Is green growth possible?

Philippe Aghion

CREATIVE DESTRUCTION…

- Process whereby new innovations displace old technologies
  - Joseph Schumpeter in *Capitalism, Socialism et Democracy (1942)*

Peter Howitt

BASIC "SCHUMPETERIAN GROWTH" PARADIGM

- Long-run growth driven by cumulative process of innovation
- Innovations result from entrepreneurial activities motivated by prospect of innovation rents
- Creative destruction: new innovations displace old technologies

At the heart of the paradigm

- Contradiction :
  - The innovator is motivated by prospect of monopoly rents
  - But those rents can be used ex post to prevent future innovations and to block new entry

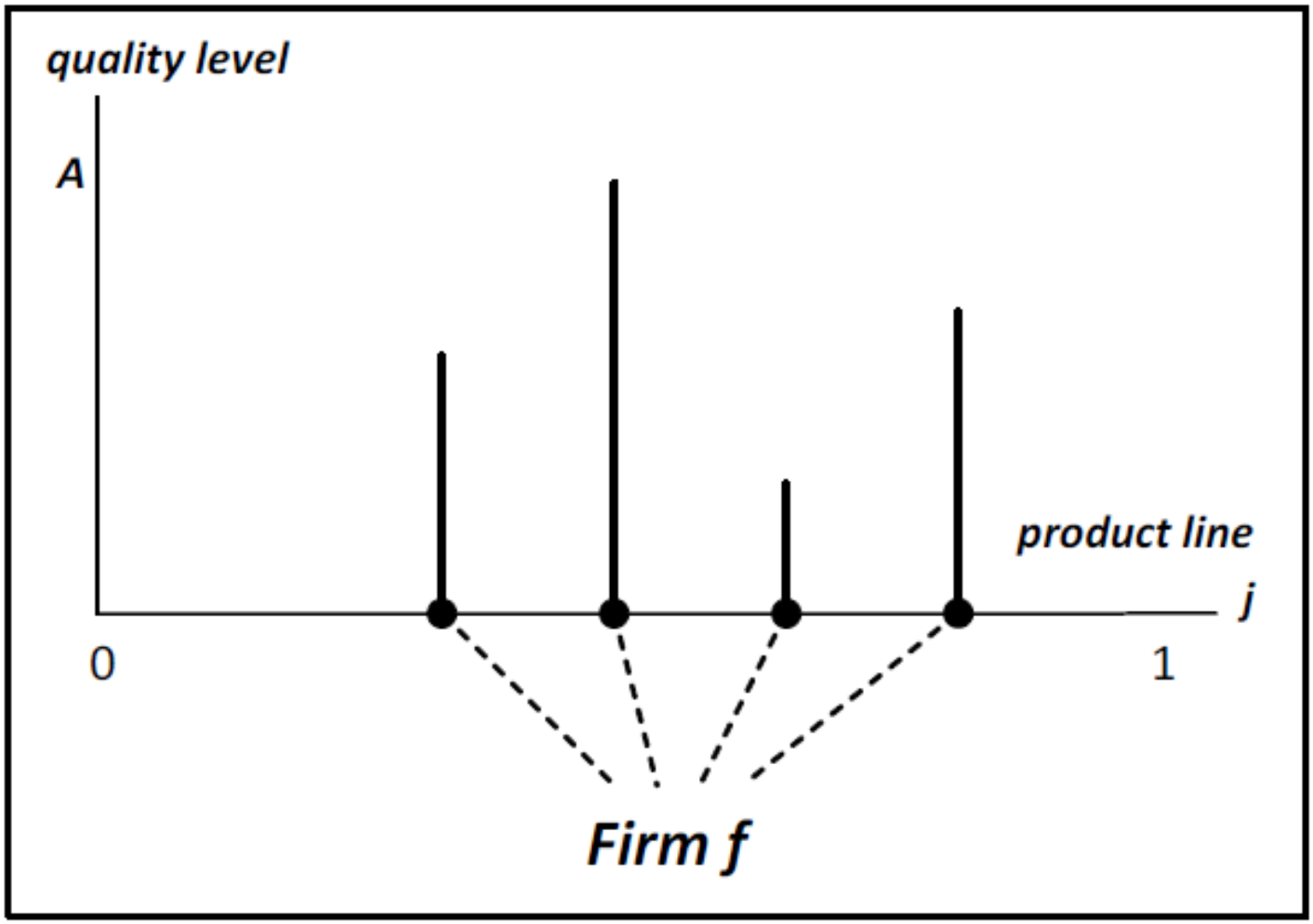
- Regulating capitalism is largely about how to manage this contradiction

why this paradigm changes the landscape

- It gives centerstage to cross-firm heterogeneity
  - Between incumbents and entrants
  - Between leaders and followers
  - Between small and large firms

why this paradigm changes the landscape

- It gives centerstage to firm dynamics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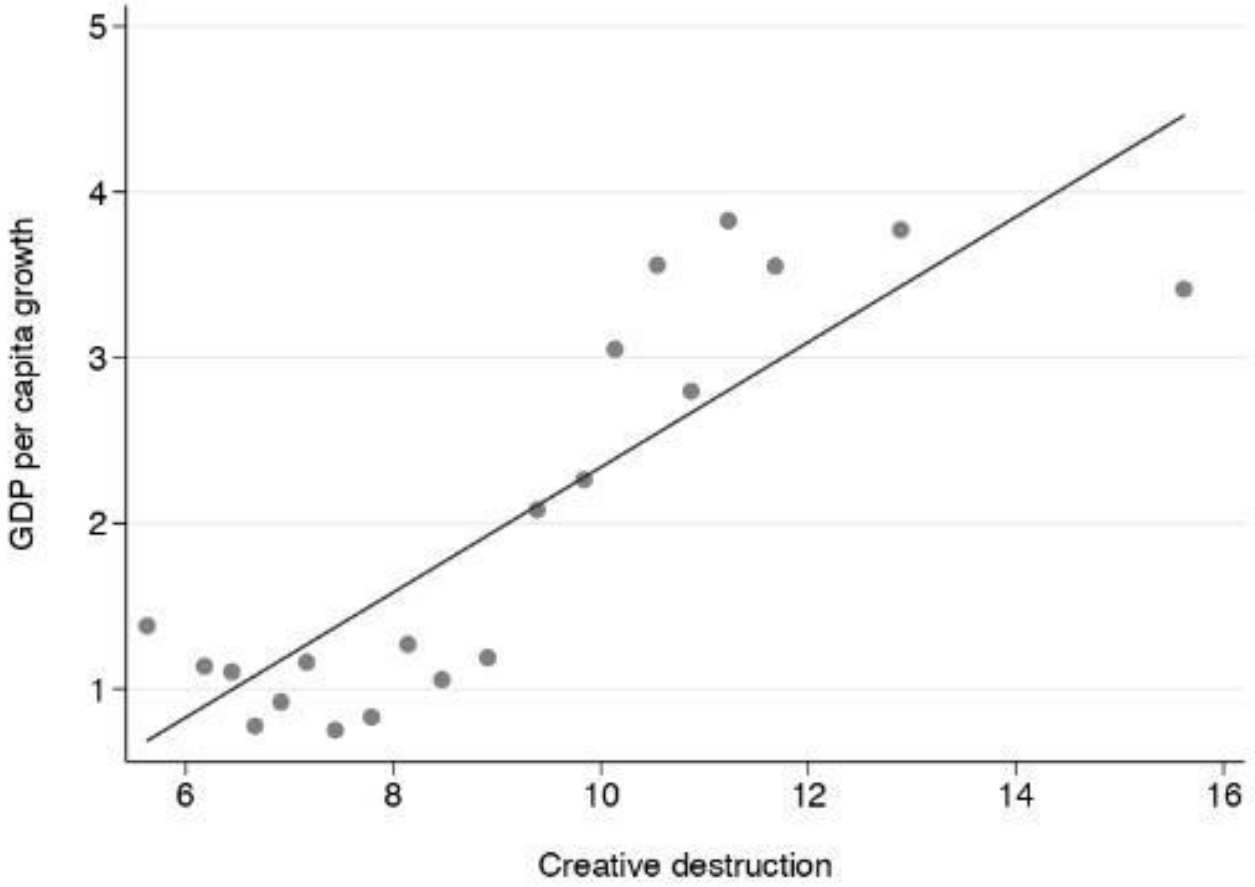
Two distinctive predictions

TWO DISTINCTIVE PREDICTIONS

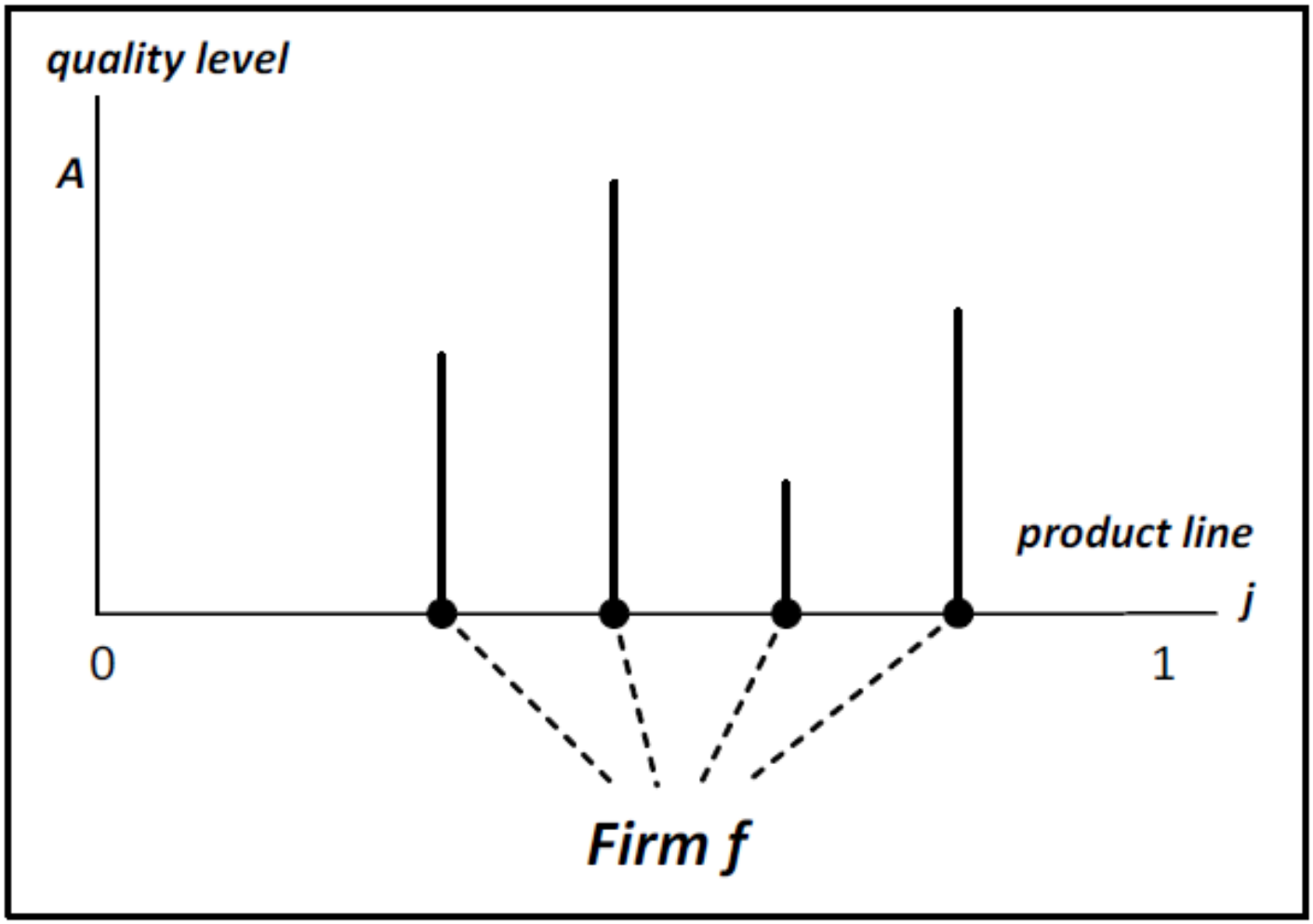
- Growth is positively correlated with firm turnover
- More intense competition enhances innovation in « frontier » firms but discourages it in « non-frontier » firms

Growth and turnover

- Firm and job turnover



Positive correlation between GDP per capita growth and the rate of creative destruction.
Source: Eurostat.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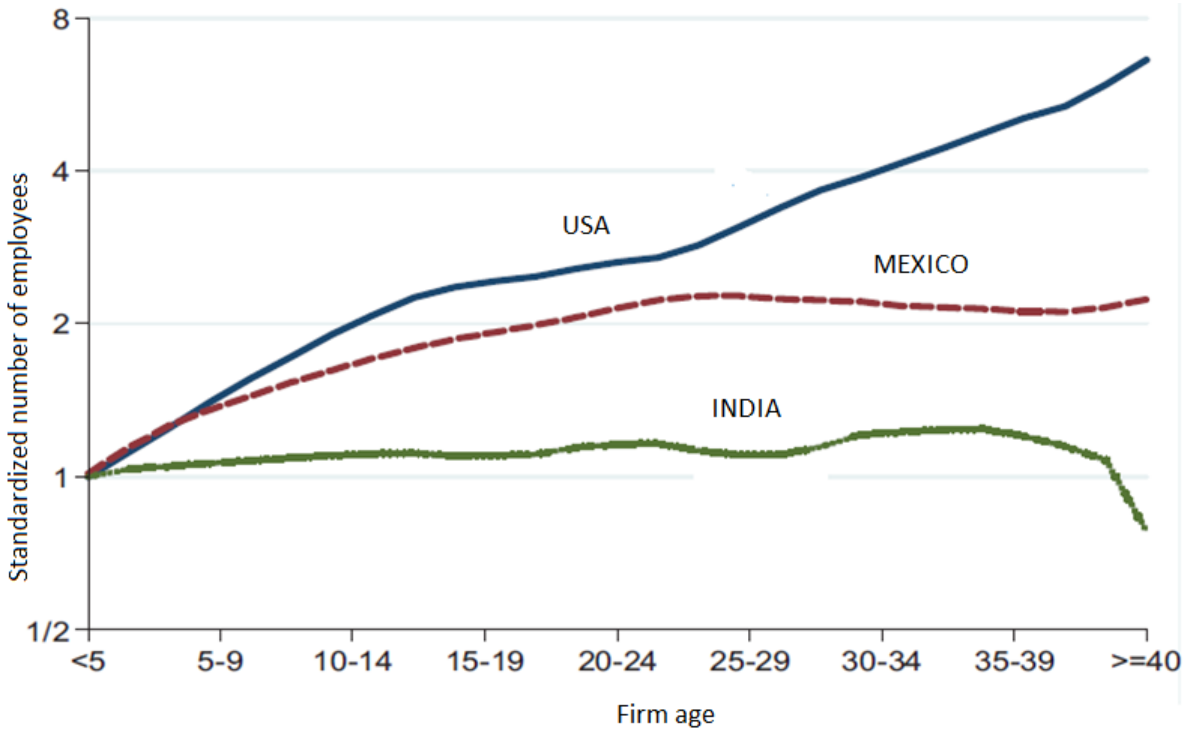
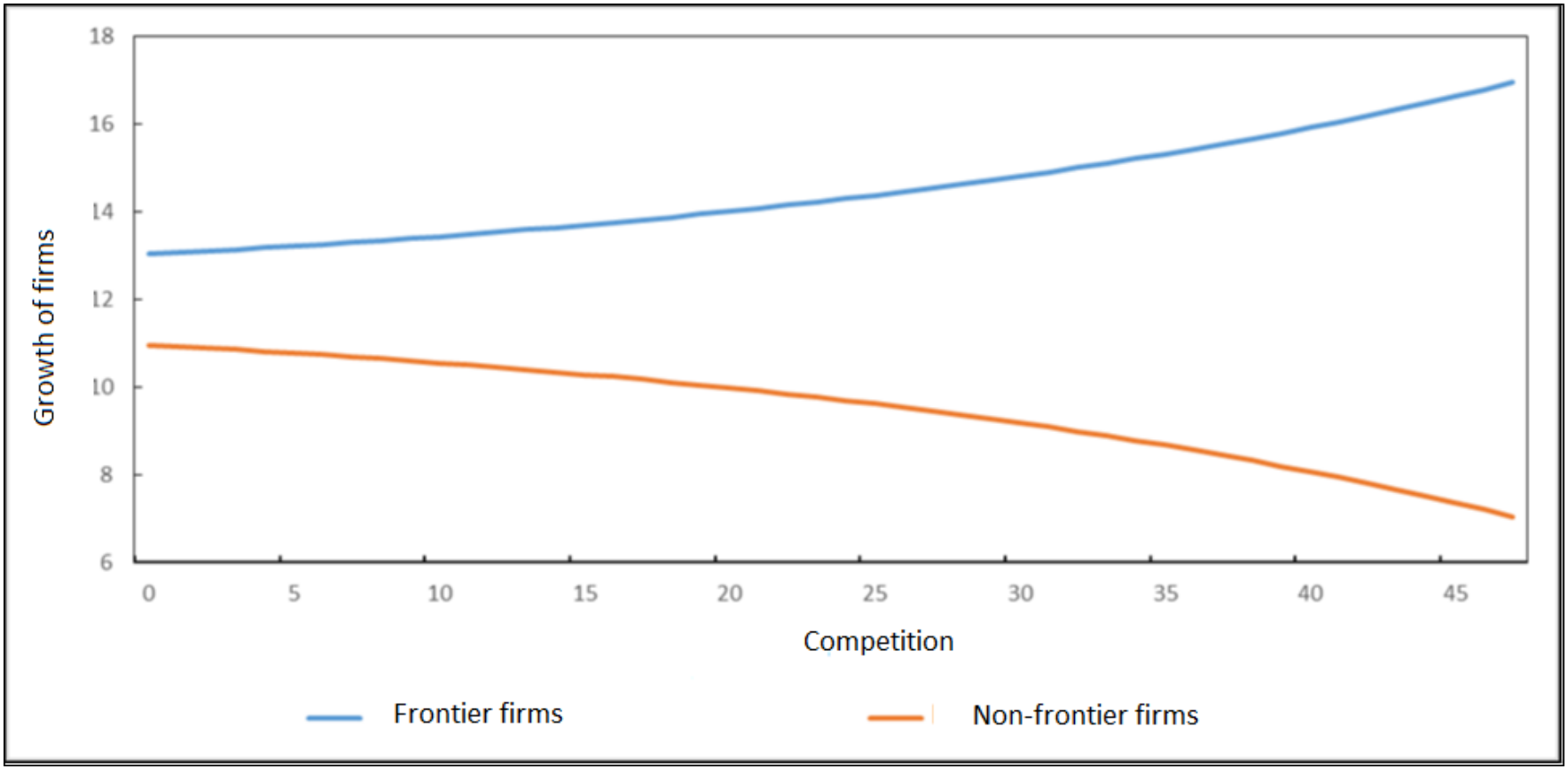
Link between the age and the size of firms



TWO DISTINCTIVE PREDICTIONS

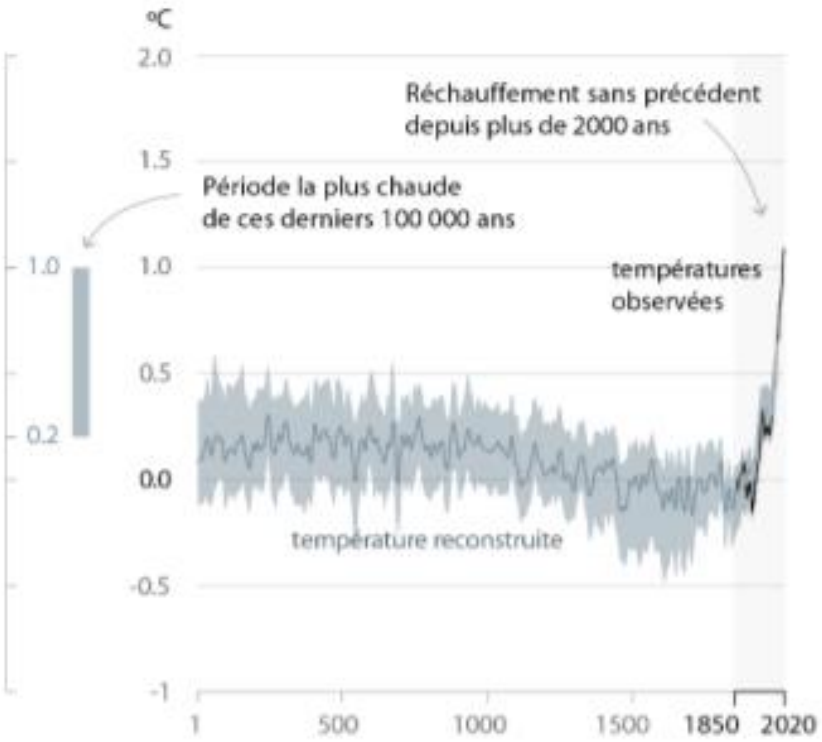
- Growth is positively correlated with firm turnover
- **More intense competition enhances innovation in « frontier » firms but discourages it in « non-frontier » firms**

Competition, growth and distance to frontier

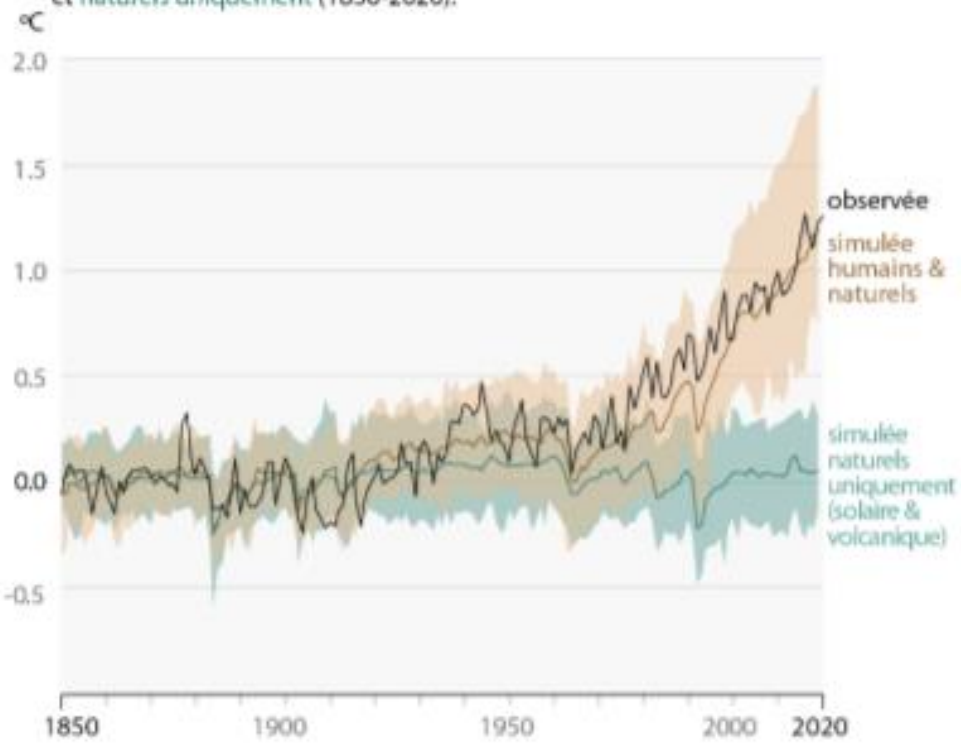


Innovation, growth and climate

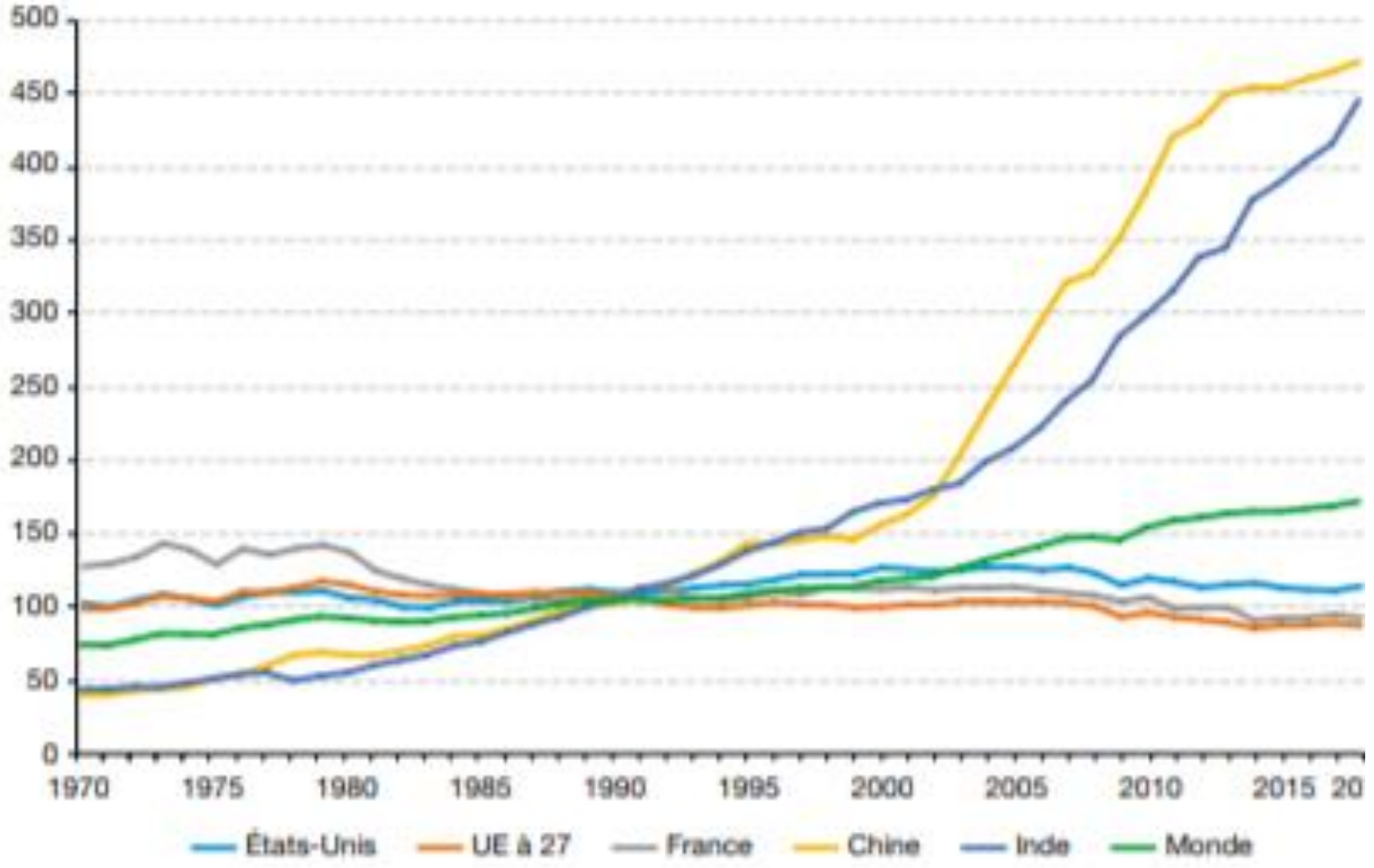
a) changement de la température de surface mondiale (moyenne décennale) reconstruite (1-2000) et observée (1850-2020)



b) changement de la température de surface mondiale (moyenne annuelle) observée et simulée utilisant les facteurs humains et naturels, et naturels uniquement (1850-2020).



Evolution of CO2 emissions worldwide between 1970 and 2018 – Base 100 index in 1990



Source : *EDGAR, 2019*

INTRODUCE INNOVATION IN THE CLIMATE DEBATE

- **Innovation versus de-growth?**
- **Implications of introducing endogenous and directed innovation for the climate debate?**

PATH-DEPENDENCE IN GREEN VERSUS DIRTY INNOVATION

DATA

- World Patent Statistical Database (PATSTAT) at European Patent Office (EPO) over period 1978-2005
  - All triadic patents filed in 80 patent offices in world
- Extracted all patents pertaining to "clean" and "dirty" technologies in the automotive industry (following OECD IPC definition)
- Tracked applicants and extracted all their past patents.

INTERNATIONAL PATENT CLASSES (IPC)

Description	IPC code	
Electric vehicles		
Electric propulsion with power supplied within the vehicle	B60L 11	
Electric devices on electrically-propelled vehicles for safety purposes; Monitoring operating variables, e.g. speed, deceleration, power consumption	B60L 3	
Methods, circuits, or devices for controlling the traction- motor speed of electrically-propelled vehicles	B60L 15	
Arrangement or mounting of electrical propulsion units	B60K 1	
Conjoint control of vehicle sub-units of different type or different function / including control of electric propulsion units, e.g. motors or generators / including control of energy storage means / for electrical energy, e.g. batteries or capacitors	B60W 10/08, 24, 26	
Hybrid vehicles		
Arrangement or mounting of plural diverse prime-movers for mutual or common propulsion, e.g. hybrid propulsion systems comprising electric motors and internal combustion engines	B60K 6	"Clean"
Control systems specially adapted for hybrid vehicles, i.e. vehicles having two or more prime movers of more than one type, e.g. electrical and internal combustion motors, all used for propulsion of the vehicle	B60W 20	
Regenerative braking		
Dynamic electric regenerative braking	B60L 7/1	
Braking by supplying regenerated power to the prime mover of vehicles comprising engine -driven generators	B60L 7/20	
Fuel cells		
Conjoint control of vehicle sub-units of different type or different function; including control of fuel cells	B60W 10/28	
Electric propulsion with power supplied within the vehicle - using power supplied from primary cells, secondary cells, or fuel cells	B60L 11/18	
Fuel cells; Manufacture thereof	H01M 8	
Combustion engines		"Dirty"
Combustion engines	F02 (excl. C/G/ K)	

ESTIMATION

Number of clean triadic patents by firm *i* in year *t*

Clean and dirty spillovers

$$PAT_{CLEAN,it} = \exp(\beta_{C,P} \ln FP_{it} + \beta_{C,1} \ln SPILL_{C,it} + \beta_{C,2} \ln SPILL_{D,it}$$

$$+ \beta_{C,3} \ln K_{C,it} + \beta_{C,4} \ln K_{D,it}$$

Lagged firm's own innovation stocks

$$+ \beta_{C,w} w_{it} + \ln \eta_{C,i} + T_{C,t}) + u_{C,it}$$

Other controls (GDP, GDP/capita, other policies)

Firm fixed effect

Time dummies

Random error

TABLE 3: MAIN RESULTS

	Clean	Dirty
Fuel Price	0.886**	-0.644***
ln(FP)	(0.362)	(0.143)
Clean Spillover	0.266***	-0.058
$SPILL_C$	(0.087)	(0.066)
Dirty Spillover	-0.160*	0.114
$SPILL_D$	(0.097)	(0.081)
Own Stock Clean	0.303***	0.016
K_C	(0.026)	(0.026)
Own Stock Dirty	0.139***	0.542***
K_D	(0.017)	(0.020)
#Observations	68,240	68,240
#Units (Firms and individuals)	3,412	3,412

Notes: Estimation by Conditional fixed effects (CFX), all regressions include GDP, GDP per capita & time dummies. SEs clustered by unit.

THUS

- Bad news is that path-dependence implies that under laissez-faire the economy may get stuck with dirty technologies
- Good news is that government can avoid disaster by redirecting innovation towards clean technologies and early action now can become self-sustaining later due

Further implications

Creative destruction helps!!

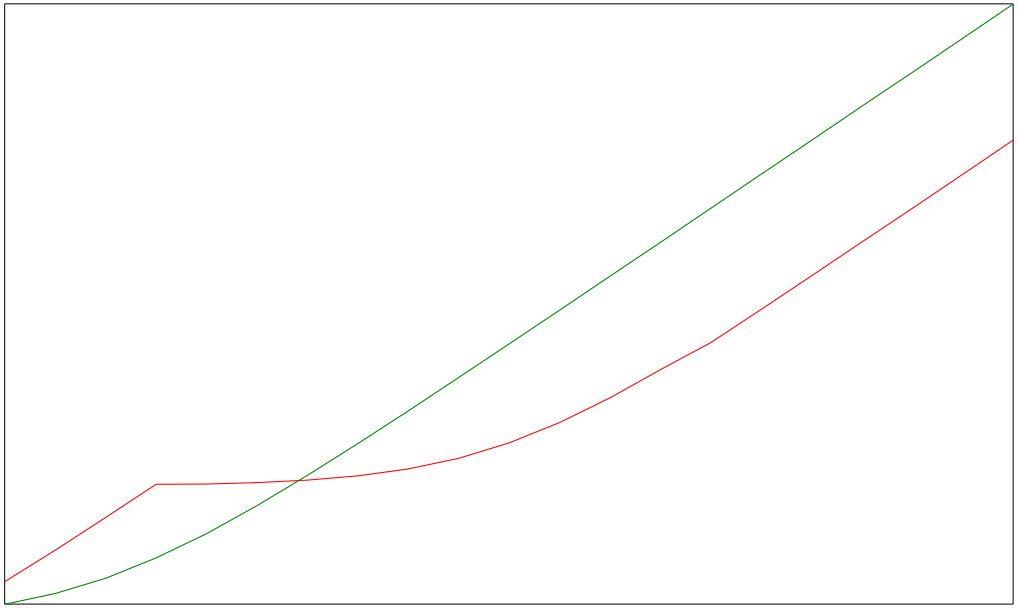
Act now

- Without intervention, innovation is directed towards dirty inputs
- Thus the gap between clean and dirty technology widens
- Hence cost of intervention (reduced growth as long as clean technologies catch up with dirty technologies) increases

Policy implications : act now

Discount rate	1%	1.5%
Lost consumption, delay of 10 years	5.99%	2.31%
Lost consumption, delay of 20 years	8.31%	2.36%

Policy implications : act now



Two instruments, not only carbon tax

- Two externalities:
  - Environmental externality
  - Knowledge externality (path-dependence)
- Thus need two instruments, not just carbon tax

Two instruments

Discount rate	1%	1.5%
Lost consumption	1.33%	1.55%

$\longrightarrow$ using one instrument instead of two, when discount rate of 1 percent, leads to a consumption loss of 1.33 percent...

$\longrightarrow$ ....or to a carbon tax 15 times higher during first five years and 12 times higher during following five years.

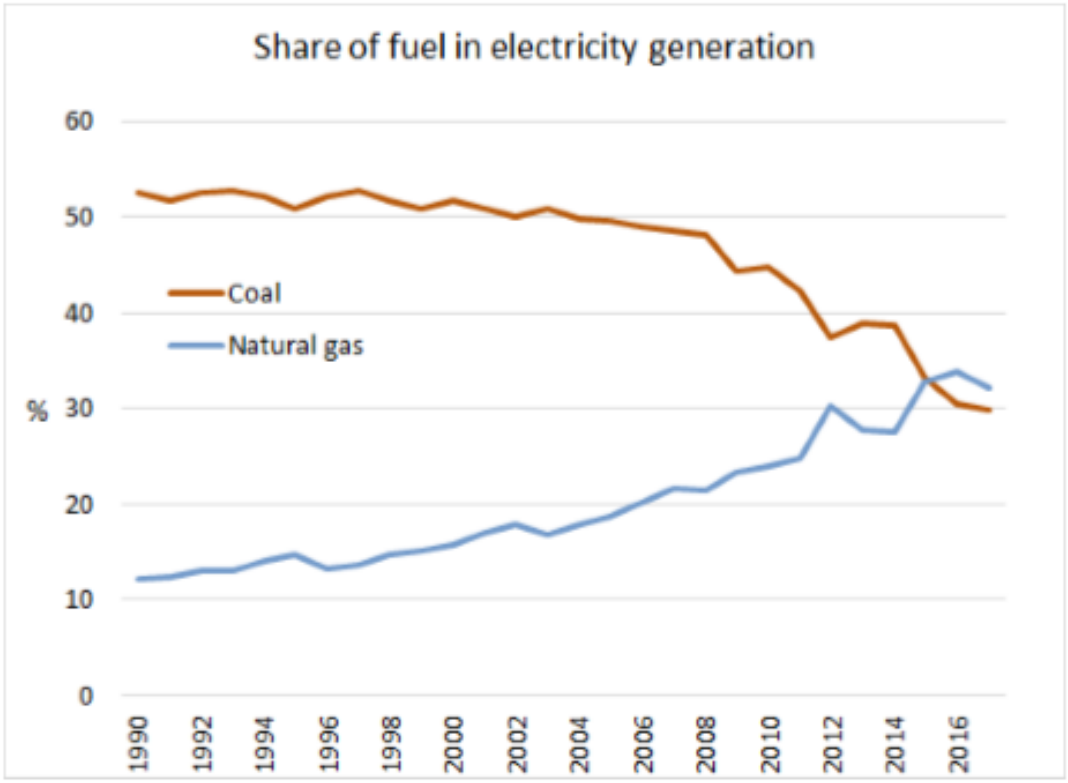
Reinforcing the case for green innovation subsidies

- Introduce an intermediate source of energy (e.g. shale gas)
- How should design the energy transition strategy?

Climate Change, Directed Innovation and Energy Transition: The Long-run Consequences of the Shale Gas Revolution

Daron Acemoglu (MIT), Philippe Aghion (Collège de France, LSE),
Lint Barrage (Brown) and David Hémous (University of Zurich)

Rise of gas


Share of fuel in electricity generation
60
50
40
30
20
10
0
%
Coal
Natural gas
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

- Analyze effects of an exogenous improvement in extraction technology for gas (shale gas boom) on aggregate pollution in short run and long run

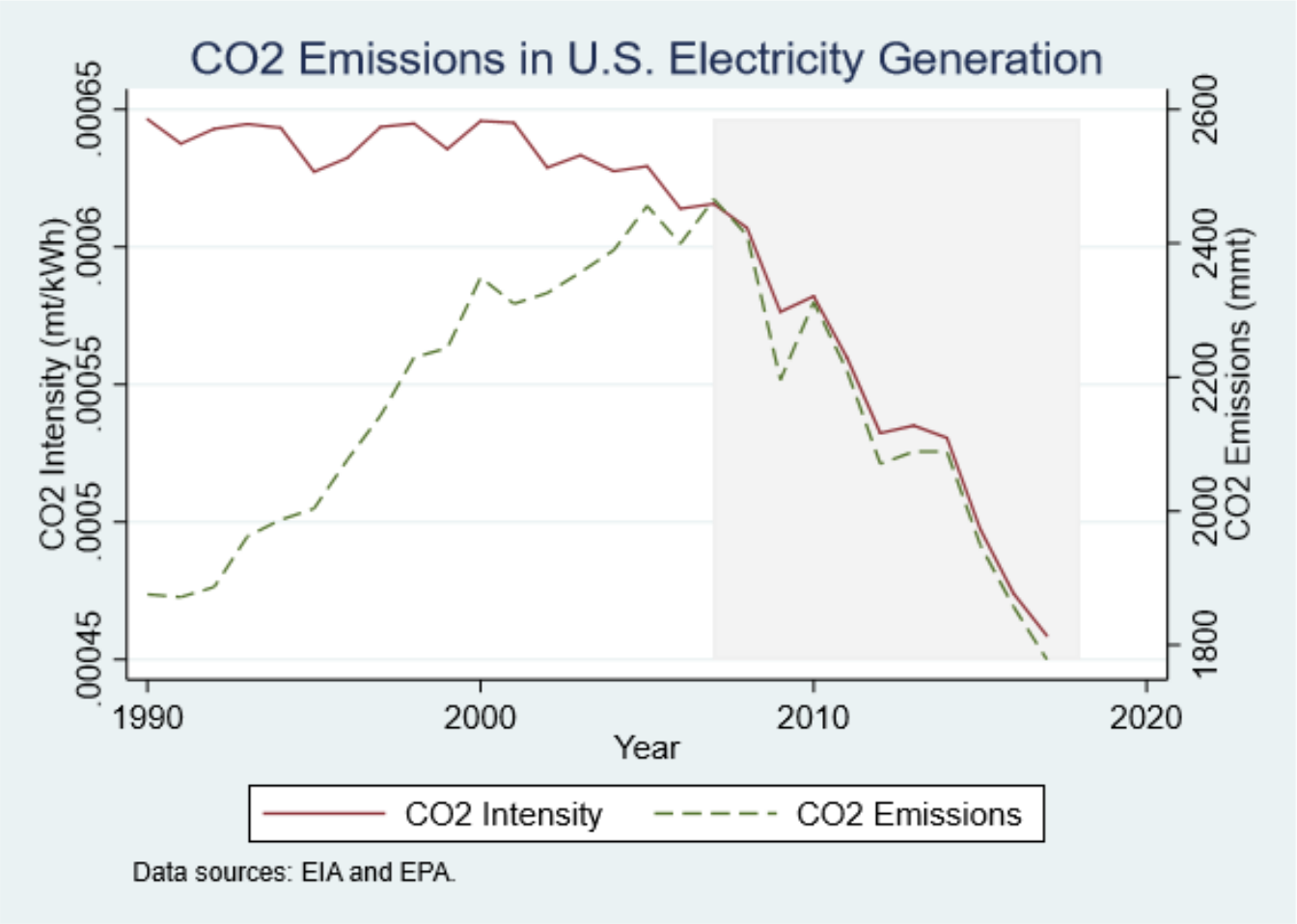
Short-Run Effects

- Absent innovation (short-run), there are two opposite effects of shale gas boom:
  - Substitution effect
  - Scale effect
- Substitution effect dominates if gas sufficiently cleaner than coal

Short-Run Impact Estimates

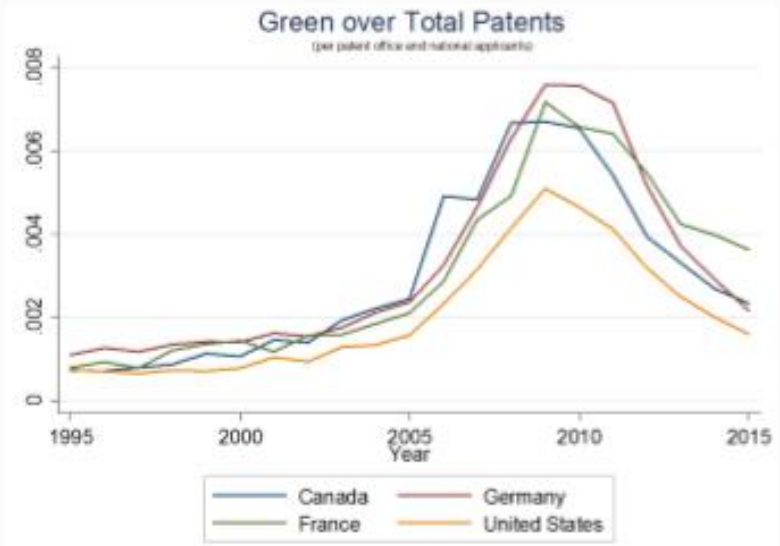
Total Effects of Improved Shale Extraction Technology B_{s0}			
	$\%\Delta$Emiss.	$\%\Delta$Energy	$\%\Delta CO_2$
	Intensity	Consumption	Emissions
Baseline Parameters			
$+10\%$ Increase in B_{s0}	-16.7%	+5.5%	-12.1%
$+50\%$ Increase in B_{s0}	-21.0%	+9.6%	-13.4%

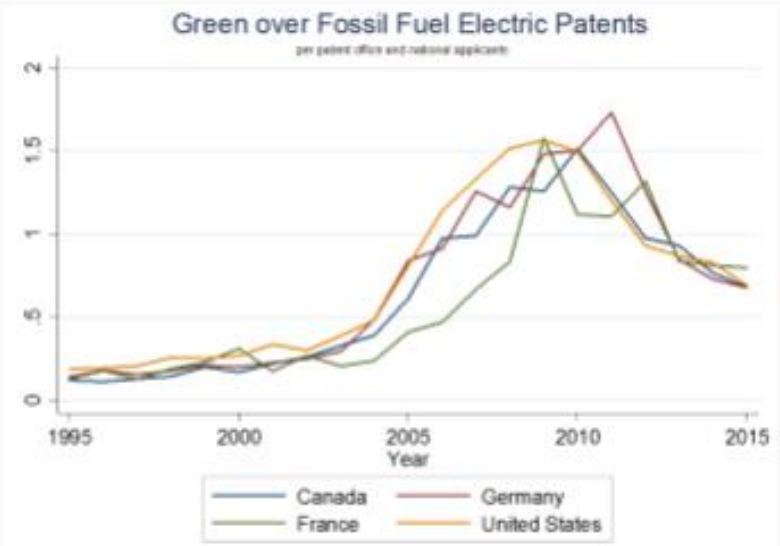
Emissions and Emissions Intensity



Long-Run Effect

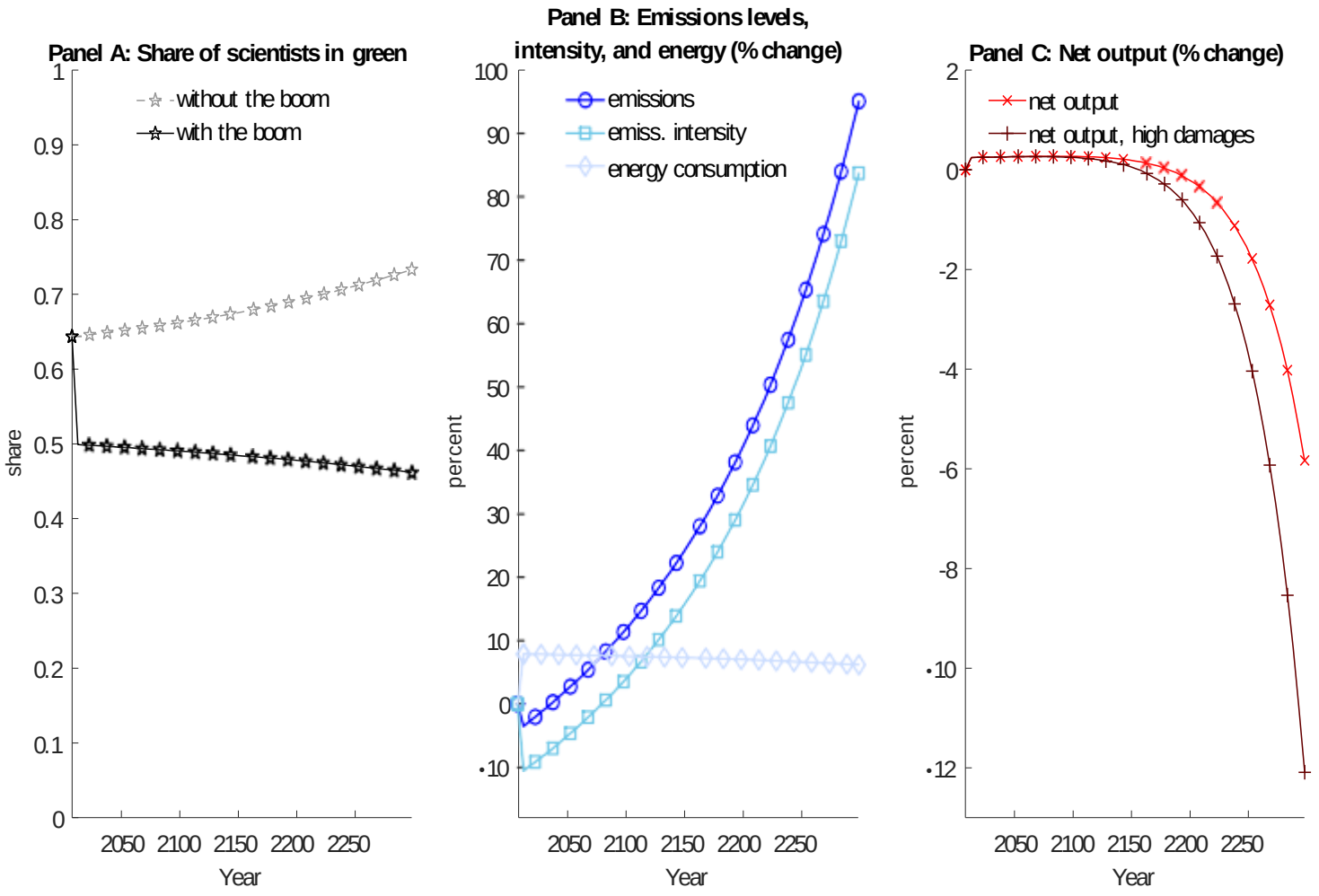
- Assume endogenous innovation on power plant technologies using the different sources of energy
- Shale gas boom directs innovation away from both, coal and clean production technologies into gas production technologies
- In the long-run, it may move the economy from a path with declining CO2 emissions to a path with increasing CO2 emissions


Green over Total Patents
0
.002
.004
.006
.008
1995
2000
2005
2010
2015
Year
Canada
Germany
France
United States

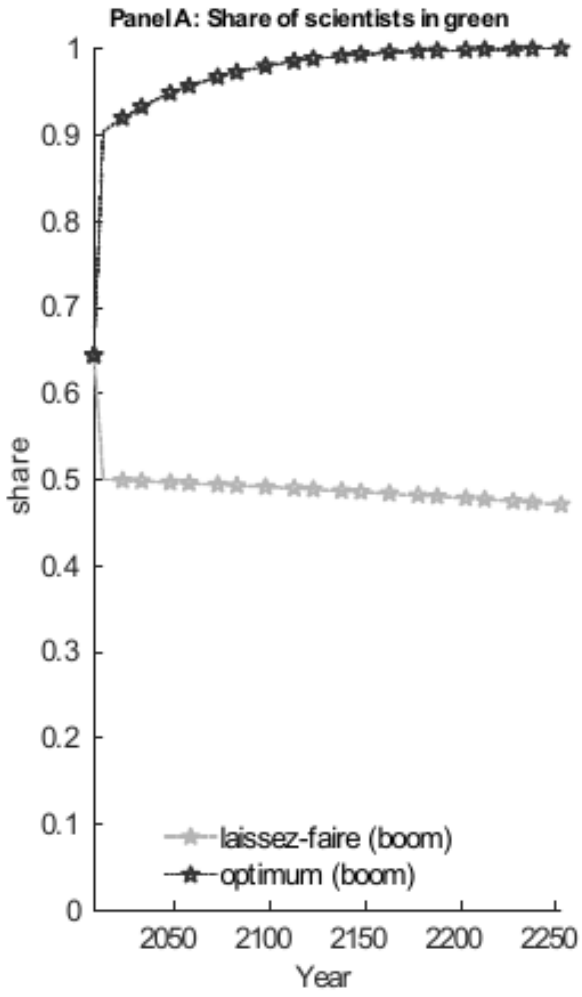

Green over Fossil Fuel Electric Patents
0
.5
1
1.5
2
1995
2000
2005
2010
2015
Year
Canada
Germany
France
United States

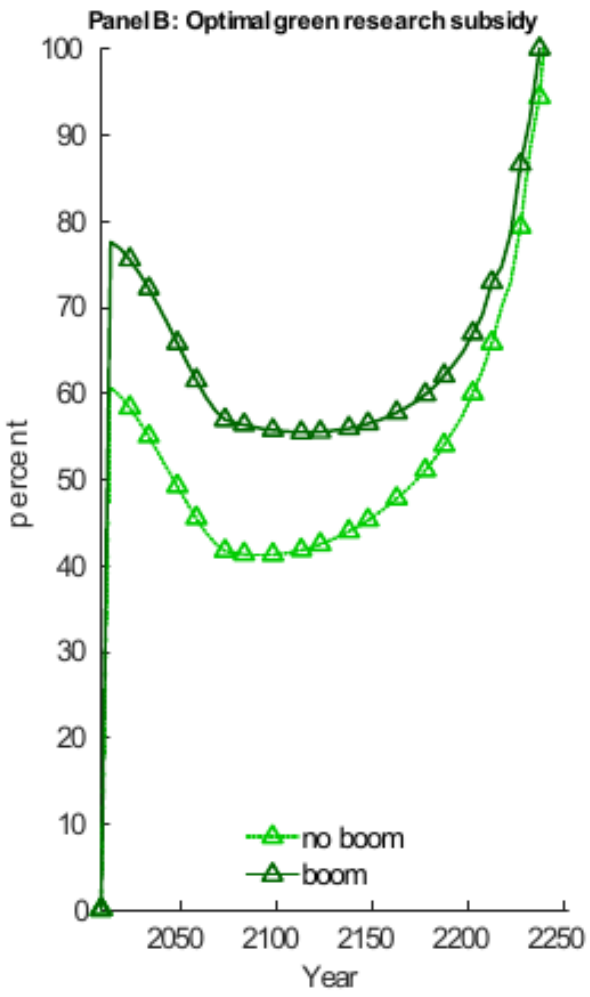
Effects of shale gas boom

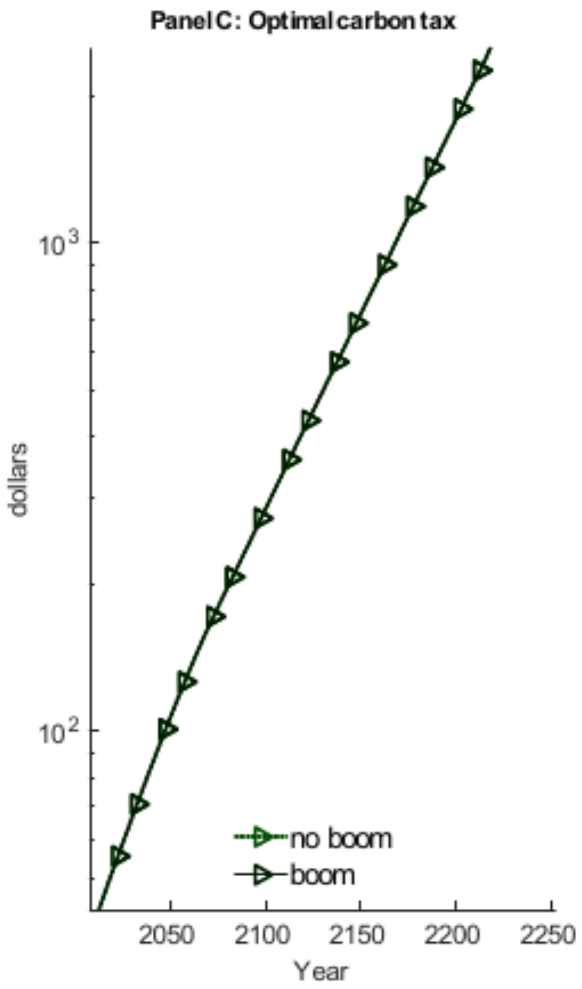
Unmanaged boom



Optimal Policy: effect of the boom







THE ROLE OF CIVIL SOCIETY

- **Competition and Social Values**
  - Above analysis suggests a role for the State in directing firms' production and innovation
  - Question: Is there also a role for "Civil Society"?

Environmental Values and Technological Choices: Is Market Competition Clean or Dirty?

Philippe Aghion [1] Roland Bénabou [2]
Ralf Martin [3] Alexandra Roulet [4]

[1]College de France [2]Princeton University

[3]Imperial College London [4]INSEAD

Positive effect of consumers valuation of the environment

- Firms innovate green to cater to their consumers' demand for green

VARIABLES	(1)	(2)	(3)	(4)
	Log (1+#clean)- Log (1+#dirty)			
Values	0.170***	0.229***	0.233***	0.594***
	(0.0397)	(0.0500)	(0.0524)	(0.144)
Competition	0.189***	0.161***	0.325**	-0.0223
	(0.0614)	(0.0605)	(0.139)	(0.0305)
ValuesXCompetition	0.109***	0.0703***	0.0875***	0.0620**
	(0.0370)	(0.0234)	(0.0231)	(0.0243)
Log fuel price	0.766***	0.601**	0.151	0.856
	(0.235)	(0.244)	(0.236)	(0.663)
Competition measure	OECD	OECD	World Bank	Lerner
Values measure	Higher tax	Index	Higher tax	Higher tax
Observations	17,124	17,124	17,124	2,706
R-squared	0.121	0.122	0.121	0.199
Number of xbvdid	8,562	8,562	8,562	1,854

Two opposite effects of competition

- **More competition:**
  - **Scale effect**: it increases output, thereby increasing emissions (« Chinese » effect)
  - **Innovation effect**: if consumers value the environment, then more competition induces more green innovation, thereby reducing emissions

VARIABLES	(1)	(2)	(3)	(4)
	Log (1+#clean)- Log (1+#dirty)			
Values	0.170***	0.229***	0.233***	0.594***
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Conclusion

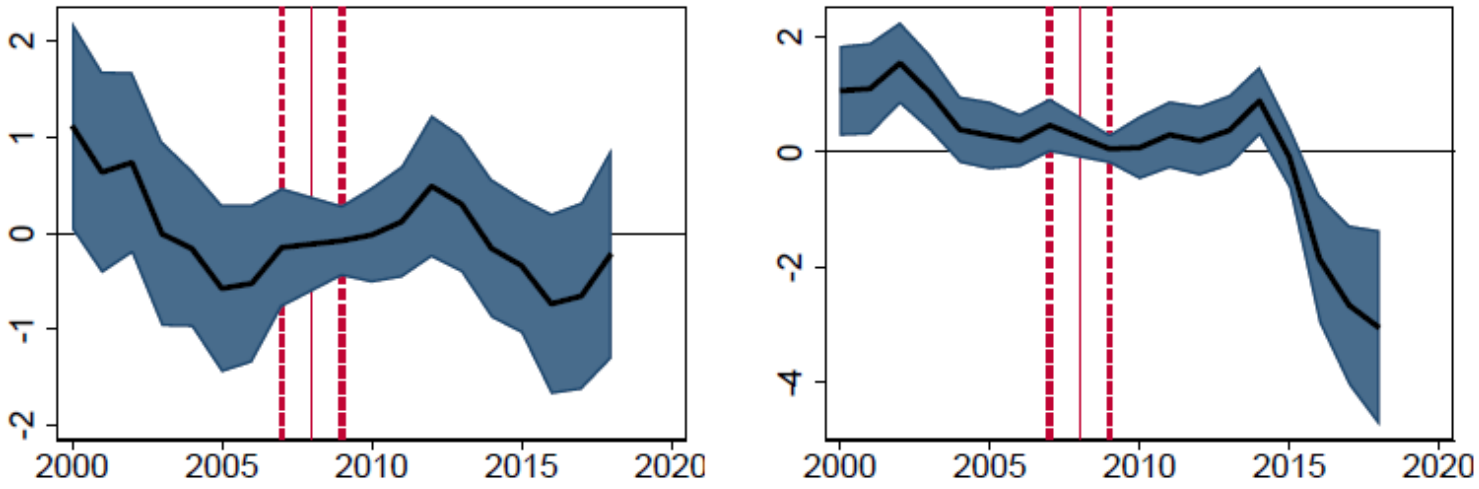
- Innovation-based climate models suggest that laissez-faire leads to disaster due to path-dependence in the direction of innovation
- One must act now and multiple instruments must be used, not just the carbon tax
- Triangle between firms, the State, and Civil Society

Conclusion

- **The role for green industrial policy (Aghion, Hemous, Liu)**
- We consider the green / energy transition along the value chain in the presence of Pigovian taxation.
- Complementarities across sectors can lead to multiple equilibria where either clean technologies are adopted along the value chain or where they are not adopted.
- This speaks to the role of industrial policy to coordinate the clean transition.
- With a pigovian tax alone, to remove multiplicity then one would need too large of a tax!

Conclusion

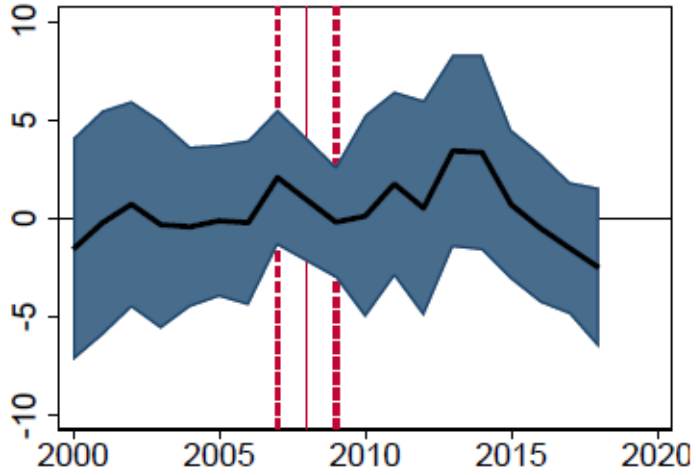
- **The role of finance (Aghion, Bergeaud, De Ridder, Van Reenen)**
- Look at effect of exposure to German banking crisis (2009) on green innovation
- Fraction of firm's bank relationships that involves Commerzbank
- Commerzbank cut lending after losses to international trading portfolio



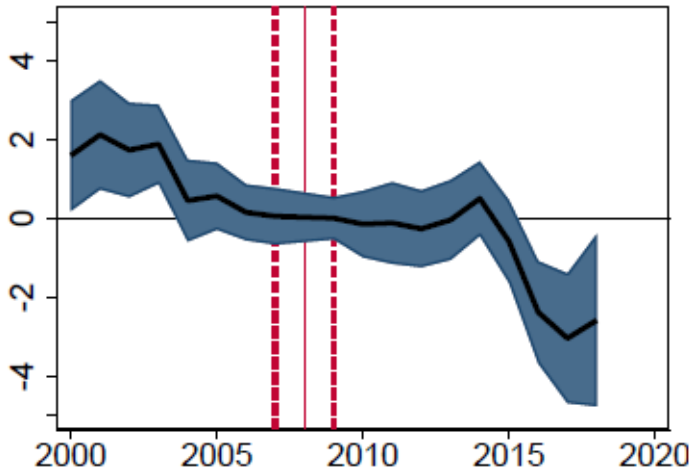
(a) Overall Patents

(b) Green Patents

The figure plots the effect of exposure to Commerzbank on patenting in the year on the horizontal axis. Estimates from PPML. Confidence bounds are at the 95% level using firm-clustered standard errors.



(e) Old Firms



(f) Young Firms

The figure plots the effect of exposure to Commerzbank on patenting in the year on the horizontal axis. Estimates from PPML. Confidence bounds are at the 95% level using firm-clustered standard errors.

Conclusion

- **Rethink macro policy**
  - Raising interest rates too much will slow down the transition to a low carbon economy
  - Arbitrage between the current public debt and the environmental debt

Conclusion

- **Do not disregard the amelioration margin on top of the mitigation and adaptation margins**
- Plan A and Plan B type innovations