Introducing innovation into the climate debate

Philippe Aghion

CREATIVE DESTRUCTION…

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

Peter Howitt

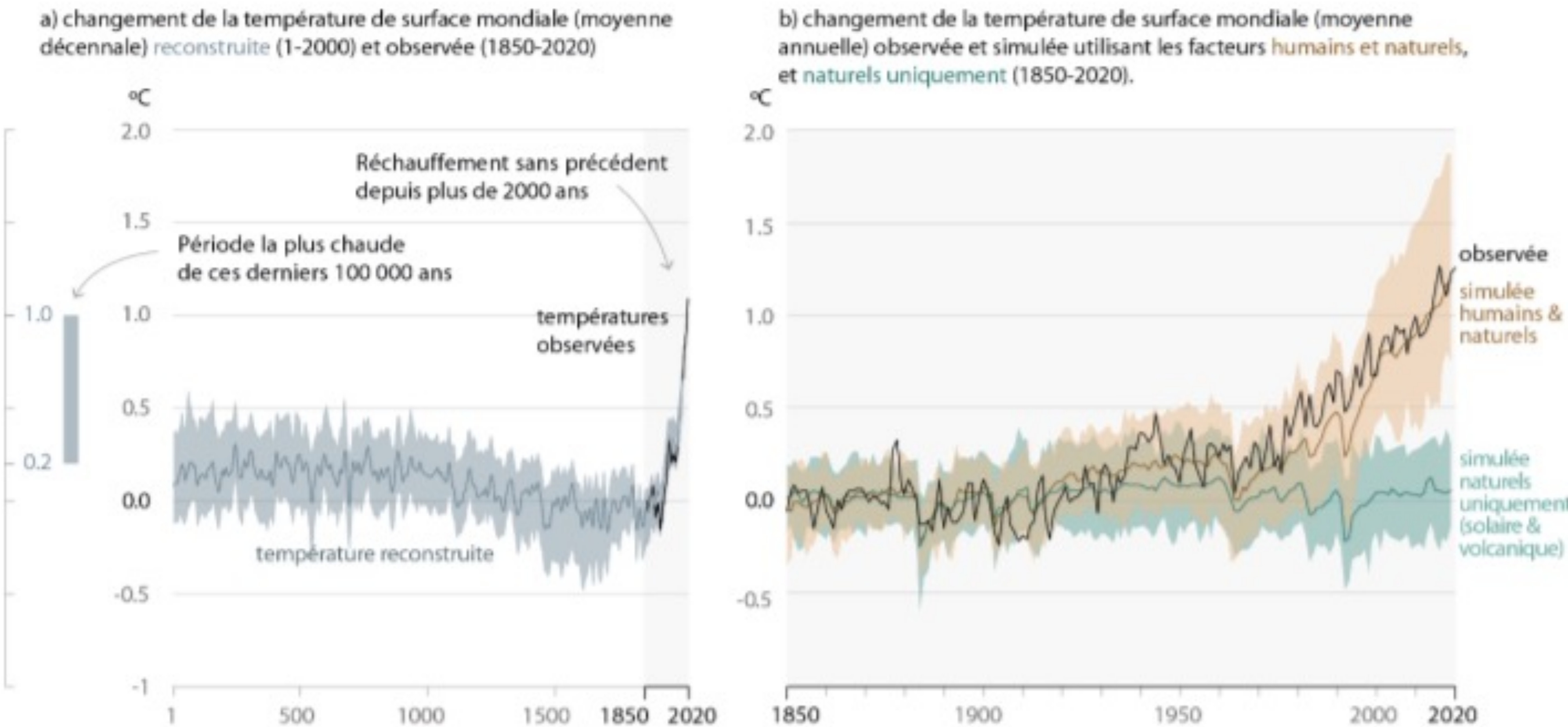
BASIC “SCHUMPETERIAN GROWTH” PARADIGM

- 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

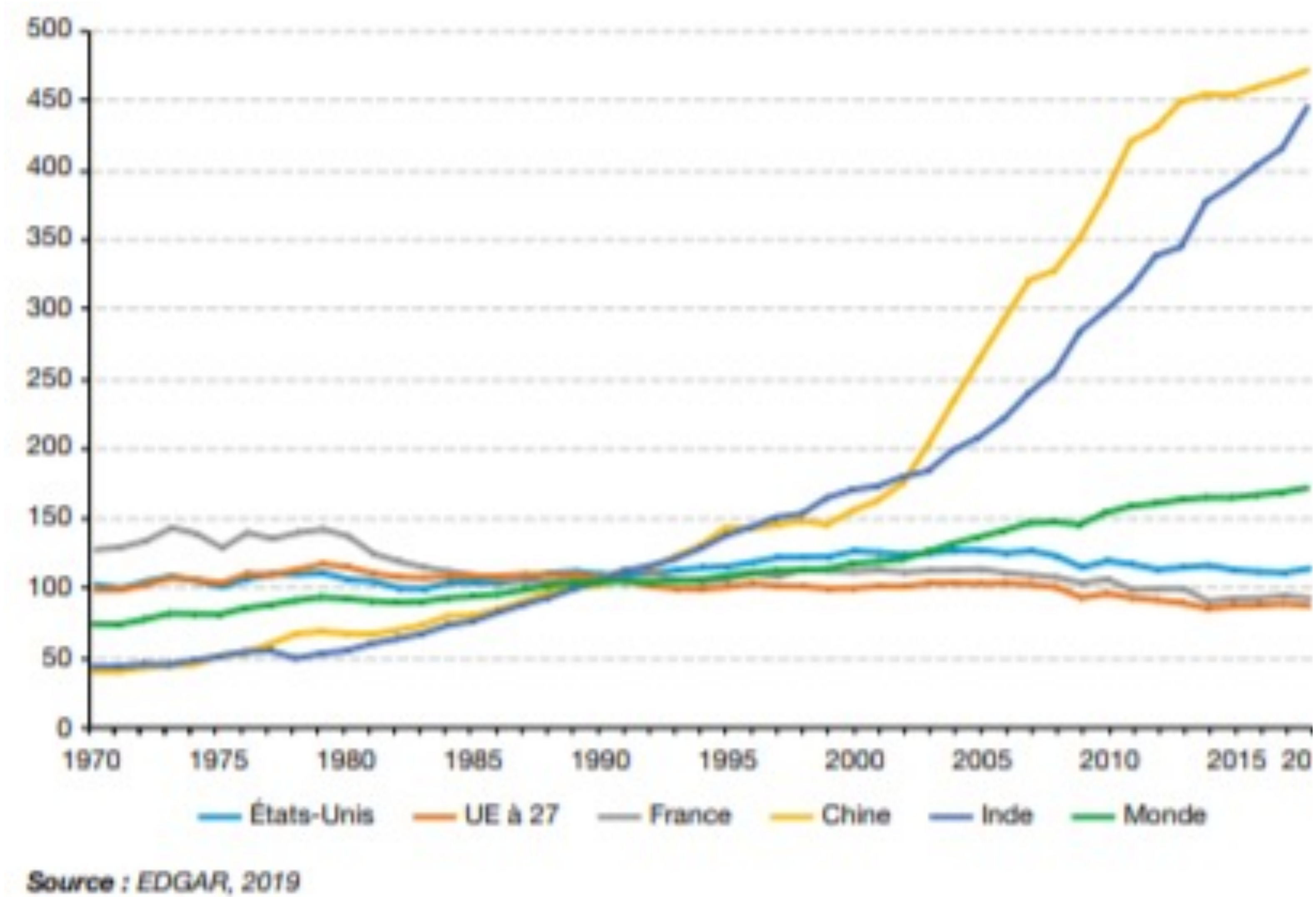
At the heart of the paradigm

- 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
- Schumpeter was pessimistic, we are « Gramscian » optimists


a) changement de la température de surface mondiale (moyenne décennale) reconstruite (1-2000) et observée (1850-2020)
°C
2.0
1.5
1.0
0.5
0.0
-0.5
-1
1.0
0.2
Réchauffement sans précédent depuis plus de 2000 ans
Période la plus chaude de ces derniers 100 000 ans
températures observées
température reconstruite
1
500
1000
1500
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).
°C
2.0
1.5
1.0
0.5
0.0
-0.5
observée
simulée humains & naturels
simulée naturels uniquement (solaire & volcanique)
1850
1900
1950
2000
2020

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



INTRODUCE INNOVATION IN THE CLIMATE DEBATE

- **Climate change Policies**
  - Main climate change models (e.g. Nordhaus, Stern) assume exogenous technology
  - Then the debate revolves around discount rate considerations
- **Implications from introducing endogenous and directed innovation?**

INTRODUCE INNOVATION IN THE CLIMATE DEBATE

- **Path-Dependence in Green versus Dirty Innovation**
- **Government can avoid disaster by redirecting innovation towards green technologies**
- **Act now**
- **Use several instruments, not just carbon tax**

  - **Aghion, Dechezlepretre, Hemous, Martin, Van Reenen (2016)**
  - **Acemoglu, Aghion, Bursztyn, Hemous (2012)**

PATH-DEPENDENCE IN GREEN VERSUS DIRTY INNOVATION

DATA

- World Patent Statistical Database (PATSTAT) at European Patent Office (EPO)
  - All patents filed in 80 patent offices in world (focus from 1965, but goes further back for some countries)
- Extracted all patents pertaining to "clean" and "dirty" technologies in the automotive industry (Table 1 over follows OECD IPC definition)
- Tracked applicants and extracted all their patents. Created unique HAN firm identifier
  - 4.5m patents filed 1965-2005

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
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	
Combustion engines	F02 (excl. C/G/ K)

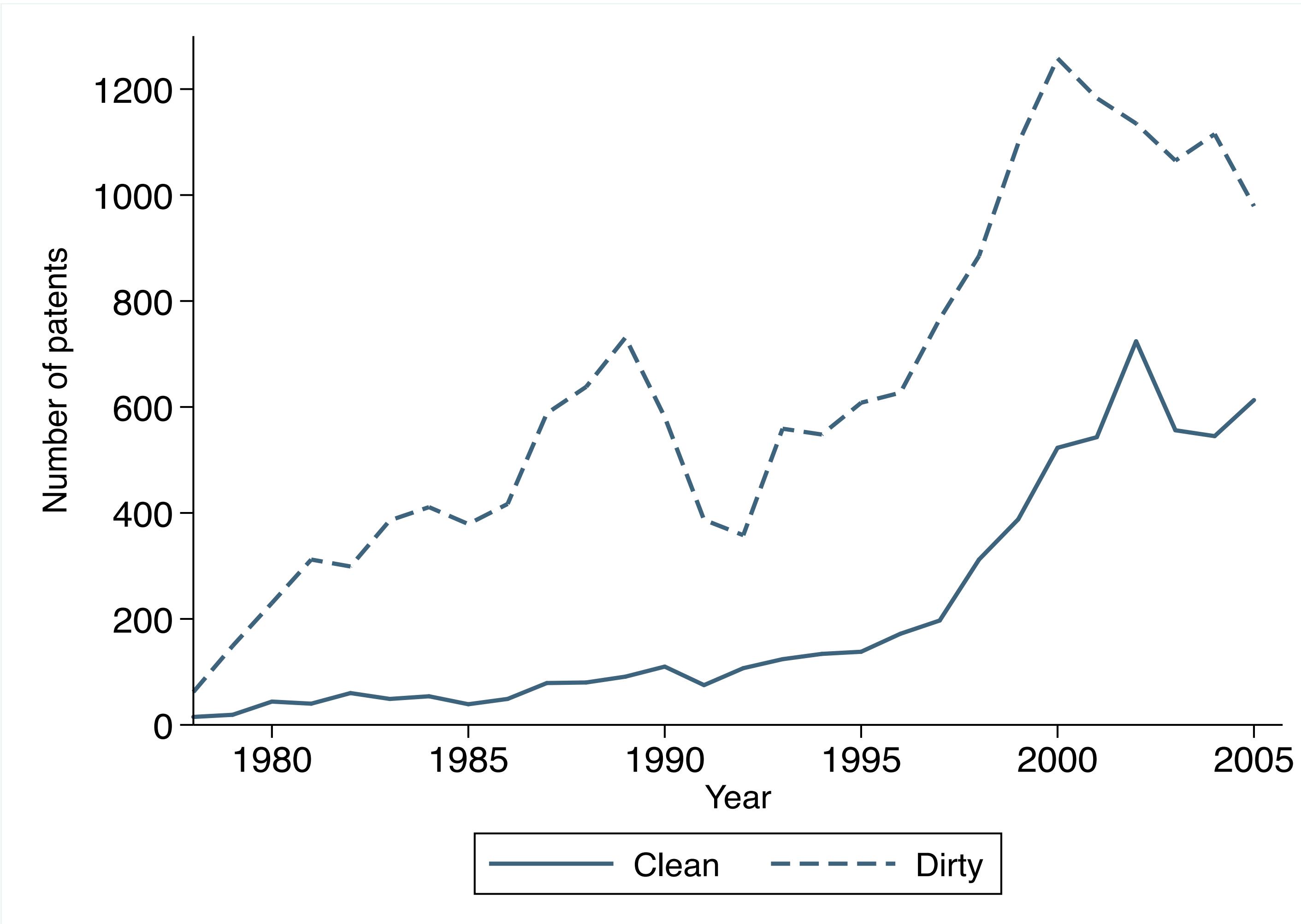
"Clean"

"Dirty"

DATA

- Since patent values very heterogeneous (Pakes, 1983) main outcome is “triadic” patents filed at all 3 main patent offices: USPTO, EPO & JPO
  - Screens out low value patents
- Over 1978-2005
  - 18,652 patents in “dirty” technologies (related to regular internal combustion engine)
  - 6,419 patents in “clean” technologies (electric vehicles, hybrid vehicles, fuel cells,..)
  - 3,423 distinct patent holders (2,427 firms & 996 individuals)

AGGREGATE TRIADIC CLEAN AND DIRTY PATENTS PER YEAR



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

POLICY VARIABLES: FUEL PRICES & TAXES

- Fuel prices vary over countries and time (mainly because of different tax regimes)
- Firms are likely to be affected differentially by fuel prices as (expected) market shares different across countries
  - We would like to weight country prices by firm's expected future market shares in different countries
  - Use information on where patents filed (use in pre-sample period & keep these weights fixed)
  - Compare with firm sales by country

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.

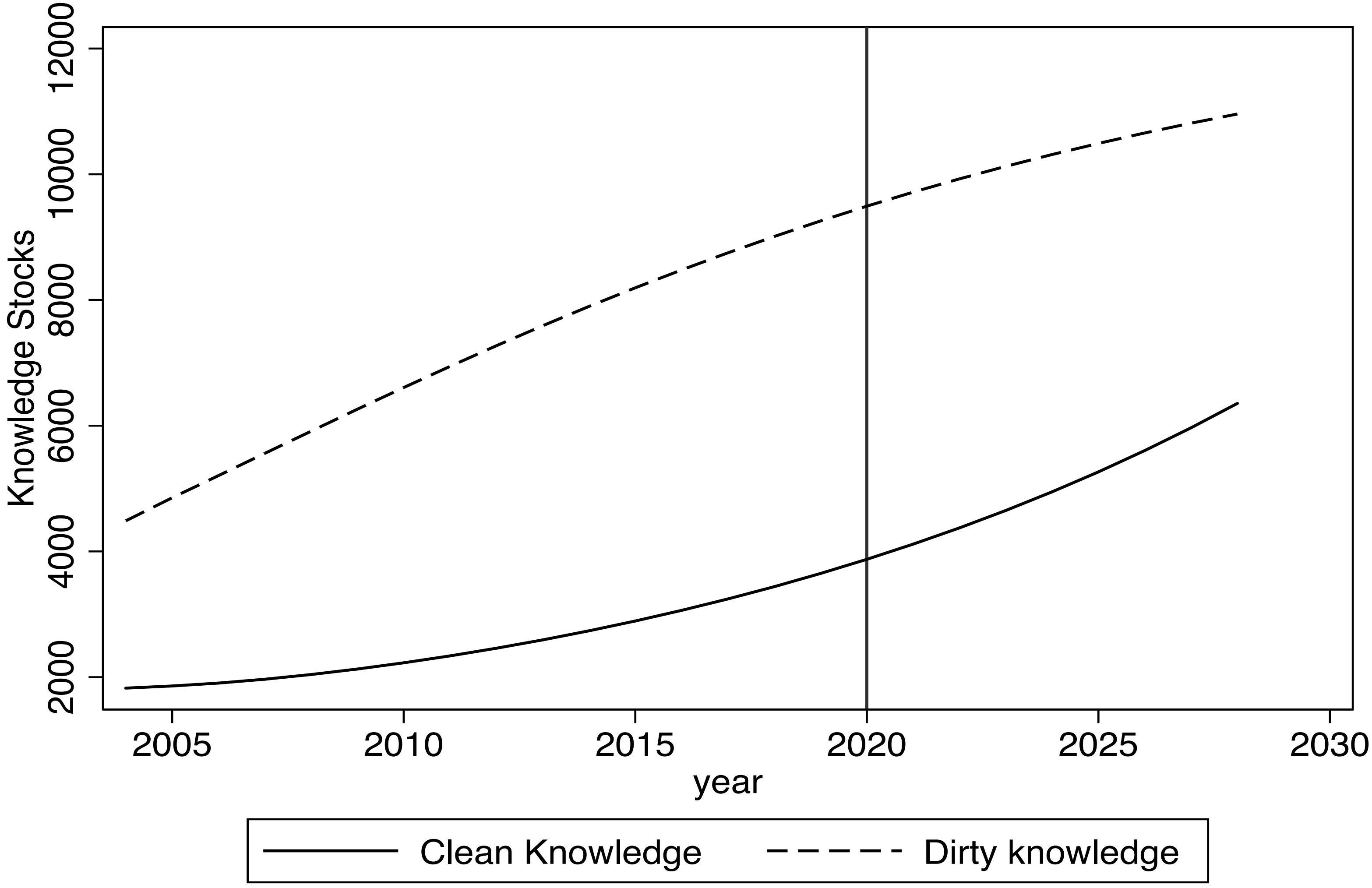
THUS

- Bad news is that path-dependence implies that under laissez-faire the economy maty 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

SIMULATIONS

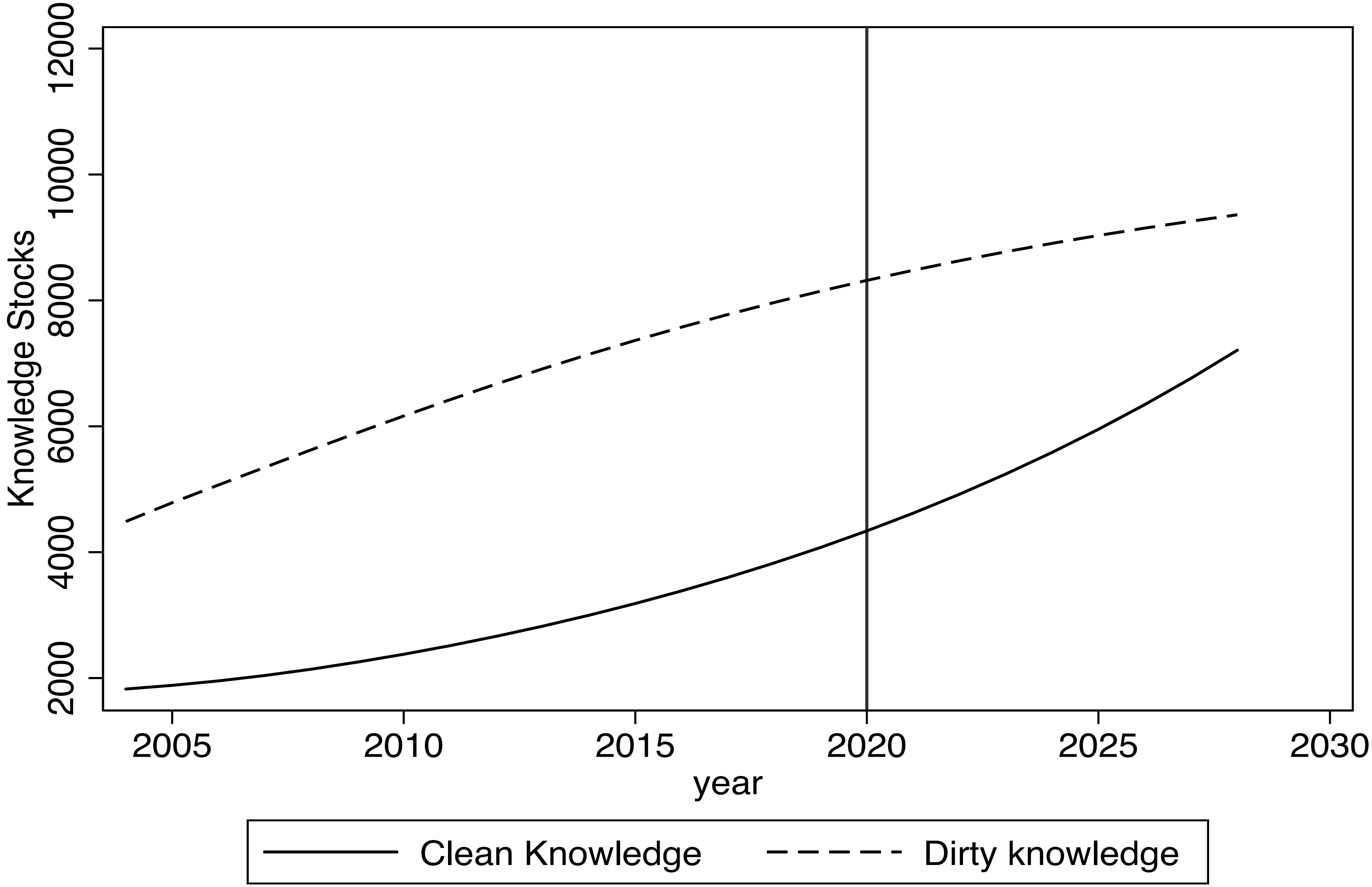
- Take estimated model & aggregate to global level taking dynamics into account (Spillovers & lagged dependent variables)
- Simulate the effect of changes in fuel tax compared to baseline case (where we fix prices & GDP as “today”, 2005)
- At what point (if ever) does the stock of clean innovation exceed stock of dirty innovation
- Just illustrative scenarios – sense of difficulty & importance of path dependence

FIGURE 5A: BASELINE: NO FUEL PRICE INCREASE



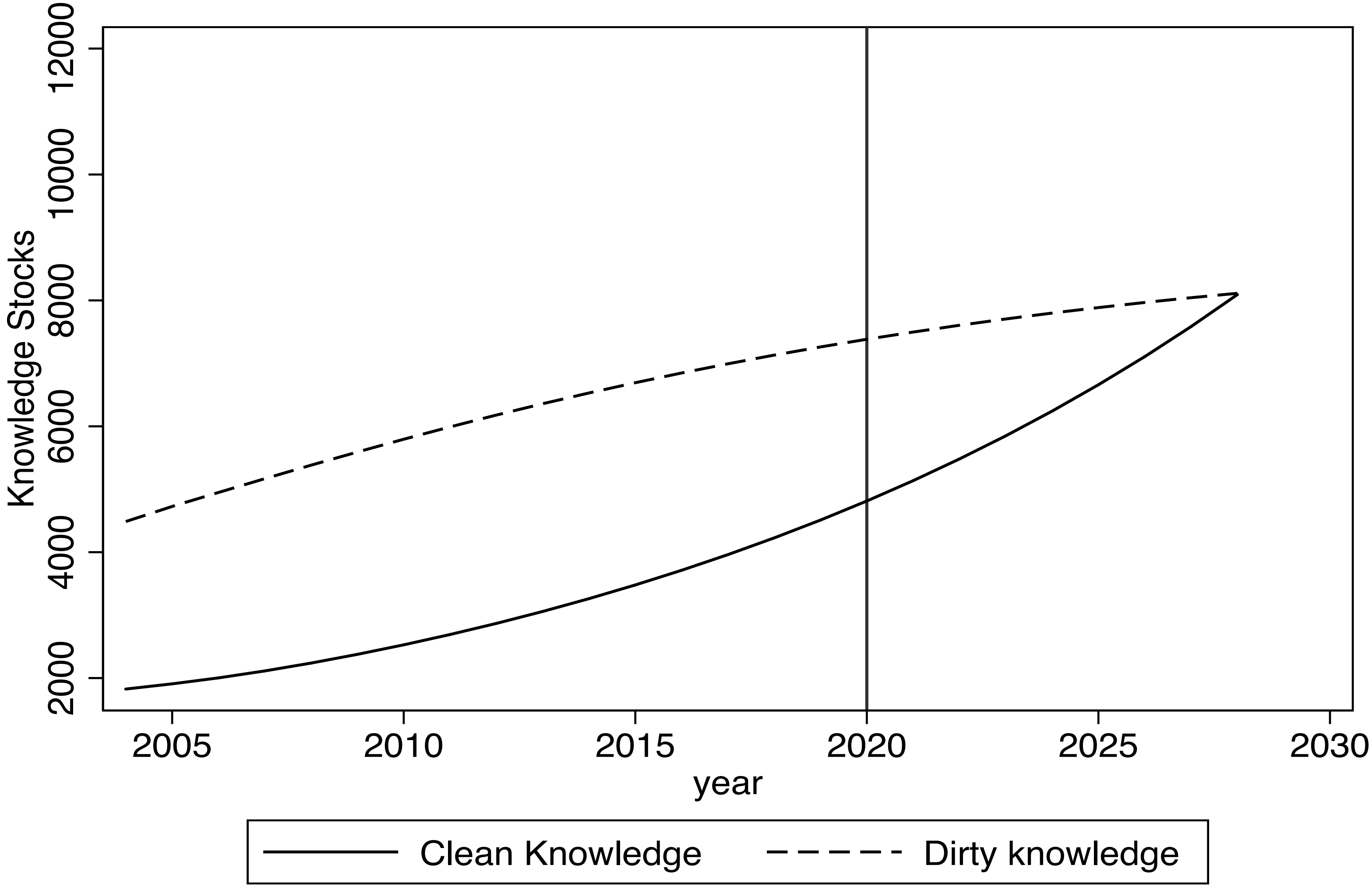
Price increase of 0%

FIGURE 5B: BASELINE: 10% INCREASE IN FUEL PRICE



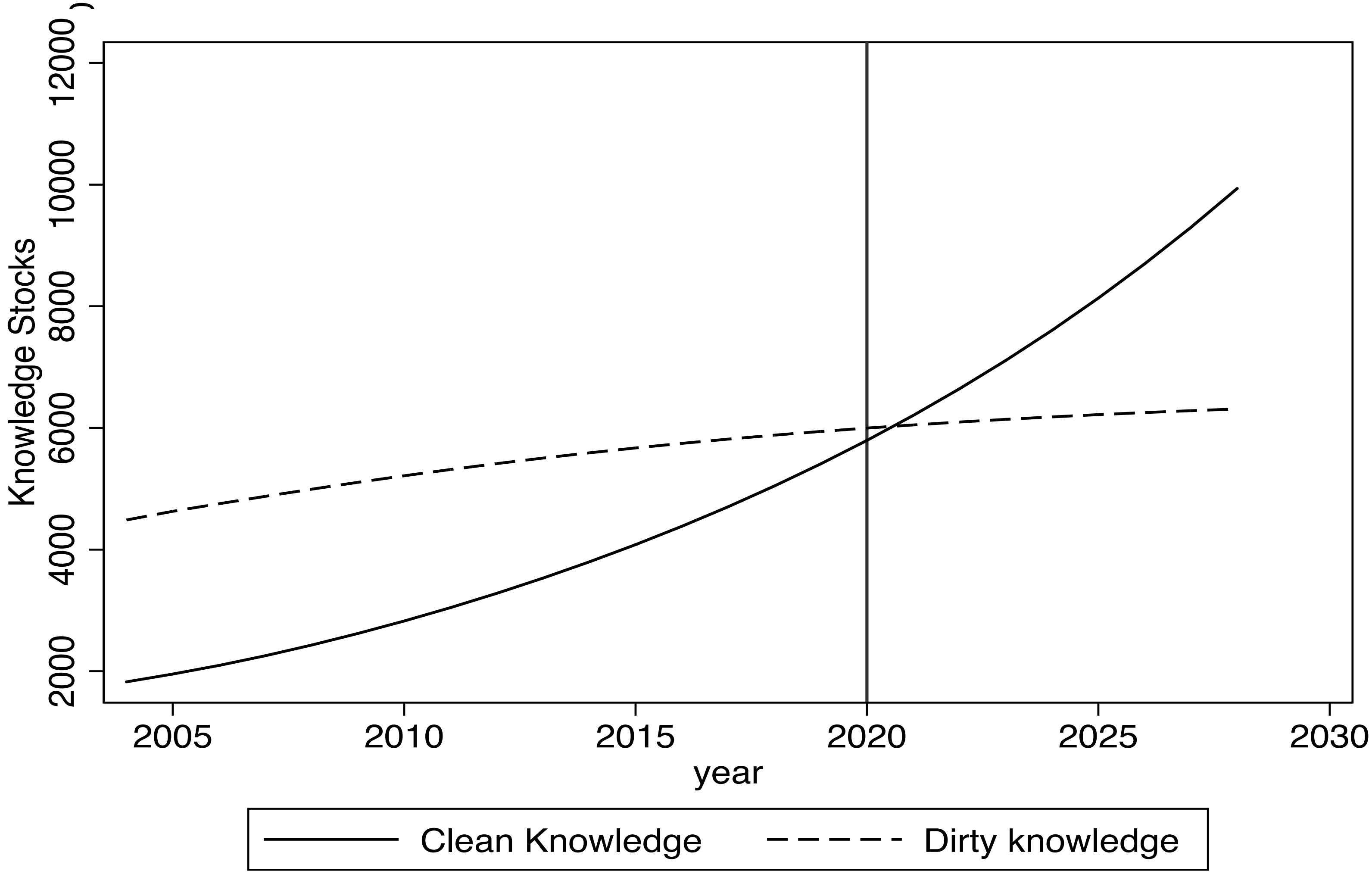
Price increase of 10%

FIGURE 5B: BASELINE: 20% INCREASE IN FUEL PRICE



Price increase of 20%

FIGURE 5D: BASELINE: 40% INCREASE IN FUEL PRICE



Price increase of 40%

Further implications

Creative destruction helps!!

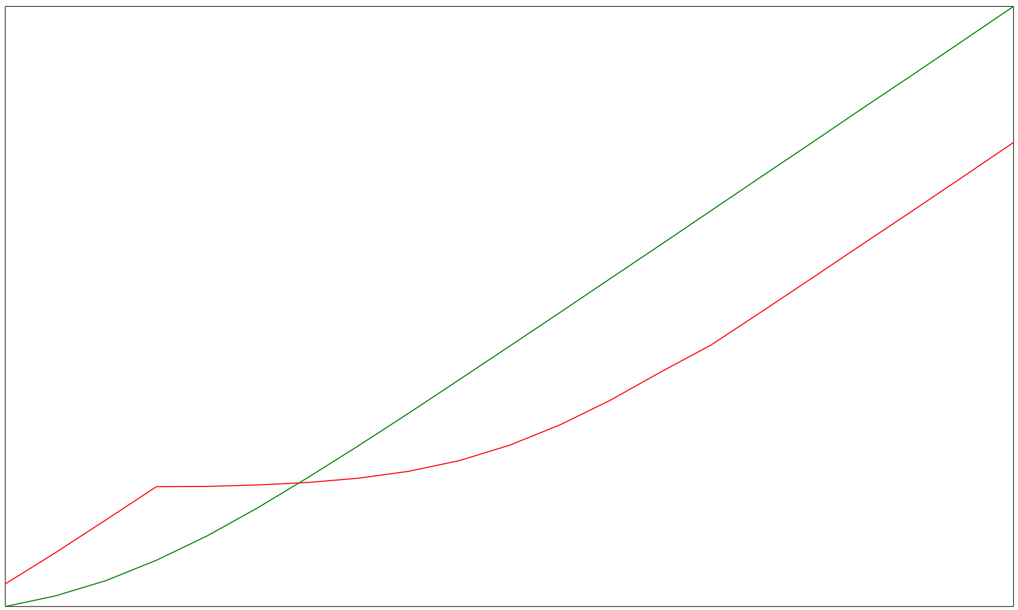
Act now

- 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

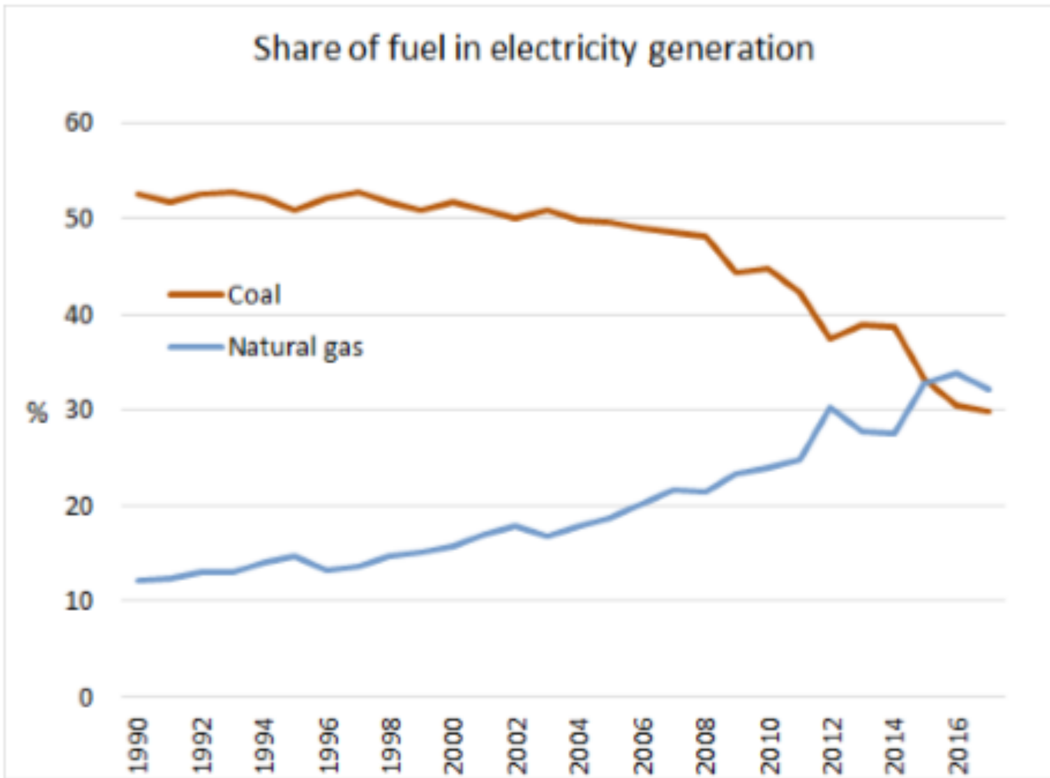
Discount rate	1%	1.5%
Lost consumption	1.33%	1.55%

→ using one instrument instead of two, when discount rate of 1 percent, leads to a consumption loss of 1.33 percent...
→ ....or to a carbon tax 15 times higher during first five years and 12 times higher during following five years.

ENERGY TRANSITION

- **Energy transition**
  - Introduce an intermediate source of energy (e.g. shale gas)
  - Should we subsidize production and research in that intermediate source?

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

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)

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

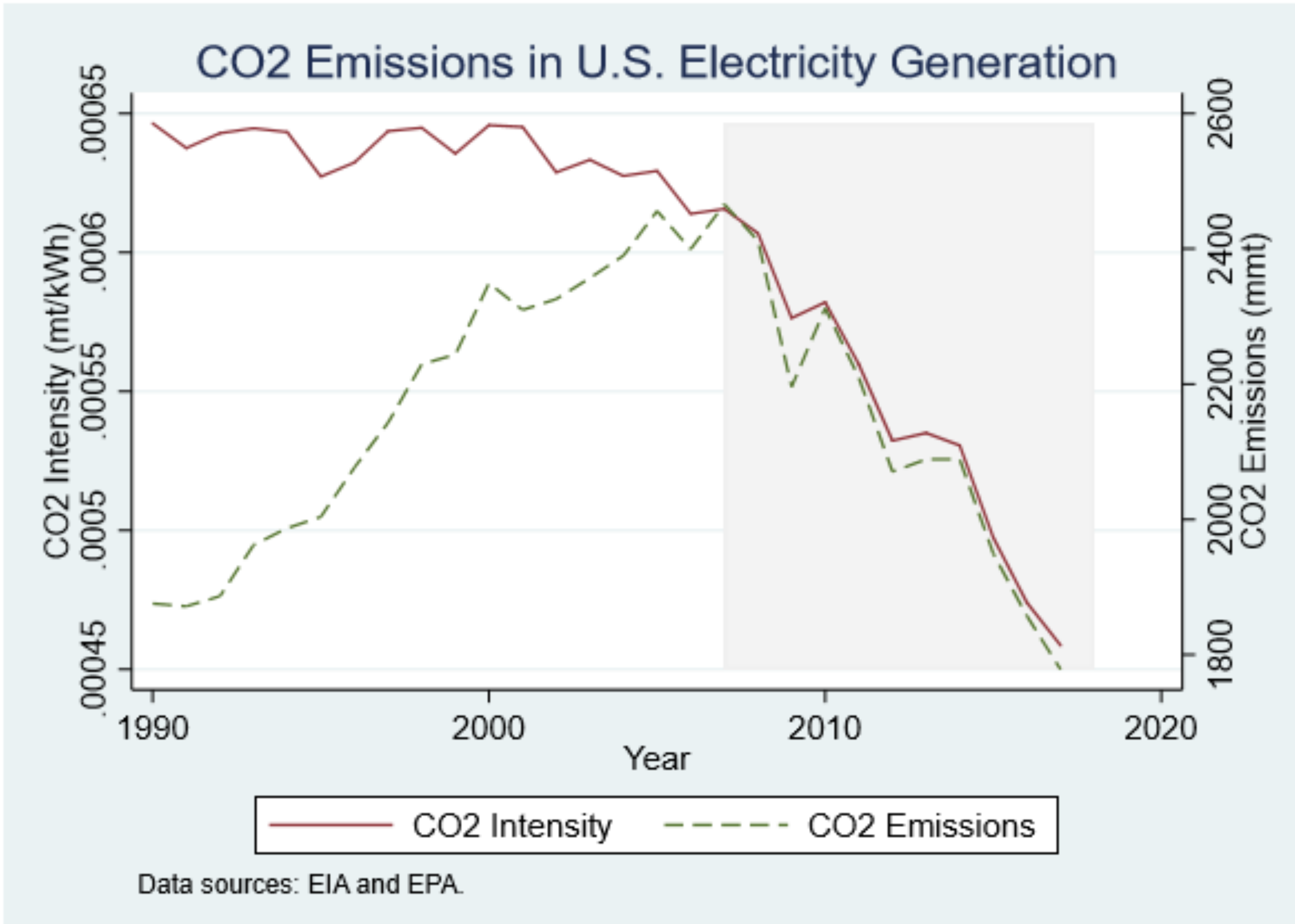
Short-Run Effects

- 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

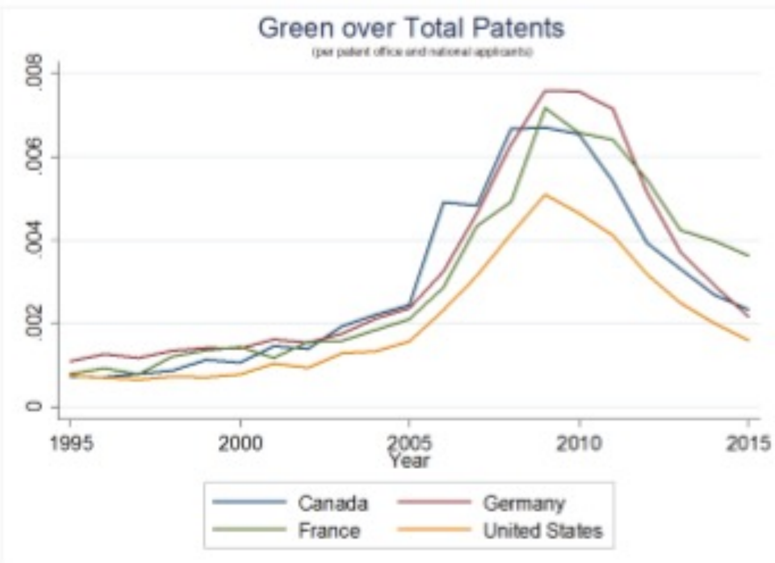
Total Effects of Improved Shale Extraction Technology B_{s0}			
	$\%\Delta$Emiss.	$\%\Delta$Energy	$\%\Delta CO_2$
	Intensity	Consumption	Emissions
Baseline Parameters			
+10% Increase in B_{s0}	-16.7%	+5.5%	-12.1%
+50% Increase in B_{s0}	-21.0%	+9.6%	-13.4%

Emissions and Emissions Intensity

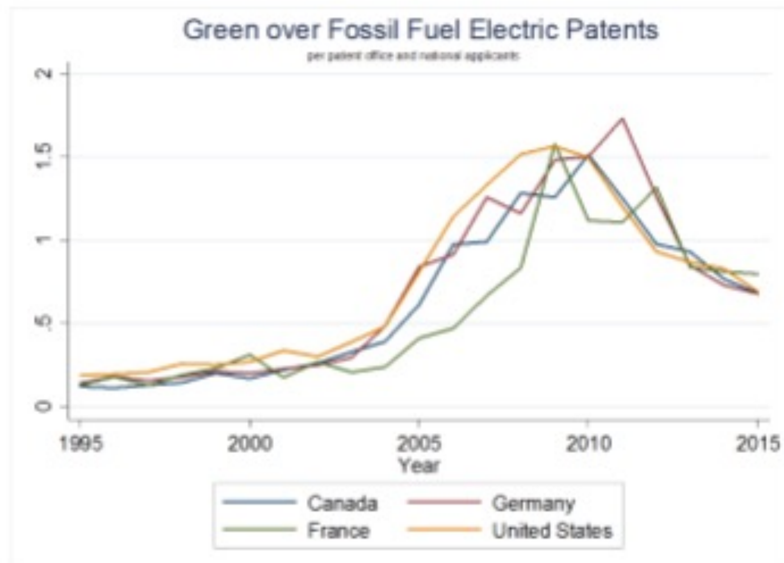


Long-Run Effect

- Assume endogenous innovation on power plant technologies
- 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 CO_2 emissions to a path with increasing CO_2 emissions



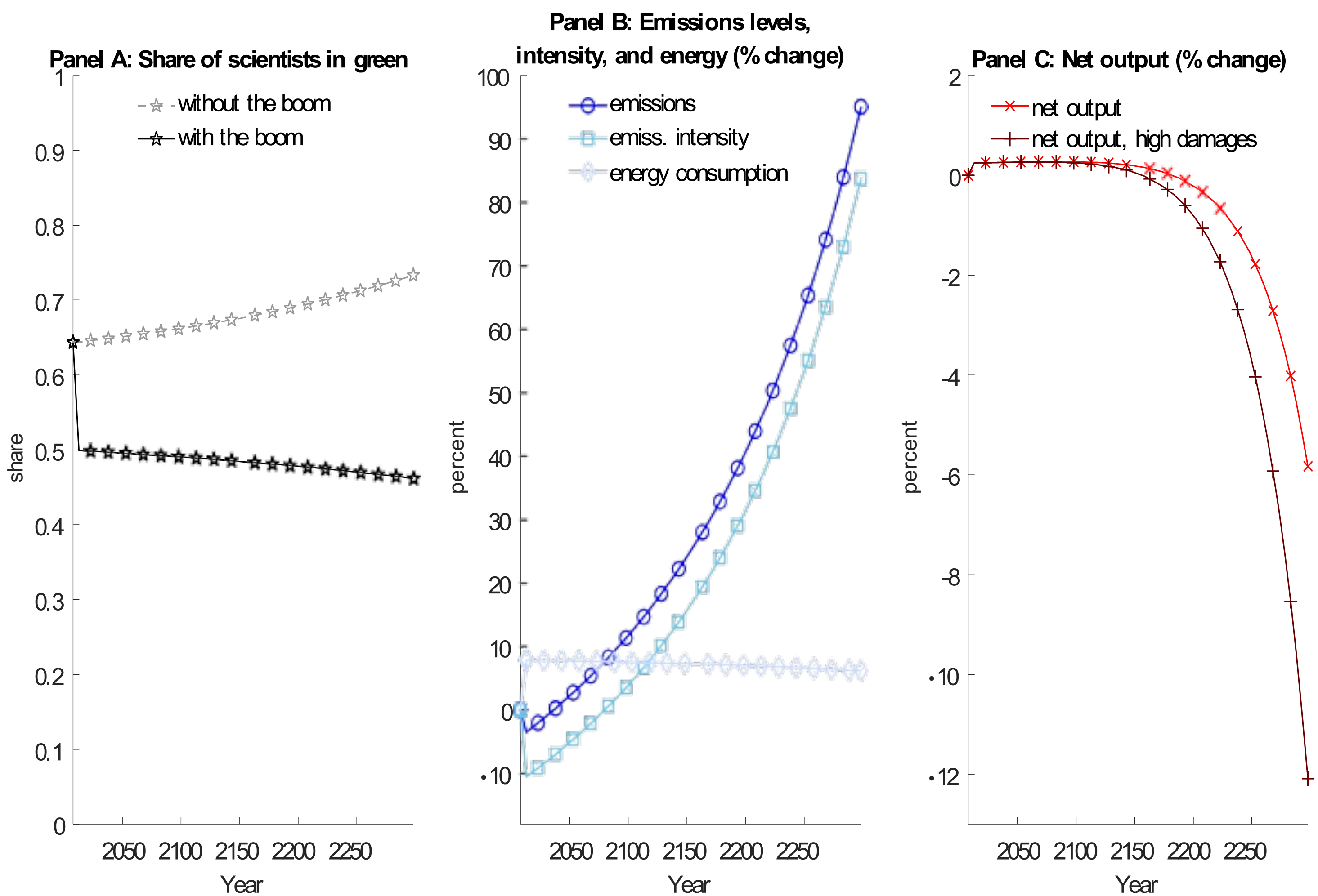
Green over Total Patents
(per patent office and national applicants)
0
.002
.004
.006
.008
1995
2000
2005
2010
2015
Year
Canada
Germany
France
United States



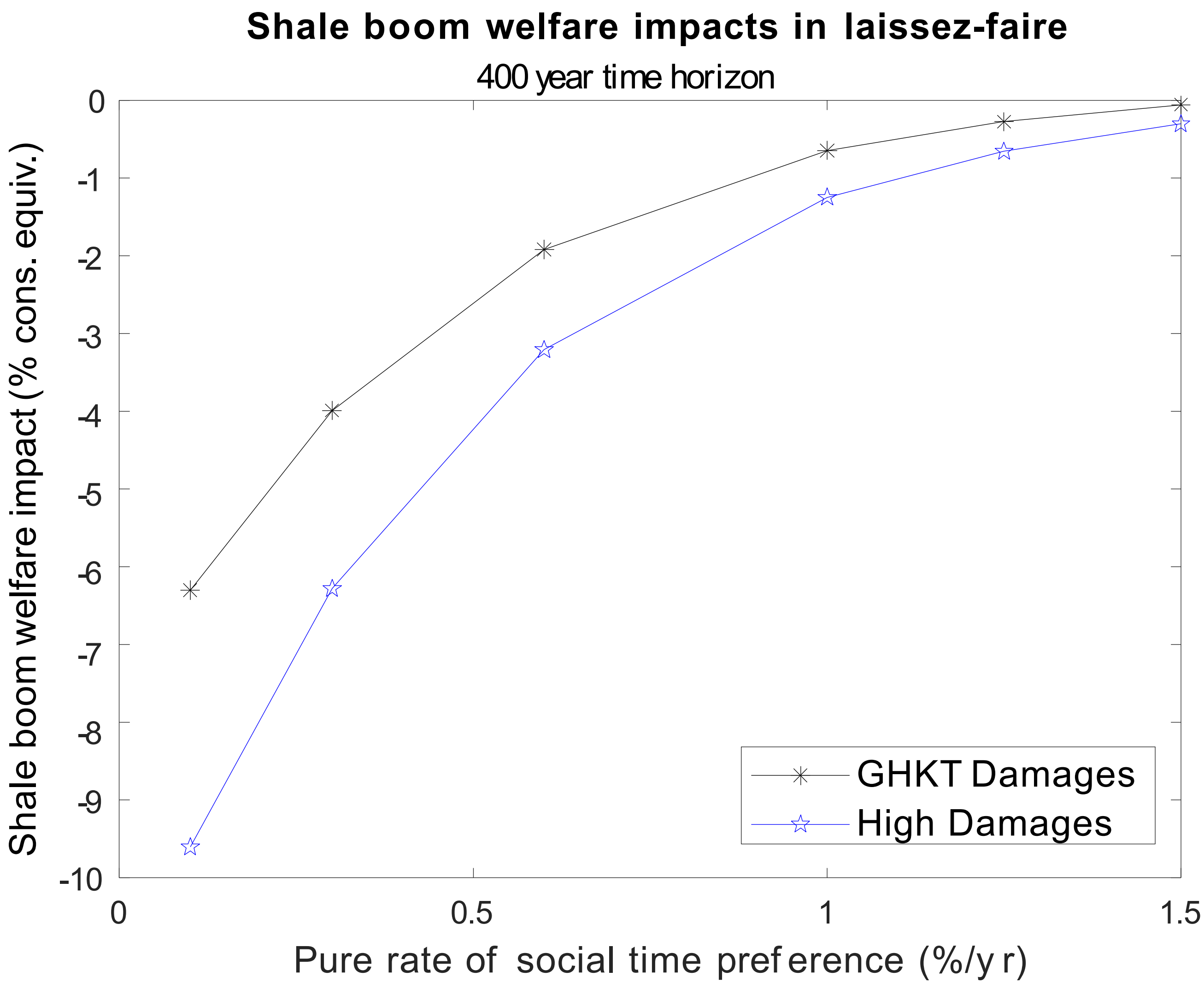
Green over Fossil Fuel Electric Patents
per patent office and national applicants
0
.5
1
1.5
2
1995
2000
2005
2010
2015
Year
Canada
Germany
France
United States

Effects of shale gas boom

Unmanaged boom



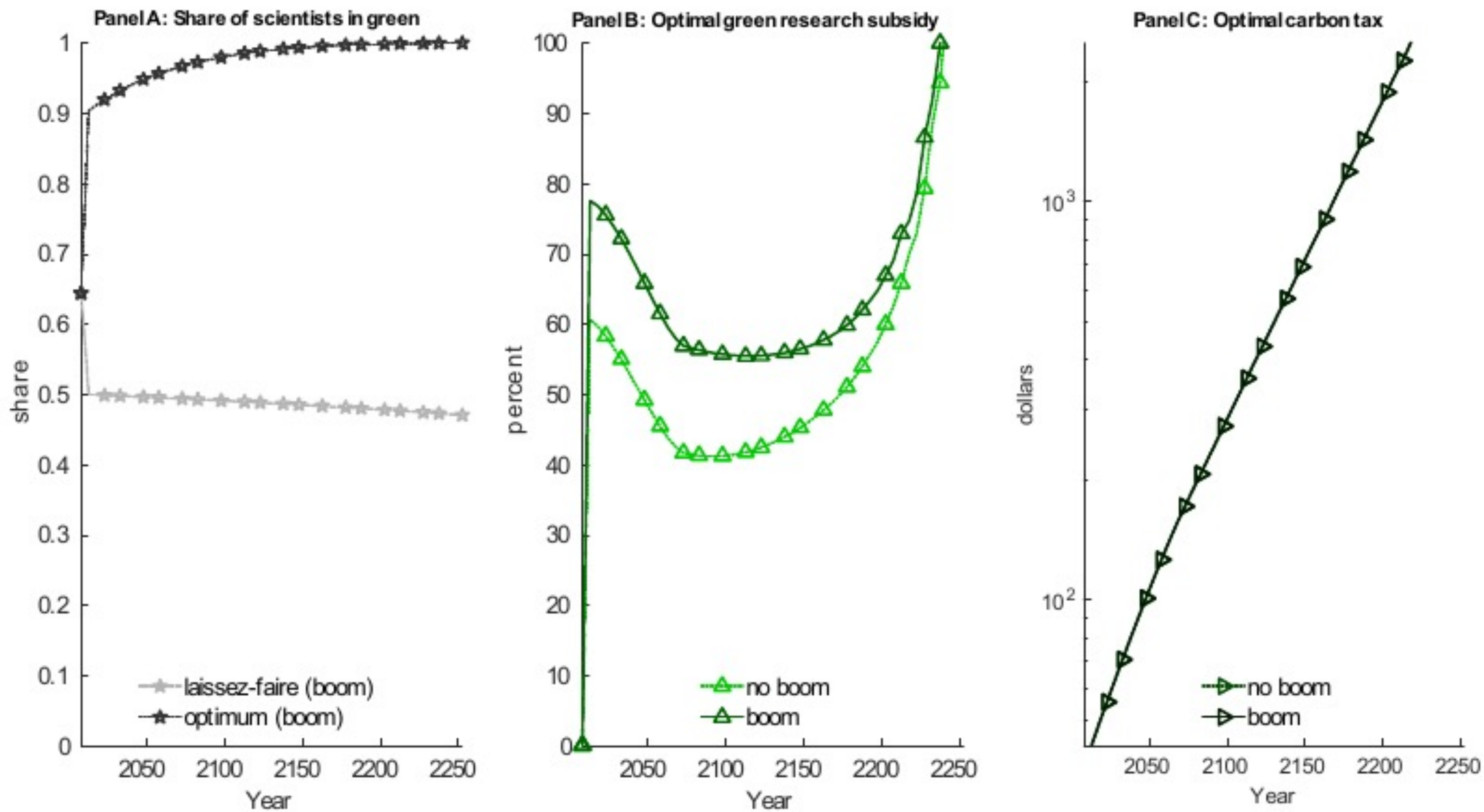
Welfare effects



Optimal policy: Setup

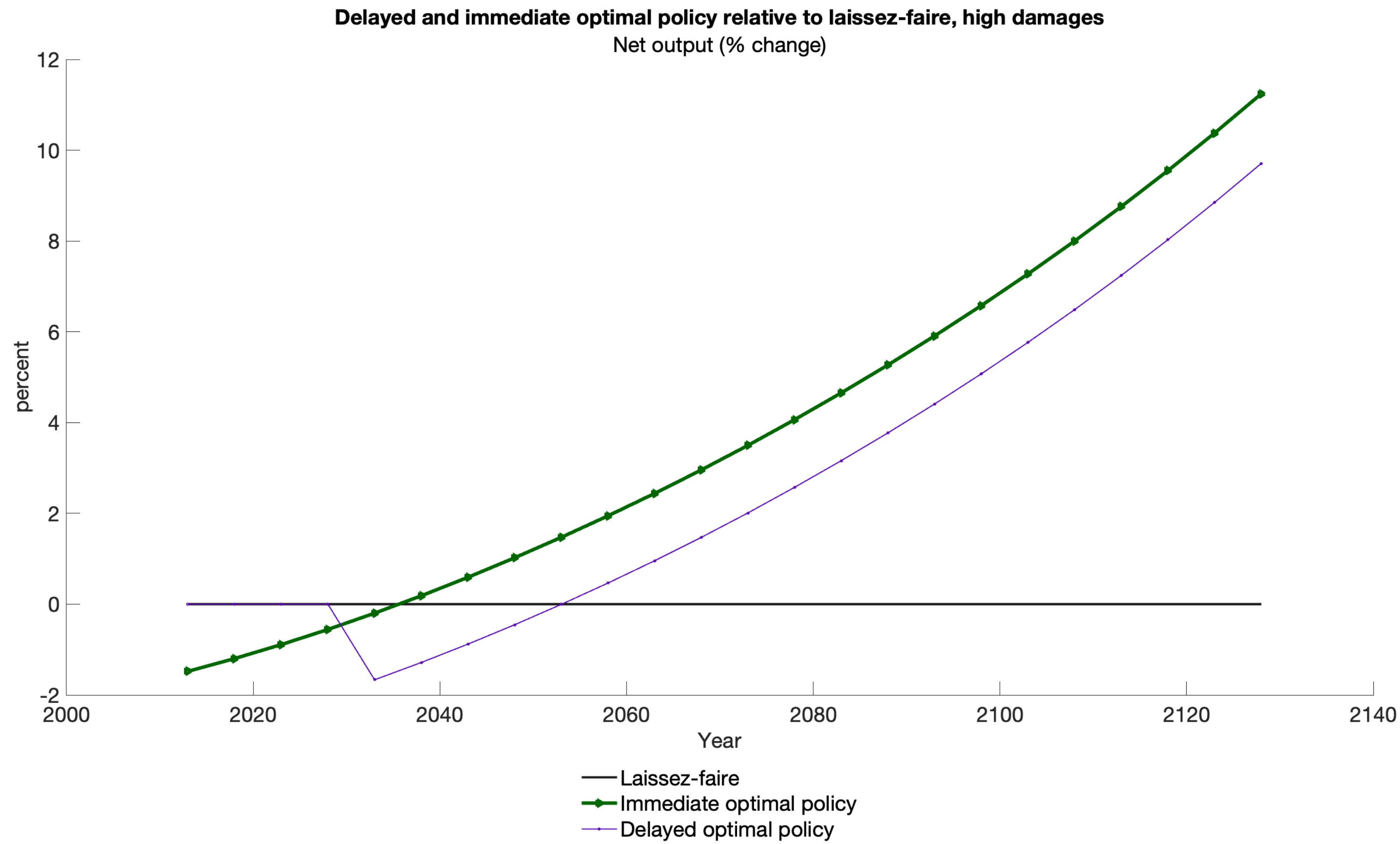
- Consider a social planner who maximizes US welfare but takes emissions from ROW (and outside electricity) as given
- Two externalities ⇒ two instruments:
  - Carbon tax to correct for environmental externality
  - Clean research subsidy to take into account that private value of innovation is too short-sighted

Optimal Policy: effect of the boom



Now consider shale gas boom as given

- All simulations here take the shale gas boom as given.
- We look at effect of delaying or not the optimal policy and of using one versus two instruments



Delayed and immediate optimal policy relative to laissez-faire, high damages
Net output (% change)
percent
12
10
8
6
4
2
0
-2
2000
2020
2040
2060
2080
2100
2120
2140
Year
Laissez-faire
Immediate optimal policy
Delayed optimal policy

	Welfare compared to laissez-faire, in percentage points	
	GKHT damages	High damages
Optimal Policy	19.59	49.17
Delayed Policy (20 years)	14.85	34.13

Note: The optimal policy increases welfare by 19.59% compared to laissez-faire, in the GHKT damages case.

	Welfare compared to optimal policy, in percentage points	
	GKHT damages	High damages
Optimal Policy	*reference*	*reference*
Delayed Policy (20 years)	-3.65	-8.45

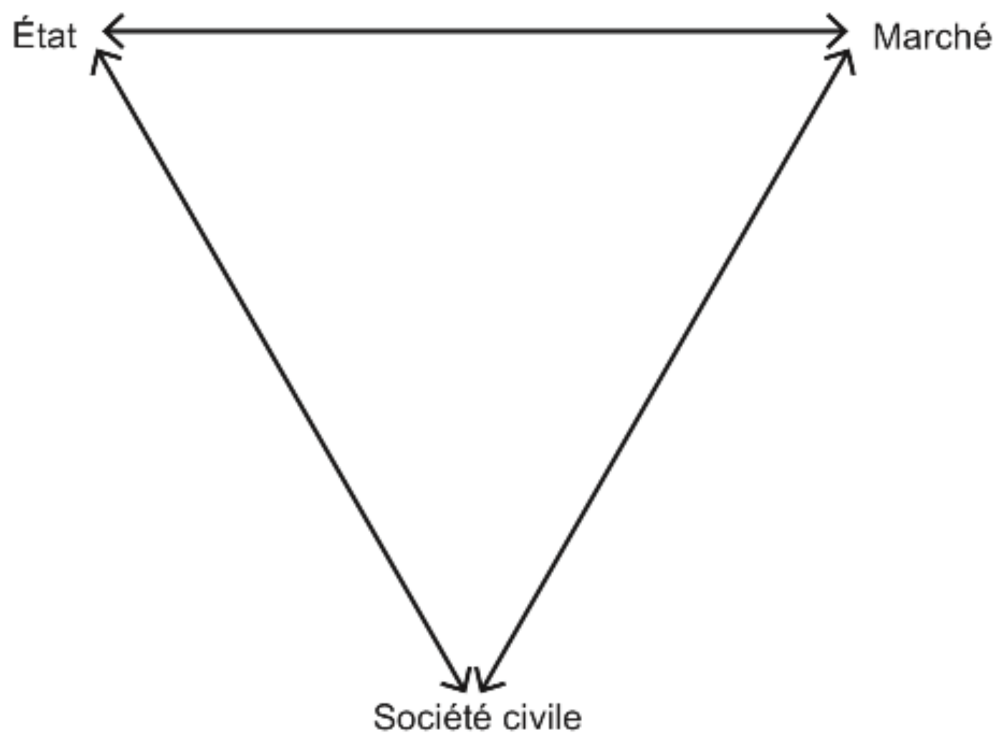
Note: The delayed policy reduces welfare by 3.65% compared to the optimal policy, in the GHKT damages case.

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”?

Rethink capitalism

- Magic triangle: Firms/Market – State – Civil Society (Bowles and Carlin)



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

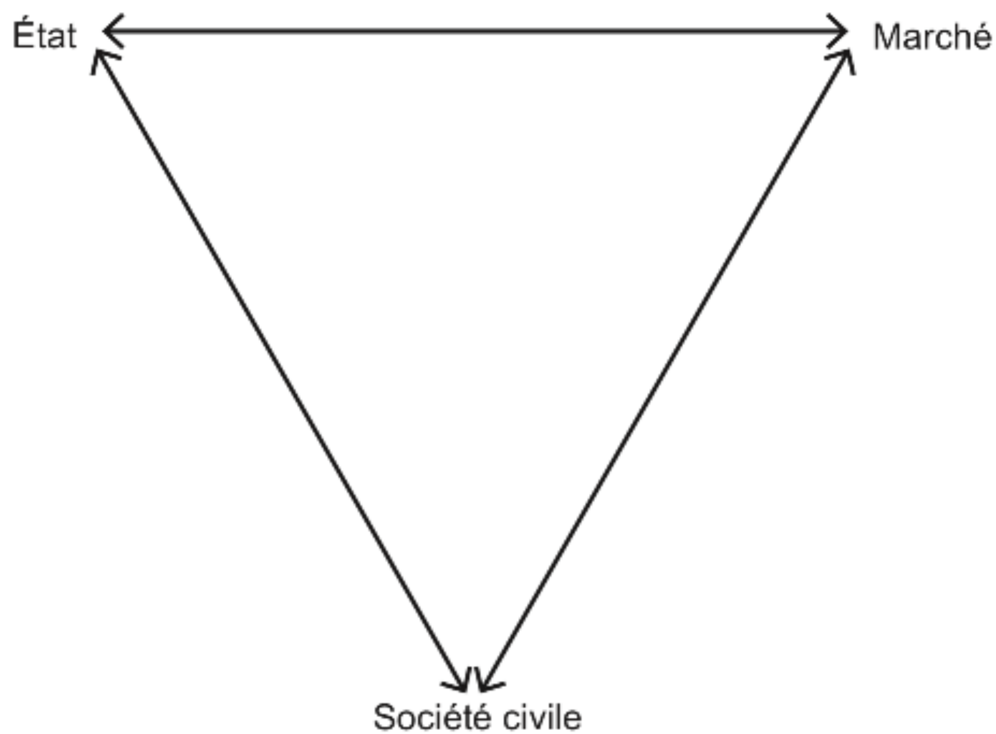
VARIABLES	(1)	(2)	(3)	(4)
	Log (1+#clean)- Log (1+#dirty)			
Values	0.170***	0.229***	0.233***	0.594***
	(0.0397)	(0.0500)	(0.0524)	(0.144)
Competition	0.189***	0.161***	0.325**	-0.0223
	(0.0614)	(0.0605)	(0.139)	(0.0305)
ValuesXCompetition	0.109***	0.0703***	0.0875***	0.0620**
	(0.0370)	(0.0234)	(0.0231)	(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

Conclusion

- Innovation-based climate models suggest that action must be taken urgently and that multiple instruments should be used
- One must act now and multiple instruments must be used, not just the carbon tax
- Triangle between firms, the State, and Civil Society

Rethink capitalism

- Magic triangle: Firms/Market – State – Civil Society (Bowles and Carlin)



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!