Regulation and innovation – the case of renewable energy

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Content

- Background and heuristics
- Measuring innovation for renewable energy technologies
- Regulation for increased use of renewable energy
- Relationship between regulation and innovation
- Preliminary Conclusions

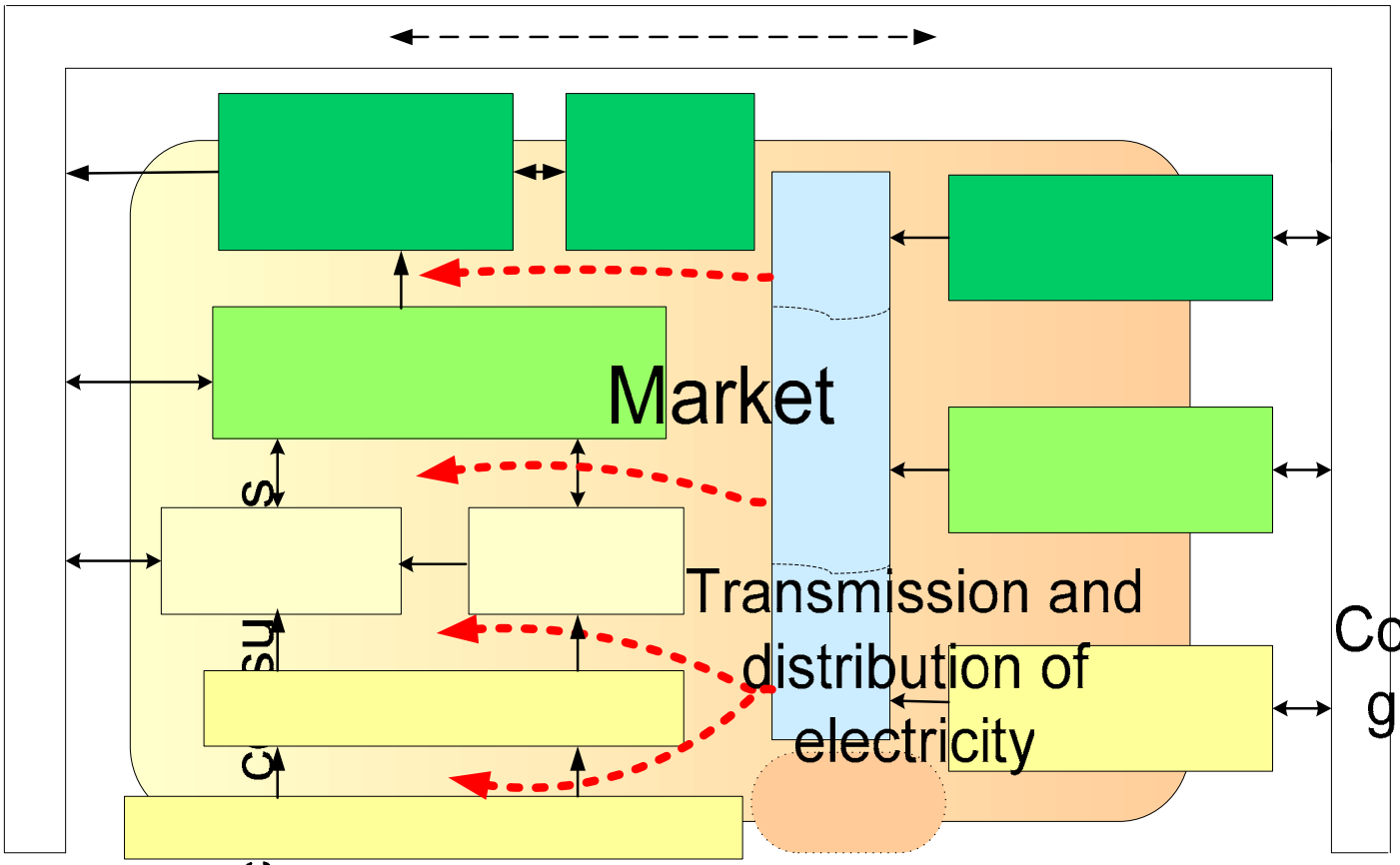
How does innovation occur

- Innovation is not a linear process, but consists of many feedback loops between invention, technology development, and diffusion
- Innovation is embedded in production of knowledge and socioeconomic development and institutions leading to path dependency
- Producer-user interaction and learning in the market makes early diffusion important
- Selection towards a dominant design and need for diversity of solution
- Stability of framework conditions
- Communication between actors

Paradigms for analyzing the effects of innovation

- Theoretical paradigms
  - Neoclassical economics
    - Induced innovation hypothesis: changing relative prices
    - Type of instrument decides on innovation effects
  - Evolutionary and institutional economics
    - Bounded rationality, acting according to routines
    - Importance of transaction costs and institutional regimes
  - Policy analysis (political science)
    - Importance of agenda-setting process instead of instrument
    - Policy style (e.g. long term character and stability of targets)
- Pragmatic heuristics used for case studies: systems of innovation
  - Broad framework which includes the determinants mentioned above
  - Underlines communication between actors and feedback mechanisms between the different determinants
  - Evaluation according to how functions of an innovation system are fulfilled

Innovation system of renewable energy technologies



Triple regulatory challenge

- Monopolistic bottlenecks require regulation of access to the grid
- external environmental effects must be internalised
- good general framework condition

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Demand for renewable energy technologies

Policy-coordi-

trade / electric

Link between regulation and innovation: the functions of an innovation system

Func-
tions
of
inno-
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tem

- Regulation creates demand and is prerequisite for
  => Market formation
  => Supply of resources
  => exchange of information by user-producer interaction
- Regulation to foster R&D can also help to establish research networks
  => exchange of information, supply of resources, guidance
- Stability and long term vision of target setting
  => legitimacy of technology
  => guidance of search
- Design of regulation (e.g. feed in versus quota; degression of feed in tariffs)
  - Risk perception and transaction costs (ESV vs. Quote)

  => supply of resources, market formation
  - Number of technologies which are promoted

  => Variety of solutions, guidance of search

Measurement of innovation: indicators and technologies

Feedback loops between different phases of innovation process lead to different **innovation indicators**

- Intermediate indicators, e.g. **patents**
- Input indicators, e.g. R&D expenditure
- Output indicators, e.g. production, exports

Different levels of analysis

- Innovation dynamics: are renewable energy patents increasing more rapidly than other areas?
- Technological capability of countries: shares of patents and specialization of countries

Database

- R&D: OECD/IES statistics
- Patents: international patents
- Trade: UN-COMTRADE (all countries)

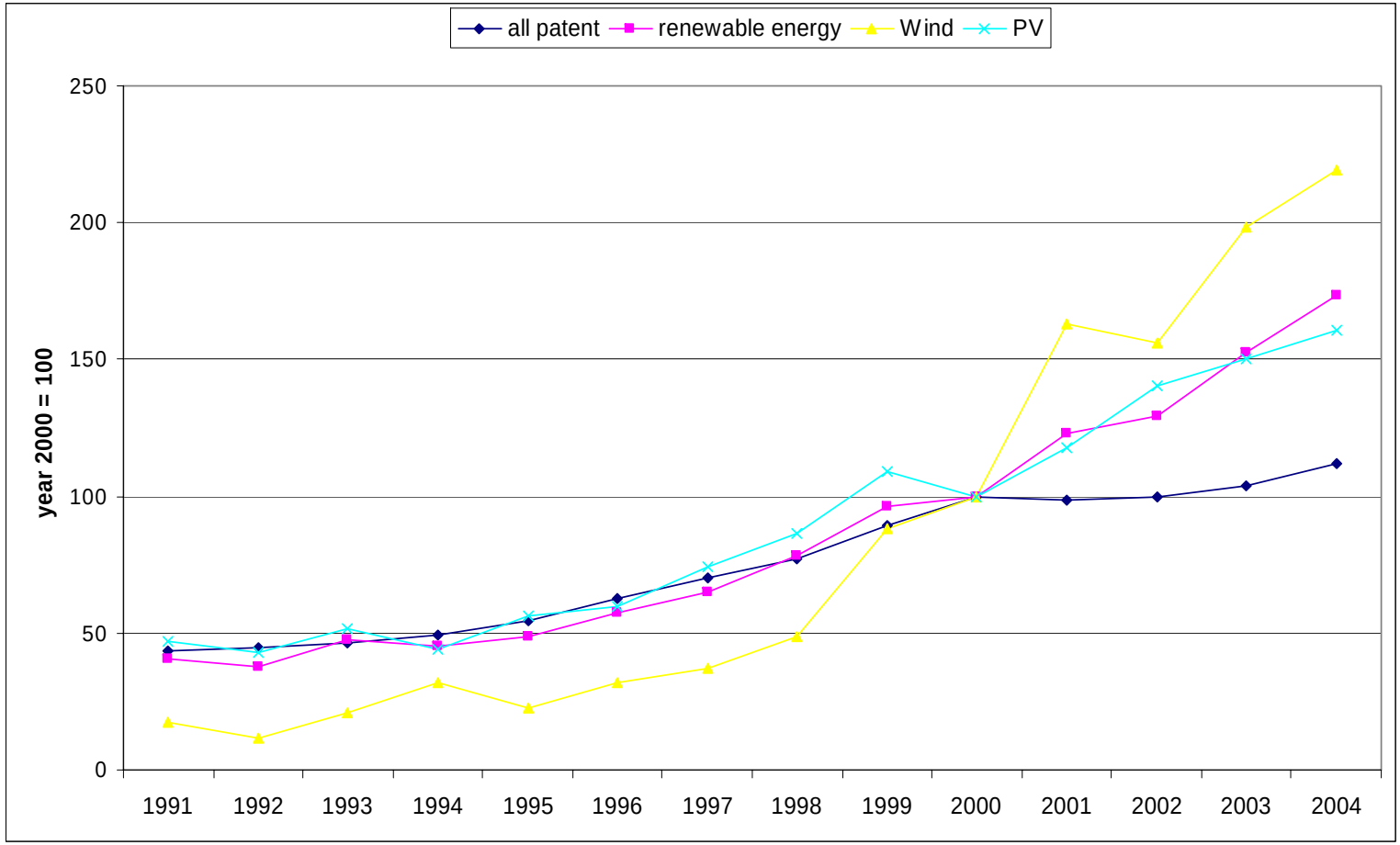
Renewable energy technologies

- Solar thermal
- Photovoltaics
- Wind
- Water
- Biomass
- Geothermal

Detailed **technology based** bottom up **analysis necessary** to translate technologies into trade classification and patent search strategy

Dynamics of innovation

above average dynamics of renewable energy since 2000



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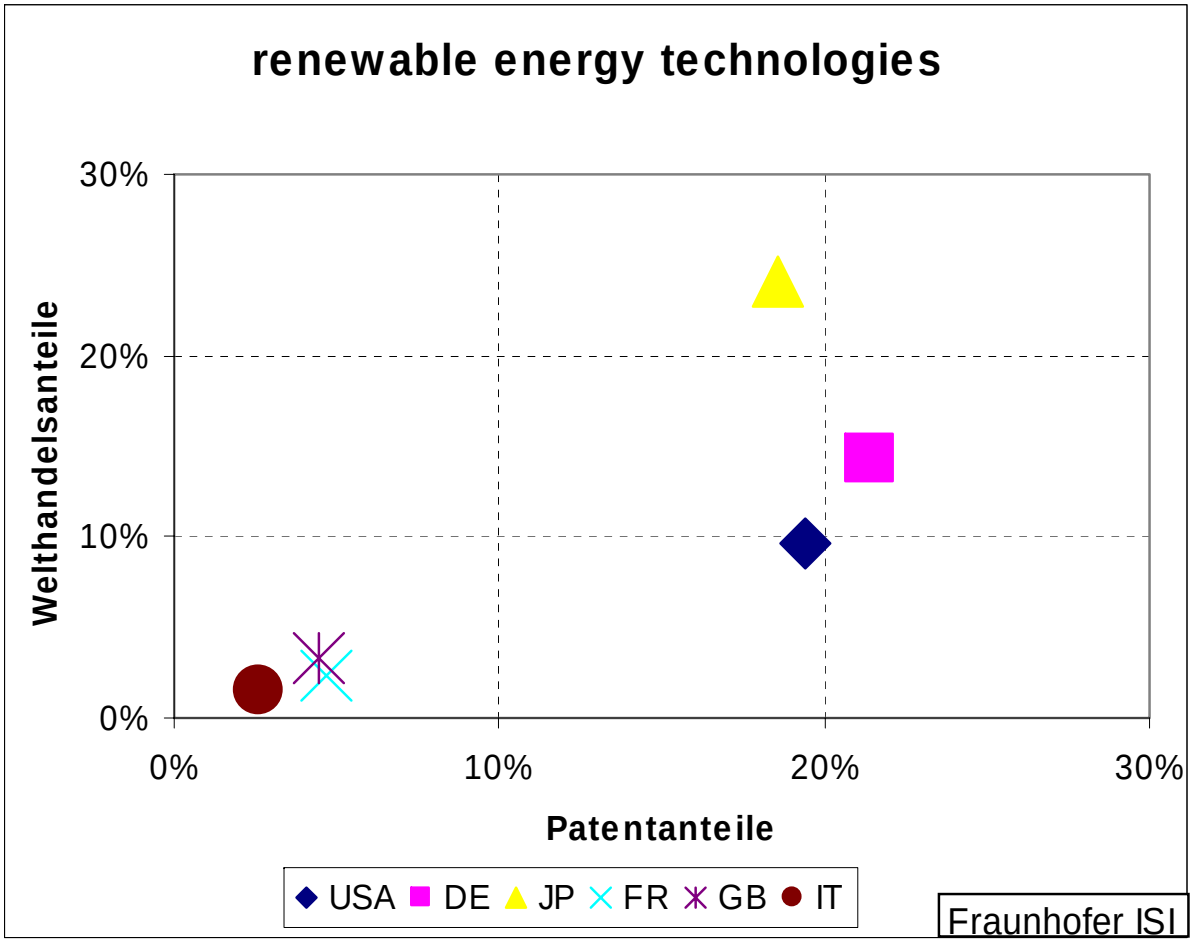
Innovation indicators for renewables

Leading countries

- Germany has emerged as leader in patents
- Japan leads in exports
- US now trailing behind Germany and Japan



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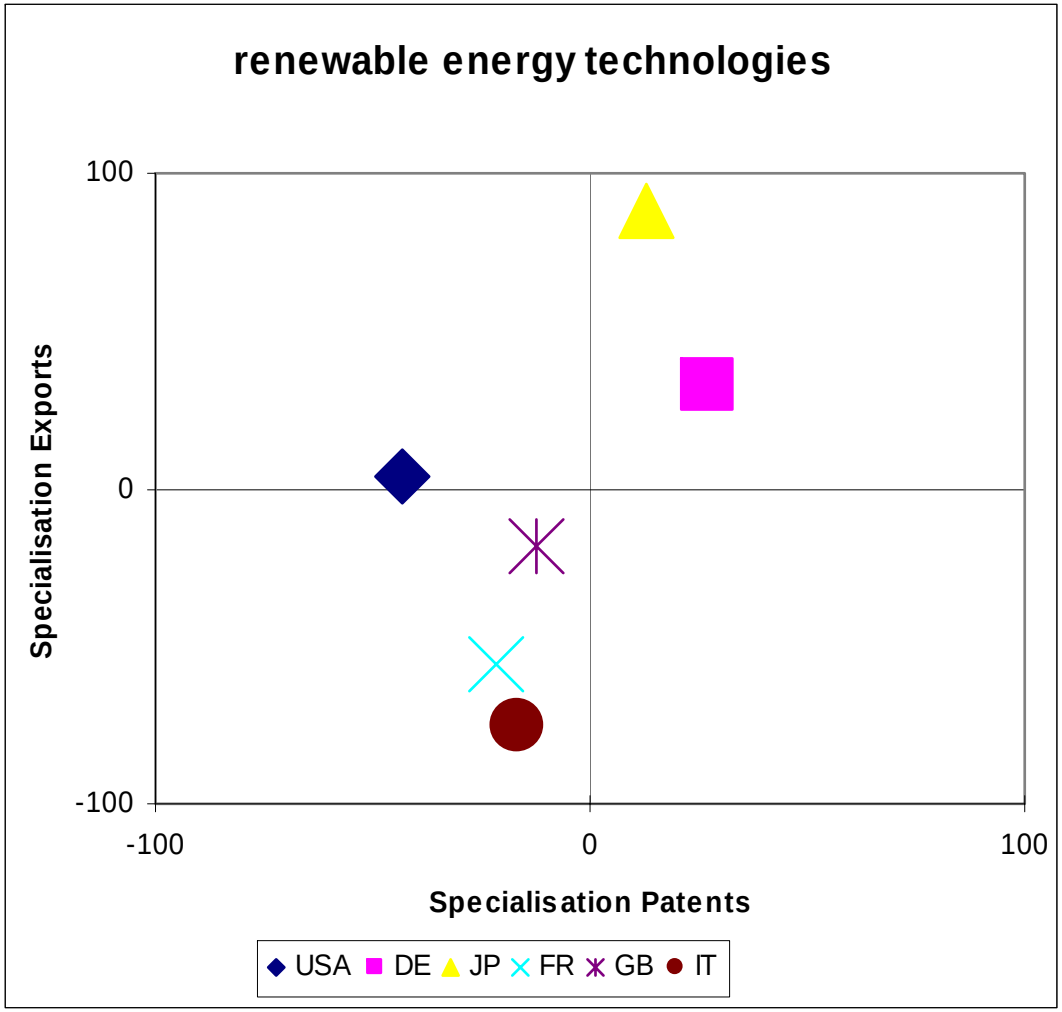
Specialization of Countries

- Indicators (RPA and RTS) normed between +100 and -100
- Positive value: country is specializing on renewable energy technologies
- Japan and Germany with positive specialization



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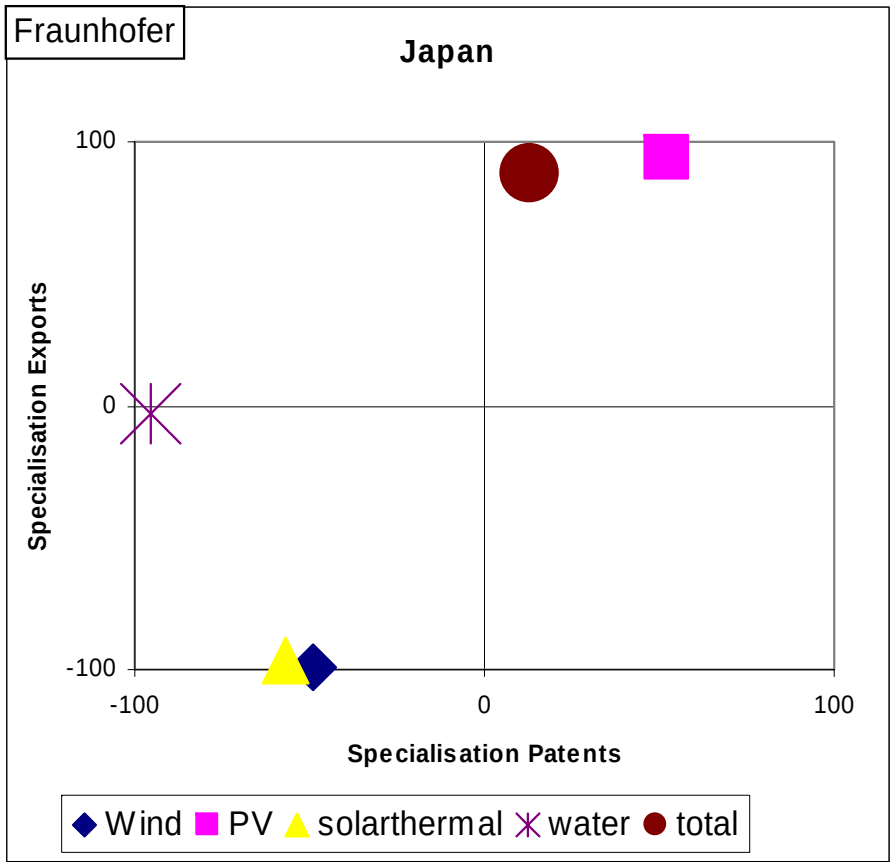
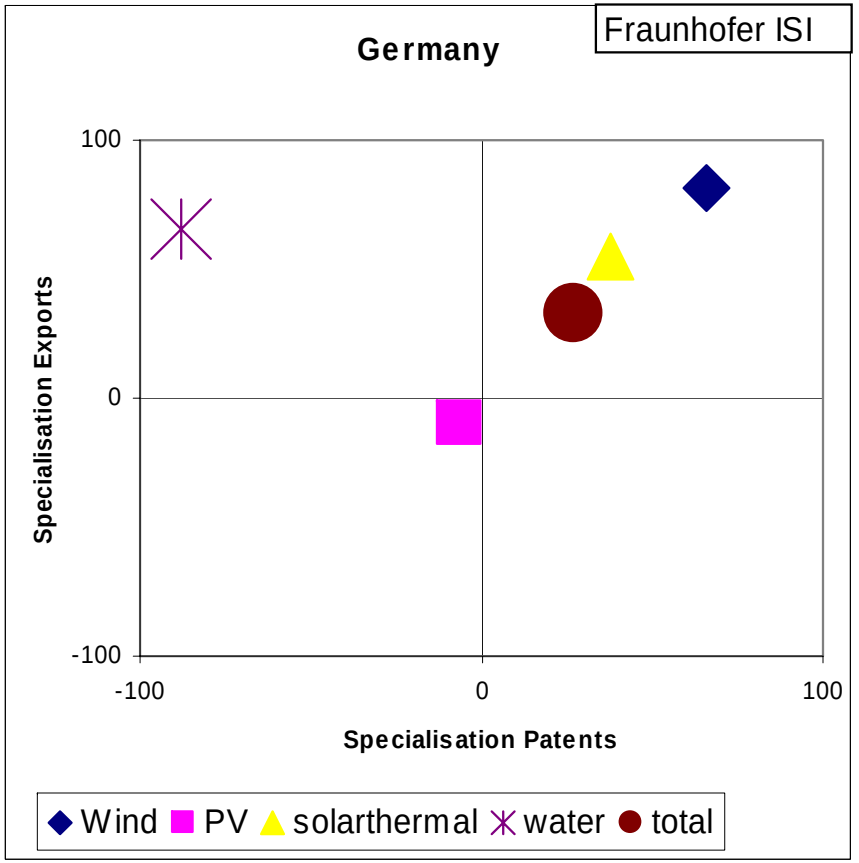
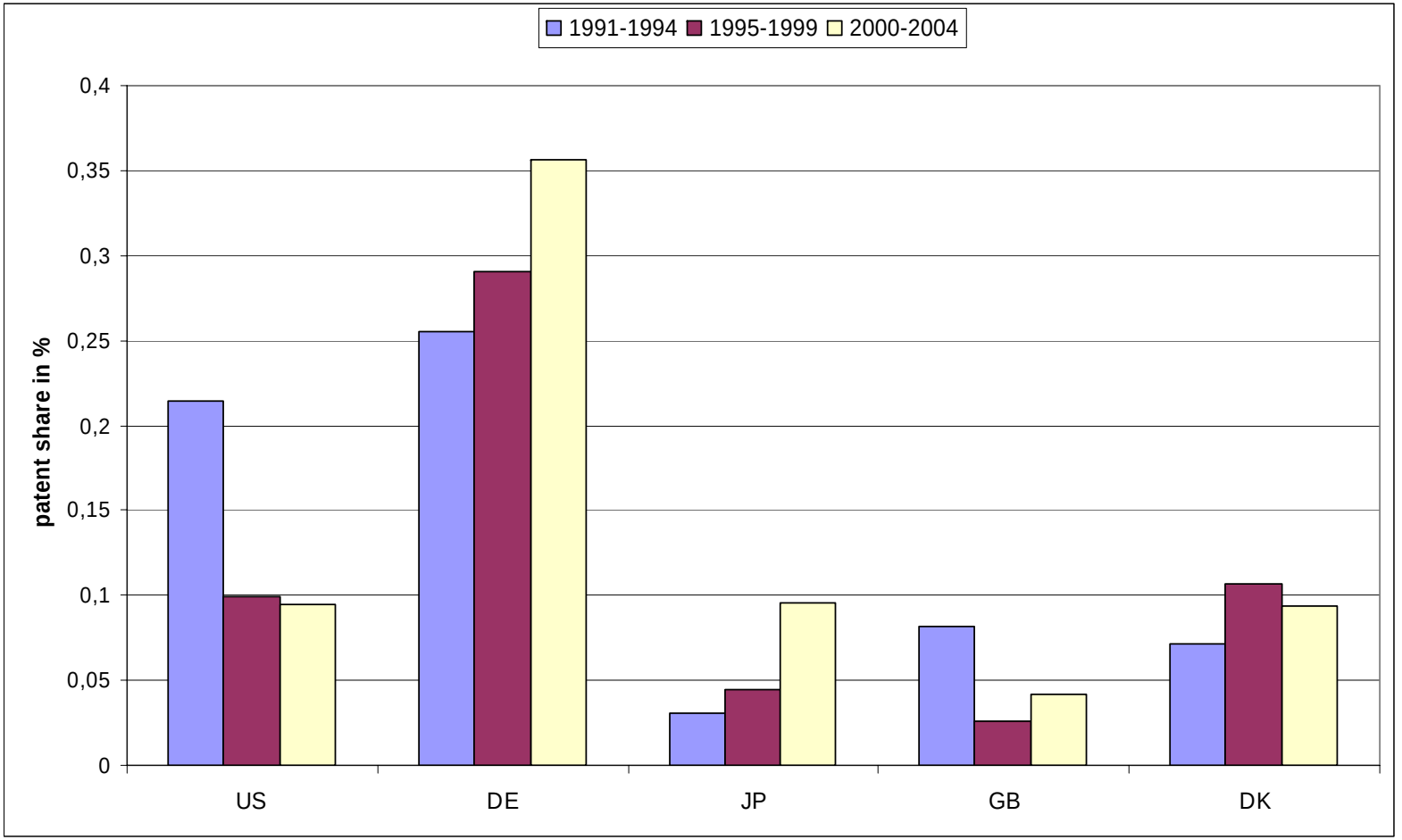
Specialization in the different technologies in Japan and Germany

technology specific analysis necessary to account for differences





Differences over time: the case of wind energy



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Policy background – forms of regulation

1. Public R&D

2. Feed-in tariffs (FIT)

- Renewable electricity can be fed into the grid at a guaranteed tariff for a determined period of time
- The electricity output depends on the support level → price-based
- FITs may also consist of premium tariffs paid in addition to the market price (e.g. in Spain) → stronger market orientation

2. Quota obligation with tradable green certificates (TGC)

- Determination of quota target
- Renewable electricity is sold at the market electricity price
- Additional revenue from selling TGCs
- Certificate price depends on predefined quota target and is determined on the market → quantity-based

Policy background – forms of regulation

3. Tender procedures

- A predefined target of additional capacity or generation is set
- In a bidding round projects with the lowest generation costs can obtain financial support i.e. in form of long-term feed-in tariffs => quantity-based

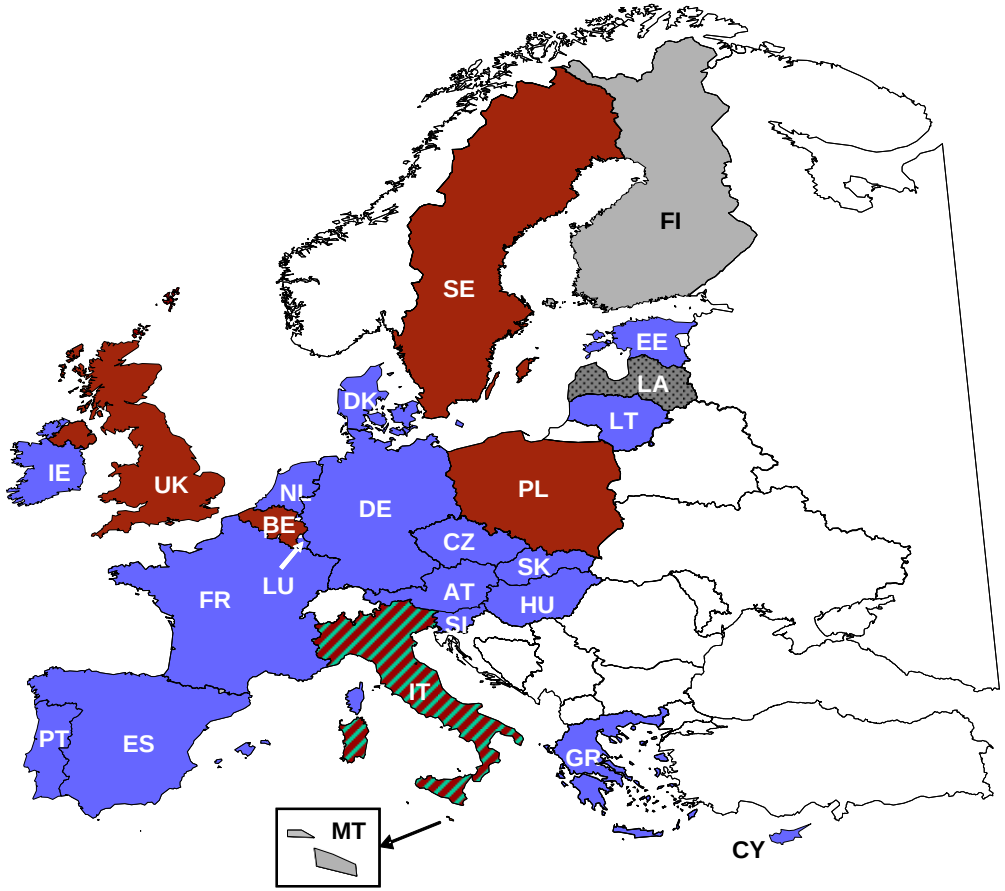
4. Fiscal incentives/investment grants

- Tax incentive: Reduction or exemption of tax payment → price-based
- Investment grants: Reduction of capital costs → price-based

Classification of policy measures

Price-based mechanisms	Quantity-based mechanisms
• Feed-in tariff • Fiscal incentives • Investment grants	• Quota/TGC • Tender schemes

Dominating support schemes for RES-E in the EU



- Feed-in tariff
- Quota / TGC
- Feed-in tariff and Quota / TGC
- Tax incentives / Investment grants
- Other system

A clear majority of EU countries uses feed-in tariffs as main instrument

5 countries have implemented a quota obligation with TGCs

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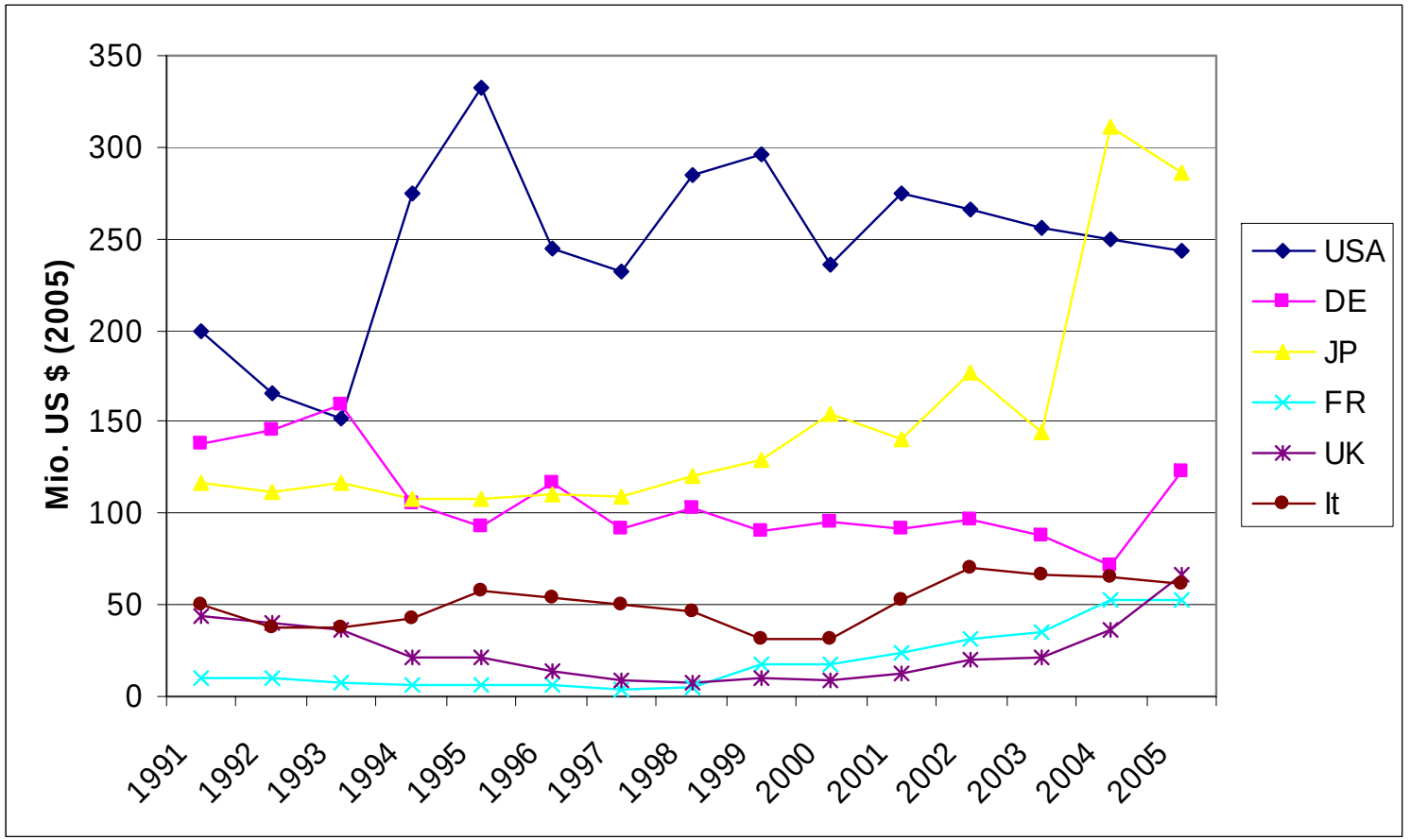
Policies in other countries analysed

- **US** Quota System (State level renewable portfolio standard - RPS) combined with federal production tax incentive
- **Japan** Quota obligation system (Federal renewable portfolio standard - RPS) & investment incentives
- **Korea** Feed-in Tariff for photovoltaic, wind, small hydro and landfill gas electricity
- **Switzerland**: Feed-in Tariff for all renewable technologies (hydro < 1 MW)

Indicator of regulation I: R&D expenditure

- Public R&D expend-iture on renewa-bles (OECD data)
- US in the 1990s ahead
- Decline in the 1990s for most countries (not Japan)
- Increase in most countries after 2000



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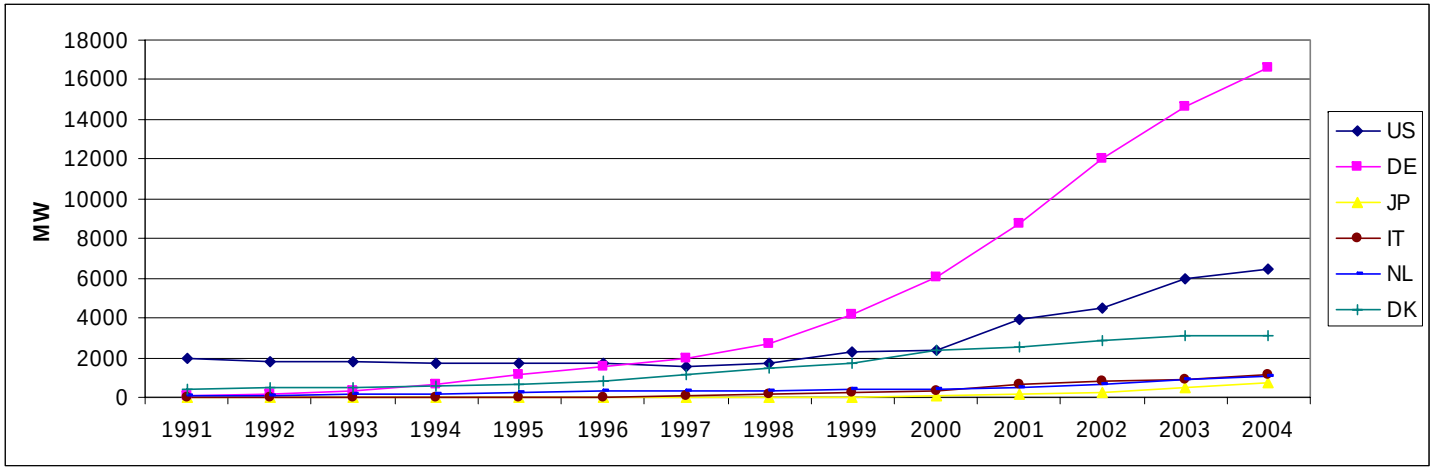
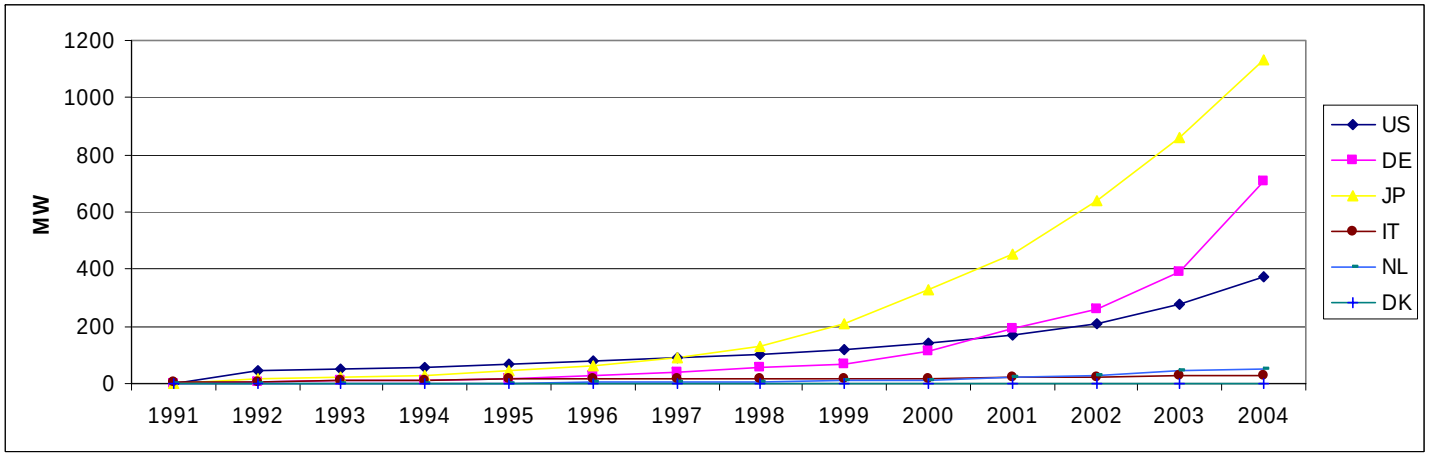
Indicator of regulation II: Diffusion of renewable energy technology

- Diffusion of the technology is rough proxy for aggregated regulation on the demand side
- Installed capacity important for market formation and producer-user interaction
- Leading countries differ for the technologies
- Take off in the leading countries after the mid 1990's



Wind



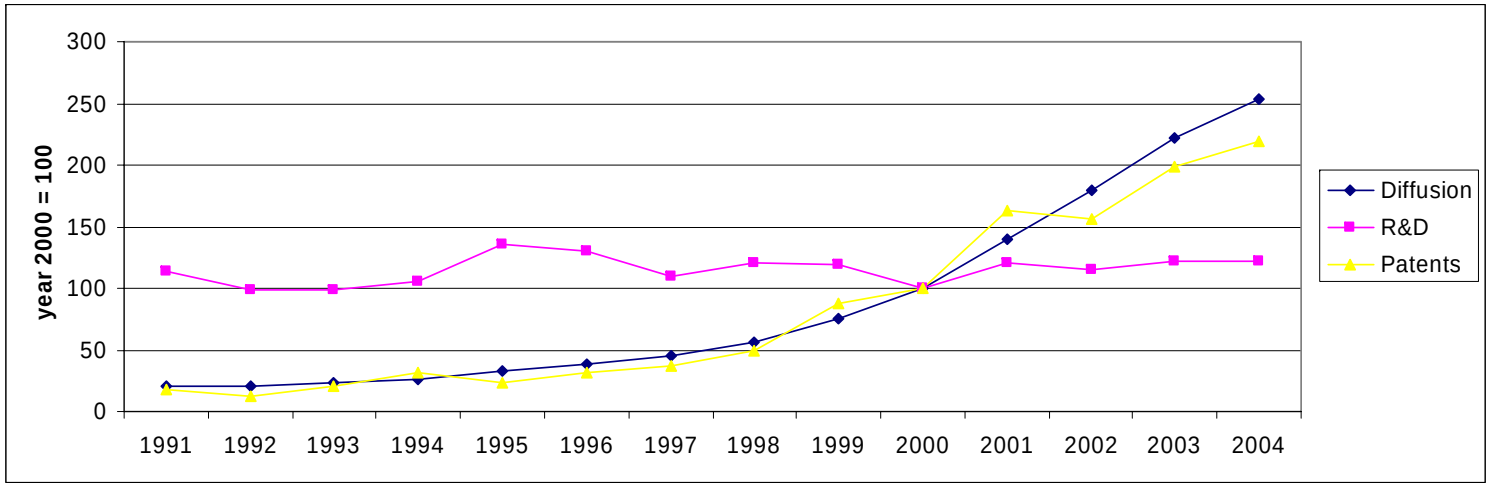
PV

Towards a policy index of innovation friendliness of regulation

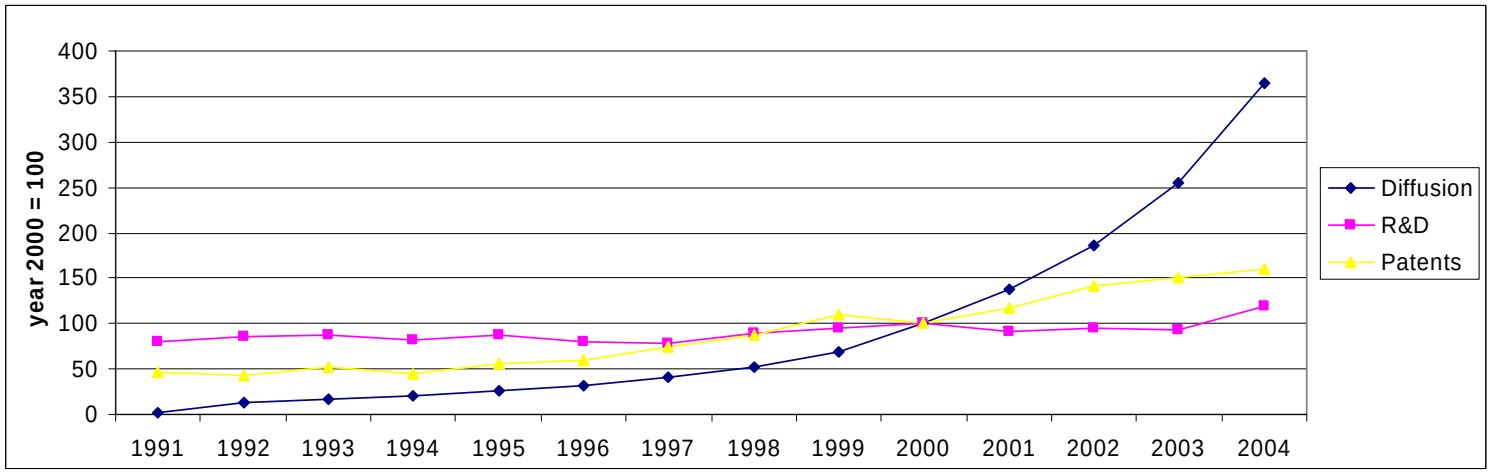
- Demand side regulation mostly directed to increase diffusion
- Additional influence: specific effects from details of regulation on functions of an innovation system
  - Stability and long-term character of regulation
  - Transaction costs and risk perception, especially for new entrants
  - Variety of technological solution
- Construction of indicator
  - Experiences with numerous case studies and latest OECD/IEA comparison of regulation for renewable energy
  - Bundling of experience in scoring indicator (0-3) by expert opinion
- Problems of indicator
  - (subjective) basis for valuation
  - Distinguishes only rough difference
  - Not all possible effects on functions of innovation system covered

Development of Patents, diffusion, R&D

Wind



PV



Variables of econometric estimation for wind

Dependent Variable:

- Number of patents applied for at IPO from companies in country i (measure for innovation output)

Explanatory Variables:

- R&D expenditures in country i (measure for innovation input)
- Installed capacity in country i (measure for technology diffusion, reflects impact of domestic regulation)
- Export of wind mills from country i (measure for impact of regulation abroad)
- Revealed comparative advantage (RCA) of complementary sector (here: mechanical engineering) (measure for relevance of spill over effect)
- policy index of innovation "friendliness"

Econometric issues:

- Observations on 10 countries for 1991 to 2004
- All variables are used in first difference form (some as lags) (i.e. dummy on policy index takes on value of -1, 0, +1 depending on whether innovation friendliness in country i was judged to have deteriorated, remained or improved from the previous year)
- Use GLS estimation procedure (in essence fixed-effects model)
- Allow for different types of heteroscedasticity (homoscedasticity/heteroscedasticity without correlation across countries/heteroscedasticity with correlation across countries) (get more efficient estimators)

Econometric results for Wind (with and without policy index)

	Model 1 (homosk.)		Model 2 (heterosk.)		Model 3 (heterosk. w/ X-sect. correl.)	
R&D	0.179	**	0.228	***	0.232	***
	0.088		0.072		0.028	
Capacity (cum, t-1)	0.158		0.194		0.266	***
	0.185		0.158		0.071	
Export (t-1)	0.214		0.240		0.193	***
	0.187		0.165		0.064	
RCA compl. Sector	1.595		1.424		1.441	***
	1.812		1.605		0.523	
Constant	0.097		0.102		0.059	
	0.081		0.066		0.036	
Sample size	120		120		120	
Log likelihood	-108.6024		-99.86127		-49.9031	

	Model 1 (homosk.)		Model 2 (heterosk.)		Model 3 (heterosk. w/ X-sect. correl.)	
R&D	0.181	**	0.239	***	0.245	***
	0.086		0.069		0.037	
Capacity (cum, t-1)	0.152		0.195		0.251	***
	0.181		0.152		0.065	
Export (t-1)	0.217		0.208		0.117	*
	0.184		0.162		0.067	
RCA compl. Sector	2.161		2.045		2.418	***
	1.801		1.604		0.652	
Policy	0.402	**	0.378	**	0.337	***
	0.193		0.159		0.074	
Constant	0.073		0.076		0.035	
	0.080		0.064		0.038	
Sample size	120		120		120	
Log likelihood	-106.4818		-97.18263		-48.7573	

* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Interpretation of results of econometric estimation for wind

- Parameters exhibit expected signs
- If allow for heteroscedasticity across countries, all parameter estimates are statistically significant at 1% level
- Results are consistent with hypotheses that increase in R&D, installed capacity (more favorable domestic regulation), exports (more favorable foreign regulation) and RCA of complementary sector (spill over) increase innovation (as measured by number of patents)
- Policy index of innovation friendliness turns out to be statistically significant at least at 5% level in all three models
- Results are fairly robust to inclusion of policy index

Preliminary conclusions

- Triple regulatory challenge make renewable energy an extremly important example for the influence of regulation
- Systems of innovation as pragmatic heuristic; effects of regulation on different functions of an innovation system must be evaluated
- Measurement of innovation with indicators
  - Innovation dynamics of renewable energy technologies is above average
  - Germany (especially wind) and Japan (PV) are leading innovation
  - Analysis must be performed on technology specific level
- Empirical results for importance of regulation
  - High importance of regulation to foster diffusion, plus R&D subsidies
  - Complementary sectors as source for knowledge spillover
  - First attempts with policy indicator for innovation friendliness promising
- Future research
  - Improve construction of policy indicator (more formal coding; more innovation functions; other methodological approaches for valuation?)
  - Statistical work for additional sectors and technologies