THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

Grantham Research Institute on Climate Change and the Environment

Climate policies, innovation and growth

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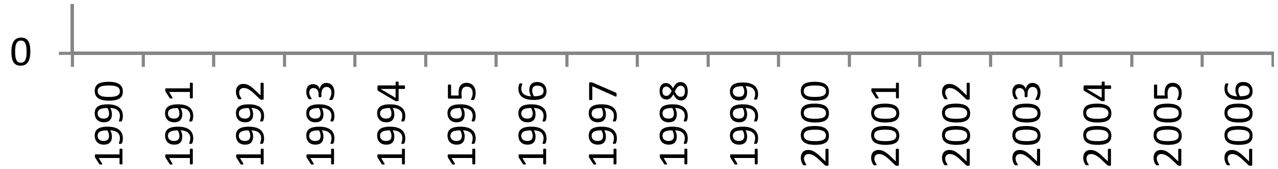
The problem

- We need rapid and deep reductions in fossil-fuel use
  - Limiting temperature increase to 2°C
  - Reducing local pollution
- This requires significant changes in technologies and policies to get us there

Types of technological change

1. Changing the mix of what existing technologies we use over time
2. Changing the cost or productivity of clean technologies over time

Price of PV modules 1990-2011



Source: see Annex 1

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Source: de la Tour, Glachant & Ménière 2013

Average FiT for solar energy

Source: de la Tour & Glachant, 2013

Types of technological change

1. Changing the mix of what existing technologies we use over time
2. Changing the cost or productivity of clean technologies over time
3. Developing new breakthrough or backstop technologies

How to get there?

- What policy tools can achieve these goals in a decentralized manner?
- Carbon emissions are a *negative externality*: the associated costs need to be internalized
  – Carbon price!

Question 1

- Is carbon pricing working?
  - Does it induce innovation in clean technologies?

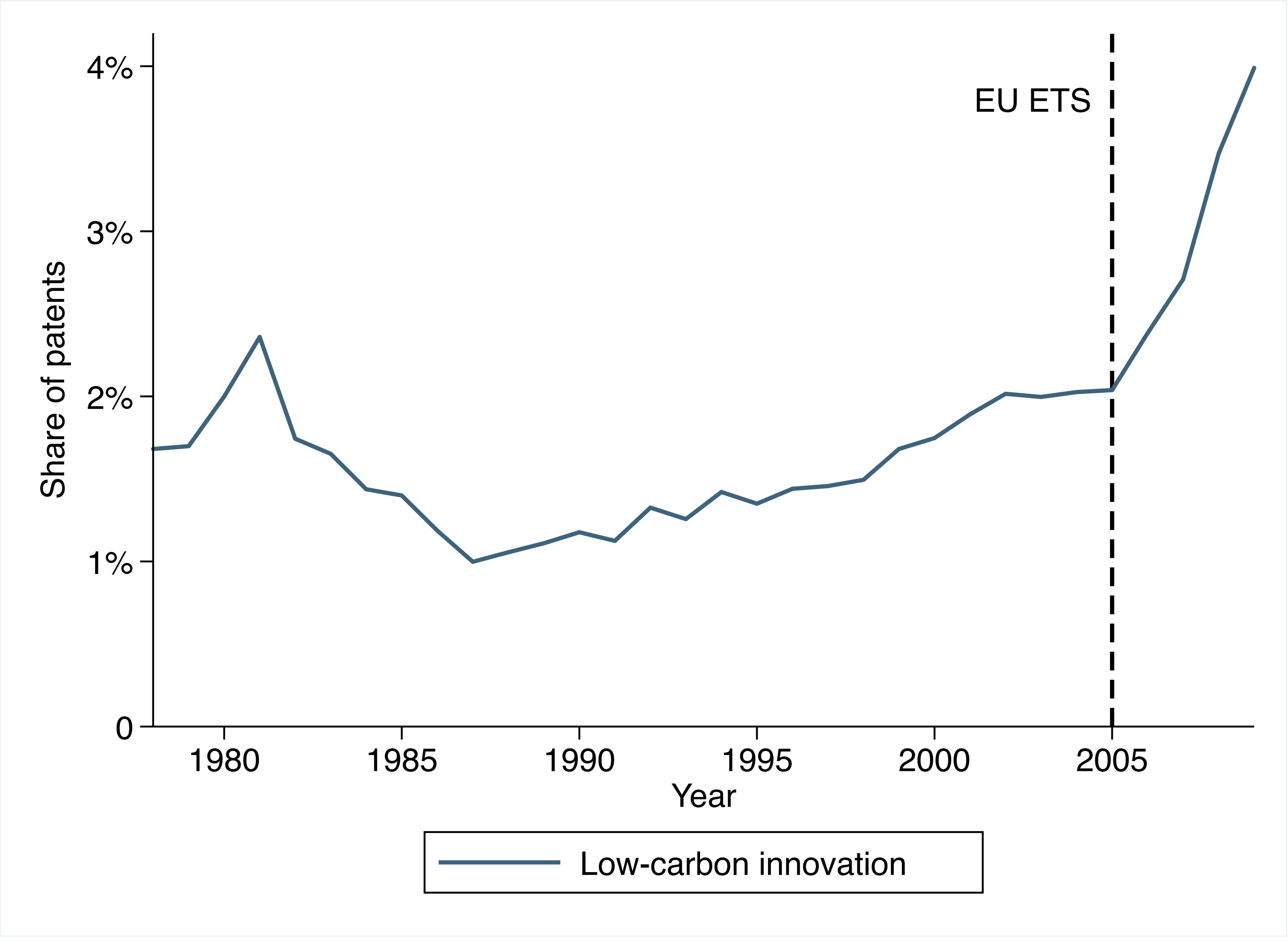
Environmental Policy and Directed Technological Change: Evidence from the European carbon market

Joint with Raphael Calel (UC Berkeley)

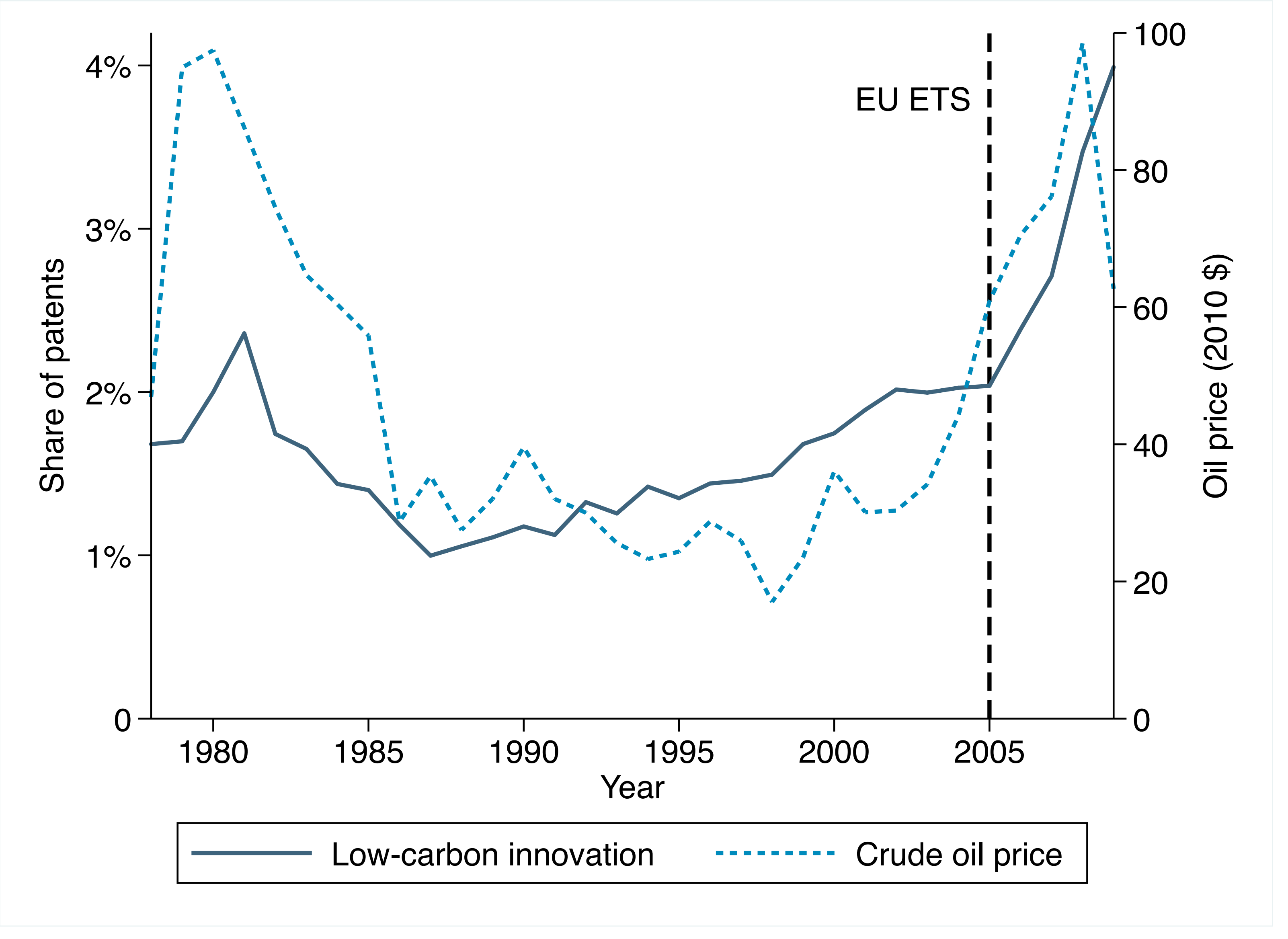
The paper

- Empirically analyse the impact of the EU ETS on low-carbon technological change
- Use patents filed with the European Patent Office (EPO) to measure innovation
- Use new EPO ‘low carbon patents’ classification

Share of low-carbon patents at EPO

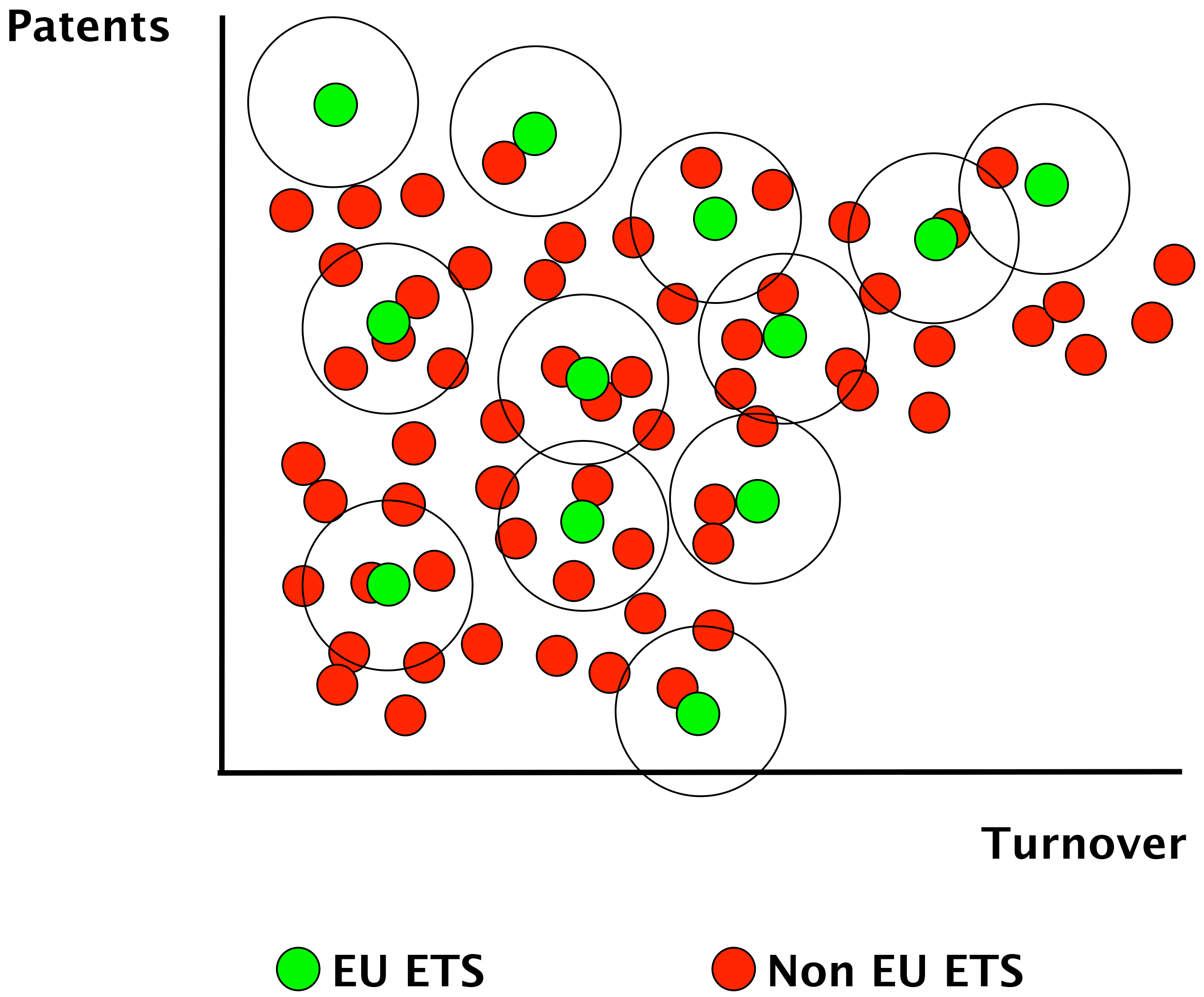


A consequence of the EU ETS?



A matching analysis

- Identify regulated companies
- Compare them with unregulated companies in the same economic sectors and countries, same size, same innovation activity
  - Owners of smaller installations

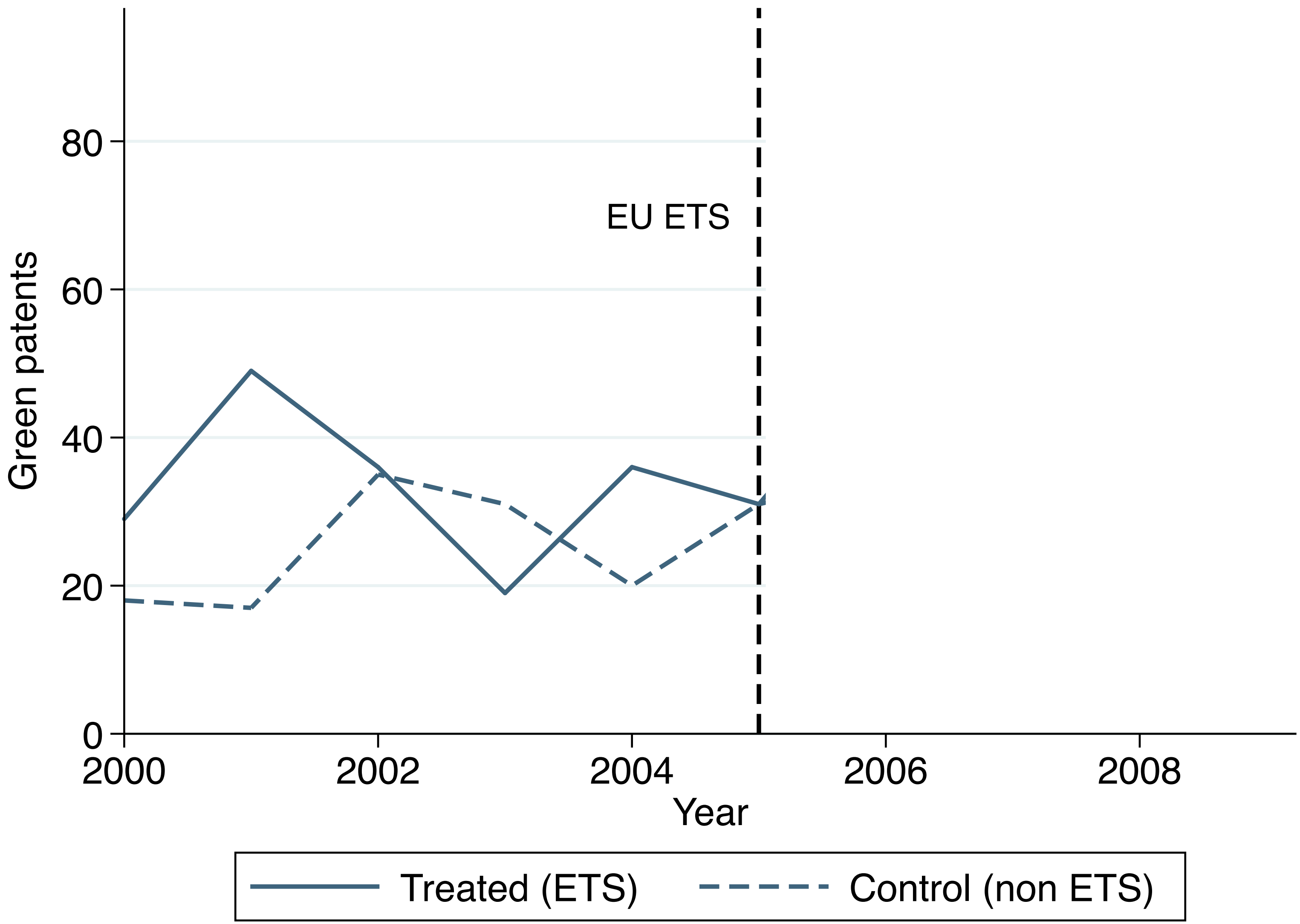


Patents
Turnover
EU ETS
Non EU ETS

A matching analysis

- Identify regulated companies
- Compare them with unregulated companies in the same economic sectors and countries, same size, same innovation activity
  - Owners of smaller installations
- Use this control group as an estimate of what regulated firms would have experienced in the absence of the ETS
- Good comparators for **3,428 EU ETS firms in 18 countries**

Low-carbon patents: treated (ETS) vs control group (non-ETS)



Results

- Compare treated (ETS) with control group, pre-ETS (2000-2004) with post-ETS (2005-2009)
- Impact of EU ETS = **+ 10% low-carbon patents**
- **No crowding out** of other innovation

Message #1

- Carbon pricing works!
  - It induce innovation in clean technologies
  - Also shown in car sector, electricity production, renewable energy…

Question 2

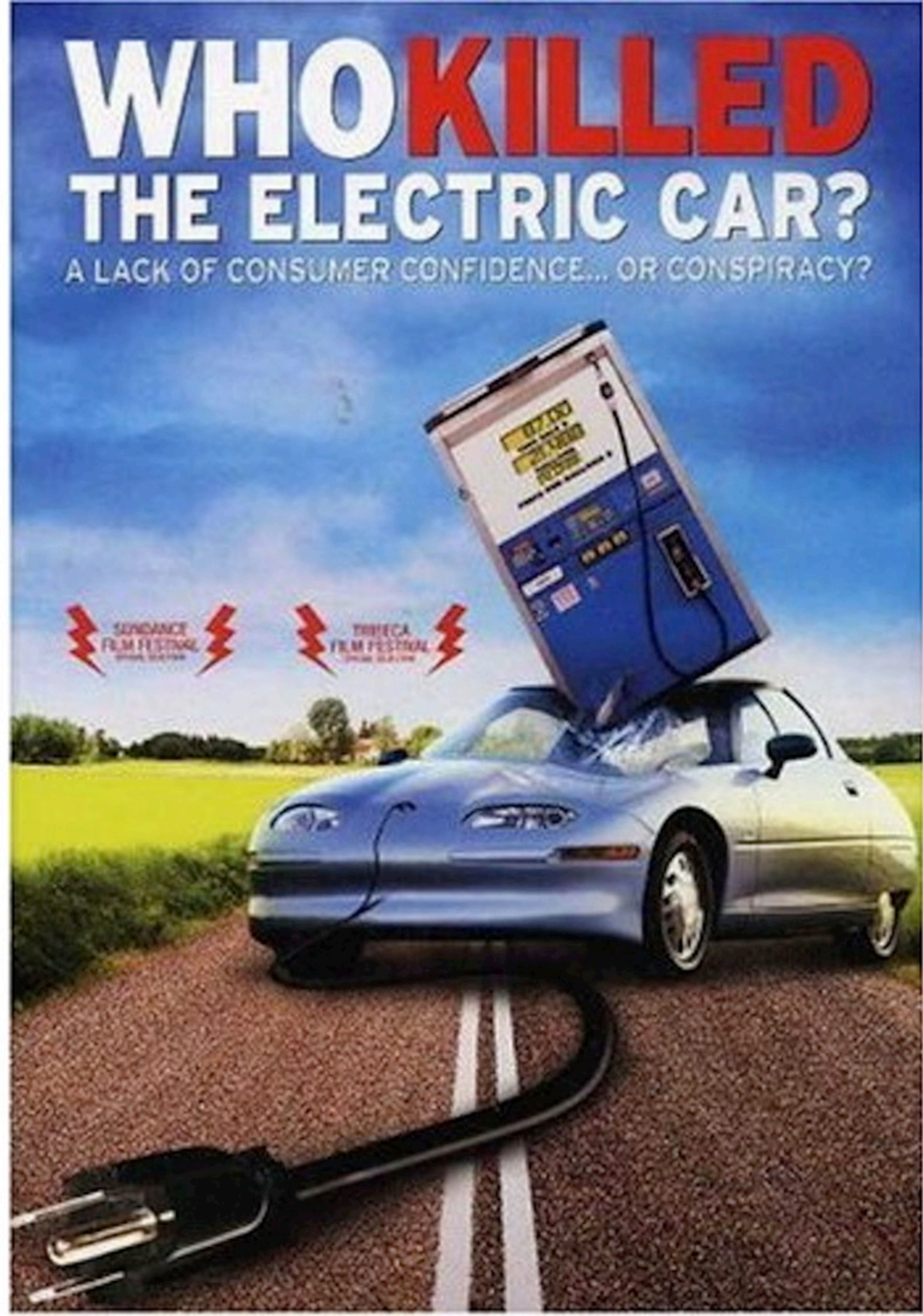
- Is carbon pricing enough?
  - If carbon emissions were taxed at the value of their social cost, would this induce enough technical change?

Market failures and other concerns relevant for energy policy

- Lock-in & path dependence
- Knowledge spillovers – inability of innovators to appropriate all the gains
- Network effects
- Market or regulatory barriers to adoption
- Competitiveness & international emissions leakage
- Behavioral gaps: energy efficiency valuation, uncertainty, discounting
- Option values and uncertainty

Carbon Taxes, Path Dependence and Directed Technical Change: Evidence from the Auto industry

Joint with
Philippe Aghion (Harvard),
David Hemous (INSEAD),
Ralf Martin (Imperial) &
John Van Reenen (LSE)



Data

- All patents filed from 1978 to 2005 pertaining to "clean" and "dirty" technologies in the car industry
  - “Clean”=Electric, Hybrid, Hydrogen
    9065 innovations
  - “Dirty”=Internal Combustion Engine
    28115 innovations
- 3412 firms

Results

- Evidence of **strong path-dependence** in innovation activity
- Faced with the same incentives, firms innovating in carbon intensive technologies **twice as likely** to continue innovating in dirty rather than switching to clean
- Same for firms located in economies specialized in carbon intensive technologies

Path dependency justifies strong policy intervention

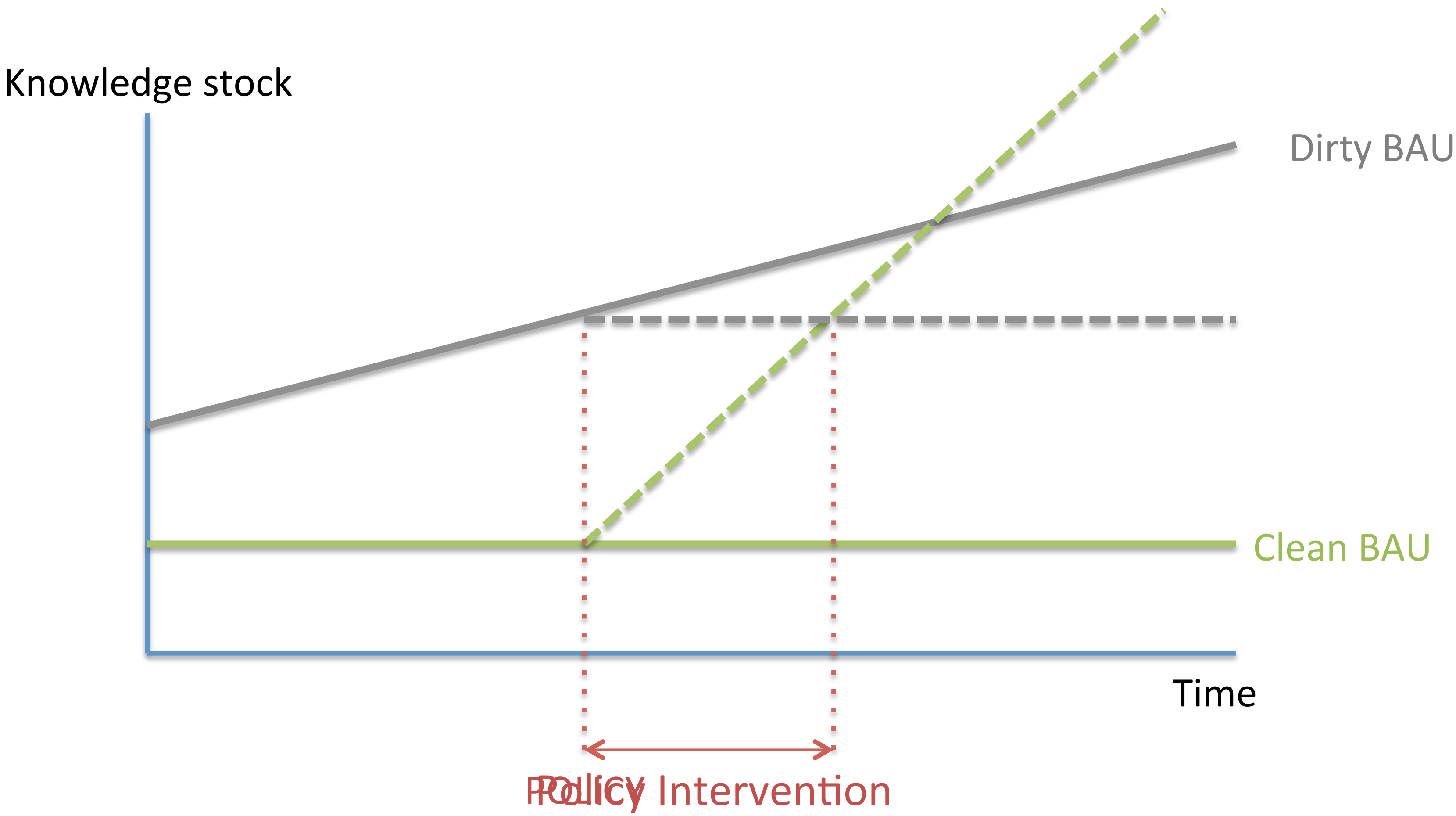
No increase in fuel prices

based on CFX estimations presented in Tabl

40% increase in fuel prices

based on CFX estimations presented in Table 6

The advantages of path dependency



Policy intervention can be only temporary

Market failures and other concerns relevant for energy policy

- Lock-in & path dependence
- Knowledge spillovers

Knowledge spillovers from clean and dirty technologies: A patent citation analysis

Joint with
Ralf Martin (Imperial) &
Myra Mohnen (UCL)

What we do

- Compare the extent of knowledge spillovers between clean and dirty technologies
- Focus on 4 sectors, including **electricity production** (renewables vs fossil fuel)

- Measure knowledge spillovers using patent citations
- 1 million patented inventions, 3 million citations received by these patents

(12) United States Patent
Ikeda

(10) Patent No.: US 8,186,322 B2
(45) Date of Patent: May 29, 2012

(54) **IGNITION APPARATUS, INTERNAL-COMBUSTION ENGINE, IGNITION PLUG, PLASMA EQUIPMENT, EXHAUST GAS DEGRADATION APPARATUS, OZONE GENERATING/STERILIZING/DISINFECTING APPARATUS, AND ODOR ELIMINATING APPARATUS**

(75) Inventor: **Yuji Ikeda**, Kobe (JP)

(73) Assignee: **Imagineering, Inc.** (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/242,054**

(22) Filed: **Sep. 23, 2011**

(65) **Prior Publication Data**

US 2012/0012077 A1 Jan. 19, 2012

Related U.S. Application Data

(62) Division of application No. 12/083,608, filed as application No. PCT/JP2006/319850 on Oct. 4, 2006.

(30) **Foreign Application Priority Data**

Sep. 20, 2006 (JP) 2006-255109

(51) **Int. Cl.**
F02P 23/00 (2006.01)

(52) **U.S. Cl.** .... **123/143 B**; 123/536

(58) **Field of Classification Search** 123/536, 123/143

See application file for complete search history.

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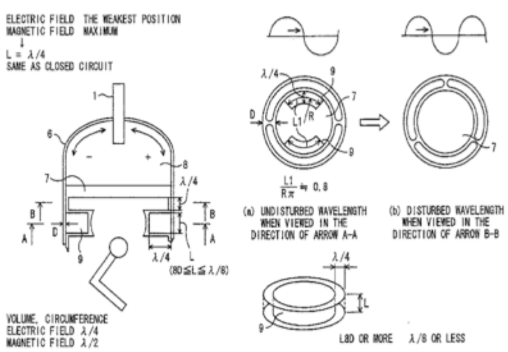
Primary Examiner — Stephen K Cronin
Assistant Examiner — Arnold Castro
(74) *Attorney, Agent, or Firm* — Bacon & Thomas, PLLC

(57) **ABSTRACT**

Stable and highly efficient combustion/reaction is provided, even when fuel ratio of mixture is decreased and combustion/reaction of the lean mixture is performed in a heat engine such as a reciprocating engine, for controlling dielectric constant of mixture in a combustion/reaction chamber **8** by introducing water and/or exhaust gas into the combustion/reaction chamber, by introducing water and/or exhaust gas into the combustion/reaction chamber. A microwave radiation antenna for irradiation of the combustion/reaction chamber, and a discharge unit for igniting the mixture in the combustion/reaction chamber are provided. The dielectric constant of the mixture before the combustion/reaction of the mixture is controlled so that the resonance frequency of the mixture corresponds to the frequency of the microwave.

4 Claims, 12 Drawing Sheets



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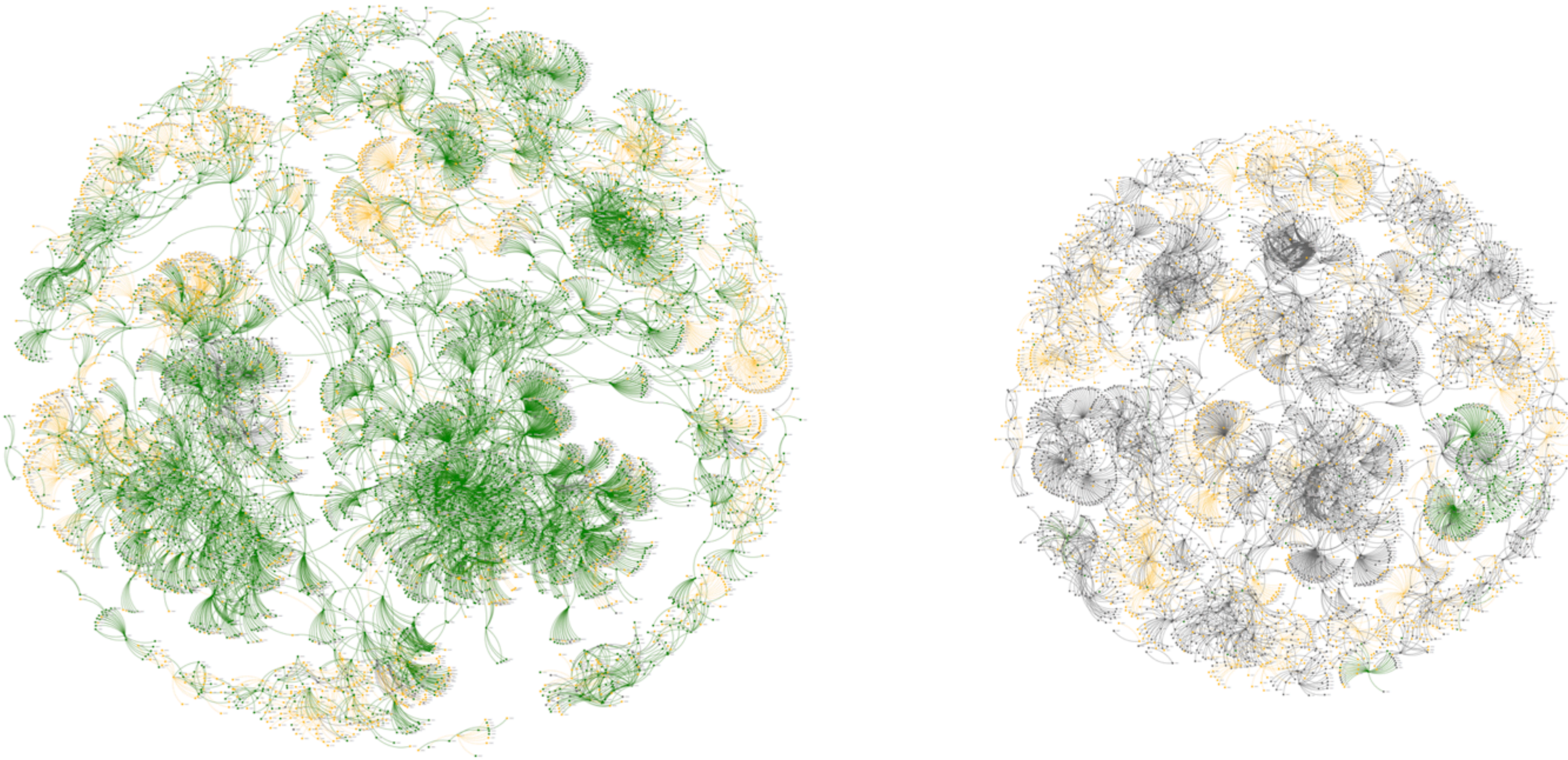
Knowledge diffusion flowers



Spillovers from clean are larger

	(0.000)	(0.00
Triadic	0.567***	0.239*
	(0.000)	(0.00
Granted	1.142***	0.728*
	(0.000)	(0.00
Observations	417,696	38,64

Notes: R[illegible]t standard errors, p-values in pare
p<0.00[illegible]e dependent variable is the total nu
self-ci[illegible]s by inventors. All equations include p
[illegible]nns are estimated by Poisson pseu

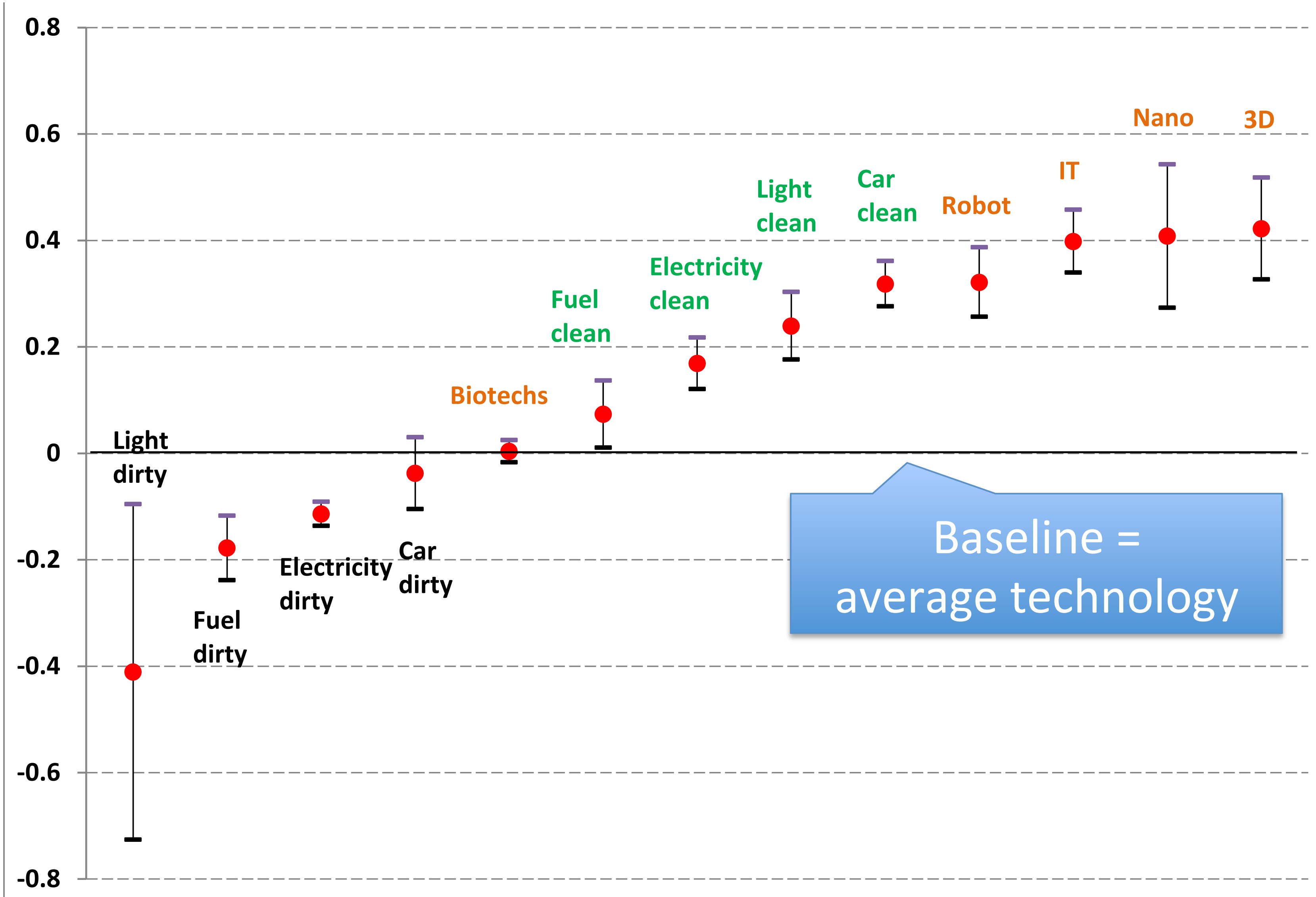
+ 48% spillovers

17

Understanding the larger spillovers

- Clean inventions have wider technological applications
  - More likely to be cited/used outside of their originating field
- Clean inventions are radically new compared to more incremental dirty innovation
  - Knowledge spillovers from clean technologies are comparable in scope to those in the IT sector

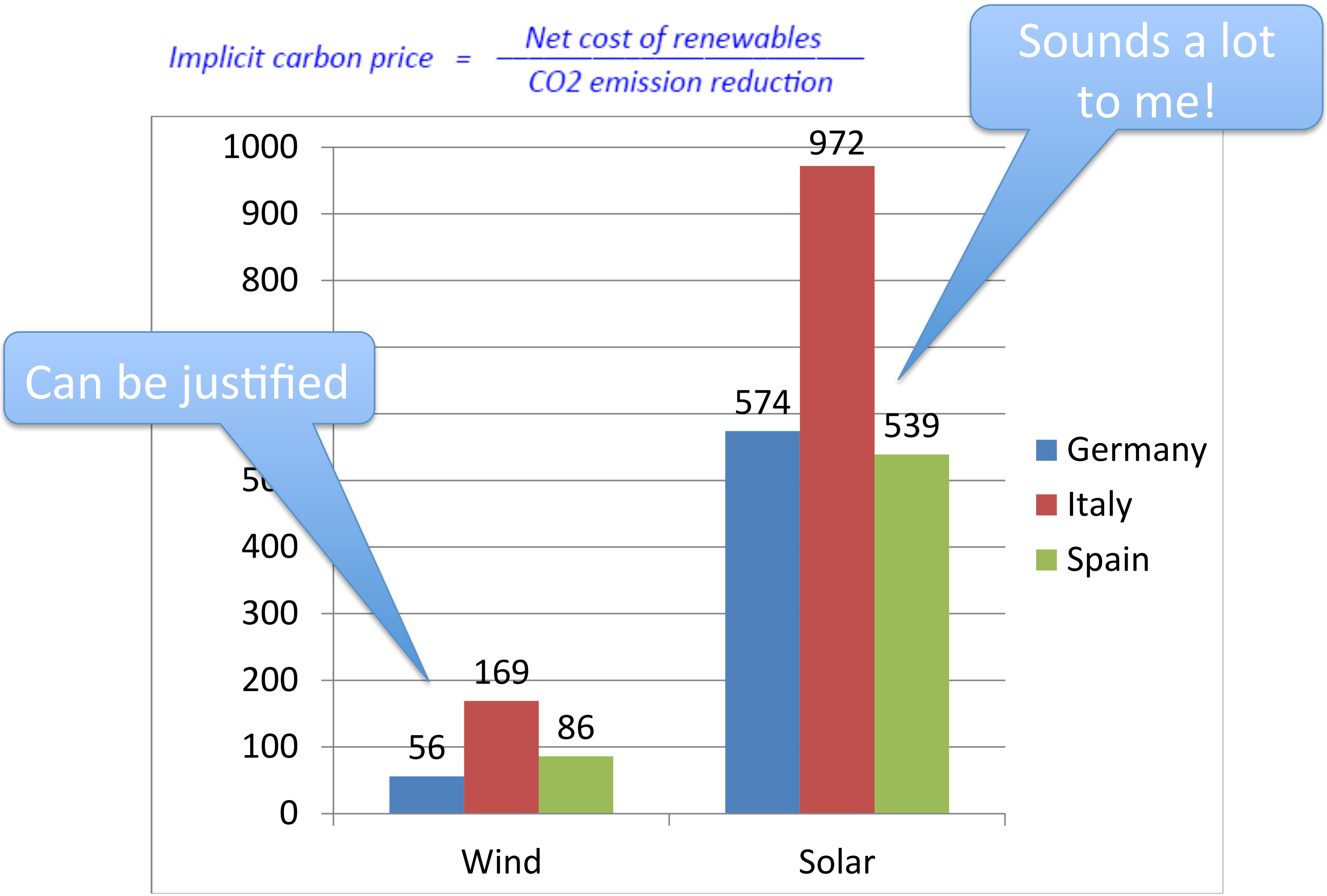
Clean, dirty and other new techs



Message #2

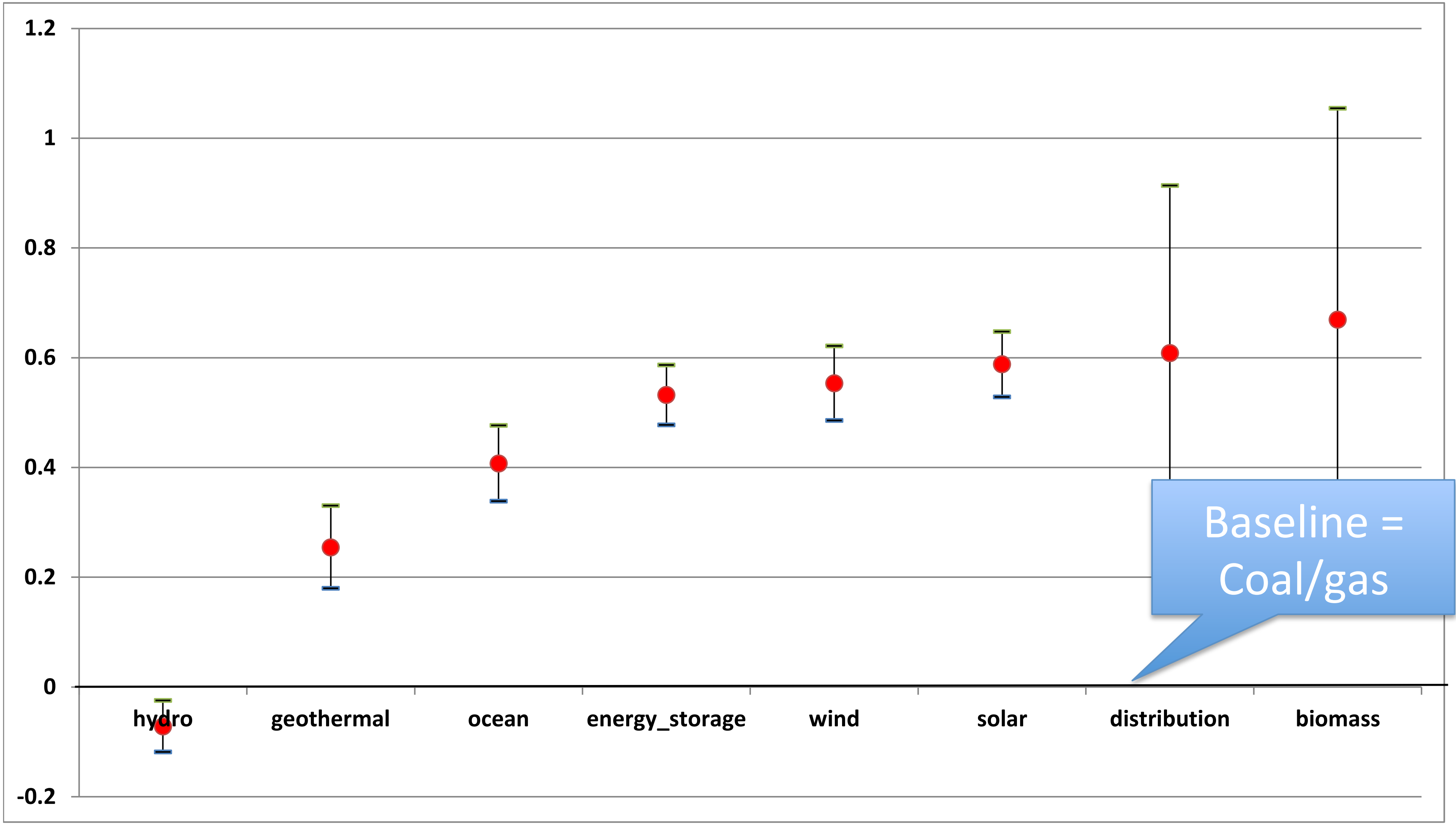
- Carbon pricing is not enough
- Lock-in and other market failures justify stronger policies
- Large knowledge spillovers from clean technologies justify *higher R&D subsidies*
  - If subsidizing private R&D in clean technologies is impossible, higher carbon taxes / FiTs can be used

Cost of abatement with renewables



Marcantonini and Ellerman (2013)

Spillovers from clean electricity techs



Question 3

- What do we get from supporting clean technologies?

From spillovers to growth

- Redirecting innovation away from clean and towards dirty increases knowledge spillovers in the economy
- This reduces the net cost of the policy and can **induce economic growth** through productivity improvements

Growth for whom?

- We live in a globalized world
- **Do climate/energy policies support local growth?**
  - Are climate change policies in Spain creating growth in China?

Localized spillovers

- 51% of spillovers in clean technologies stay within the country of the inventor
  - Spain: 40%

Message #3

- Supporting clean technologies may induce economic growth
- The effects are likely to be *strongest* locally
- There are strong international spillovers

Take home messages

- Price intervention can change the direction of technological progress
  - **Carbon policy can induce low-carbon innovation**
- Evidence of path dependency in innovation
  - **Need to act soon**
  - **But policy can be only temporary**
- Other market failures (knowledge spillovers) + policy constraints (jobs, distributional concerns)
  - **Clean techs deserve additional support (higher carbon price, R&D policies)**
- Green policies might have local economic benefits
  - **More evidence needed**

Thanks

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Does environmental policy influence foreign innovation? Evidence from the wind industry

Joint with
Matthieu Glachant
(Ecole des Mines, Paris)

Data

- 28 OECD countries, 1990-2010
- Innovation in wind power
  - 15,835 patent applications
- Demand-pull policies
  - Annual installations of new wind power capacities
- Technology-push policies
  - Public R&D expenditures

Results

- A 100 MW wind farm installed induces
    - 1 invention domestically
    - 2 inventions abroad
- Demand-pull policies have a higher aggregate impact on foreign than on domestic innovation
- Technology-push policies (R&D subsidies) benefit mostly domestic inventors