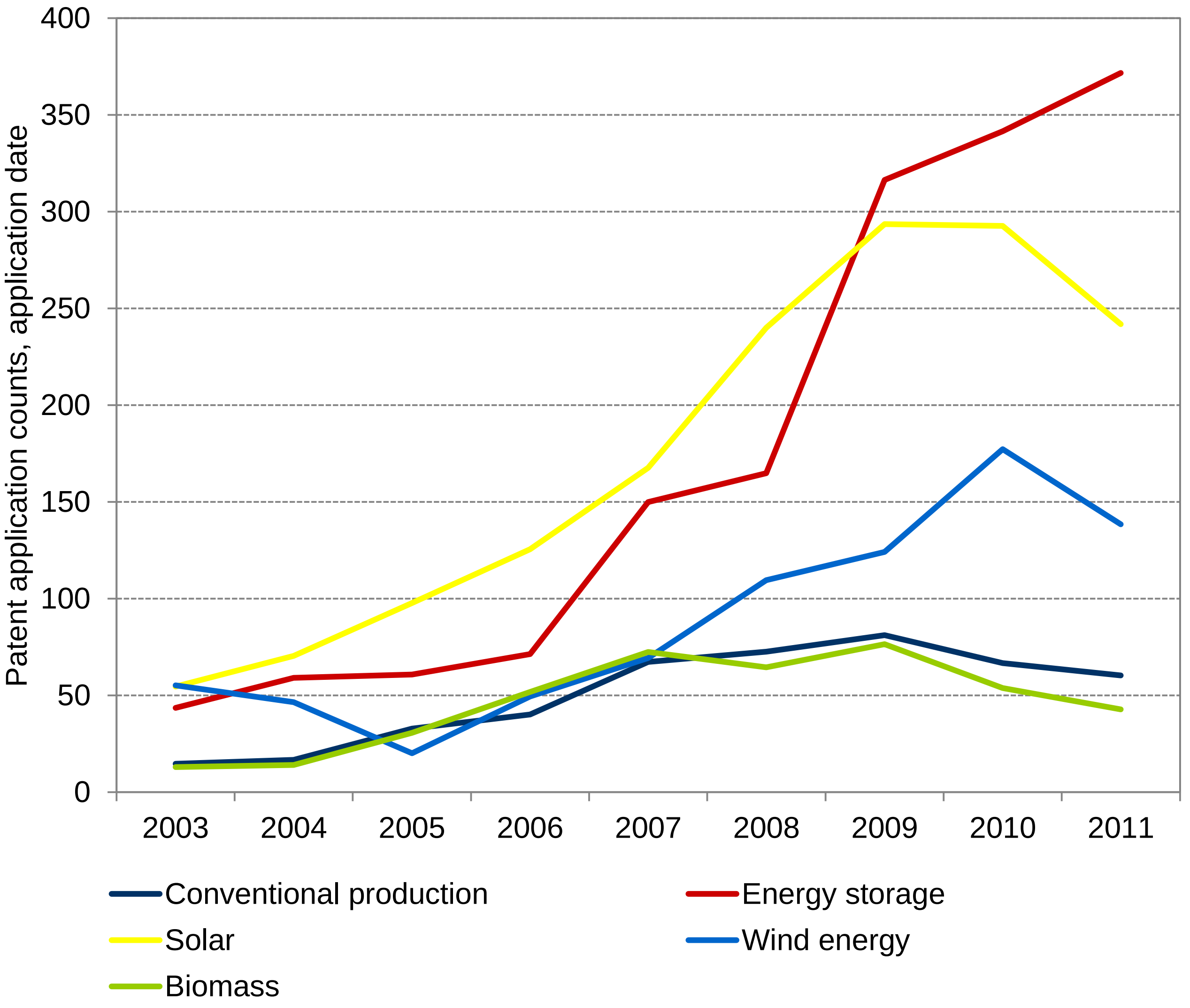
  → Analysis of transition to other life cycle stage by mean value comparisons over time through “Scheffé Tests”

Patent data research – CPC codes from previous studies and key word research (example)

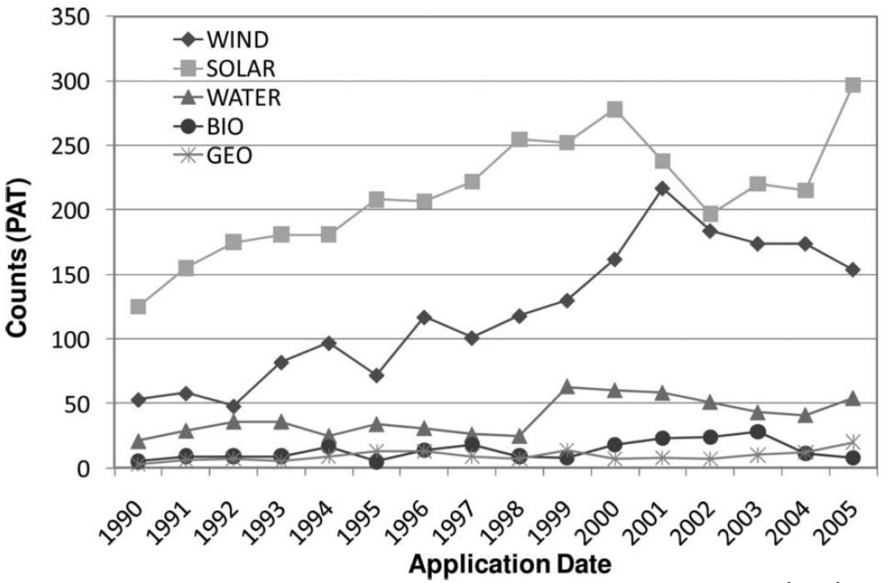
Technology	Class	IPC Class Name	Keyword Combination
1. Solar Photovoltaic			
S	H01L 21%	Processes or apparatus specially adapted for the manufacture or treatment of semiconductor or solid state devices or of parts thereof	((%monocrystalline_silicon% |%monocrystal_silicon% |%crystal_silicon% |%silicon_crystal%|%silicon_wafer%) + (%photovoltai% |%solar%)) | %back_surface_passivation% | (%pyramid% +%etching% +%silicon%)
S	H01L 31%	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength or corpuscular radiation and adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation	
S	C30B 15%	Single-crystal growth by pulling from a melt, e.g. Czochralski method	
S	C01B 33%	Silicon; Compounds thereof (C01B 21/00, C01B 23/00 take precedence; persilicates C01B 15/14; carbides C01B 32/956)	((%polycrystalline_silicon% |%multicrystalline_silicon% |%poly_Si% |%polysilicon%) + (%photovoltai% |%solar%)) | (%ribbon% + (%photovoltai% |%solar% |%silicon%)) | (%Edge_defined_film_fed growth% +%silicon%)| %Metal_wrap_through% | %Emitter_wrap_through% | %Ribbon_growth%
S	C30B 15%	Single-crystal growth by pulling from a melt, e.g. Czochralski method	
S	C30B 29%	Single crystals or homogeneous polycrystalline material with defined structure characterized by the material or by their shape	
S	H01L 21%	Processes or apparatus adapted for the manufacture or treatment of semiconductor or solid state devices or of parts thereof	
S	H01L 31%	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength or corpuscular radiation and adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation	
		…	

Codes and keywords adapted from: Johnstone et al. (2010), Popp et al. (2011), Wangler (2013), Cantner et al. (2016), Böhringer et al. (2017)

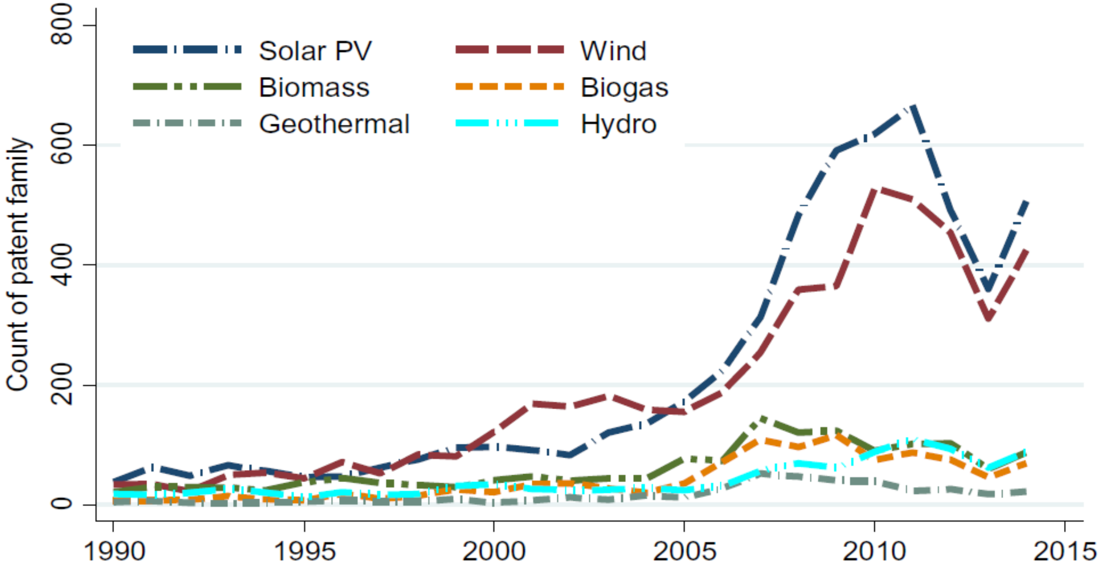
Stylised facts on RE patent activities in Germany:



Source: OECD (2016)



Source: Wangler (2017: 217)



Source: Böhringer et al. (2017: 548)

Haupt et al. (2007): Development Patterns (DP) for Patent Indicator Analysis I

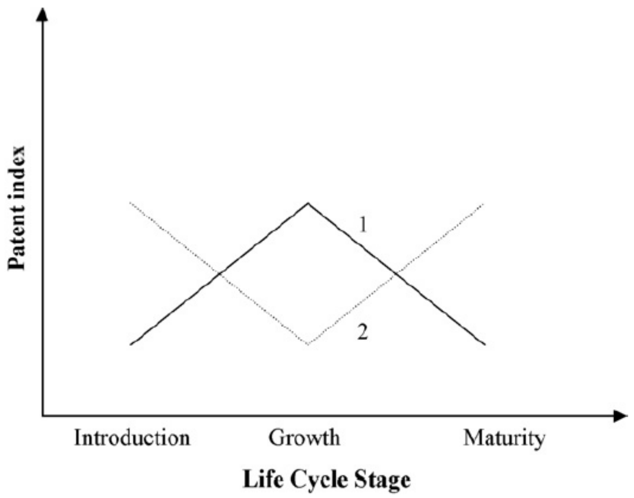
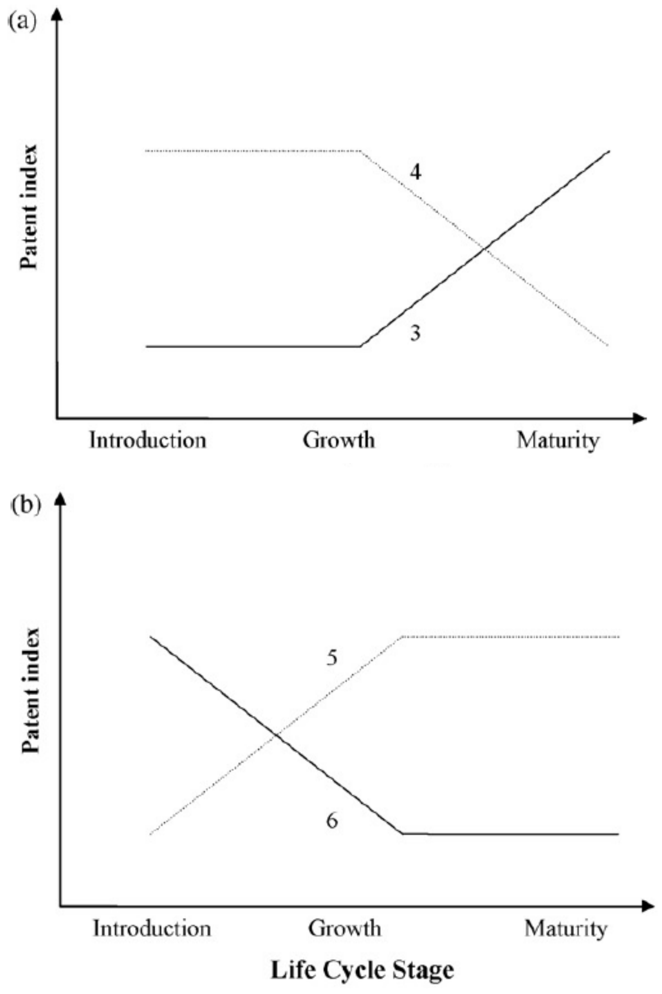


Fig. 1. Development patterns (1–2) of patent indices which are appropriate as technology life cycle indicators for both stage transitions.

Indicators can be of different value for life cycle analysis – DPs for both technology life cycle transitions:

- DP1: mean value increase (transition from introduction to growth) combined with mean value decrease (from growth to maturity)
- DP2: mean value decrease (from introduction to growth) combined with mean value increase (from growth to maturity

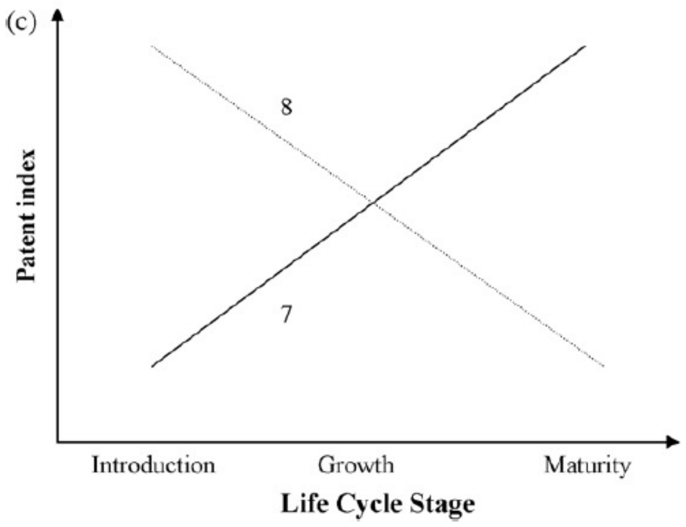
Haupt et al. (2007): Development Patterns (DP) for Patent Indicator Analysis II



Six other index development patterns are only sufficient for indicating one life cycle transition:

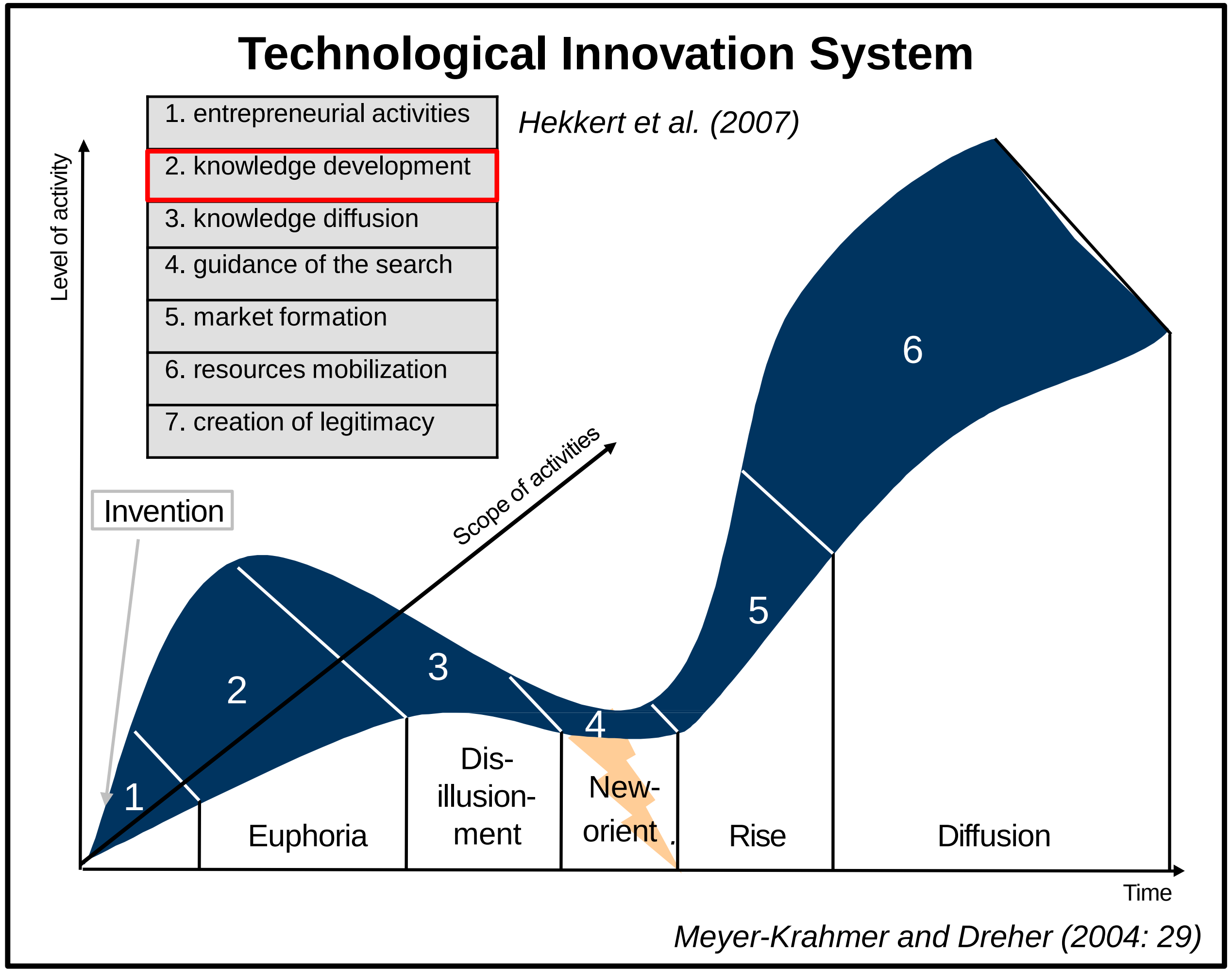
- DP3: stagnation/non-significant change of the mean value (from introduction to growth) combined with mean value increase (from growth to maturity)
- DP4: stagnation/non-significant change of the mean value (from introduction to growth) combined with mean value decrease (from growth to maturity)
- DP5: mean value increase (from introduction to growth) combined with stagnation (non-significant change of the mean value (from growth to maturity)
- DP6: mean value decrease (from introduction to growth) combined with stagnation/non-significant change of the mean value (from growth to maturity)

Haupt et al. (2007): Development Patterns (DP) for Patent Indicator Analysis III



- DP7: mean value increase throughout the three observed life cycle phases
- DP8: mean value decrease throughout the three observed life cycle phases

Modelling technology life cycles via a double boom for identifying TIS dynamics



If data provide several ups and downs: application of the phases delineation of the Science-Technology-Cycle (Meyer-Krahmer and Dreher 2004):

Introduction
→ (first euphorical) Growth
→ Introduction (re-orientation)
→ Growth (Rise)
→ Maturity (Diffusion)

“Patent Indicators for Technology-Life-Cycle Development” (Haupt et al. 2007)

Hypothesis 1: (a) **Backward literature citations** increase significantly only at the transition from introduction to growth. (DP 5)
(b) **Backward patent citations** increase significantly at both stage transitions. (DP 7)

Hypothesis 2: The **average immediacy of patent citations** is significantly higher in the growth stage than in the introduction stage and in the maturity stage significantly lower than in the growth stage. (DP 1)

Hypothesis 3: The **number of forward citations** decreases significantly at the transition from introduction to growth.

Hypothesis 4: The **number of dependent claims** is significantly higher at later technology life cycle stages than in earlier ones. (DP 7)

Hypothesis 5: The **number of priorities referred to in a patent application** is significantly higher at later technology life cycle stages than in earlier ones. (DP 7)

Hypothesis 6: **Examination processes** take longer in the phases of introduction and maturity than at the growth stage. (DP6)

Preliminary conclusions

- Measuring the innovation impact (more than patents!) is crucial for evaluating feed-in tariffs.
- Patent data important, but with inconveniences, notably for econometric modelling.
- Technology-Life-Cycle assessment might be an alternative method coping with these inconveniences.
- Patent data collection strategies and results different in empirical studies.

My research steps

- Should patent data collection via CPC codes and keyword research be validated by further actions (expert interview)?
- Replication for granted patents and different dates in order to validate the results.
- Interpretation of the results considering the functional dynamics of the related technological innovation systems (Dreher et al. 2016).
- Overview on further methods and empirical studies measuring the innovation impact.

Subject of further research

- Comprehensive study on the innovation impact has to consider more innovation indicators and qualitative research for a better interpretation.
- Lack of a solid data base on cost structures a severe problem.
- The study of Wangler (2013) should be conducted again with current data in order to see, whether the EEG induced a structural change in the data.
- Application of the model on other technology fields subject to demand-sided support policies. (mobility sector? food sector?)

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