Green Growth: Technology and Policy

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Outline

Aim of the talk: A “growth and technology perspective” on “Green Growth”

1. What is a Green Growth policy?

2. What Mechanisms can Green Growth Policy exploit?

3. How costly is Green Growth policy?

4. Policy instruments

1. What is a Green Growth policy?

Green Growth Policy objectives

What type of growth should policy aim at?

- Economic growth: per capita income (in market prices) grows
- Green growth: economic growth + (more) environmental improvements
- Genuine growth: welfare growth

Is “green growth” possible?

- Theory: YES, through substitution and innovation
- Practice: barriers from leakage, rebound, weak decoupling, externalities.

A tentative answer

Maybe most environmental economists would agree on the following:

- Best to focus on Weak green growth: substantial reduction in pollution without substantial reduction in pace of growth
- “weak green growth” is needed, possible and acceptable…
- but requires immediate, permanent, coordinated, and consistent action.

Green Growth – being concrete

Needed	*Practice*	*Conflict*
Energy transition	Shale gas, Coal	Density versus green
Phosphates, nutrients	Economies of scale	Scale versus control
Circular economy, waste, transport	e-commerce	Fast versus slow property rights, coordination failures
Deforestation	Agro-fuels	Local versus global
Land use	Globalization and land grabbing	
Biodiversity	Development and privatization	

Small open economies

- prepare for inevitable transitions
- avoid “stranded assets”

2. What Mechanisms can Green Growth Policy exploit?

Proximate and Ultimate Green-Growth Drivers

Substitution – technology – instruments – preferences and behavior

from dirty to clean
Problem:
cost, effectiveness

innovation reduces cost of clean
innovation itself is costly
(crowding out, leakage, rebound)

social cost of innovation
lower than private cost
→ technology policy
Problem: interactions and imperfect policies

environmental awareness, nudges, lifestyles
→ bigger market and more effective policy

1. Substitution

Produce more with less polluting inputs.
I.e. switch to available alternatives. “Abatement”

Triggered by *price* effects and *income* effects

- Trends (“Business as Usual”)
  General growth – Income growth
  Differential growth – relative price changes

- Policy (“scenarios”)
  Taxes/subsidies – relative price changes
  Deadweight losses and distributional implications – income effects

How strong are these effects?

Regional Trends in Decoupling

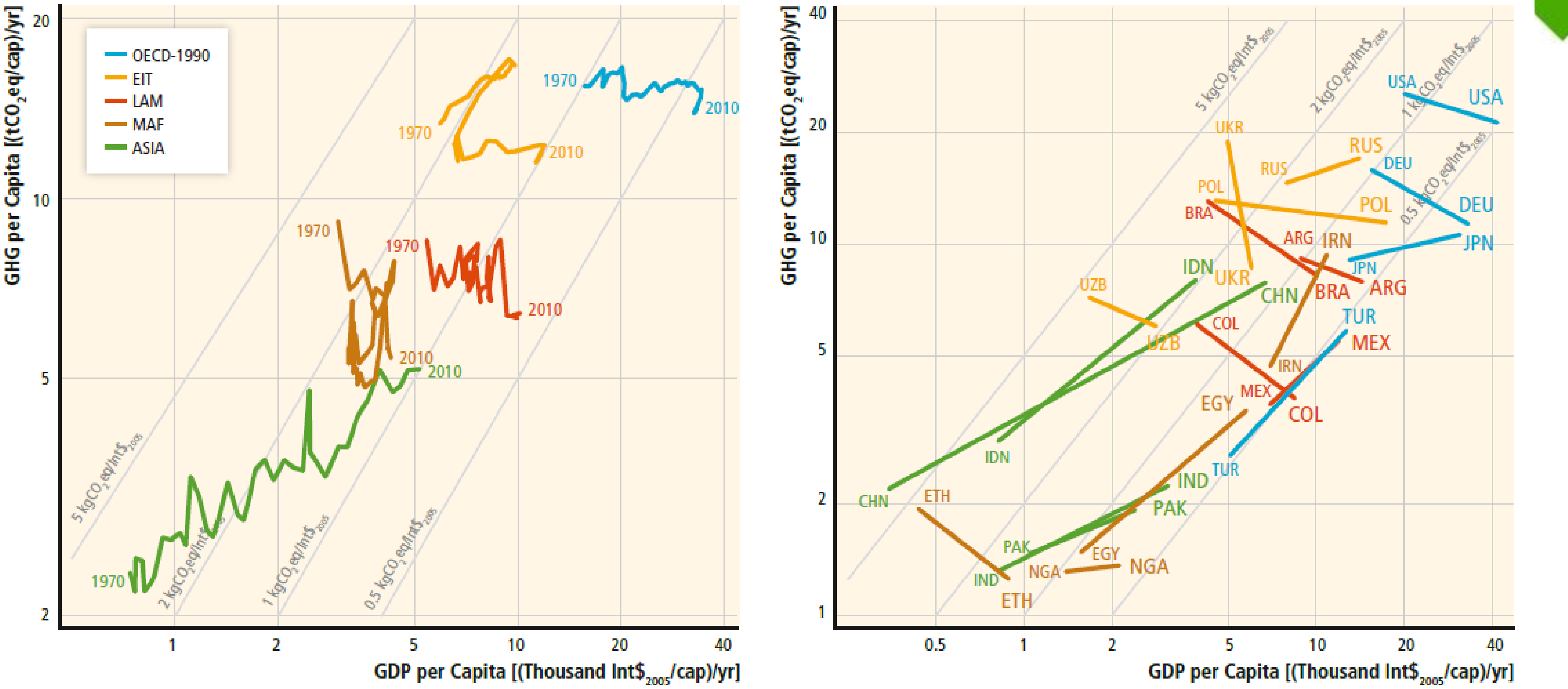


Figure 5.12 | Regional trends in per capita production and GHG emissions (left panel), and for each region the four most populous countries in 2010 (right panel). Regions are defined in Annex II.2. Grey diagonals connect points with constant emission intensity (emissions/GDP). A shift to the right presents income growth. A flat or downwards line presents a decrease in energy intensity, 1971 and 2010. Right panel: The small labels refer to 1970, the large labels to 2010. The figure shows a clear shift to the right for some countries: increasing income at similar per capita emission levels. The figures also show the high income growth for Asia associated with substantial emissions increase. Data from JRC/PBL (2013) and IEA (2012).

(Source: IPCC 2014)

Trends at household level: Environmental Engel Curves

Richer households pollute more but less than proportionately. Reduction in Poll/$ 50% due to income, 50% due to time shifts [i.e. aggregate shifts applying to all household income levels, due to prices and/or policies].

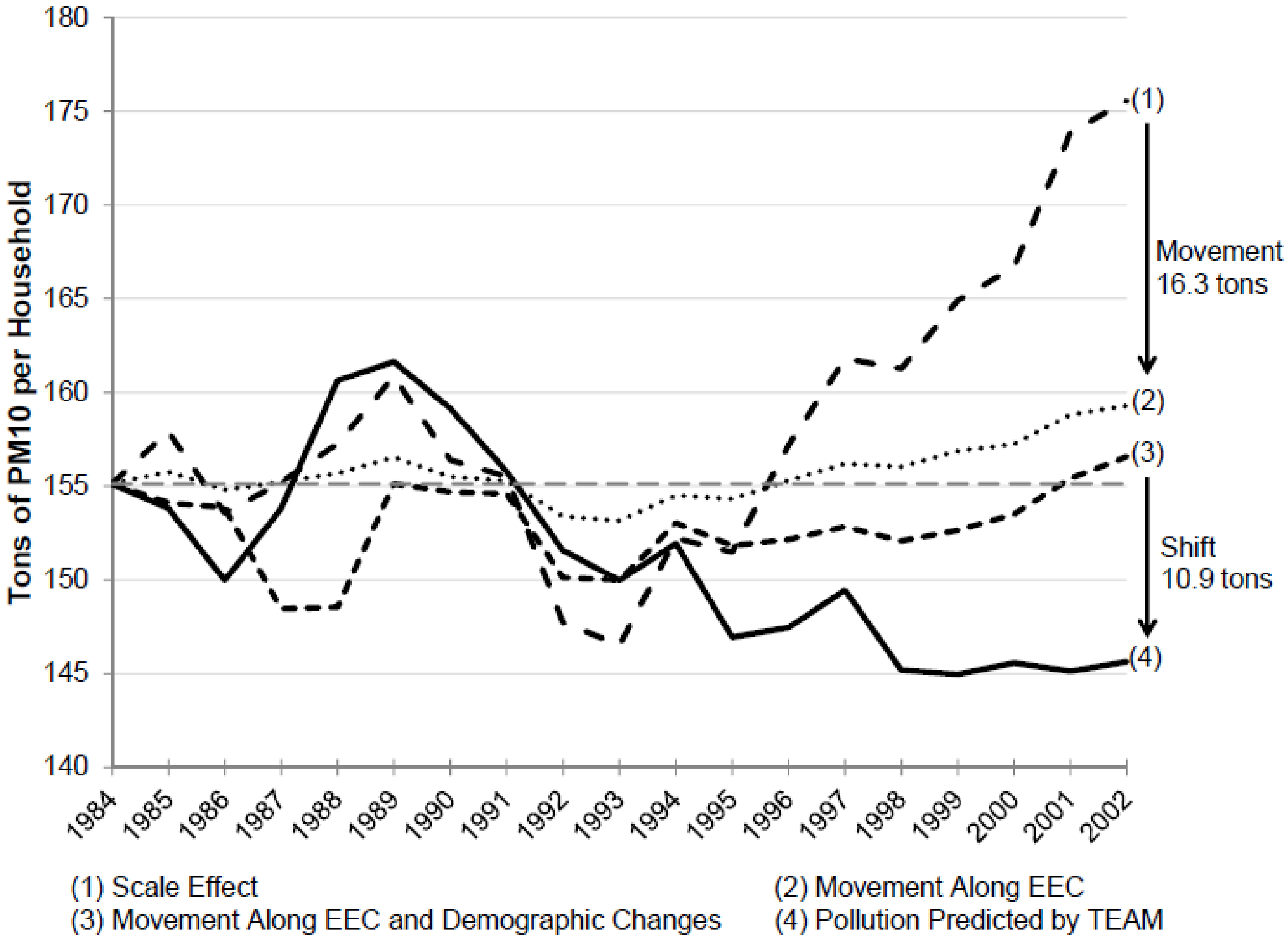
Figure 2a. Pollution Embodied in Household Consumption and After-Tax Income

Income and consumption are adjusted for inflation using the core CPI.
Food and energy consumption are adjusted seperately using the corresponding CPI

Source: Levinson & O’Brien (2015)

Environmental Engel Curves

Figure 4. Decomposition of Predicted Pollution from Household Consumption



Source: Levinson & O'Brien (2015)

Abatement in case of the energy transition: switch to renewable energy.

Abatement has a cost, is expensive. Why?

- Explains why brown (rather than green) alternatives are in use in the first place.
- Basic investment problem: incur cost before reaping benefits.
- Fossil episode.
- Scale problems: difficult to scale up renewable energy.
- Less effective because of “leakage”: some start reducing energy use, others increase their use.

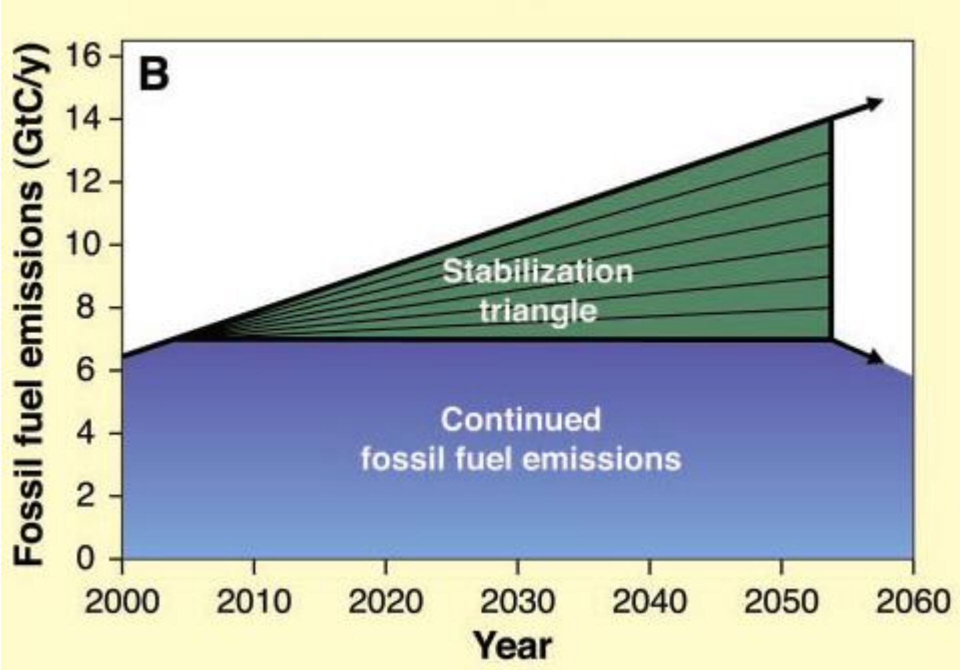
Maybe not so expensive

- Low ETS price for CO2.
- A lot of substitution has taken place already – composition and income effects.
- Policy can trigger substitution – stabilization wedges.
- Empirics: Rebound effects are small.

Technology for CO2 stabilisation is available!

Pacala en Sokolov 2004:

- Energy saving (cars, buildings, power plants)
- From coal to gas, wind, solar (and nuclear).
- CCS
- forest management, conservation tillage.



← requires substitution ← requires policy.

2. Technology

Technological innovation makes substitution easier and cheaper in future periods.

Pure technique effect (Levinson 2015)

“From 1990 to 2008, pollution per dollar of output from US manufacturing declined by 64%–77%. More than 90% of this cleanup can be attributed to technique changes, directly.”

So, pollution falls since every sector pollutes less per unit of value added

→ Pure technique effect.

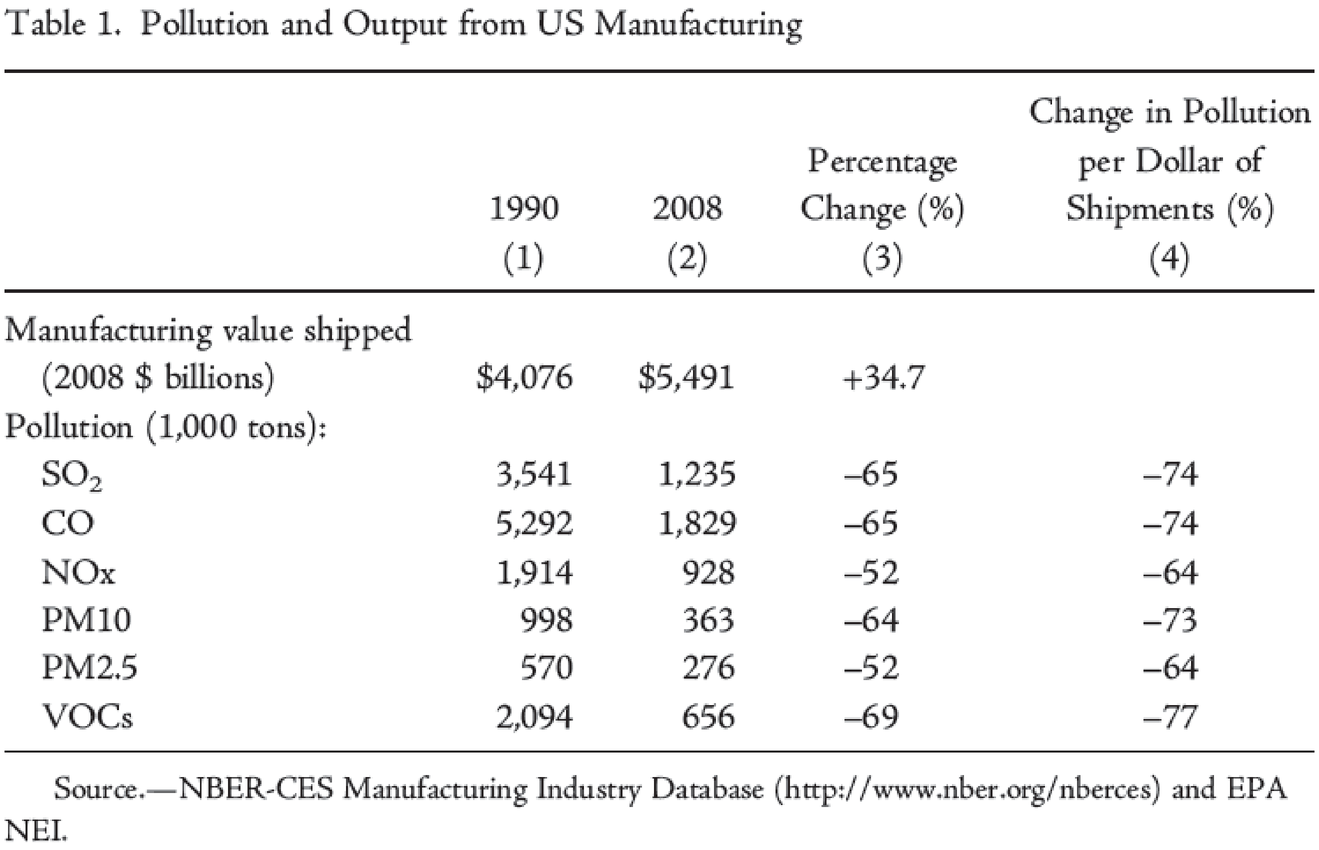


Table 1. Pollution and Output from US Manufacturing

	1990 (1)	2008 (2)	Percentage Change (%) (3)	Change in Pollution per Dollar of Shipments (%) (4)
Manufacturing value shipped (2008 $ billions)	$4,076	$5,491	+34.7	
Pollution (1,000 tons):				
SO_2	3,541	1,235	–65	–74
CO	5,292	1,829	–65	–74
NOx	1,914	928	–52	–64
PM10	998	363	–64	–73
PM2.5	570	276	–52	–64
VOCs	2,094	656	–69	–77

Source.—NBER-CES Manufacturing Industry Database (http://www.nber.org/nberces) and EPA NEI.

Source: Levinson 2015.

Role technology versus composition effects (SO2 in US)

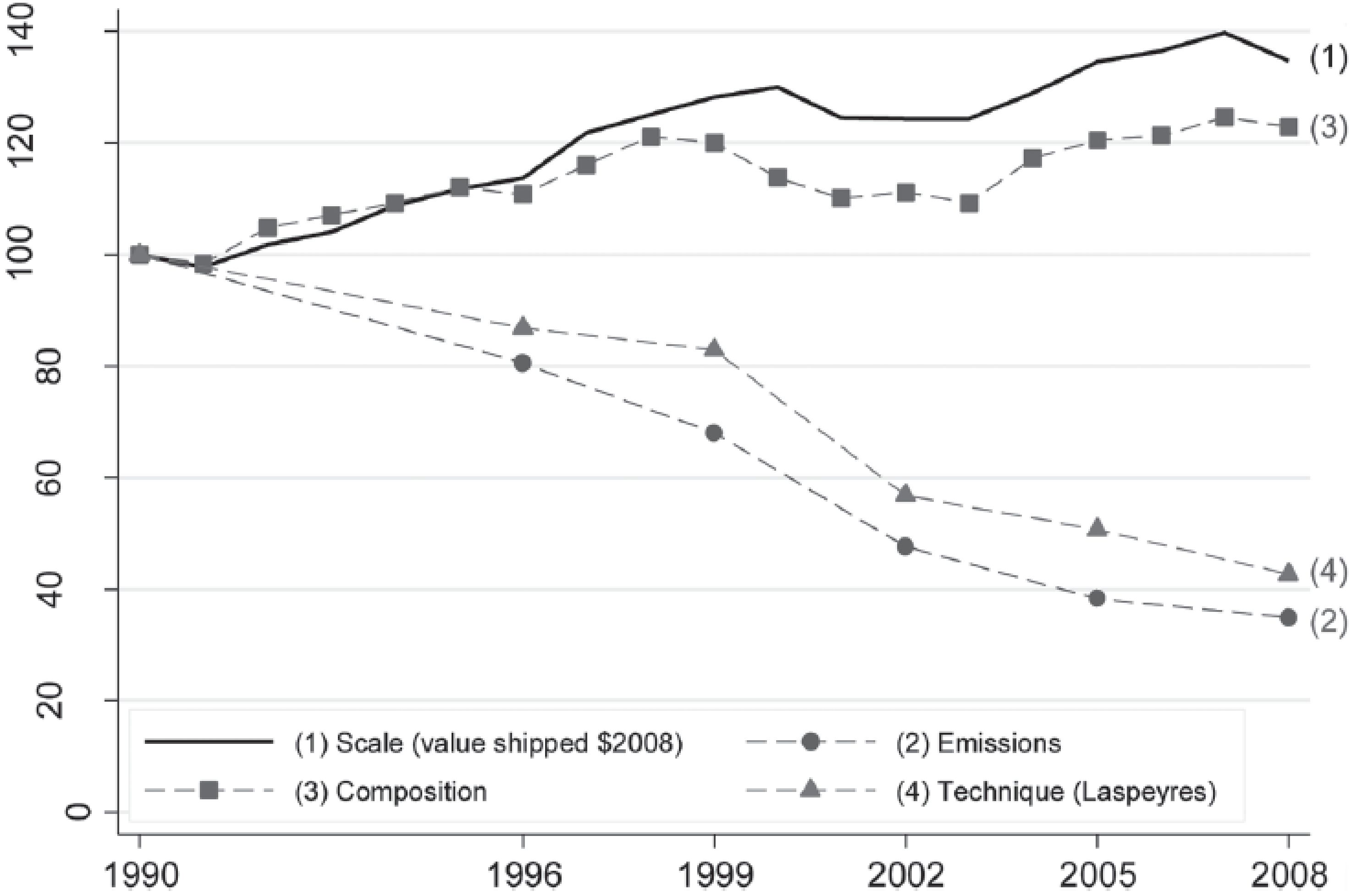


Figure 1. US manufacturing output and sulfur dioxide. Source: NBER-CES Manufacturing Industry Database (http://www.nber.org/nberces) and EPA NEI.

Source: Levinson 2015.

How does this apply to Energy?

Energy intensity (Energy/Value Added) declines

- Shift across countries to countries with *high* energy intensity
- Shift within countries to sectors with *low* energy intensity
- Shift within sectors to lower energy intensity → Technique effects.

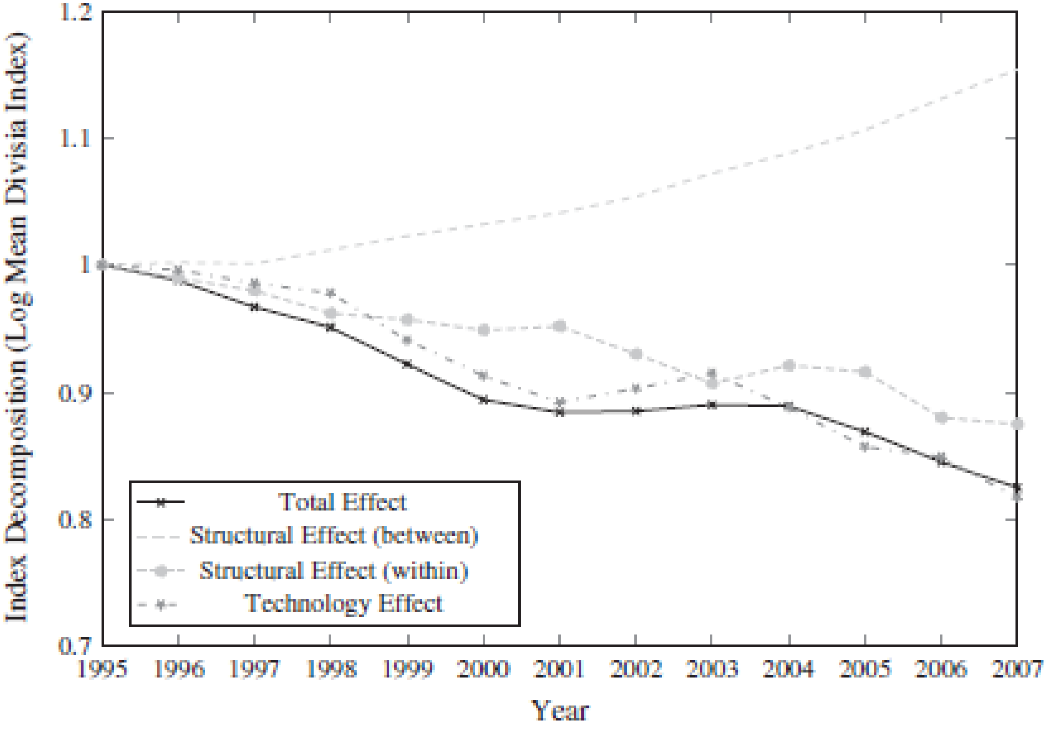


Fig. 11. Three factor LMDI decomposition of global energy intensity.

Voigt et al (2014).

Technique = technology?

The technique effect is the result of the combination of

- substitution (replacing inputs), and… ← less pollution through a change in price or income
- …technology (productivity of inputs). ← less pollution at same price and income

Direct estimate of “technology effect”?

What drives innovation?

Private R&D cost-benefit analysis:

- Future market size for innovations (future total profits as a result of the innovation)
- Cost of technology development
- Knowledge base “kennisspillovers” and “knowledge stock” (cumulated experience within own firm and related firms in sector)
- Complementary patents → GPTs, network effects.
- Appropriability (IPR, labor market, product market)

Empirics

- Noailly & Smeets (2015): market size, fossil fuel prices, cumulated experience important drivers of green innovation.
- Popp (2006): patents for SO2 and NOx reduction follow environmental policy in US, Japan, Germany.

How hard is it to create green patents?

A study with support for optimism:
Green innovation creates more spillovers, as measured by patent citations.

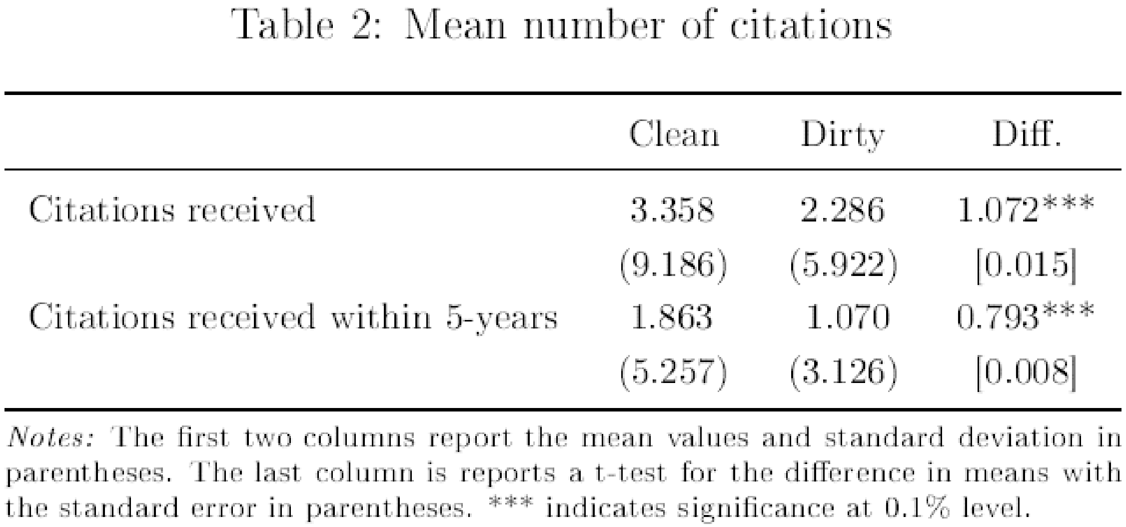


Table 2: Mean number of citations

	Clean	Dirty	Diff.
Citations received	3.358	2.286	1.072***
	(9.186)	(5.922)	[0.015]
Citations received within 5-years	1.863	1.070	0.793***
	(5.257)	(3.126)	[0.008]

Notes: The first two columns report the mean values and standard deviation in parentheses. The last column is reports a t-test for the difference in means with the standard error in parentheses. *** indicates significance at 0.1% level.

Dechezlepretre et al 2013

3. How costly is Green Growth policy?

Optimists versus Pessimists?

Optimists:

- temporary environmental policy makes the economy permanently “green” without loss of growth in long run (Acemoglu et al 2012)

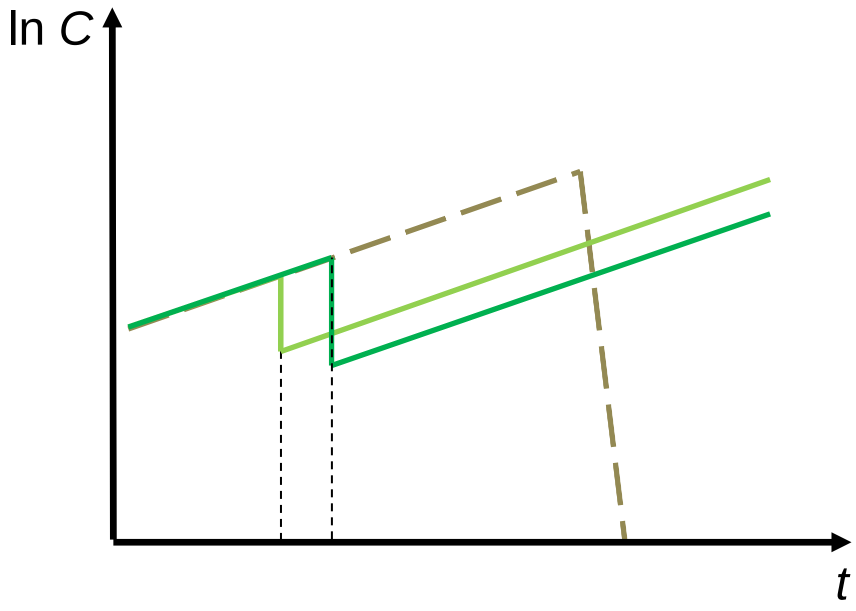
Pessimists:

- Diminishing returns to innovation and (non-environmental) externalities → slower growth.

Why Green Growth might be very easy

Acemoglu et al 2012

Clean and dirty are good substitutes
Technological opportunity for clean the same as for dirty
Historical lack of innovation in clean.
→ Lock in because of history
→ Optimistic policy implications: temporary, no loss of growth.



Why Green Growth might be easy…
…but still does not materialize
The role of expectations

If technology investment is crucial, expectations become crucial:
forward looking investment strategies

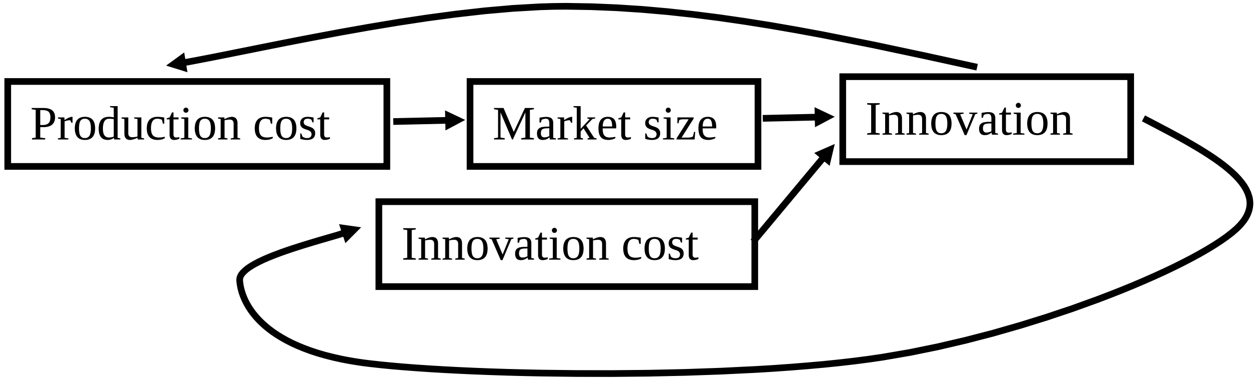
The role of expectations (I)

a. Creation of green markets **Smulders and Zhou 2017**

Consumers care about services and are happy to substitute clean goods for polluting goods (pure price effect).

Producers invest in cost reduction in clean sector or polluting sector (Directed Technical Change). Investment in clean increases market share in clean.

Technology spillovers: future clean (dirty) innovations build on current clean (dirty) innovations.



Production cost

Market size

Innovation

Innovation cost

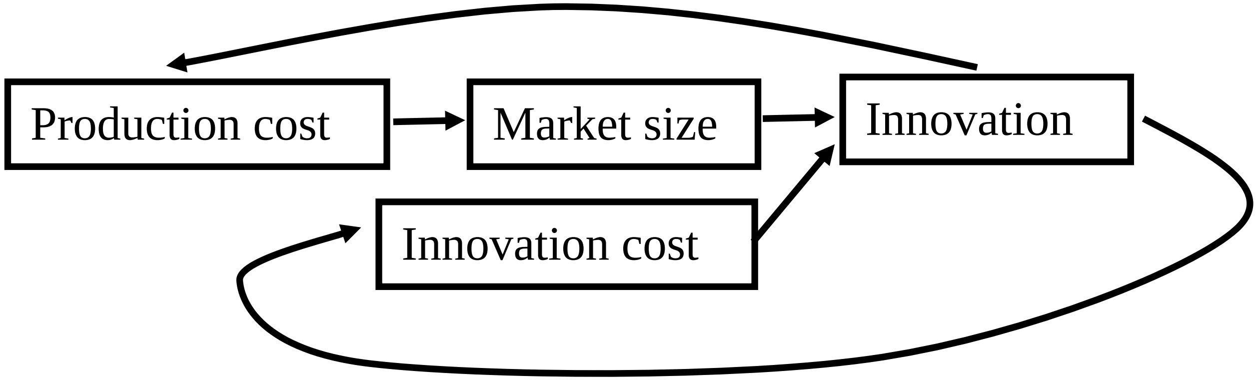
The role of expectations (I)

a. Creation of green markets **Smulders and Zhou 2017**

Starting point: dirty is cheaper than clean, so the current market for dirty is bigger than for clean.

- Case 1: producers expect dirty innovation to continue. Future market for dirty is biggest. No transition.
- Case 2: producers expect a transition. Future green markets will be big. Invest in clean now. Future costs of green R&D are low (and dirty R&D is expensive). Self-fulfilling prophecy.

Math: self-fulfilling prophecy if current market for green is not too small and if substitution is good and if sector-specific spillovers strong.



Production cost

Market size

Innovation

Innovation cost

The role of expectations (I)

a. Creation of green markets **Smulders and Zhou 2017**

Policy:

- Tax and subsidy, as usual. Now needs to eliminate the “bad equilibrium” (=dirty)
- Government R&D in clean. Only a small fraction of total R&D by Government – private sector will follow.

The role of expectations (II)

b. Energy transition and Carbon Lock-In **Van der Meijden & Smulders 2017**

Multiple equilibria possible:
Case 1. The market expects that alternative energy remains *non-competitive*.
→ investment in conventional energy efficiency.
→ no market for alternative energy investment.
→ self-fulfilling prophecy
Case 2. The arket expects that alternative energy becomes *competitive soon*.
→ no longer investment in conventional energy efficiency (no time for pay-back).
→ alternative energy becomes competitive.
→ self-fulfilling prophecy

Lesson: transition may be difficult because of conservatism and expectations.

Policy: tipping tax and commitment.

Why Green Growth might be expensive

Okullo et al 2015

Clean and dirty are poor substitutes.

- Fossil episode: transition from cheap fossil to expensive renewables.
- Fossil: constant cost
- Renewables: increasingly costly (decreasing returns to scale).

Output: $F(L,X,E)=C+\dot{K}+\delta K$

Capital input: $X=\left[\int_0^{A_X}(k_{Xi})^{\frac{\varepsilon-1}{\varepsilon}}di\right]^{\frac{\varepsilon}{\varepsilon-1}};$ $\dot{A}_X=\xi_X(L_X)^{\lambda}(A_X)^{\varphi_X}$

Energy input: $E=\underbrace{\left[\int_0^{A_R}(k_{Rj})^{\theta}(\eta_{Rj})^{1-\theta}dj\right]}_{\text{renewables}}+\underset{\text{fossil}}{\eta_F K_F};$ $\dot{A}_R=\xi_R(L_R)^{\lambda}(A_R)^{\varphi_R}$

Factor markets: $K=\int_0^{A_X}k_{Xi}di+\int_0^{A_R}k_{Rj}dj+K_F;$ $\dot{L}=\dot{L}_X+\dot{L}_R=g_L L$

Why Green Growth might be expensive

Okullo et al 2015

Simulating the emergence of fossil ("long history"):

- Initially, relatively little capital and lots of renewable resource opportunities (K/A_R small)
- As capital is accumulated, fossil is introduced, vanishing renewables share.

Simulating the phasing out of fossil ("(far) future"):

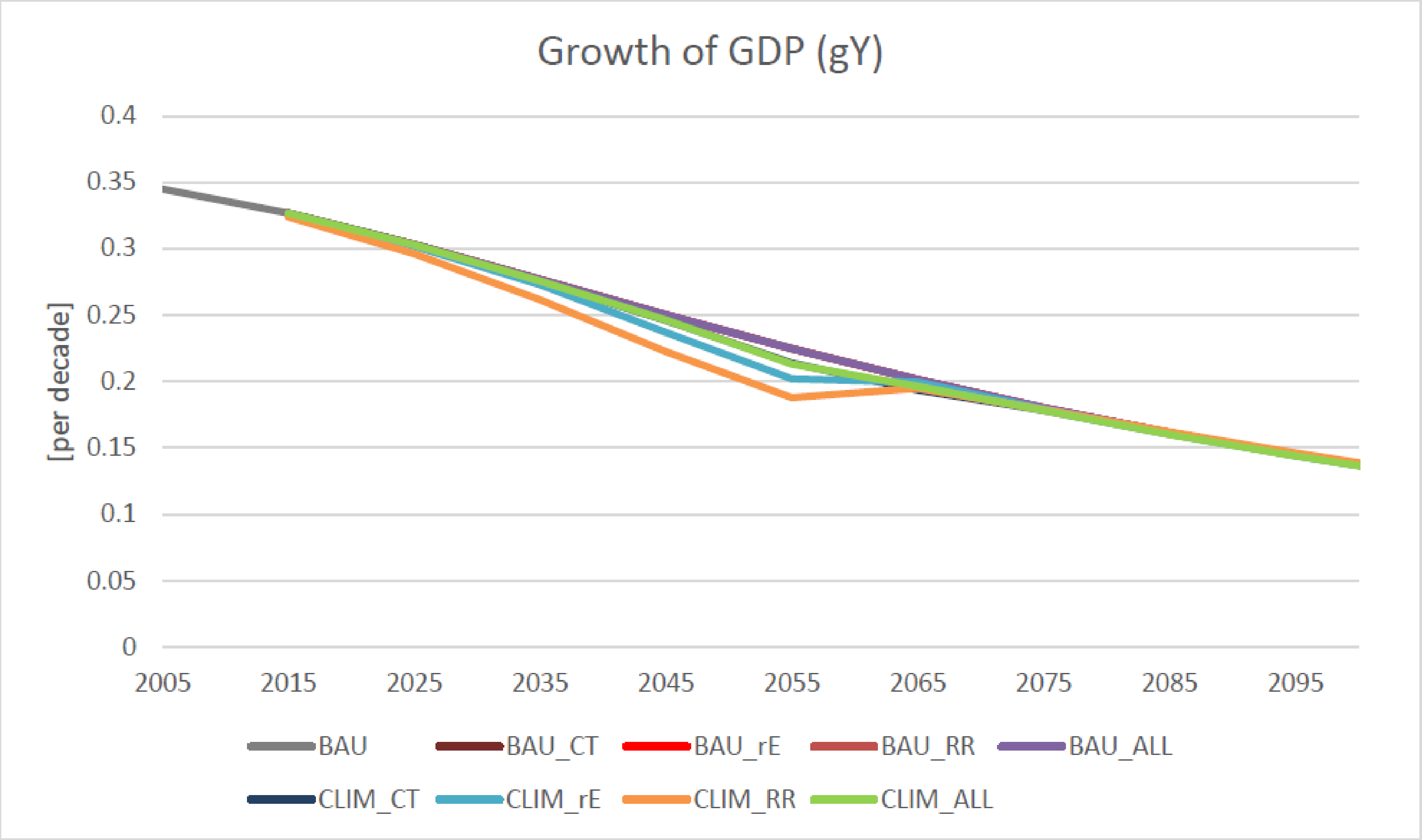
- policy: Carbon tax and/or renewables R&D subsidy
  → Permanent carbon tax needed
  → Redirect technical change to renewables in order to reduce cost
  → Loss of growth.

Scenarios

- Instruments:
  - carbon tax (CT),
  - renewable energy subsidy (rE),
  - renewable R&D subsidy (RR),
  - all three instruments used simultaneously (ALL).

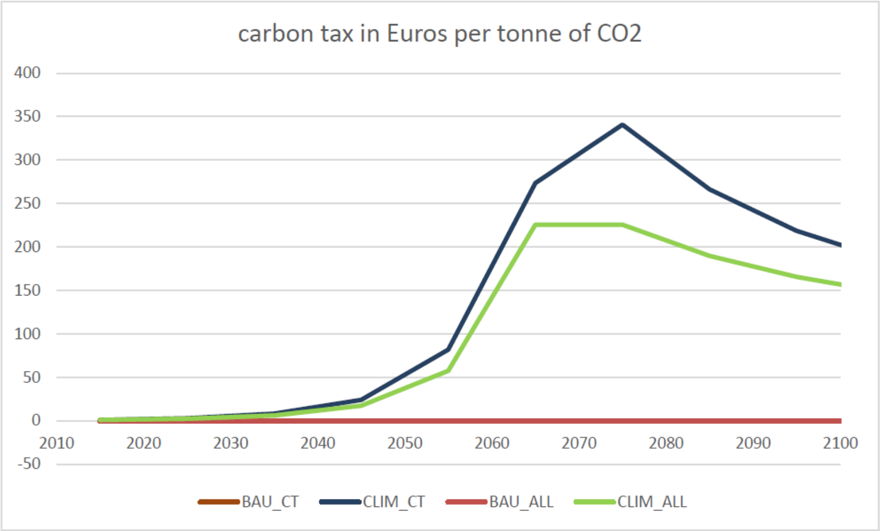
- Policy target:
  - constrained welfare maximization with cumulative emission target “CLIM_xx”
  - constrained welfare maximization without cumulative emission target “BAU_xx”

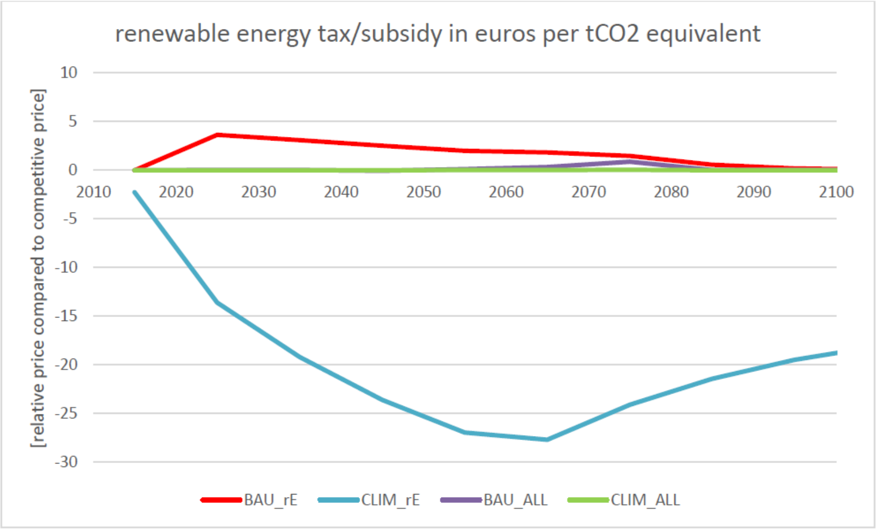
Growth hardly affected

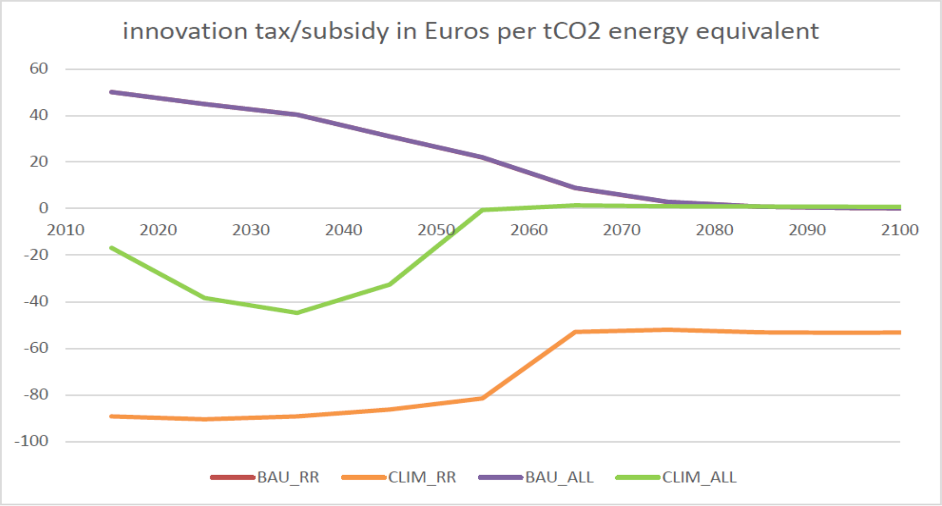


Growth slows down anyway,….
…but climate policy hardly affects growth.

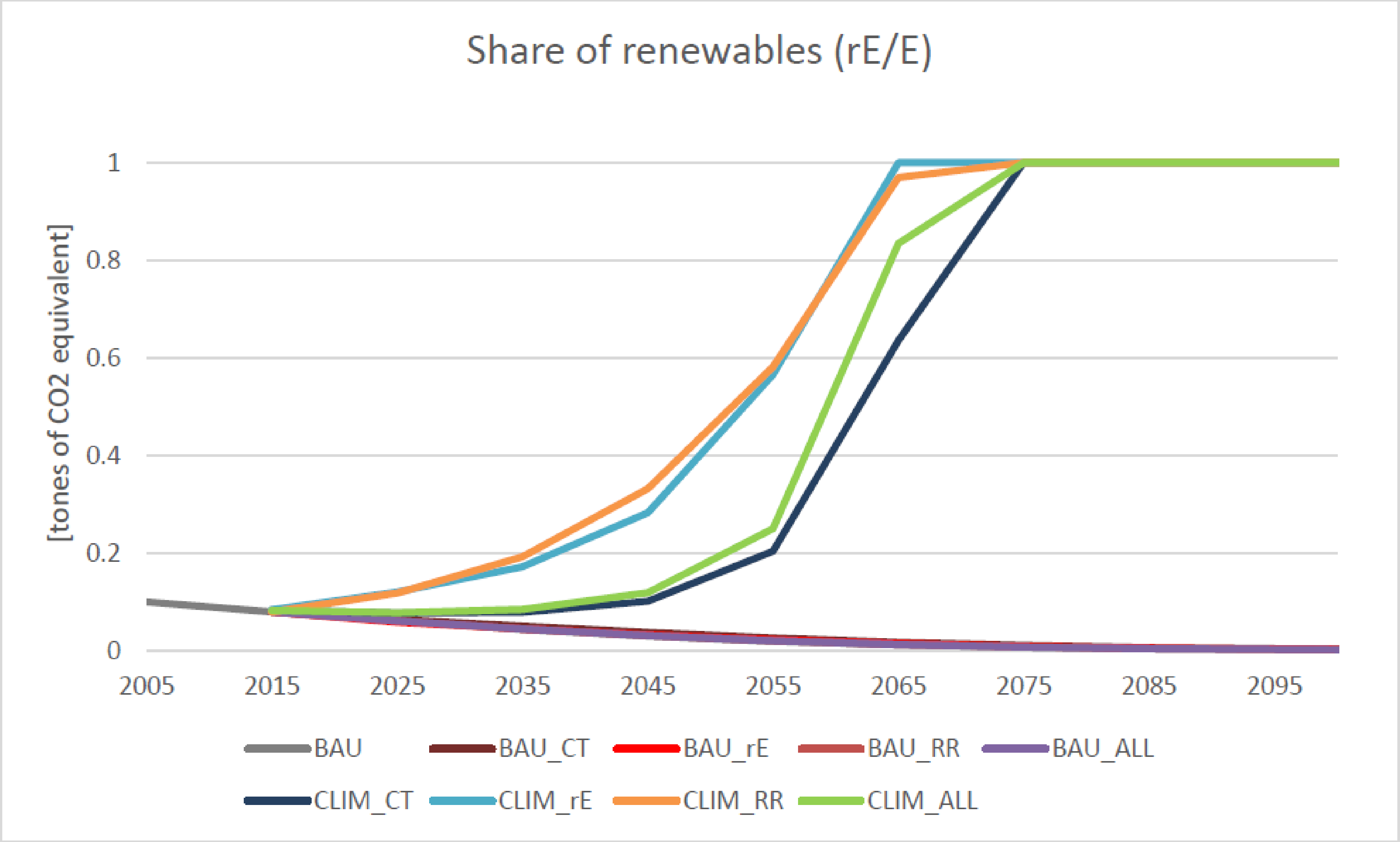
Technology first, then carbon tax


carbon tax in Euros per tonne of CO2


renewable energy tax/subsidy in euros per tCO2 equivalent


innovation tax/subsidy in Euros per tCO2 energy equivalent

Carbon tax and R&D subsidy are complements, but carbon tax most important (cf. Fischer and Newell 2008).


Share of renewables (rE/E)
[tones of CO2 equivalent]
1
0.8
0.6
0.4
0.2
0
2005
2015
2025
2035
2045
2055
2065
2075
2085
2095
BAU
BAU_CT
BAU_rE
BAU_RR
BAU_ALL
CLIM_CT
CLIM_rE
CLIM_RR
CLIM_ALL

Growth – environment trade-off → How costly?

Conclusions

- Okullo et al (2015): deviating from fossil is costly but very small growth effects!

- Acemoglu et al (2012): temporary effects, no loss of long-run growth

- Other studies (cf. Ricci 2007 survey): win-win possible through:
    - productivity effects:
      Higher environmental quality increases productivity: soil quality, workers health (Pautrel 2012, Oueslati 2002).
    - depreciation and defensive activities (e.g. Bretschger)
    - reallocation effects:
      Shifting way from polluting production stimulates growth-promoting activities: education, R&D.

4. Policy instruments

Green Growth Policy Instruments

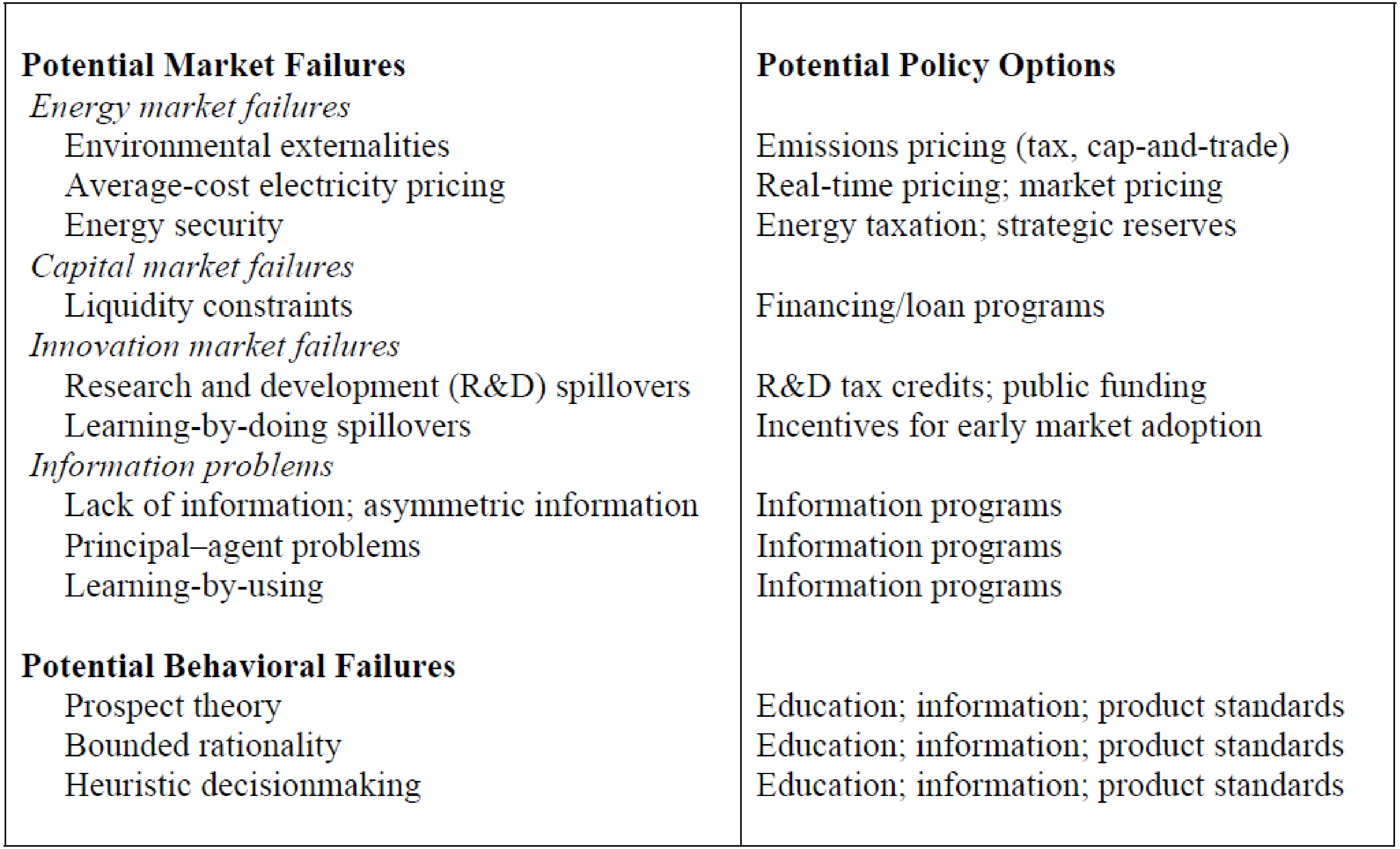
Instrument choice

- Tinbergen:
  - each externality requires a separate policy instrument

- Vollebergh and Van der Werf (2014):
  - reappraisal of technology standards in context of environmental innovation
  - network effects and labeling

- McAusland and Najjar (2014), Smulders and Vollebergh (2015):
  - reappraisal of input and consumption taxes

Energy efficiency policy – Market and Behavioral Failures



Potential Market Failures	**Potential Policy Options**
Energy market failures	
Environmental externalities	Emissions pricing (tax, cap-and-trade)
Average-cost electricity pricing	Real-time pricing; market pricing
Energy security	Energy taxation; strategic reserves
Capital market failures	
Liquidity constraints	Financing/loan programs
Innovation market failures	
Research and development (R&D) spillovers	R&D tax credits; public funding
Learning-by-doing spillovers	Incentives for early market adoption
Information problems	
Lack of information; asymmetric information	Information programs
Principal–agent problems	Information programs
Learning-by-using	Information programs
Potential Behavioral Failures	
Prospect theory	Education; information; product standards
Bounded rationality	Education; information; product standards
Heuristic decisionmaking	Education; information; product standards

Source: Table 2 in Gillingham et al 2009

Carbon pricing and energy taxes

Theory:
Textbook policy: carbon tax equal to “social cost of carbon” = net present value of future damage costs.

Practice:
Textbook environmental tax is way too simple

- A carbon tax is not a simple tax: many fuels, many agents
- Tax design matters a lot: incentives vs. revenue
- Environmental taxes on emissions are the exemption not the rule
- Indeed transaction cost matter too: incentives are not cheap
- Same for overlapping instruments: multi-objective key in practice

What is the best tax system to address environmental externalities?

- Tax base: What things to tax? Who to exempt?
- Tax rate: At what rate?

Complications:

- Administrative costs: costs of implementing, administering, and enforcing the tax, and the cost of monitoring emissions and compliance.
- Pre-existing taxes and regulation (e.g. interaction with ETS).

Taxes with administrative costs

Tax policy rules

- administration costs for emissions monitoring reduce optimal emission tax
- administration costs for taxes in general enhance tax interaction effects → more reason to use an emission tax
- missing taxes → may be both optimal and reason for other taxes to be higher.

Some extremes

- mining tax.
    - Works well for fossil (one-to-one link between inputs from mined fossil to CO2 emissions)
    - Works well as instrument towards circular economy (the aim is to put a price on materials = mine production)
    - Works less for other pollutants (if inputs supplied by upstream sectors have malleable emission intensity downstream, i.e. emission abatement is possible on top of input substitution)
- consumption tax (Lifecycle Analysis Tax)
    - solves border tax adjustment problem
    - but diminishes abatement incentives in the production chain.

Technology subsidies

Technology subsidies reflect externalities in R&D, in particular technology spillovers.

General principle:

- ideal technology subsidies are proportional to the value of the technology spillovers
    - A private innovator finances effort, but many future innovators benefit (spillover)
    - *Social value* of innovation depends on how much future innovators benefit from the spillover.
    - Spillovers differ across sectors but are difficult to measure/anticipate.

Heggedal (2008):

- During transition, green sector grows faster than non-green
- → green-sector-relevant spillovers have a bigger value
- → ideal technology subsidy bigger for green than for non-green.

Lifestyle policies

http://glamurs.eu/

Social Science research and non-mainstream economics:

- Individuals feel time pressure and dissatisfaction with material lifestyle
- People feel unwillingly addicted to consumption habits and trapped into status-consumption
- “Good Life”: more exposure to nature, more leisure and social interaction.

Multiple equilibria:

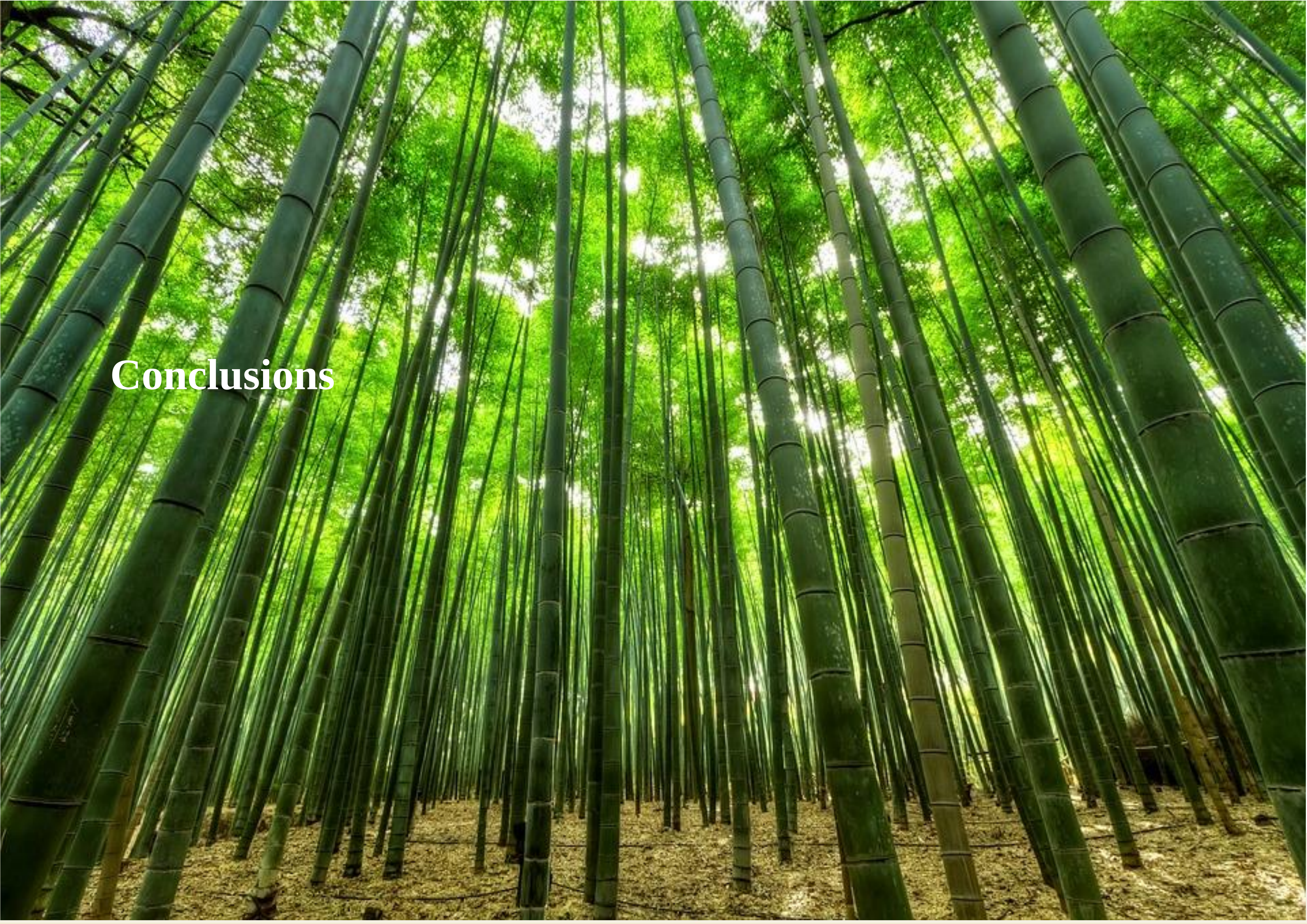
Materialistic/polluting economy …versus… Leisurely/clean economy

Debate:

- Transition to the GoodLife equilibrium: welfare improving but growth reducing?
- “Degrowth”: feasible option in a capitalist market economy?

Policy implication:

- Maybe cost of environmental policy and energy transition is much lower because of habit formation.
- Nudging policies, social benchmarking
- Support lifestyle initiatives
- Link energy policies to social cohesion and inclusion policies → another green transition?



Conclusions

Green Growth Policy challenges

Focus on “Genuine Growth” rather than “Green Growth” or “Growth”

- Report index of sustainable GDP, index of aggregate subjective well-being, indicators of transition.

Consistency, long-run orientation and commitment

- also aims at anchoring expectations
- ETS rather than tax?
- Local ownership of windmills, support local initiatives

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