Can New Ideas Make Abatement Cheap? A Quantitative Macroeconomic Analysis of Innovation and Climate

Stephie Fried
University of California, San Diego

Camp Resources
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Clean Power Plan: Reduce Carbon Emissions by 30%

Debate in Washington: how much will this cost?

"Dagger in the heart of the middle class" that "will leave millions of Americans freezing in the dark" -Mitch McConnell, Joseph Base

versus

"Spur innovation and strengthen the economy" -Gina McCartney

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Answer?

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- In turn depends on technology

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This paper: response of technology and prices to climate policy

Quantitative Model of Directed Technical Change

Key dynamic: price elasticity of energy innovation

- Few historical examples with carbon taxes
- Empirical evidence of this elasticity from oil shocks

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This paper

- Start with Acemoglu, Aghion, Bursztyn, Hemous (2012)
  - AABH $\implies$ price elasticity of innovation is infinite
- Add flexibility (allow for interior solutions)
- Aggregate oil price shocks
- Discipline primitive parameters using oil shocks

What if We Achieve a 30% Target With a Carbon Tax?

Two cases

1. Exogenous innovation: innovation can't respond to the tax
   $\Longrightarrow$ Technology growth is the same as in the baseline
2. Endogenous innovation: innovation can respond to the tax
   $\Longrightarrow$ Technology growth is different than in the baseline

Exogenous Innovation

What happens to prices?

How big is the tax?

Exogenous Innovation

What happens to prices?

- Green energy price is almost unchanged
- Overall energy costs inclusive of the tax rise 10%

How big is the tax?

Exogenous Innovation

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How big is the tax?

- $\approx$ \$14 per ton CO_2

Endogenous Innovation

What happens to R&D?

What happens to prices?

How big is the tax?

Endogenous Innovation

What happens to R&D?

- R&D in fossil energy falls by 75%
- R&D in green energy rises by almost 50%

What happens to prices?

How big is the tax?

Endogenous Innovation

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Endogenous Innovation

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What happens to prices?

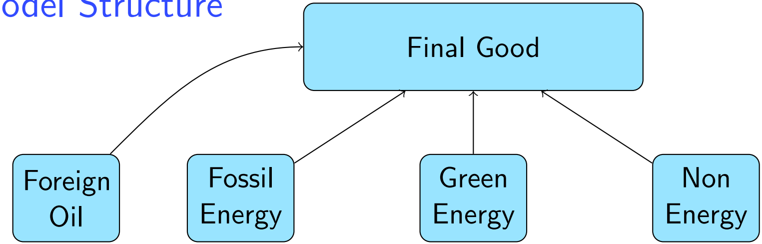
- Green energy price falls by 10%
- Overall energy costs inclusive of the tax are almost unchanged

How big is the tax?

- Almost a quarter the size
- $\approx$ \$4 per ton CO_2

Model

Model Structure



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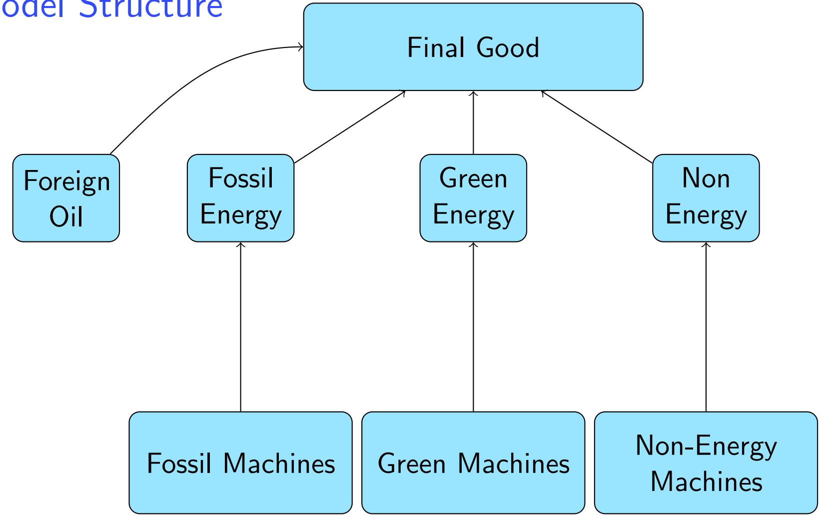

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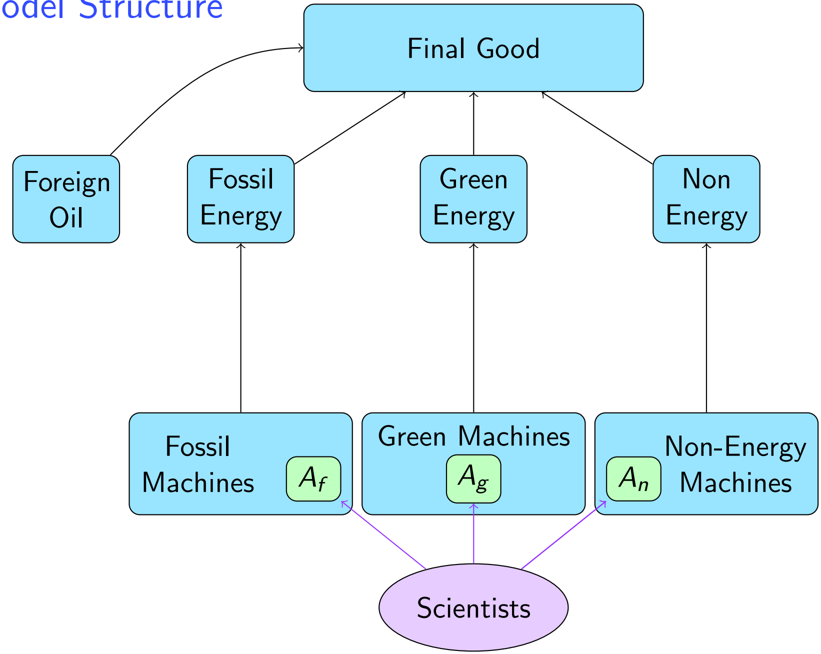

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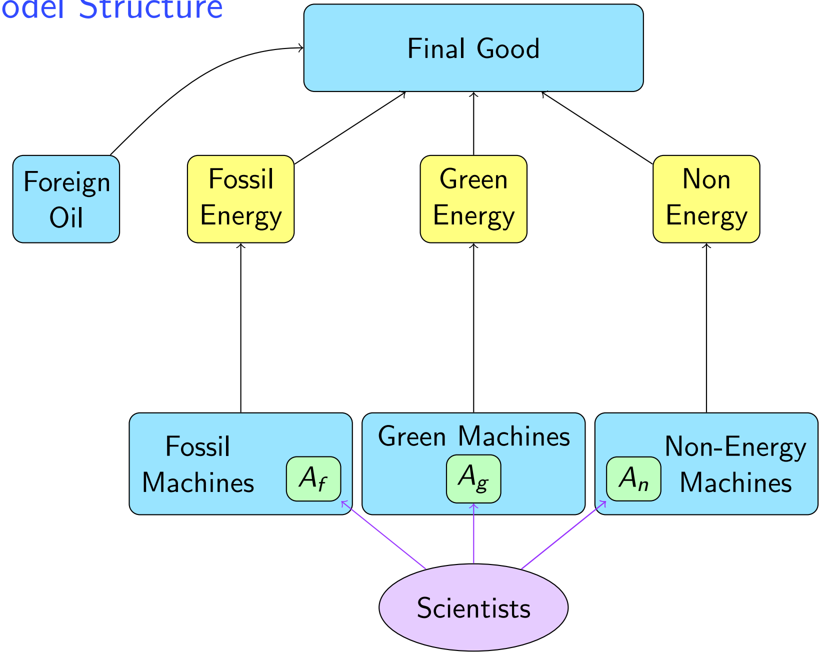


Fossil and Green Energy Production

Intermediate inputs produced competitively

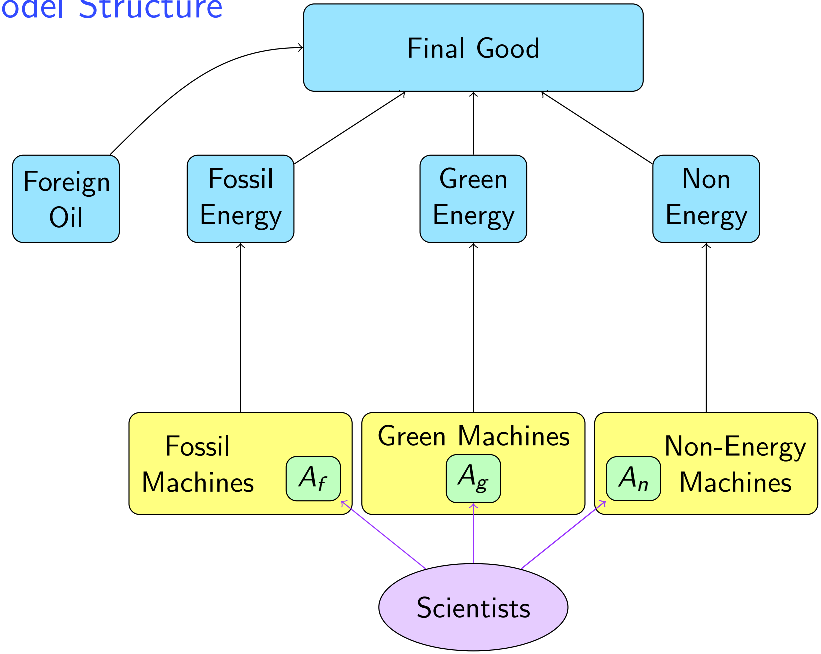
$$G_t = L_{gt}^{1-\beta} \int_0^1 X_{git}^{\beta} A_{git}^{1-\beta} di \qquad N_t = L_{nt}^{1-\beta} \int_0^1 X_{nit}^{\beta} A_{nit}^{1-\beta} di$$

$$F_t = \left(L_{ft}^{\alpha_2} \int_0^1 X_{fit}^{\alpha_1} A_{git}^{1-\alpha_1} di \right) R^{1-\alpha_1-\alpha_2}$$

Key features

- Machines embody technology
- Fossil energy production requires a fixed factor

Model Structure



Innovation: Technology Accumulation

Technology accumulation by sector

$$A_{fit} = A_{ft-1} \left(1 + \gamma S_{fit}^{\eta} \left(\frac{A_{t-1}}{A_{ft-1}} \right)^{\phi} \right)$$

where $A_{ft} = \int_0^1 A_{fit} \, di$ and $A_t = \frac{1}{3} \left(\rho_f A_{ft} + \rho_g A_{gt} + A_{nt} \right)$

Key features

- Diminishing returns to innovation in a period: $\eta \, \epsilon \, (0, 1)$
- Technology spillovers across sectors: $\phi \, \epsilon \, (0, 1)$

Carbon Tax

Constant tax per unit carbon

- Tax inclusive fossil energy price: $P_{ft} + \tau_f$
- Tax inclusive foreign oil price: $P^{\star}_{ot} + \tau_o$
- Tax revenues are returned lump sum

Final good producer's problem

$$\max_{F,G,N,O^{\star}} \{Y - (P_f + \tau_f)F - P_g G - P_n N - (P^{\star}_o + \tau_o)O^{\star}\}$$

Calibration

Approach

Goal: match the empirical response to the oil shocks

1. R&D expenditures on fossil and green energy
2. Labor in fossil energy
3. Fossil energy share of GDP

NSF data on company funds for innovation

1. Fossil Energy
   - Coal, oil, natural gas
2. Green Energy
   - Renewable energy
   - Nuclear
   - Energy conservation and efficiency

Main Parameter Values

Parameter	Model Value
Final good production	
Output elasticity of substitution: ε_y	0.05
Energy elasticity of substitution: ε_e	2.73
Fossil elasticity of substitution: ε_f	3.00
Intermediates production	
Machine share in fossil energy: α_1	0.41
Labor share in fossil energy: α_2	0.18
Labor share in non-energy: $1-\beta$	0.64
Research	
Across-sector technology spillovers: ϕ	0.47
Diminishing returns: η	0.81
Technology weight: γ	1.34
Aggregation ratio: $\frac{\rho_f}{\rho_g}$	0.86
Aggregation weight: ρ_f	8.53e-6
Number of scientists: S	0.08
Time period: 5 years	

Policy Experiments

Experiment: 30% Reduction in Emissions by 2030

Setup

- Tax is announced in 2010 and goes into affect in 2015
- Compare variables in 2030 between tax and baseline path

Analyze two scenarios

1. Exogenous innovation
2. Endogenous innovation

Aggregates: % Difference from Baseline in 2030

	Exogenous Innovation
Innovation	
Fossil R&D effort: S_f	0
Green R&D effort: S_g	0
Prices	
Fossil price: P_f	-9.0
Post-tax price: $P_f + \tau_f$	8.1
Green price: P_g	-0.2
Composite price: P_e	3.1
Tax: \$/ton CO_2	13.6
Climate	
Emissions	-30.2
Carbon stock	-5.2

Aggregates: % Difference from Baseline in 2030

	Exogenous Innovation	Endogenous Innovation
Innovation		
Fossil R&D effort: S_f	0	-75.0
Green R&D effort: S_g	0	41.1
Prices		
Fossil price: P_f	-9.0	-0.3
Post-tax price: $P_f + \tau_f$	8.1	16.8
Green price: P_g	-0.2	-9.9
Composite price: P_e	3.1	-0.9
Tax: \$/ton CO_2	13.6	3.6
Climate		
Emissions	-30.2	-30.2
Carbon stock	-5.2	-5.2

Consumption and Welfare

% Difference from baseline in 2030

	Exogenous Innovation
Consumption (No climate benefits)	-0.9
Consumption (Climate benefits)	-0.5

Consumption Equivalent Variation (CEV)

	Exogenous Innovation
No climate benefits	-0.9
Climate benefits	-0.7

Consumption and Welfare

% Difference from baseline in 2030

	Exogenous Innovation	Endogenous Innovation
Consumption (No climate benefits)	-0.9	-0.1
Consumption (Climate benefits)	-0.5	0.2

Consumption Equivalent Variation (CEV)

	Exogenous Innovation	Endogenous Innovation
No climate benefits	-0.9	-0.2
Climate benefits	-0.7	-0.03

Thank You!