

Innovations in Energy Efficient Technologies – The Case of Clean Coal Technologies

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Outline

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Introduction

- 70% of electricity generation from fossil fuels – more than half of that share from coal
- „clean coal technologies“ to reduce emissions
- econometric analysis: determine impact factors of innovations of these combustion technologies
- patents as indicator of innovation output

Background – Clean Coal Technologies

- Pulverized Coal Combustion
 - subcritical, supercritical and ultra-supercritical steam conditions
- Fluidized Bed Combustion
- Integrated Gasification Combined Cycle (IGCC)
- End of Pipe
- CCS

Background – Fluidized Bed Combustion

- used in coal combustion as well as for combustion of biomass (among others)
- fluidized bed consisting of granular solid material
- solid fuel suspended on upward-blowing jets of air → mixing of gas and solids
- combustion at approx. 800°C
- reduction of SO_x and NO_x emissions
- efficiency up to 44%

Background – IGCC

- Integrated Gasification Combined Cycle
- gas as well as steam turbine used in combustion process
- gasification of coal leads to creation of mixture of gases consisting of H_2 and CO – *syngas*
- syngas powers gas turbine
 - ➔ waste heat used for steam turbine
- so far: efficiency degrees between 40% and 43%
 - ➔ IEA predicts degrees above 50%
- capable of pre-combustion CCS

Background – Carbon Capture and Storage

CCS:

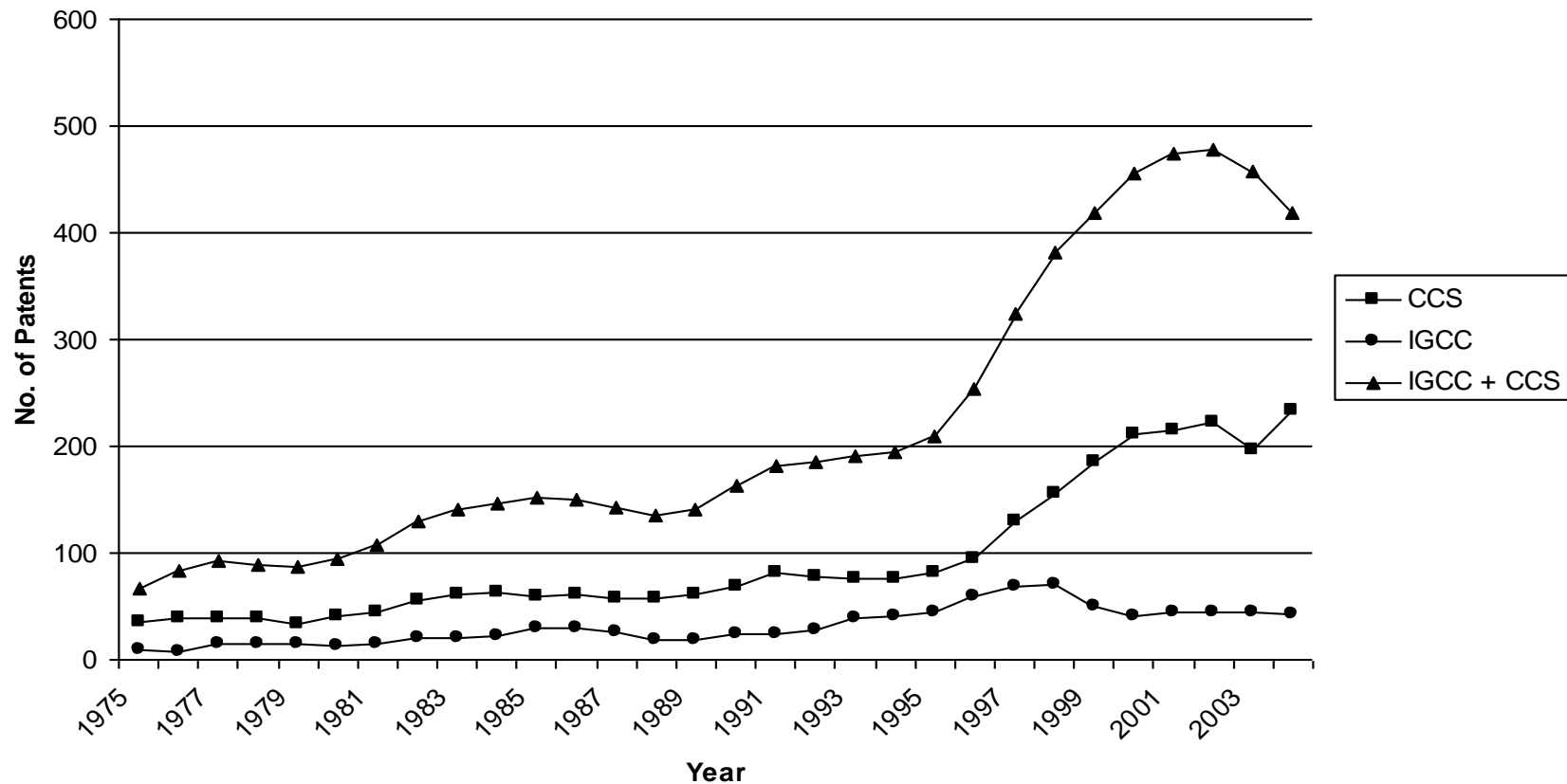
- capture, transportation, storage
- post-combustion and pre-combustion capture
- transportation covered by pipeline systems and ships
- storage: geological, deep ocean, mineral carbonation

Background – Patents

- patent data as output measure of innovative activities
- conditions:
 - invention has to be novel
 - invention has to involve non-obvious step
- national patent offices and EPO
- potential problems:
 - not each invention leads to innovation
 - different patent regimes and propensity to patent
 - choice of patent classes
- apply International Patent Classification (IPC) of World Intellectual Property Organisation (WIPO)

Clean Coal Patents

Clean Coal Patents



Variables

dependent variable:

- number of patents of specific technologies (EPO)

explanatory variables:

- energy-related R&D expenditures (coal combustion)
- coal-generated electricity consumption
- dummy for period after Kyoto with two specifications
 - stand-alone dummy for period from 1998
 - product of dummy and share of renewables in total energy production
- total patent counts (EPO)

Model and Data

Type I:

$$PAT_{i,t} = \alpha + \beta_1 R\&D_{i,t} + \beta_2 CONS_{i,t} + \beta_3 KYOTO_{i,t} + \beta_4 EPO_{i,t} + \gamma_i + \varepsilon_{i,t}$$

Type II:

$$PAT_{i,t} = \alpha + \beta_1 R\&D_{i,t} + \beta_2 CONS_{i,t} + \beta_3 KYOTO_{i,t} * REN_{i,t} + \beta_4 EPO_{i,t} + \gamma_i + \varepsilon_{i,t}$$

- fixed country effects
- estimation using negative binomial model
- panel data for 23 countries from 1974 to 2005
- data sources: OECD Patent Database, IEA Energy Technology R&D Database, IEA Energy Balances

Results – Type I

Dependent variable	IGCC	CCS	IGCC + CCS
Energy R&D for coal combustion	3.05** (1.27)	2.32** (1.08)	2.76*** (0.95)
Coal-generated electricity consumption	-0.00* (0.00)	-0.00 (0.00)	-0.00 (0.00)
Kyoto	-0.39 (0.31)	1.48*** (0.17)	1.12*** (0.17)
Total EPO filings	0.00*** (0.00)	0.00** (0.00)	0.00*** (0.00)
Constant	0.63 (0.49)	2.35*** (0.56)	2.40*** (0.52)
No. of obs.	575	575	575
Wald-test (<i>p</i> -value)	0.00	0.00	0.00

Results – Type II

Dependent variable	IGCC	CCS	IGCC + CCS
Energy R&D for coal combustion	3.34** (1.34)	1.34 (1.04)	1.93** (0.82)
Coal-generated electricity consumption	-0.00 (0.00)	-0.00*** (0.00)	-0.00*** (0.00)
Kyoto * renewables share	-0.00 (0.02)	0.06*** (0.01)	0.03*** (0.01)
Total EPO filings	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Constant	0.48 (0.50)	2.71*** (0.51)	2.72*** (0.47)
No. of obs.	575	575	575
Wald-test (<i>p</i> -value)	0.00	0.00	0.00

Results (1)

- significance of
 - R&D expenditures
 - Kyoto specifications for CCS and aggregate IGCC + CCS
- results for R&D expenditures due to public good character of both technologies
 - ➔ consider public expenditures leading to innovative activity
 - ➔ in particular for CCS (non-excludability)

Results (2)

- Kyoto results can be explained by policy signals
 - ➔ innovations mainly shifted towards renewable energy sources and CCS
 - ➔ IGCC not affected by Kyoto Protocol

Conclusions

- empirical analysis shows interrelations between patents of all technology types and coal combustion R&D
- identified impact of Kyoto Protocol for CCS technology
- Outlook:
 - introduction of a stringency variable depending on data availability
 - technology-specific R&D
 - examination of knowledge transfer

Thank you for your attention!

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