

Policies to Address Climate Change

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Economics of Climate Change

AEA Continuing Education Workshop

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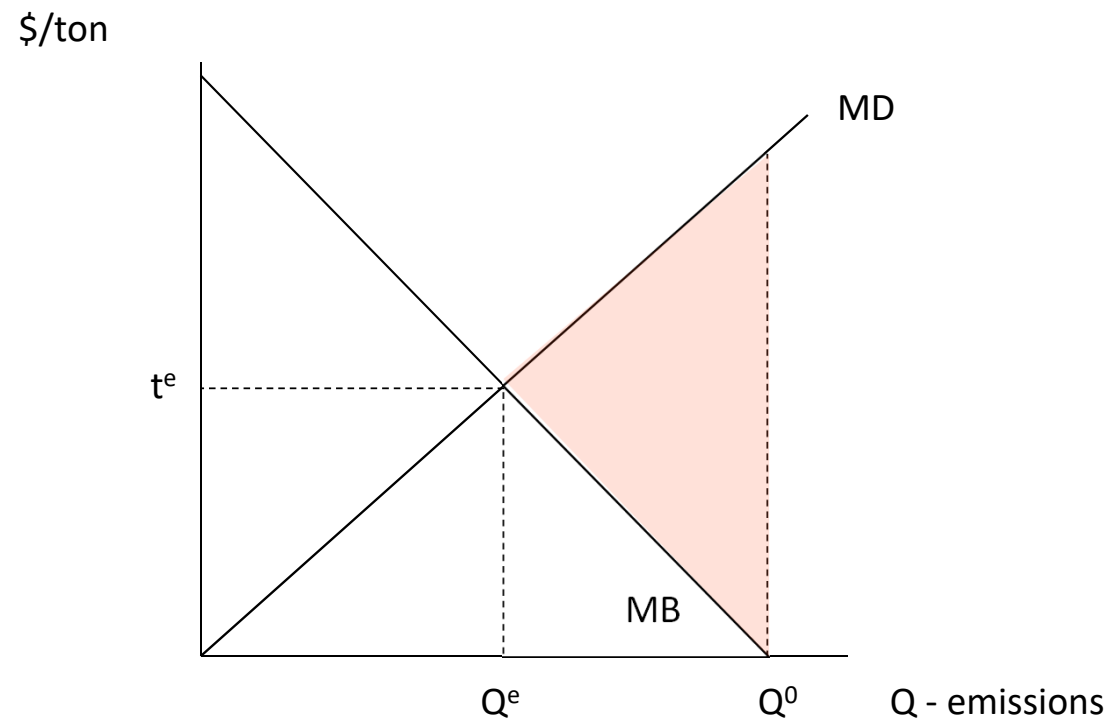
Outline of Lecture

- Market-based approaches to pollution problems
 - Carbon tax
 - Cap and trade
- Other approaches
- Assessing instruments
 - Distributional Impacts
 - Carbon pricing economic impacts
- Political economy
- Second-best considerations

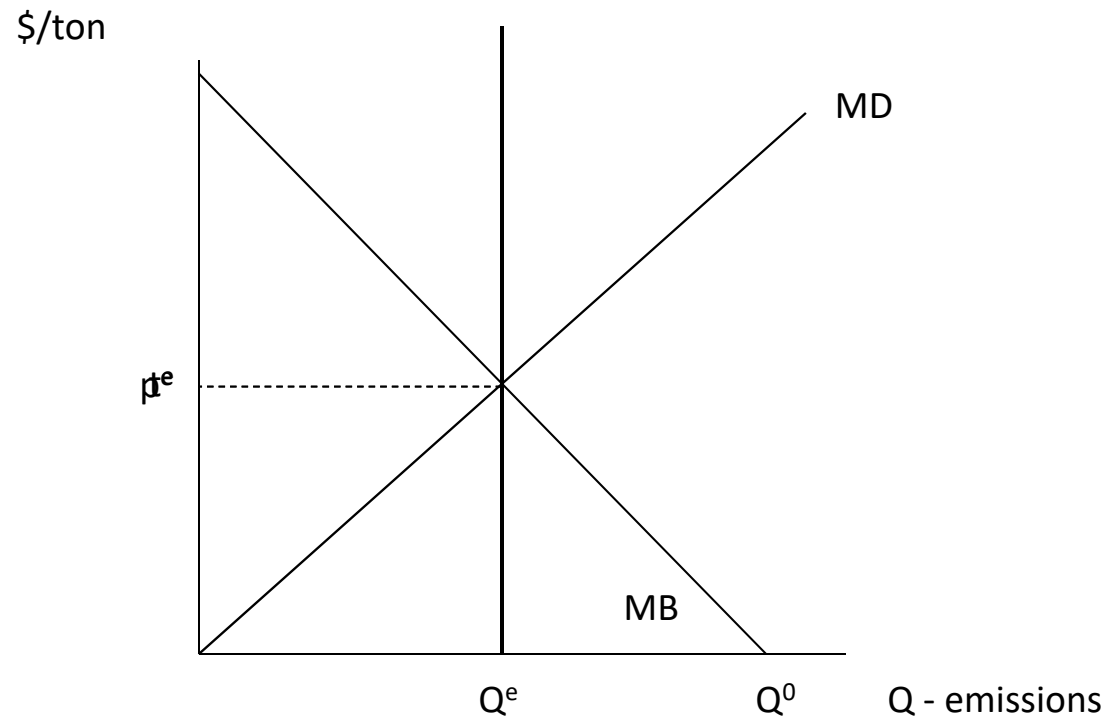
Market Based Instrument

- Pigouvian prescription
 - Set tax on pollution equal to social marginal damages
- Cap and Trade is an alternative approach
- If no uncertainty, instruments are equivalent
 - Tax: set price and emissions quantity adjusts
 - Cap and Trade: set cap and allowance trading price adjusts
- Equivalence breaks down if uncertainty over marginal costs of abatement

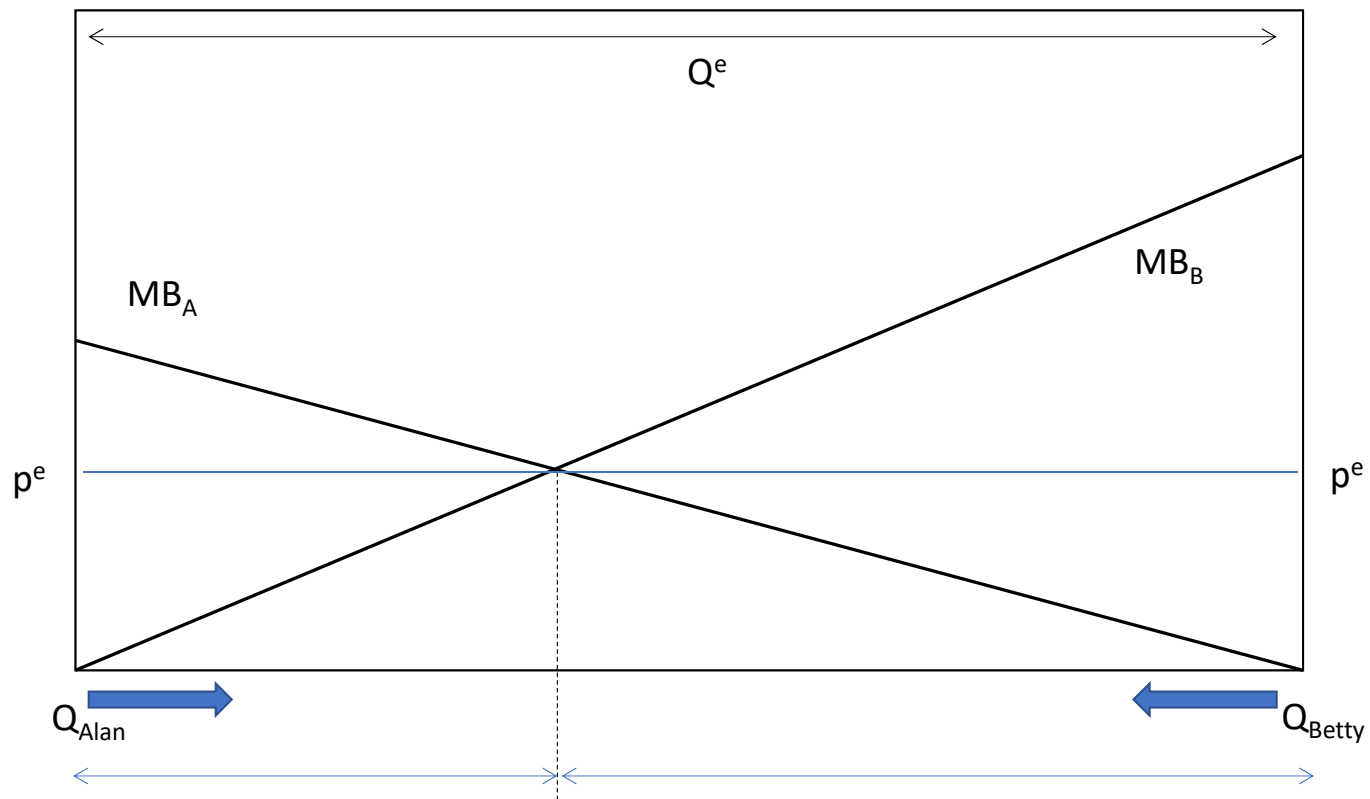
Pigouvian Tax



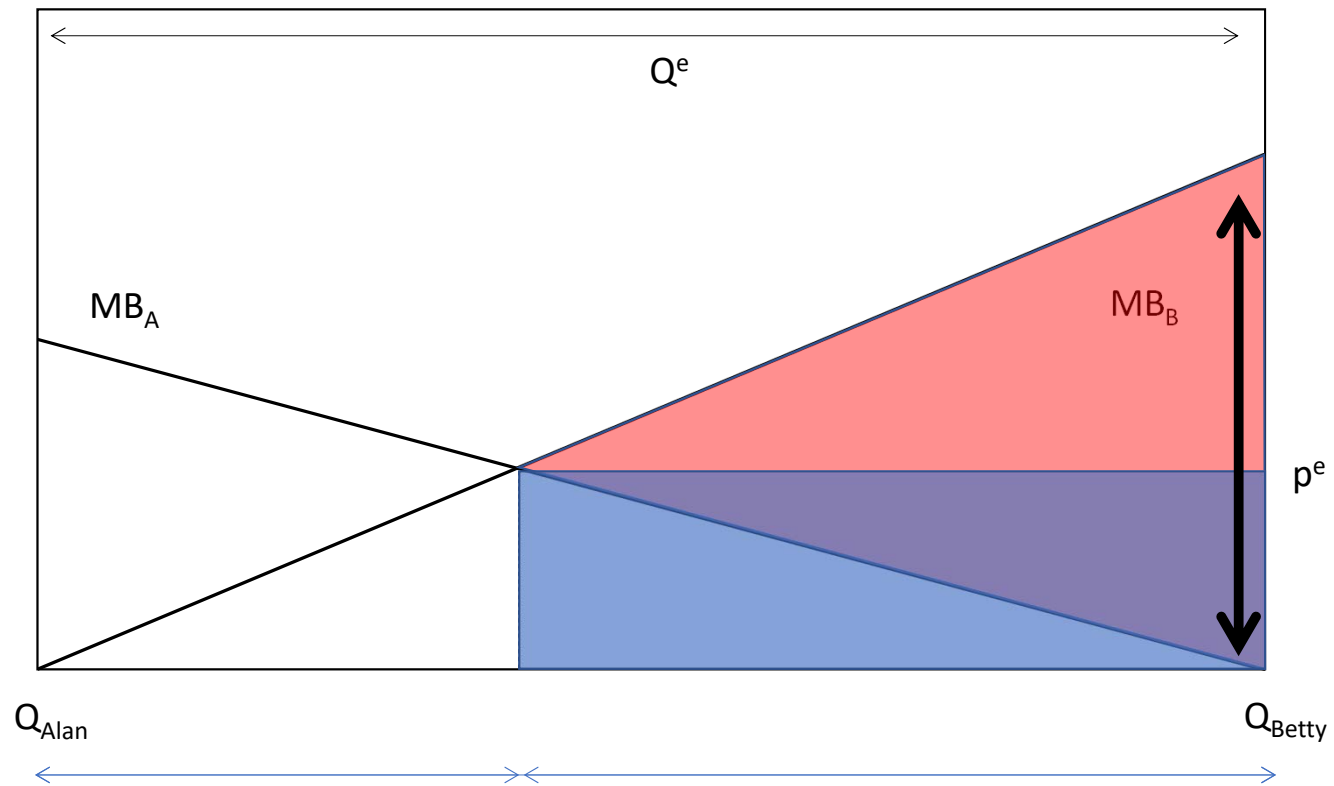
Cap Emissions



Cap and Trade



What if Alan Gets All Allowances?



Price v. Quantity: Economic Efficiency

- Weitzman (1974) is the seminal analysis
 - Simple rule for a flow pollutant
 - Model generalized by others for stock pollutant
 - Results unchanged except, perhaps, for the existence of banking and borrowing
 - Provides flexibility to firms, suggesting a tilt towards cap and trade
- Weitzman (2018) updates analysis to consider this possibility

Weitzman (2018)

- Two period model
- Period 1:
 - Government sets policy for both periods
 - Firm (but not government) observes realization of marginal abatement cost shocks in *both* periods
 - Firm chooses optimal abatement policy for period 1 and banks or borrows as desired
- Period 2:
 - Firm chooses optimal abatement policy for period 2

Weitzman (2018)

$$C_i(q_i; \theta_i) = f_i(\theta_i) + (\gamma + \theta_i)(q_i - \bar{q}) + \frac{c}{2}(q_i - \bar{q})^2, \quad i = 1, 2$$

$$MC_i(q_i; \theta_i) = \gamma + \theta_i + c(q_i - \bar{q}), \quad i = 1, 2$$

pollution
abatement

$$E(\theta_i) = 0, \quad i = 1, 2$$

$$B(q_i) = g_i + \beta(q_i - \bar{q}) - \frac{b}{2}(q_i - \bar{q})^2, \quad i = 1, 2$$

$$MB(q_i) = \beta - b(q_i - \bar{q}), \quad i = 1, 2$$

Relating Weitzman q to Policy

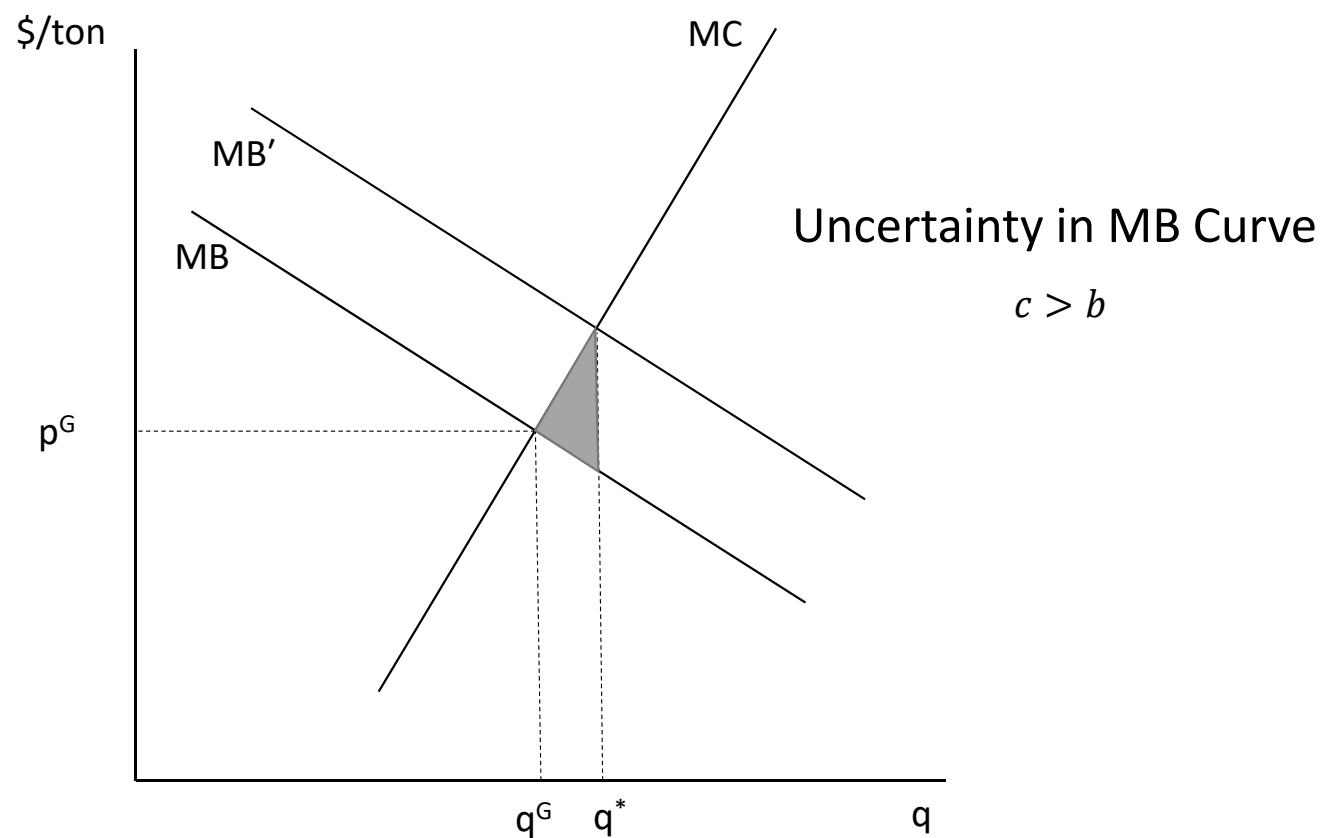
q_t - abatement in period t

E_t^{BAU} — Business as usual emissions in period t

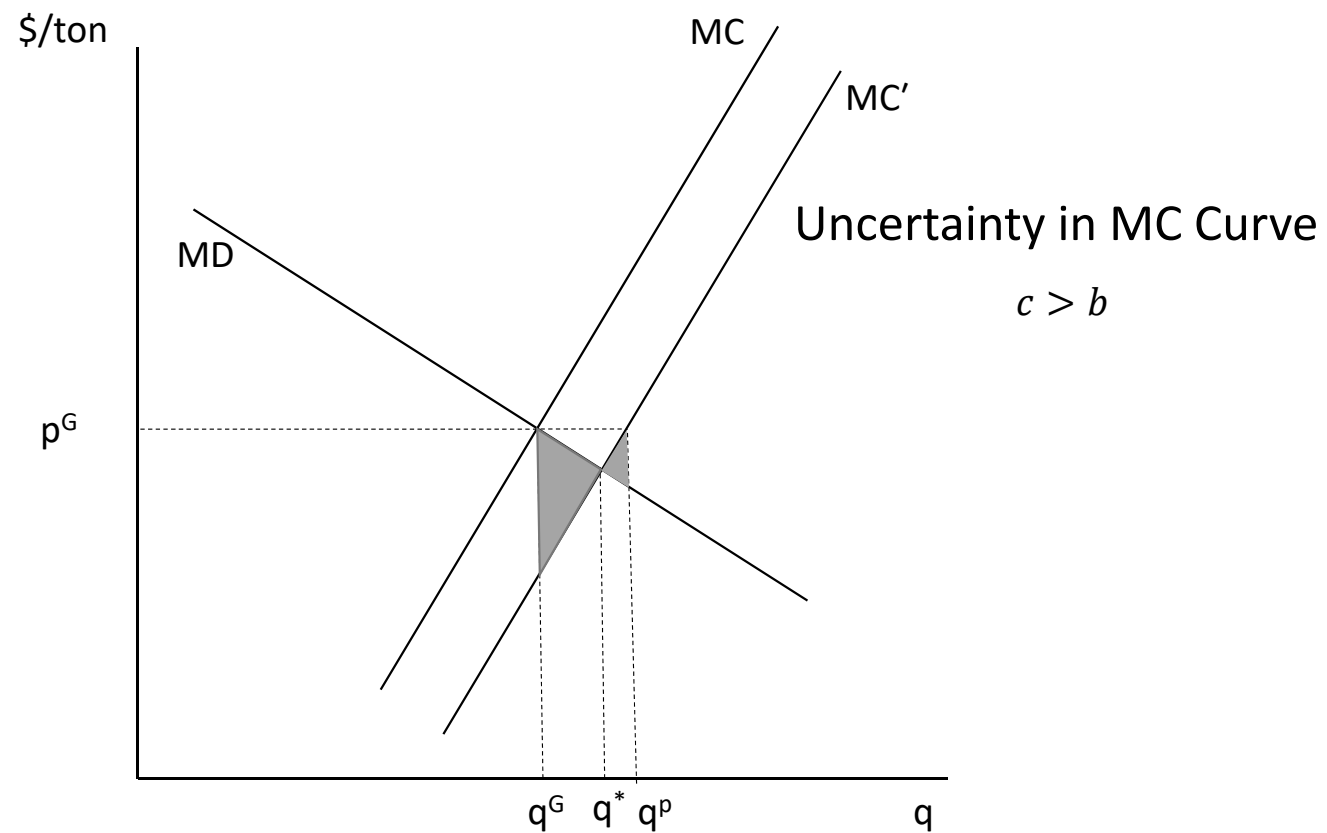
A_t — Allowances in period t

$$A_t = E_t^{BAU} - q_t$$

Intuition from Weitzman (1974)



Intuition from Weitzman (1974)



Adding Dynamics to Weitzman

- Cap and trade programs operate over a fixed time frame
 - EU-ETS Phase III: 2013 – 2020
- Allowance allocation and reconciling (typically) occur annually
- Banking: allow allowances from one year to be saved and used in future years
- Borrowing: allow firms to borrow from a future allocation
- Banking is common, borrowing uncommon (and limited when available)
- With full banking and borrowing, allowance price should rise at the rate of return of a comparable risky asset

Firm Response with Banking

- With full banking and borrowing, Government need only set total quantity of allowances:

$$Q = q'_1 + q'_2$$

- Firms respond optimally to the cap:

$$\hat{q}_1^* = \frac{Q}{2} + \frac{\theta_2 - \theta_1}{2c} \quad \hat{q}_2^* = \frac{Q}{2} - \frac{\theta_2 - \theta_1}{2c}$$

- Knowing firm response, Government sets Q to maximize expected net benefits:

$$Q = 2\bar{q}$$

Expected Net Benefits

- Cap and trade with banking/borrowing:

$$E[B(\hat{q}_1^*) - C(\hat{q}_1^*; \theta_1) + B(\hat{q}_2^*) - C(\hat{q}_2^*; \theta_2)] = k + \left(\frac{E(\theta_2 - \theta_1)^2}{4c^2} \right) (b - c)$$

- Cap and trade with no banking/borrowing:

$$E[B(\bar{q}_1) - C(\bar{q}_1; \theta_1) + B(\bar{q}_2) - C(\bar{q}_2; \theta_2)] = k$$

- Tax:

$$E[B(\tilde{q}_1(p^*; \theta_1)) - C(\tilde{q}_1(p^*; \theta_1), \theta_1) + B(\tilde{q}_2(p^*; \theta_2)) - C(\tilde{q}_2(p^*; \theta_2), \theta_2)] = k + \left(\frac{E(\theta_1)^2 + E(\theta_2)^2}{2c^2} \right) (c - b)$$

Expected Welfare Advantage

- Advantage of fixed over time-flexible quantities:

$$\Delta_{\hat{q}}^{\bar{q}} = - \left(\frac{E(\theta_2 - \theta_1)^2}{4c^2} \right) (c - b)$$

- Advantage of price over time-flexible quantities:

$$\Delta_{\hat{q}}^p = \left(\frac{E(\theta_1 + \theta_2)^2}{4c^2} \right) (c - b)$$

- Advantage of price over fixed quantities:

$$\Delta_{\bar{q}}^p = \left(\frac{E(\theta_1)^2 + E(\theta_2)^2}{2c^2} \right) (c - b)$$

Instrument Ranking

- MC curve steeper than MB curve ($c > b$)

$$E[NB(p)] > E[NB(\hat{q})] > E[NB(\bar{q})]$$

- MB curve steeper than MC curve ($b > c$)

$$E[NB(\bar{q})] > E[NB(\hat{q})] > E[NB(p)]$$

Intuition

- Why isn't time-flexible cap strictly preferred to fixed cap?
- Time flexible cap equalizes marginal costs across periods but leads to unequal marginal benefits
- Increased variability in q lowers benefits with higher b meaning higher losses in benefits from quantity variability

$$B(q_i) = g_i + \beta(q_i - \bar{q}) - \frac{b}{2}(q_i - \bar{q})^2, \quad i = 1, 2$$

More Intuition

- Time flexible caps equalize marginal costs across periods ...
- ... sort of like a price does
- Time flexible caps are a hybrid of a price and a cap
- If $b > c$, cap preferred to price, so is preferred to a hybrid of a cap and price
- If $c > b$, price preferred to cap, so is preferred to a hybrid of a cap and price

When is Flexible Cap Preferred?

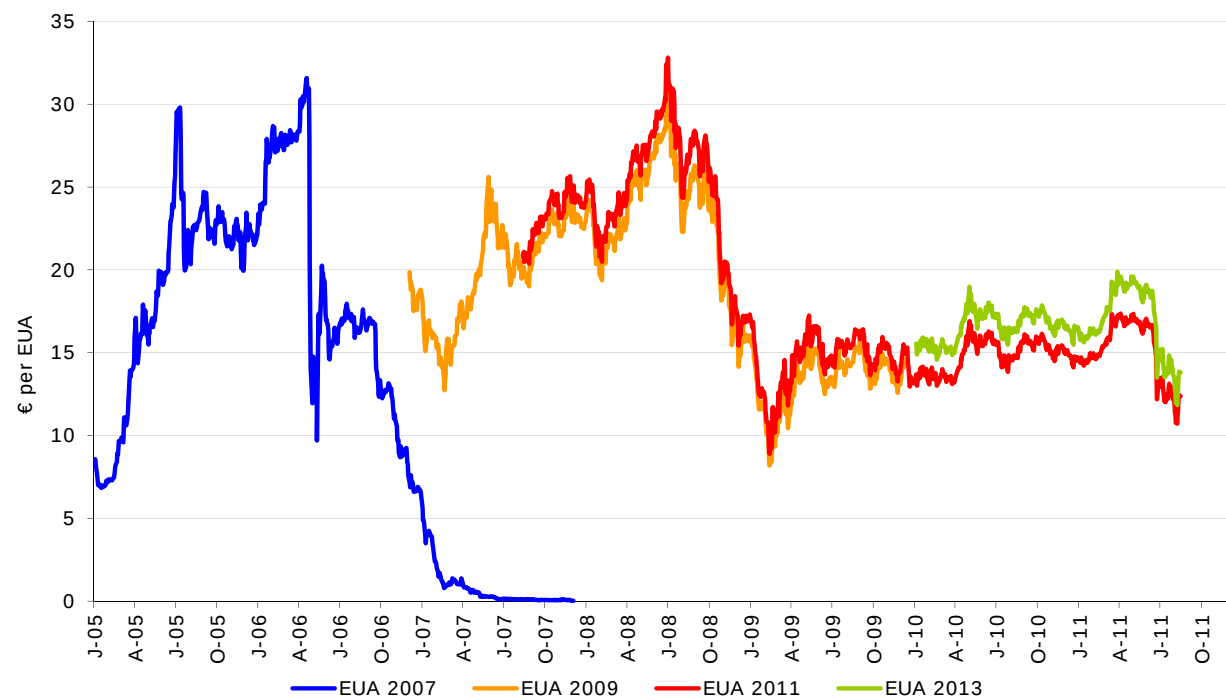
- If $b < c$, but politicians won't use a tax, then flexible cap is preferred to fixed cap
- A second best story

Other Criteria

- The Weitzman PvQ analysis focuses on maximizing expected net benefits
- Other (perhaps non-economic) considerations matter

Issues with Cap and Trade

- Price uncertainty with cap and trade



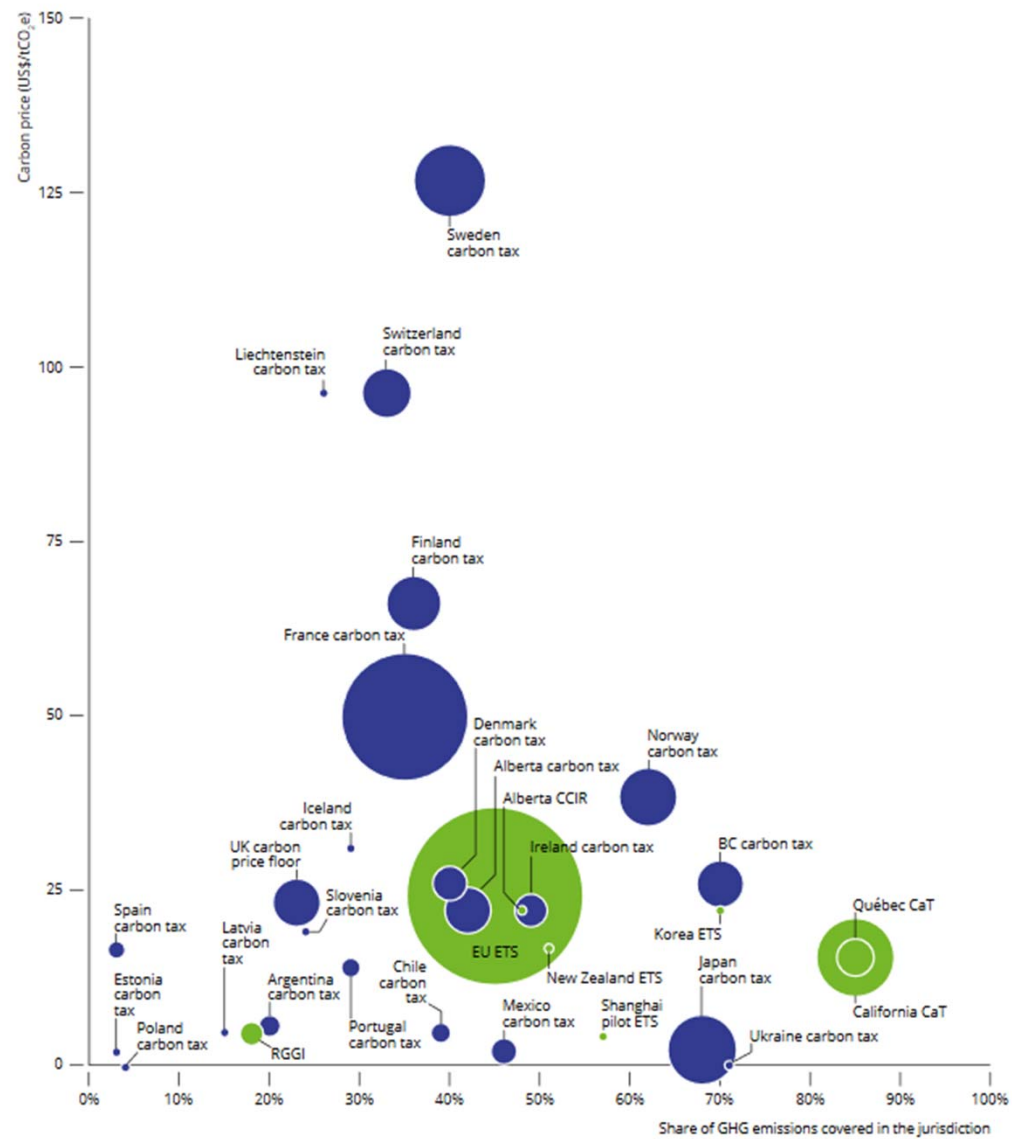
EU-ETS Phase III Prices



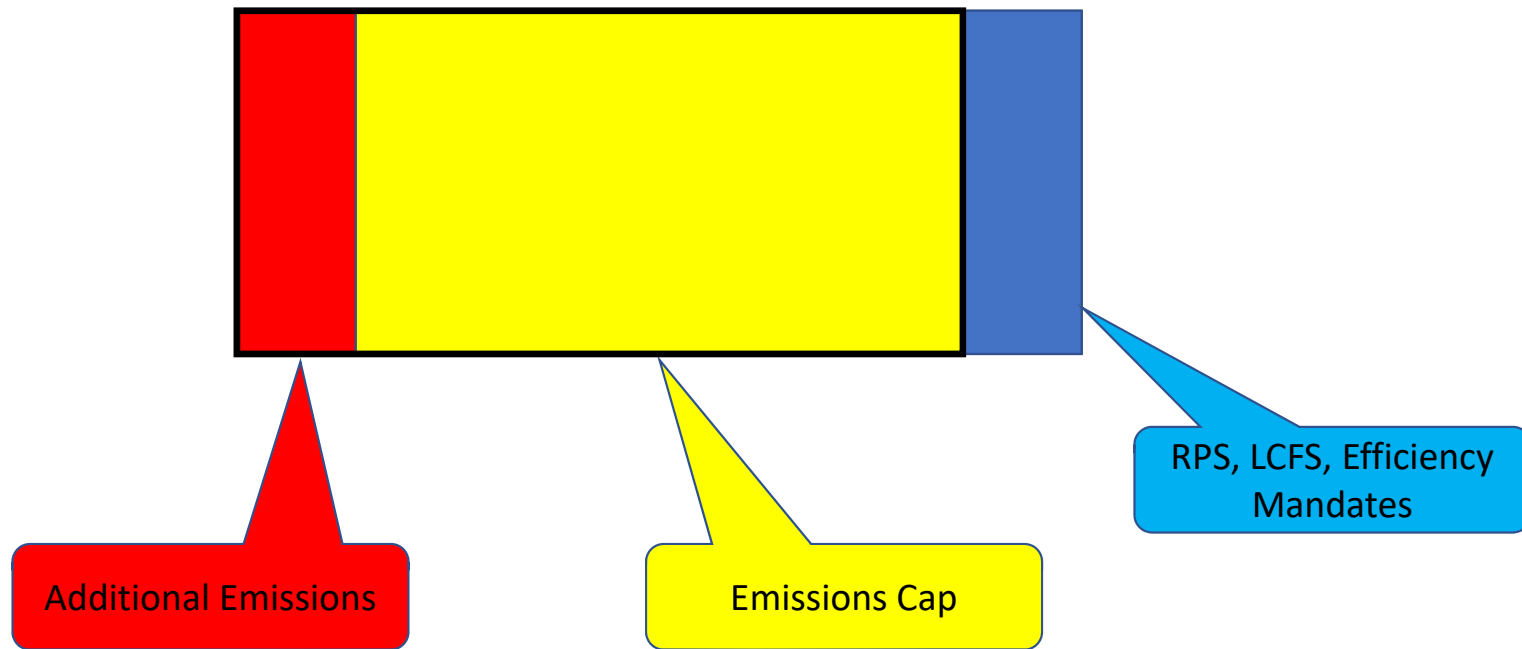
Issues with Cap and Trade

- Price volatility with cap and trade
- Cap and trade has not been able to set an ambitious price

World Bank (2019)



Role of Complimentary Policies



Issues with Cap and Trade

- Price volatility with cap and trade
- Cap and trade has not been able to set an ambitious price
 - Complimentary policies undermine price
- Administrative complexity
 - New administrative oversight needed.
 - Most fossil fuels already taxed. Easy for a carbon tax to piggy back
- Risk of fraud and abuse

European Commission

+ Add to myFT

Cyber-theft halts EU emissions trading

Joshua Chaffin in Strasbourg JANUARY 19, 2011

The European Union's emissions trading system was facing the longest disruption in its history after authorities suspended most trading activities to combat attacks by cyber-thieves.

The European Commission, the EU's executive arm, said trading would be suspended "at least" until January 26, and has called on the bloc's member states to improve security rapidly.

The Commission took the decision after the revelation that emissions allowances worth €7m (\$9.4m) were stolen from an account in the Czech Republic.

In recent days, criminals have also hacked into trading accounts in Austria, Poland, Greece and Estonia, the commission said.

Financial Times (2009)

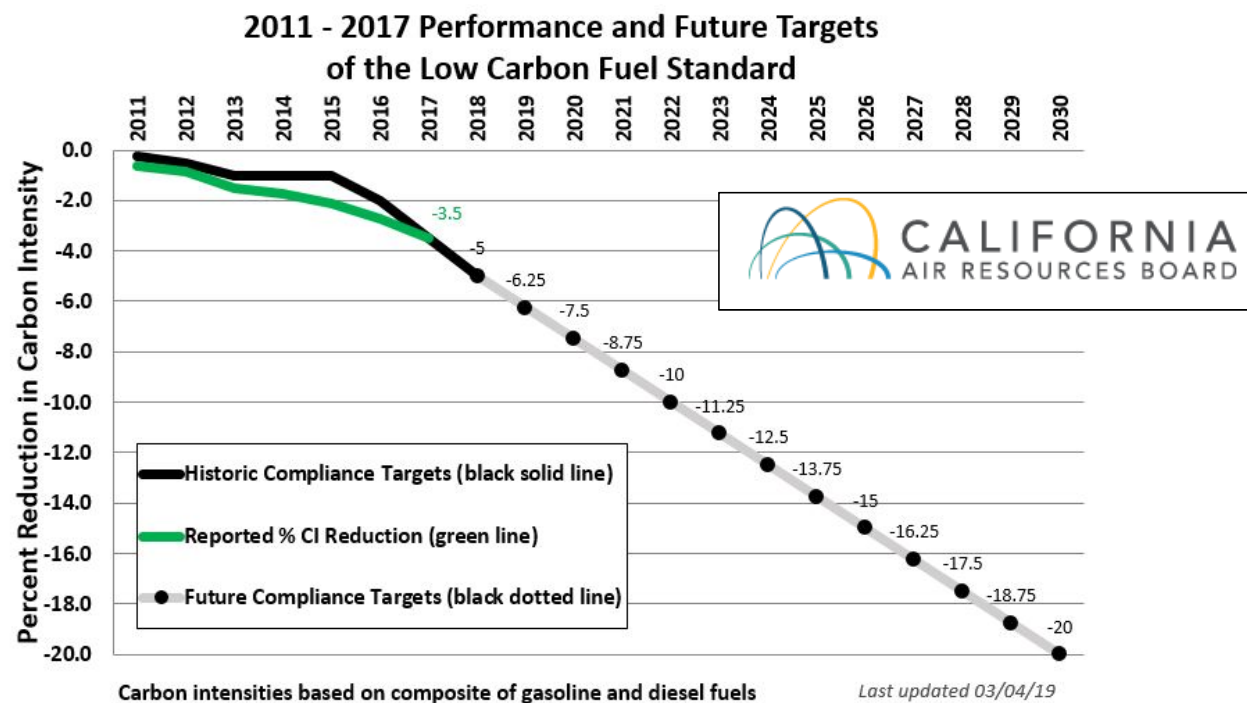
Outline of Lecture

- Market-based approaches to pollution problems
- Other approaches
 - Regulation
 - Mandates
 - Standards
 - Subsidies
 - Nudges, information, etc.
 - Geoengineering
- Assessing instruments
- Political economy
- Second-best considerations

Mandates for Green Penetration

- Many examples of such mandates
 - Low Carbon Fuel Standards
 - Renewable Portfolio Standards
 - Renewable Fuel Standard
 - Corporate Average Fuel Economy (CAFE) Standards
- Standards mandate a minimum share of a preferred fuel
- Combines a subsidy on the preferred fuel with a tax on the non-preferred fuel
- Low Carbon Fuel Standard illustrates the issues...

Low Carbon Fuel Standard



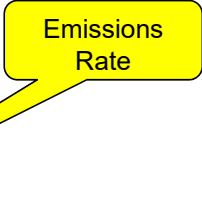
This figure shows the percent reduction in the carbon intensity of California's transportation fuel pool. The LCFS target is to achieve a 20% reduction by 2030 by setting a declining annual standard, or benchmark. The standard was frozen at 1% reduction from 2013-2015 due to legal challenges. Amendments to the LCFS effective in 2019 extended the program targets to 2030.

Low Carbon Fuel Standard

- Assume high (H) and low (L) emission fuels
- Consumers get utility from fuels
 - Marginal damages equal τ
- First best policy:

$$\max_{q_H, q_L} U(q_H, q_L) - C_H(q_H) - C_L(q_L) - \tau(\beta_H q_H + \beta_L q_L)$$

$$\frac{\partial U}{\partial q_i} = MC_i(q_i) + \tau\beta_i$$



Emissions
Rate

Low Carbon Fuel Standard

$$\frac{\beta_H q_H + \beta_L q_L}{q_H + q_L} \leq \sigma.$$

$$\max_{q_H, q_L} p_H q_H + p_L q_L - C_H(q_H) - C_L(q_L) + \lambda[\sigma(q_H + q_L) - \beta_H q_H - \beta_L q_L],$$

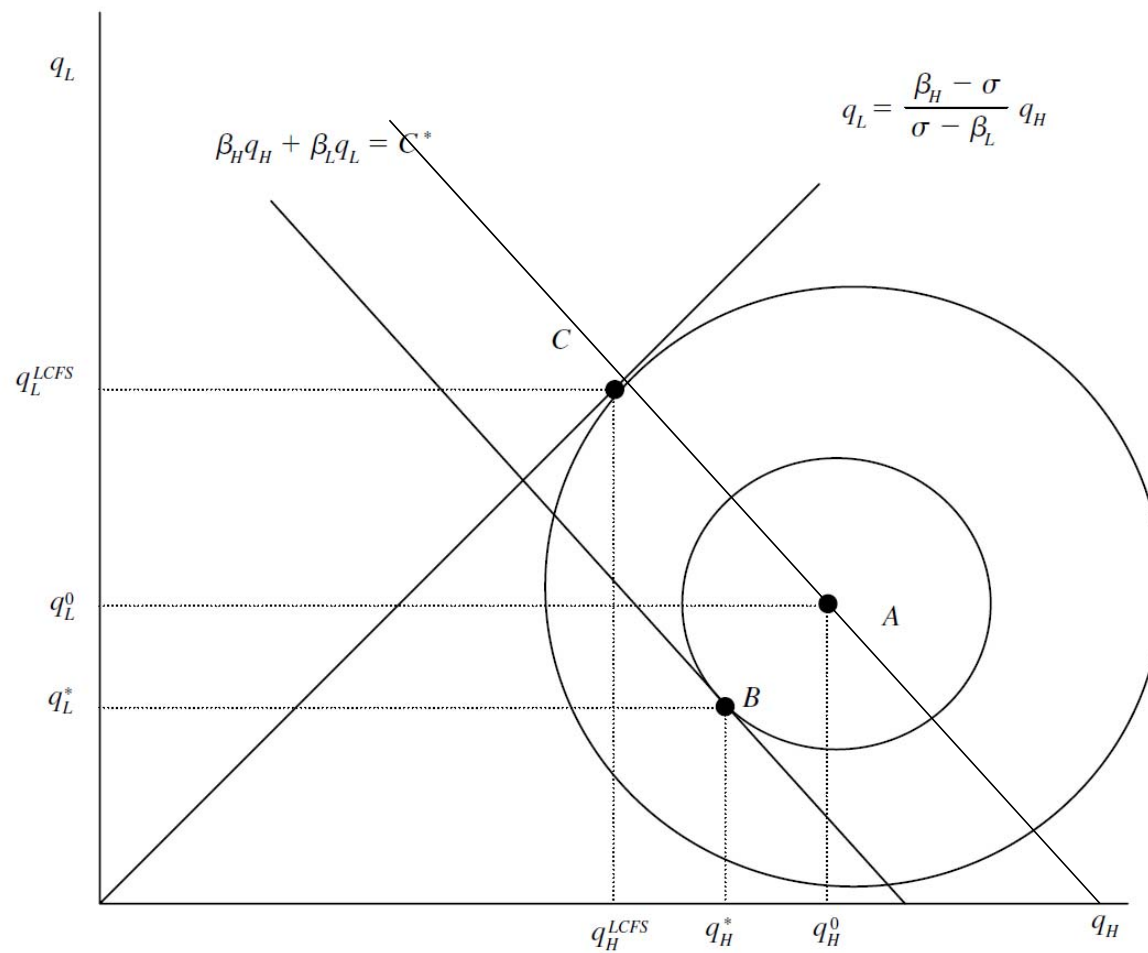
$$p_i = MC_i(q_i) + \lambda(\beta_i - \sigma)$$

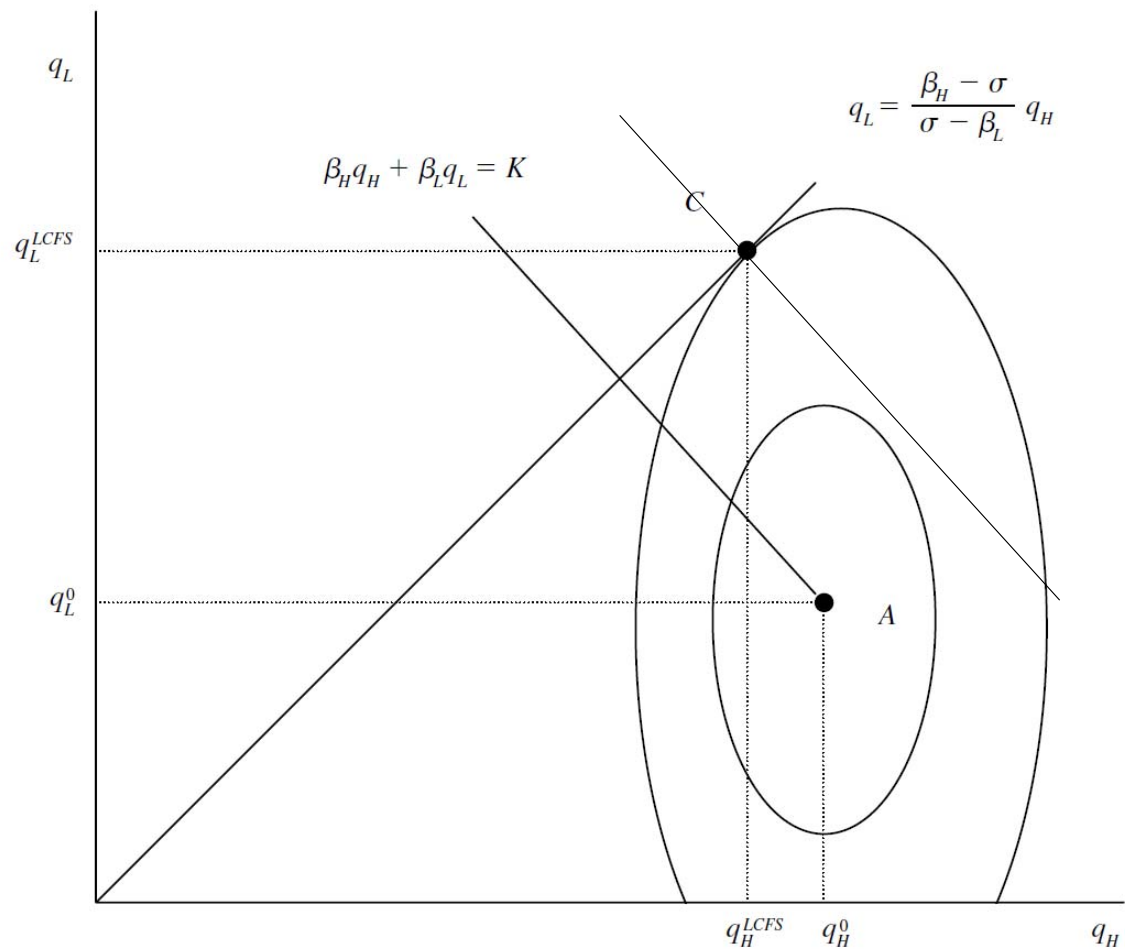
$$\beta_H - \sigma \geq 0$$

$$\beta_L - \sigma \leq 0$$

Low Carbon Fuel Standard: Key Results

- The energy-based low carbon fuel standard cannot achieve the efficient allocation of fuel production and carbon emissions if $\beta_L > 0$.
- If $\beta_L = 0$, the efficient allocation can be attained (by setting $\sigma = 0$) if and only if it is optimal only to produce the low carbon fuel.
- The energy-based low carbon fuel standard may either increase or decrease carbon emissions and may either increase or decrease total energy production.





LCFS Simulations

	LCFS simulation results: more elastic scenario			
	$\sigma = 1^a$	$\sigma = 0.99$	$\sigma = 0.95$	$\sigma = 0.90$
Emissions (MMTCO ₂ e)	1,313.96	99%	92%	80%
Fuel price (\$/gge) ^b	\$2.27	\$2.26	\$2.43	\$2.87
Fuel quantity (billion gge)	117.00	117.05	113.07	104.04
Ethanol quantity (billion gge)	2.56	7.14	24.59	42.98
Δ CS (billion \$)		\$0.25	\$(18.45)	\$(66.03)
Δ PS gasoline – transfers (billion \$)		\$(5.08)	\$(27.67)	\$(52.72)
Δ PS ethanol + transfers (billion \$)		\$3.02	\$18.44	\$38.23
Carbon market transfer (from gasoline to ethanol)		\$4.74	\$38.39	\$73.88
Abatement cost (billion \$) ^c		\$1.81	\$27.67	\$80.52
Shadow value λ (\$/MTCO ₂ e)		\$246.19	\$694.94	\$1,020.41
Average abatement cost (\$/MTCO ₂ e) ^d		\$144	\$257	\$307

SCC: \$136 at 3%, 95th percentile

LCFS Simulations

	LCFS simulation results: less elastic scenario			
	$\sigma = 1^a$	$\sigma = 0.99$	$\sigma = 0.95$	$\sigma = 0.90$
Emissions (MMTCO ₂ e)	1,313.96	99%	87%	75%
Fuel price (\$/gge) ^b	\$2.27	\$2.33	\$5.43	\$14.94
Fuel quantity (billion gge)	117.00	116.66	107.20	96.89
Ethanol quantity (billion gge)	2.56	7.12	23.32	40.02
Δ CS (billion \$)		\$(7.88)	\$(352.69)	\$(1,313.63)
Δ PS gasoline – transfers (billion \$)		\$(21.26)	\$(104.70)	\$(151.42)
Δ PS ethanol + transfers (billion \$)		\$19.49	\$237.22	\$704.64
Carbon market transfer (from gasoline to ethanol)		\$28.18	\$353.63	\$817.44
Abatement cost (billion \$) ^c		\$9.65	\$220.18	\$760.41
Shadow value λ (\$/MTCO ₂ e)		\$1,468.34	\$6,752.45	\$12,124.13
Average abatement cost (\$/MTCO ₂ e) ^d		\$569	\$1,293	\$2,272

LCFS Summary

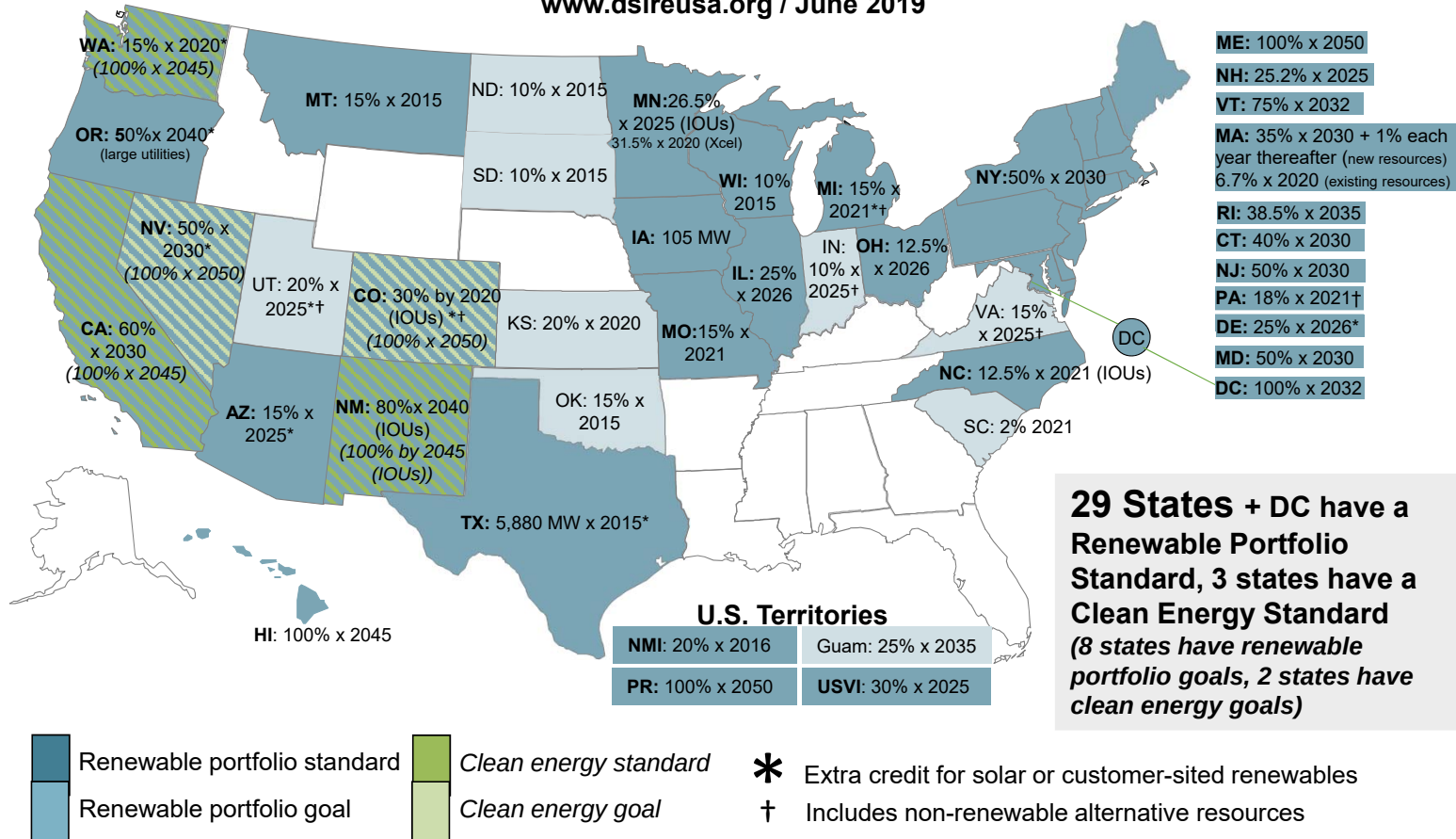
- LCFS unlikely to increase emissions
- Very expensive way to achieve emission reductions
- May be welfare *reducing*
- Consumers or producers (but not both) can be better off under a LCFS

Broader Point

- Policies mandating a certain minimum percentage of a given input combine a subsidy on the favored input and a tax on the disfavored input
 - LCFS and federal RFS subsidize ethanol while taxing gasoline
 - Renewable Portfolio Standards (RPS) require a minimum percentage of electricity from “clean” sources
 - RPS subsidizes wind and solar while taxing natural gas and coal fired electricity fuels

Renewable & Clean Energy Standards

www.dsireusa.org / June 2019



Broader Point

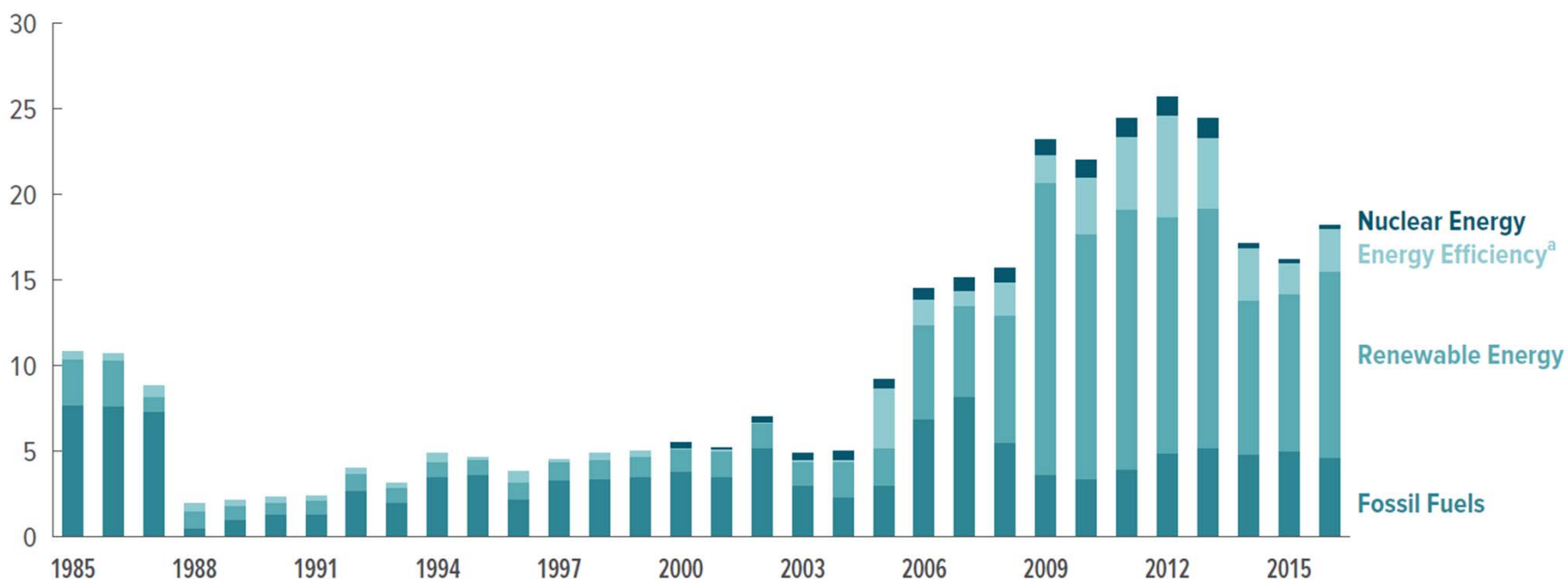
- Policies mandating a certain minimum percentage of a given input combine a subsidy on the favored input and a tax on the disfavored input
 - LCFS and federal RFS subsidize ethanol while taxing gasoline
 - RPS subsidizes wind and solar while taxing natural gas and coal fired electricity fuels
 - Greenstone and Nath (2019) find RPS programs have driven electricity prices up by 11 percent.
 - Knittel et al. (2017) find the RFS program fully passes through to wholesale fossil fuel prices but zero pass through to retail prices
 - Reflects the balancing of tax and subsidy in the mandate
- These policies are highly inefficient – high marginal abatement cost
 - Holland et al. : \$700/ton for an 8 percent reduction
 - Greenstone and Nath: \$115 - \$530/ton from existing RPS programs

Subsidies Through the Tax Code

- Direct spending and tax incentives dominate support for renewable energy production in the United States
- Tax expenditures most significant source of support
 - Production and investment tax credits for renewable energy
 - Clean burning fuel vehicles and refueling property credits
 - Energy efficient construction and renovation credits

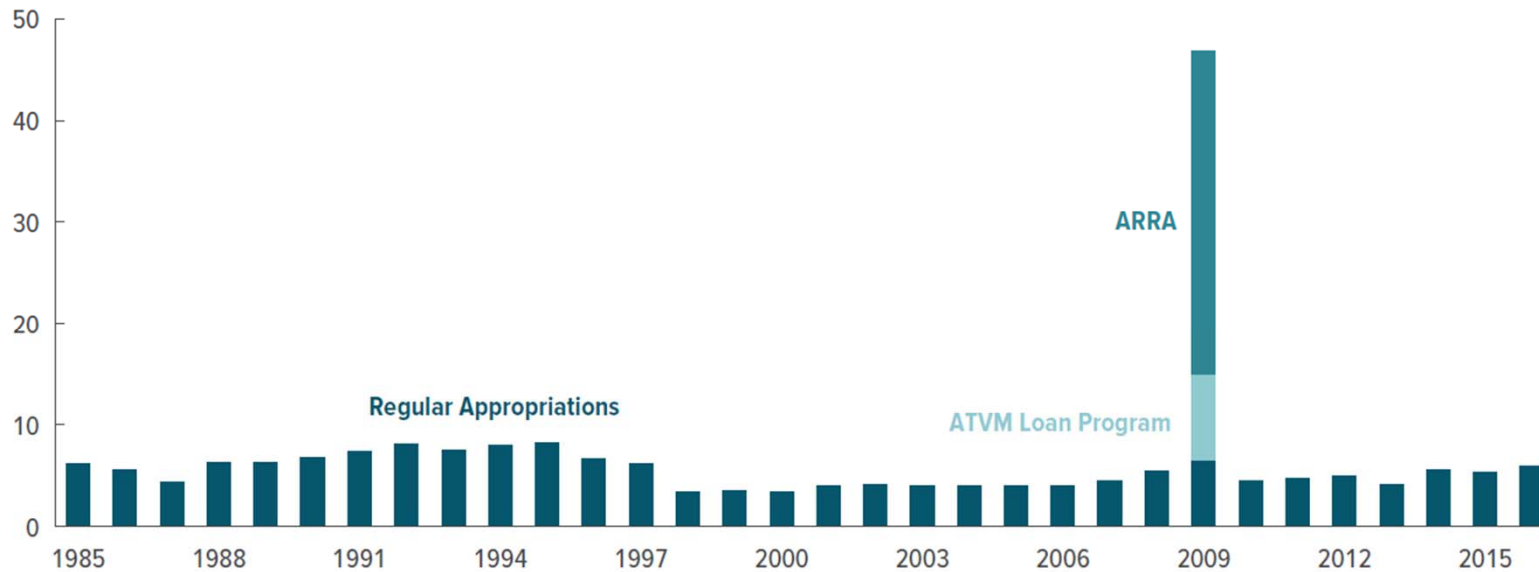
Costs of Energy-Related Tax Preferences, by Type of Fuel or Technology, 1985 to 2016

Billions of 2016 Dollars



DOE's Financial Support for Energy Technologies and Energy Efficiency, 1985 to 2016

Budget Authority, in Billions of 2016 Dollars

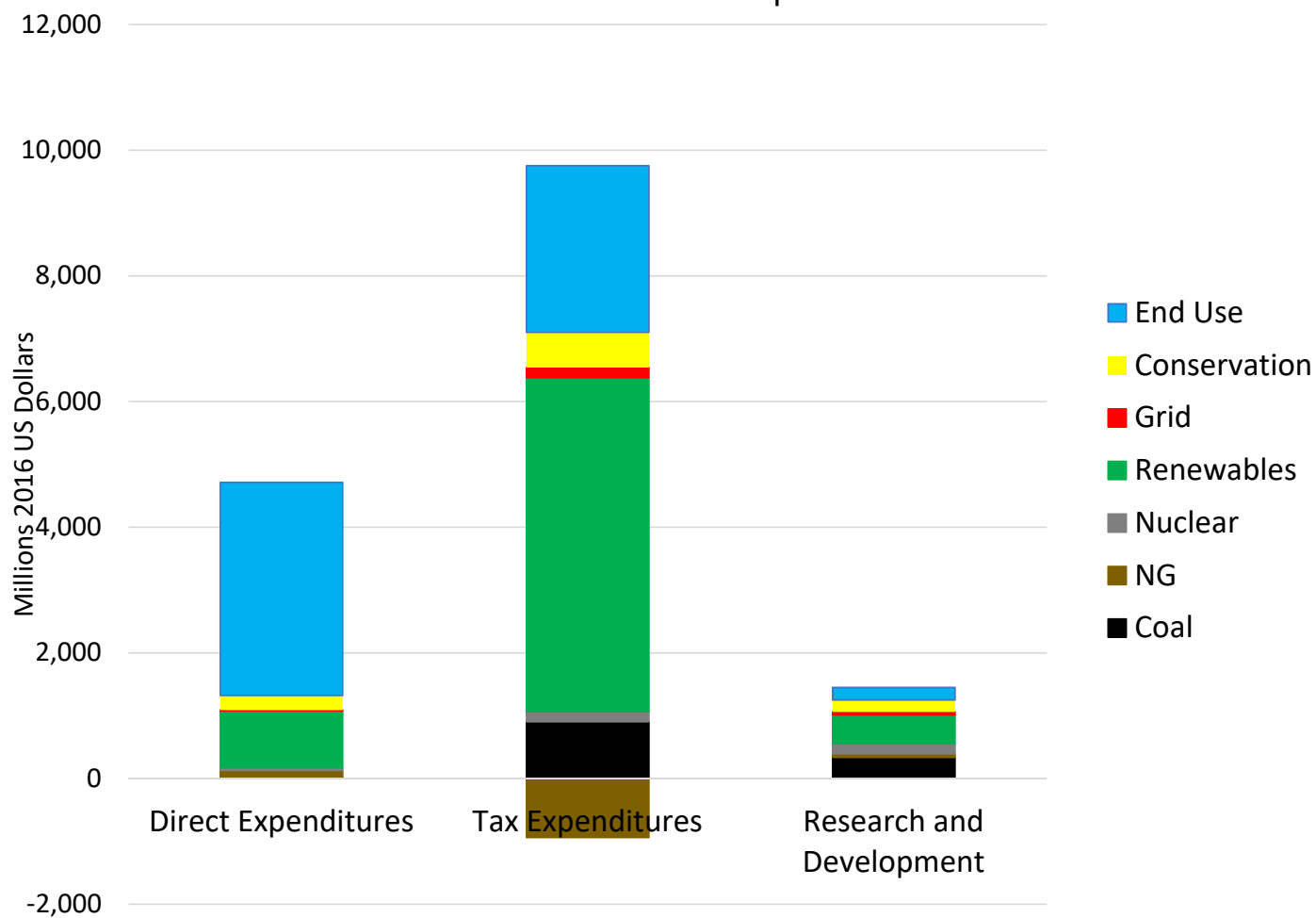


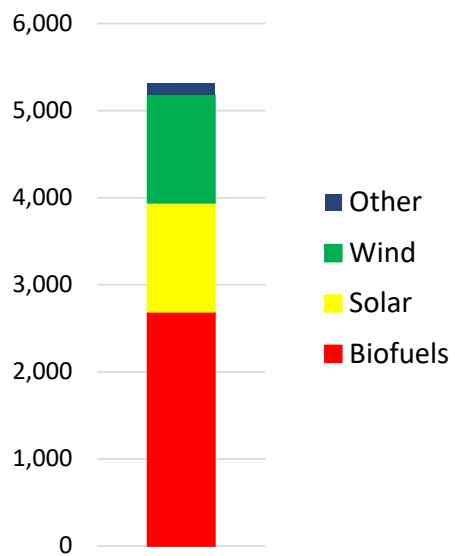
Source: Congressional Budget Office.

The amount indicated for funding provided by the American Recovery and Reinvestment Act of 2009 (ARRA) reflects transfers and rescissions of budget authority for Section 1705 loan guarantees that were made after ARRA was enacted.

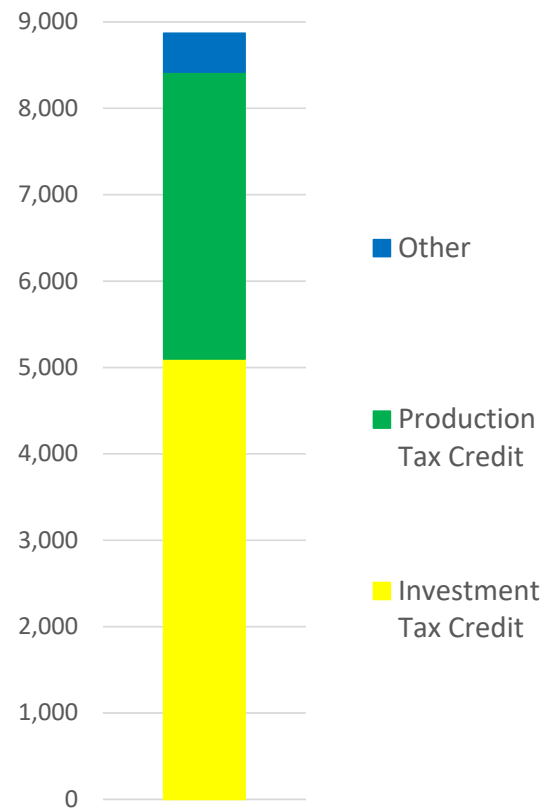
ATVM = Advanced Technology Vehicles Manufacturing; DOE = Department of Energy.

Federal Subsidies and Direct Expenditures: 2016





Renewables: FY 2016



Renewables: FY 2020

The Problem with Subsidies

- Lowers the price of energy
 - Closes off demand channel
- Often conflicts with technology neutrality
 - Tax credit for an EV but no tax credit for doubling the fuel efficiency of an ICE powered vehicle
- Often interacts in unintended ways with other policies
- Much of the subsidy is inframarginal
 - Often highly regressive

Interactions

- Tax credits encourage purchase of EV's
 - But EV's contribute to meeting CAFE requirements
 - Each EV sold allows a gas guzzling vehicle (or two) to be sold
- State RPS programs encourage deployment of wind and solar generating units
 - Drives up cost of federal tax credits for wind and solar

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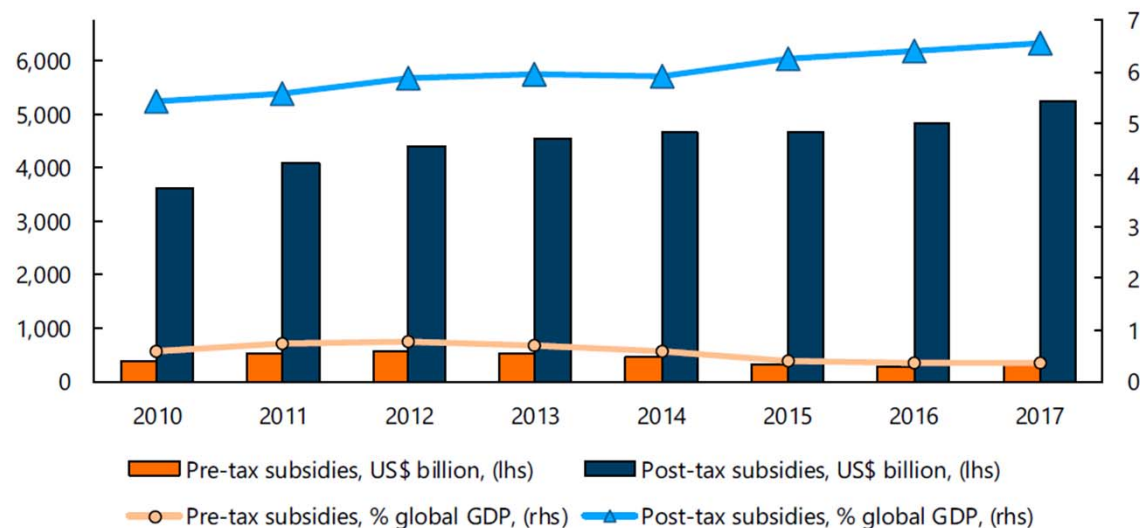
Tax Credits Have Large Inframarginal Component

- Canadian provincial tax rebates on sale of hybrid electric vehicles (2000 – 2007): 2/3 to 3/4 of rebate takers inframarginal (Chandra et al., 2010)
- Mexican energy efficiency program (2009 – 2012): 2/3 of program participants inframarginal (Boomhower and Davis, 2014)
- U.S. State Energy Efficient Appliance Rebate Program (2010 – c.2011): 70 percent of purchasers were inframarginal; another 15-20 percent delayed purchase by a few weeks (Houde and Aldy, 2017)

Global Picture

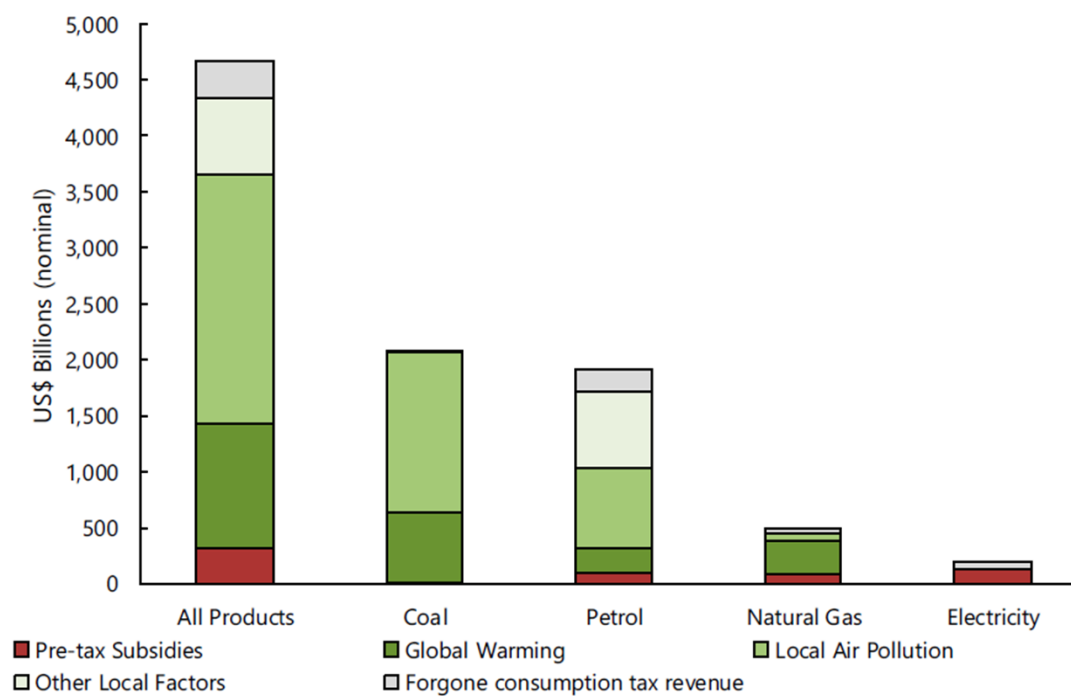
- IMF estimates fuel subsidies taking into account:
 - Difference between consumer price and cost of production (pre-tax subsidy)
 - Difference between consumer price and price accounting for all externalities (post-tax subsidy)

Figure 2. Global Energy Subsidies, 2010–2017



Nature of Subsidy

Figure 4. Global Energy Subsidies by Energy Product and Subsidy Component, 2015



Nudges, Information, and Voluntary Programs

- Nudges can have a high benefit to cost ratio when focused on value of emission reductions from energy savings compared to program costs
 - But actual savings small – on the order of 3 percent based on a study by Allcott and Rogers (2014)
- Programs also ignore costs and benefits to consumers from the nudge effect
 - Nudge can provide benefits if it provides useful information
 - It can also induce costs (guilt, discomfort)
 - Allcott and Kessler (2019) study one home energy reports and find significant heterogeneity in consumer benefits of the reports (both positive and negative)
 - For one study, they find that ignoring consumer impacts leads to an overstatement of the net benefits of over 100 percent (stated gains of \$1.22 billion versus estimated gains of \$0.6 billion).

Nudge Spillovers

- Nudges can offer the promise of an “easy out” and reduce political support for the hard choices (e.g. a carbon tax). Hagmann et al. (2019)

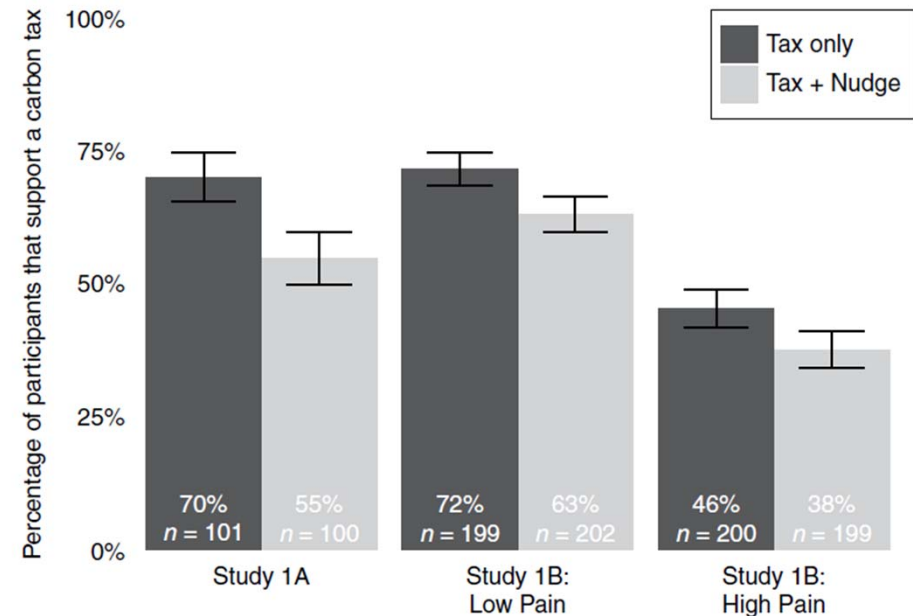
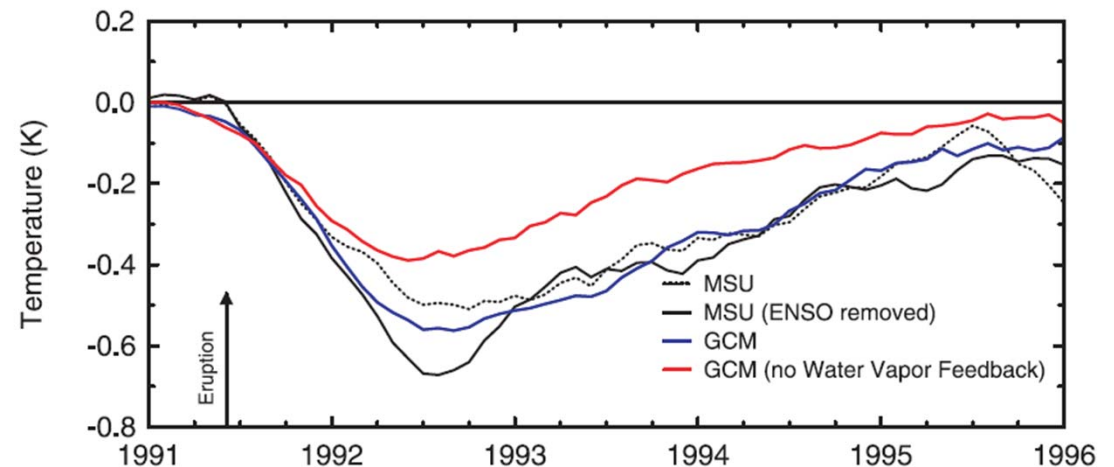


Fig. 1 | Introducing a green energy nudge reduces support for a carbon tax. Percentage of respondents that support implementing a carbon tax when presented with the tax only or the tax and the nudge (Study 1A, Study 1B: Low Pain) and under conditions in which the carbon tax is framed as more burdensome (Study 1B: High Pain). Error bars show $\pm$ one standard error.

Geoengineering

- Solar Radiation Management (SRM) is one of a number of possible geoengineering approaches
- Empirical evidence for its cooling effectiveness:



Soden et al. (2002)

Geoengineering Concerns

- SRM takes the pressure off policy makers to enact politically costly mitigation measures
 - Moreno-Cruz (2015) finds SRM can lead to too little mitigation (substitution)
- But also possible that SRM could lead to too much mitigation
- Two-country, two-period model
 - Mitigation in period 1, SRM in period 2
 - Country specific damages from temperature increase *and* SRM
 - Mitigation in period 1 reduces benefits from SRM in period 2
 - Assume country 1 wishes to do SRM but country 2 does not

Two Stage Game

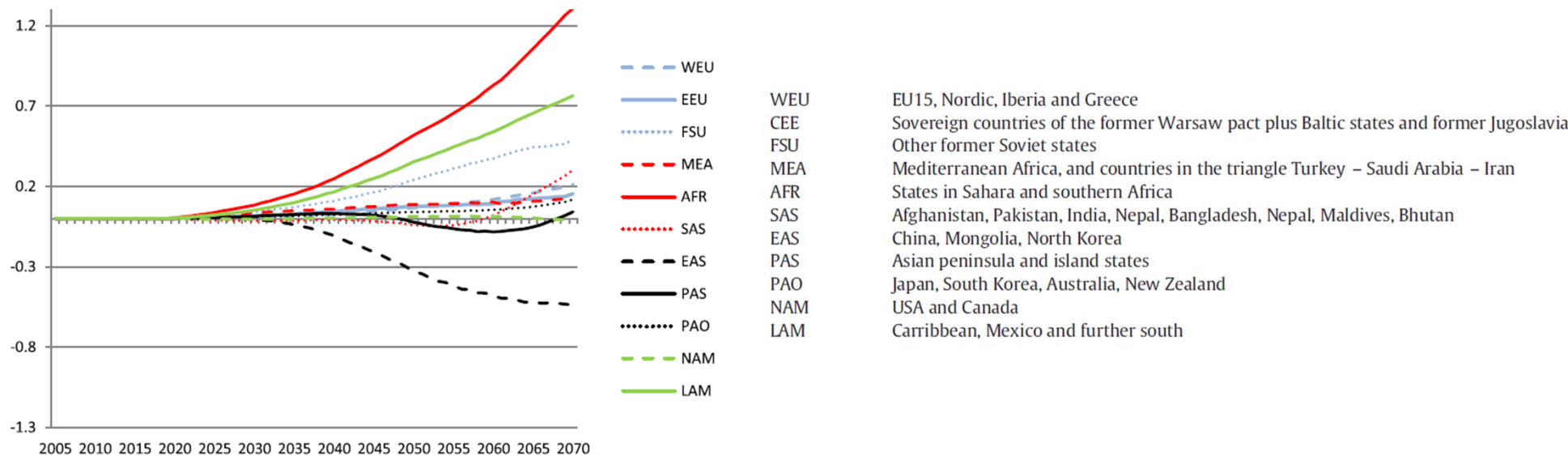
Period 1: Climate
Negotiation over
Mitigation Levels

Period 2: SRM actions
taken

- In period 1, country 1 threatens high SRM in period 2 to induce more mitigation by country 2.
- Country 2 wishes to avoid SRM damages
- Threat is credible as higher mitigation reduces benefits to country 1 from SRM in period 2
- We simply don't know how low-cost SRM availability will affect mitigation efforts

Other Issues with SRM

- Spillovers from individual country actions on SRM highlight the need for global governance (Barrett, 2008)
- SRM has heterogeneous regional impacts (Aaheim et al., 2015)



Outline of Lecture

- Market-based approaches to pollution problems
- Other approaches
- **Assessing instruments**
 - Distributional Impacts
 - Carbon pricing economic impacts
 - Emissions
 - Employment and GDP
- Political economy
- Second-best considerations

Distributional Impacts of Policy

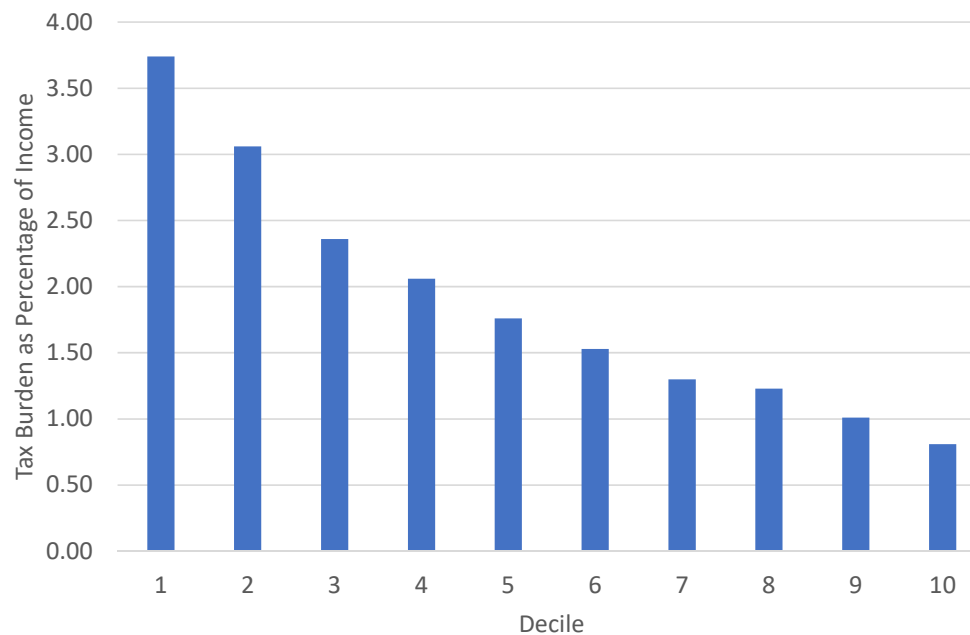
- Distributional analysis commonly done for tax and spending policies
 - Can be done for regulatory policy as well
- Use a carbon tax proposal to motivate key points

Distributional Impacts: Basics

- Burden of a policy is the money-metric measure of change in utility (EV, CV)
- Policy is progressive if burden to income ratio rises with income
 - Regressive if ratio falls with income
- Income as a proxy for well-being
 - Transfers included? Value of leisure?
- Timeframe matters: Annual? Lifetime?
- Unit of analysis: Household? Individual?
- Use of revenue matters
- Full analysis focuses on sources and uses of income

Is a Carbon Tax Regressive?

- Analyses focusing on consumer expenditure patterns tell a portion of the story
- Focus on *uses of income* makes the tax look quite regressive
- Note: use of revenue ignored



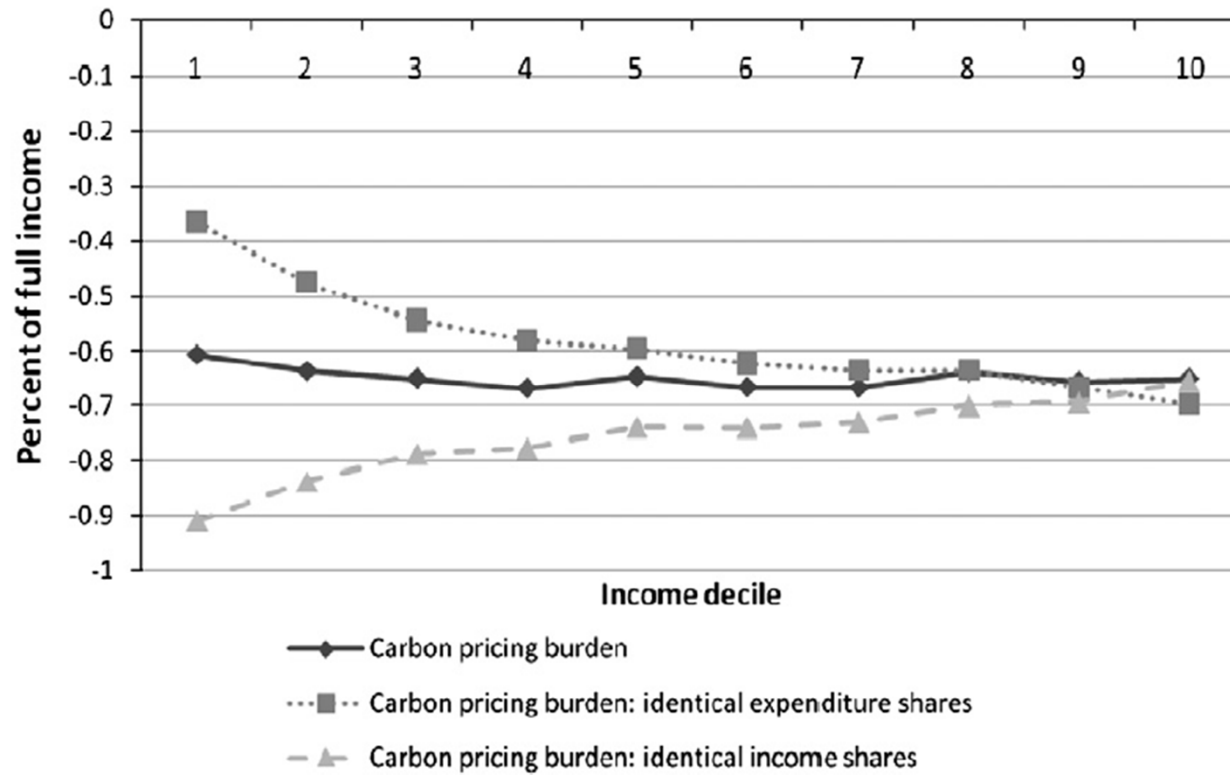
A Full Burden Analysis Accounts For...

- Heterogeneity in consumption patterns across income groups (uses side impact)
- Heterogeneity in factor price impacts across income groups (source side impact)
- Heterogeneity in transfer payments across income groups (source side impact)
- Use of carbon tax revenue
- General equilibrium analysis required

Decomposing Source and Use Impacts

- Source side impacts arise from heterogeneity in factor income shares across income groups
 - Isolate use side impacts by adjusting factor income shares to be constant across income groups
- Use side impacts arise from heterogeneity in consumption shares across income groups
 - Isolate source side impacts by consumption shares to be constant across income groups
- Isolate distributional impacts of tax by using revenue in a way that doesn't enter utility functions

A Decomposition: \$20/ton tax (2006)



Goulder et al. (2019) Decomposition

- Intuition from a one-period model

$$EV = e(P_0, U_1) - e(P_0, U_0)$$

$$C_{source} = \frac{Y_1}{P_0} \qquad U_{source} = U(C_{source})$$

$$e(P_0, U_{source}) = P_0 C_{source} = P_0 \left(\frac{Y_1}{P_0} \right) = Y_1 = e(P_1, U_1)$$

$$EV_{source} = e(P_0, U_{source}) - e(P_0, U_0) = e(P_1, U_1) - e(P_0, U_0)$$

$$EV_{Use} \equiv EV - EV_{source} = e(P_0, U_1) - e(P_0, U_0)$$

Goulder et al. (2019) Decomposition

$$EV_{Source} = e(P_1, U_1) - e(P_0, U_0)$$

$$EV_{Use} = e(P_0, U_1) - e(P_0, U_0)$$

- Adjustment for dynamic model

$$EV_{Source} = e(P_1, U_1, r_1) - e(P_0, U_0, r_0)$$

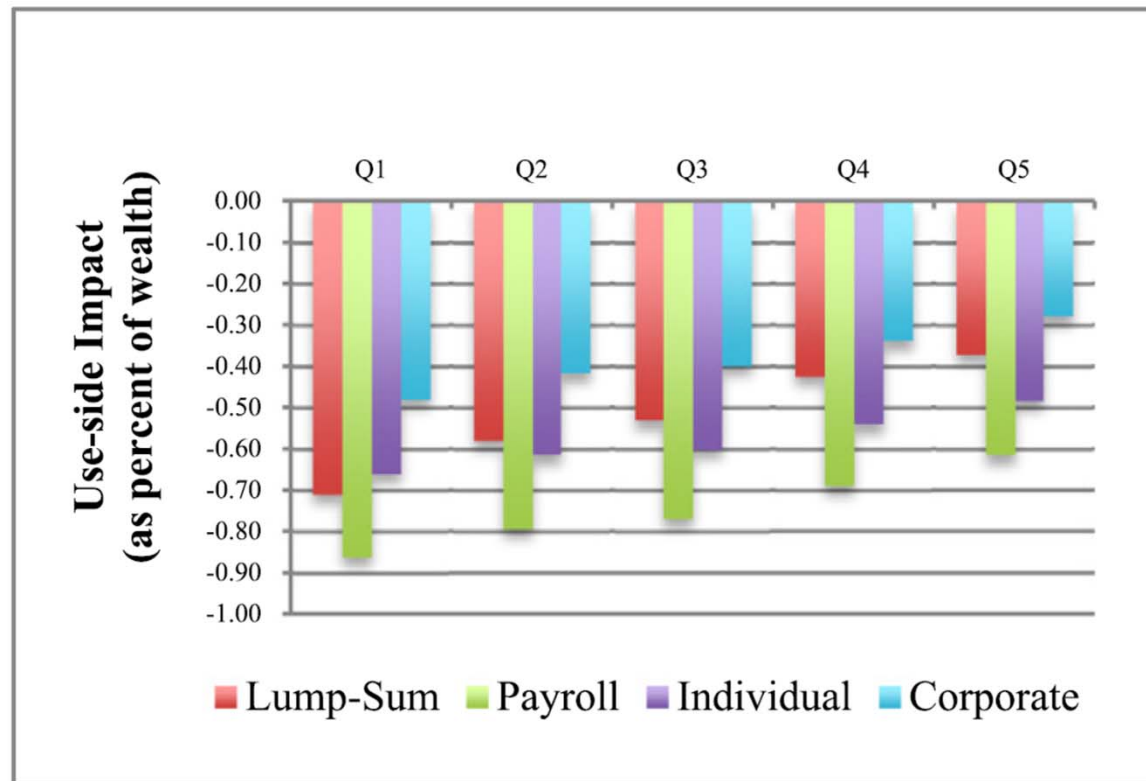
$$EV_{Use} = e(P_0, U_1, r_0) - e(P_0, U_0, r_1)$$

- Comments
 - No *a priori* theoretical basis for decomposition
 - Results similar but not identical to Rausch et al decomposition

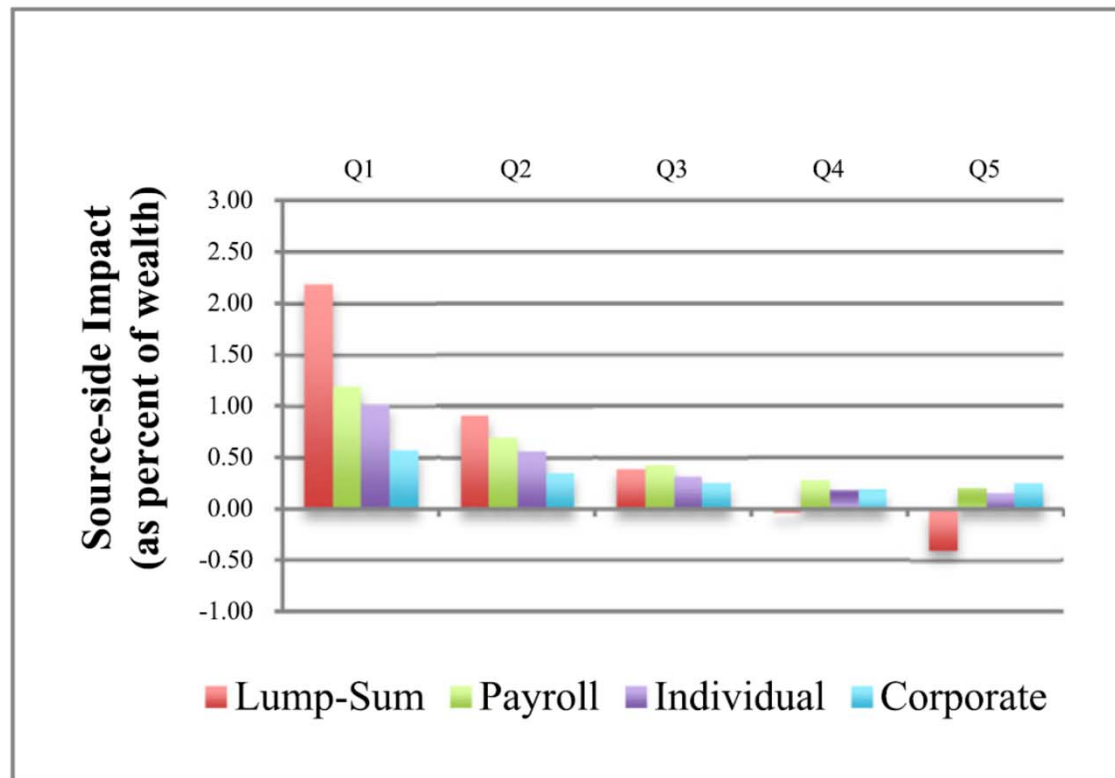
Attributing Shares to Sources and Uses

- Numeraire arbitrary in GE model
- Choice affects the share of distributional impact due to sources or uses side
 - Not a meaningful calculation
- Goulder et al. choose price of the least carbon intensive good (financial services and insurance) as the numeraire.
 - U.S. Treasury (2017) chooses aggregate price level as numeraire
- Consider a \$40/ton tax growing at 2% real annually

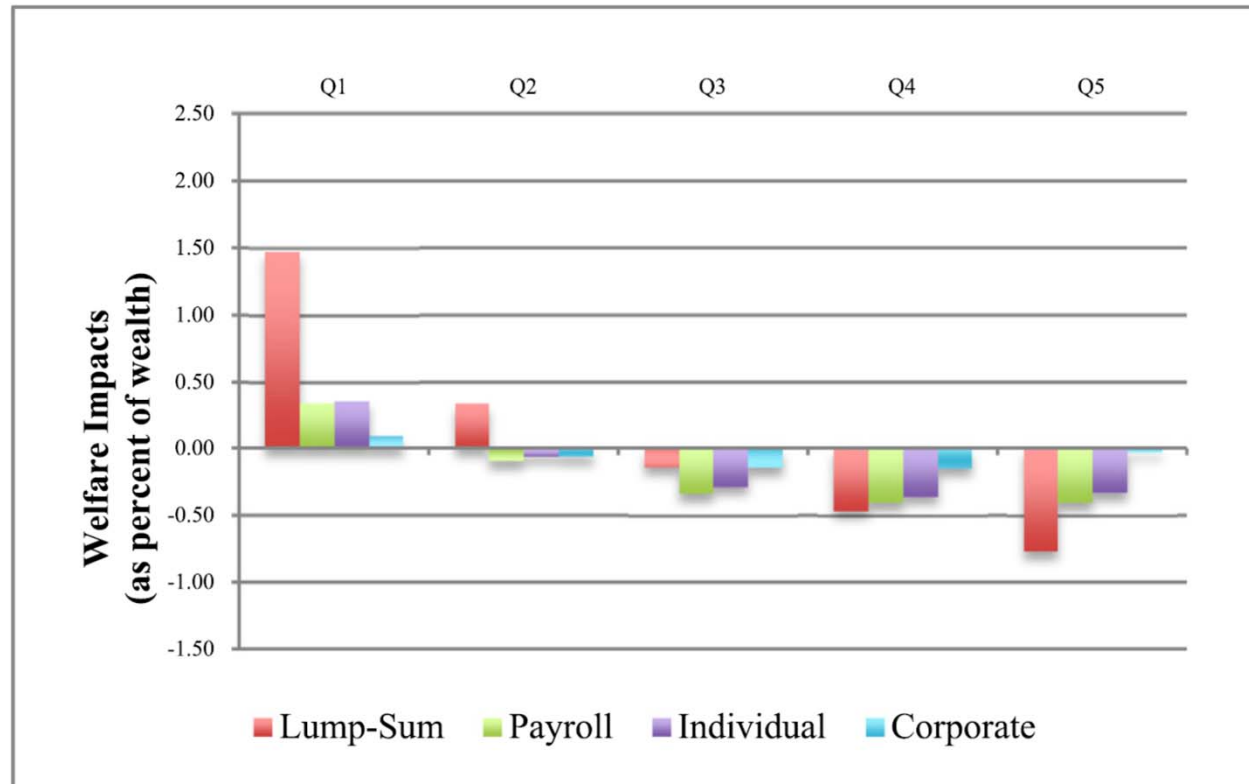
Use-Side Impacts



Source-Side Impacts



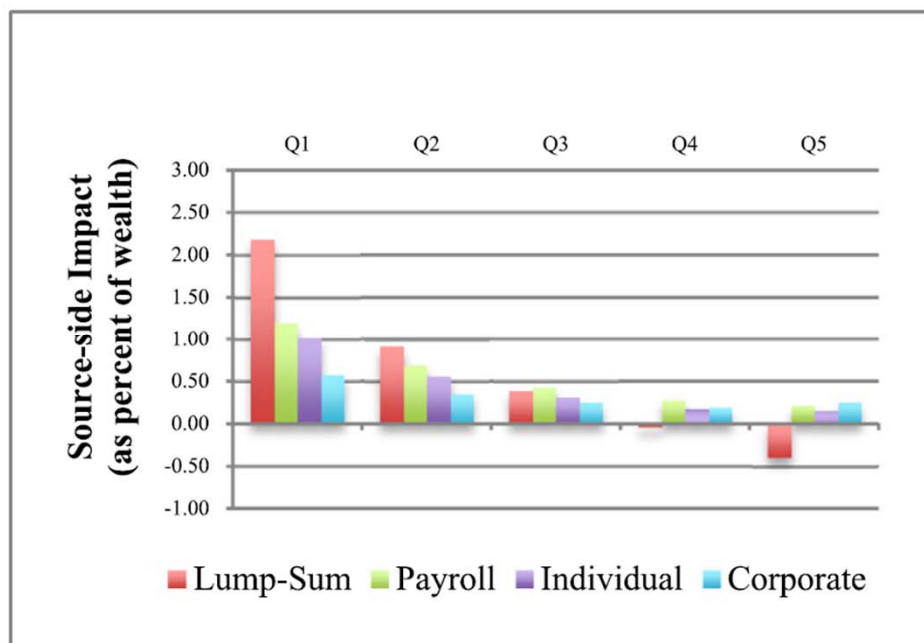
Combined Impacts



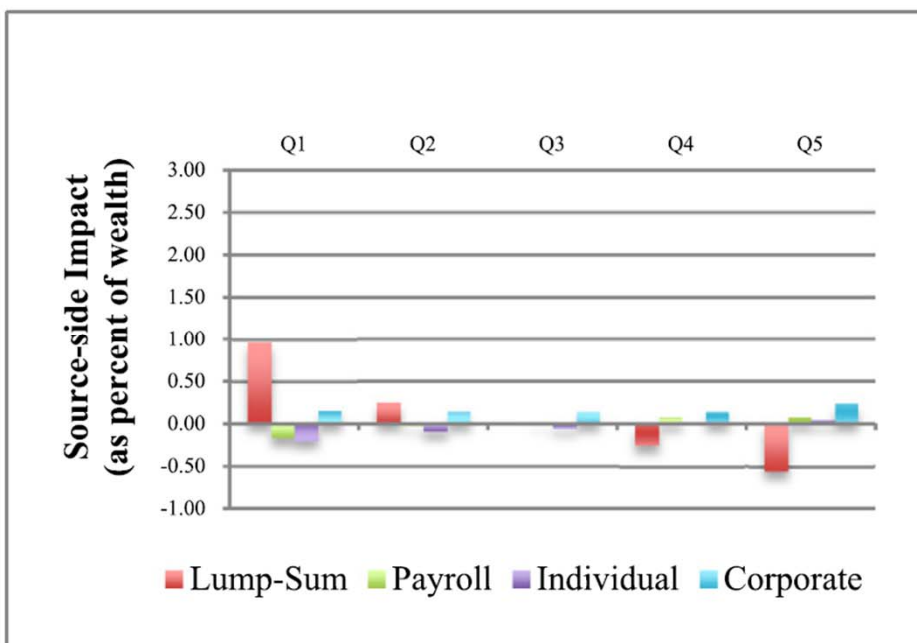
Carbon Tax Progressivity

- Progressivity driven by source-side impacts
- In most cases, the after-tax wage rises relative to the after-tax interest rate (~ 1.5 to 2.5 percent)
 - Capital income disproportionately earned by high income households
- Transfers are indexed for inflation and rise relative to factor prices
 - Transfers explicitly or implicitly indexed for inflation (Fullerton et al, 2011)
 - Transfers disproportionately earned by lower income households

Indexed Transfers and Source Side Impacts

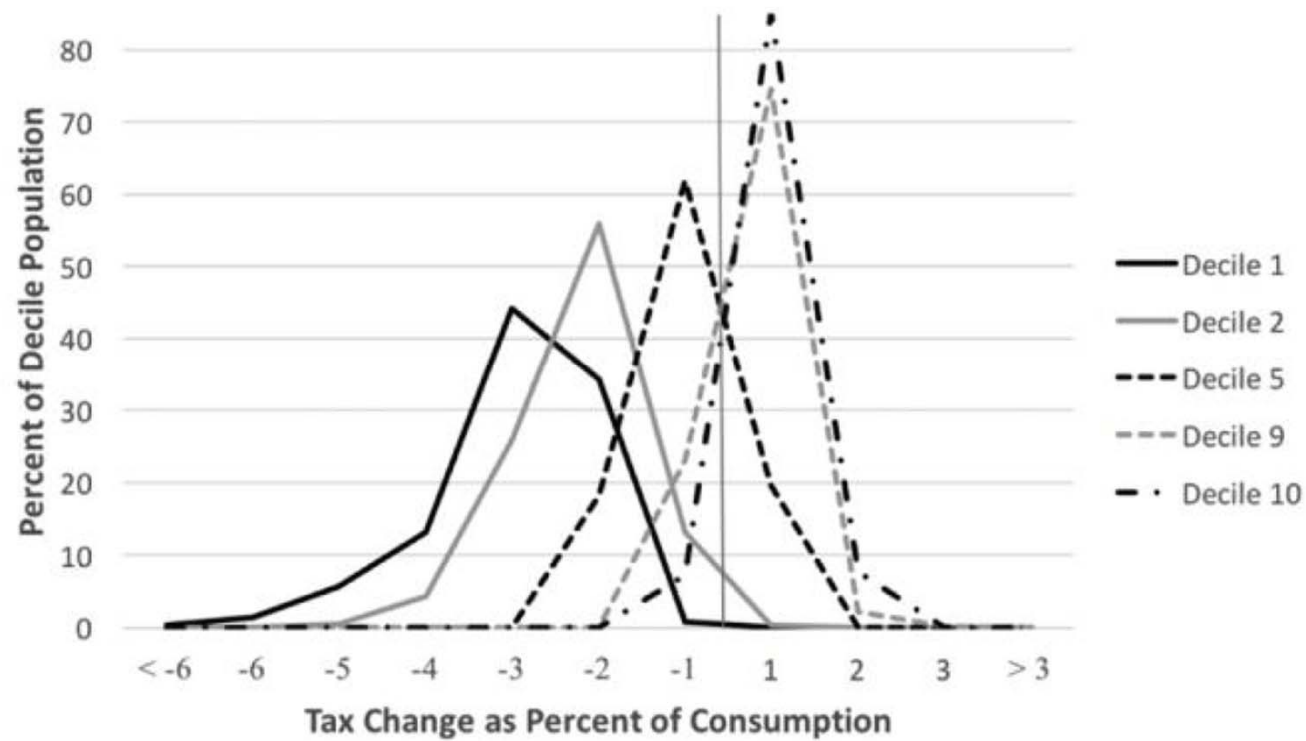


Indexed Transfer Income



Fixed Nominal Transfer Income

Decile Averages Mask Heterogeneity



Key Points

- Need to account for source and use side impacts
- Need to account for use of revenue
- Focusing on averages masks important heterogeneity
- Distributional analysis important for other policies as well
 - Regulation: fuel economy standards
 - Subsidies: clean energy tax credits

Fuel Economy Standards

- Profit maximizing manufacturers:

$$\max_{q_1, q_2, \dots, q_J} \sum_{j=1}^J [q_j p_j - c_j(q_j)]$$

- CAFE standard applied to fleet:

$$\sum_{j=1}^J [(emissions_j - target_j) * VMT_j * q_j] \leq 0$$

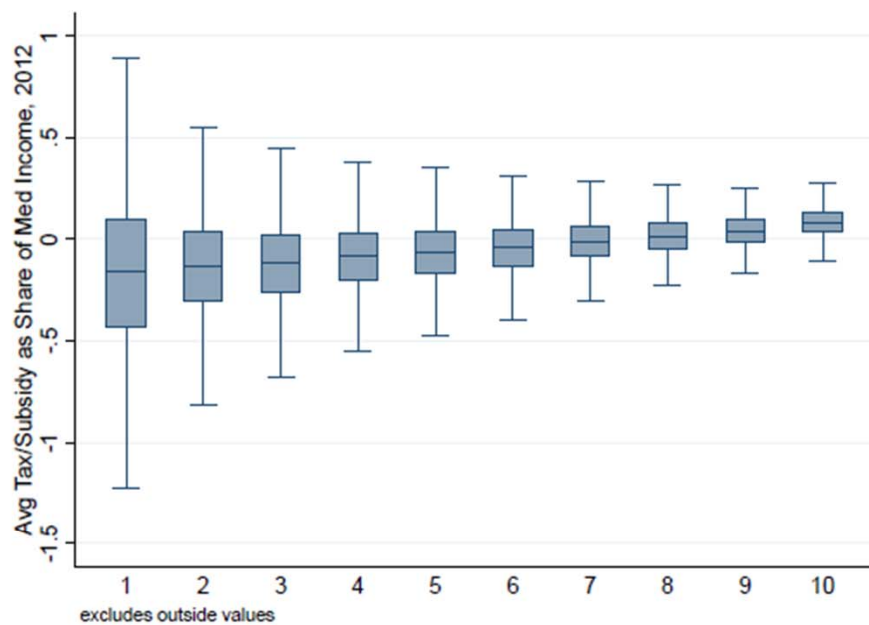
- Constrained maximization yields pricing condition:

$$p_j = c'_j(q_j) + \lambda [(emissions_j - target_j) * VMT_j]$$

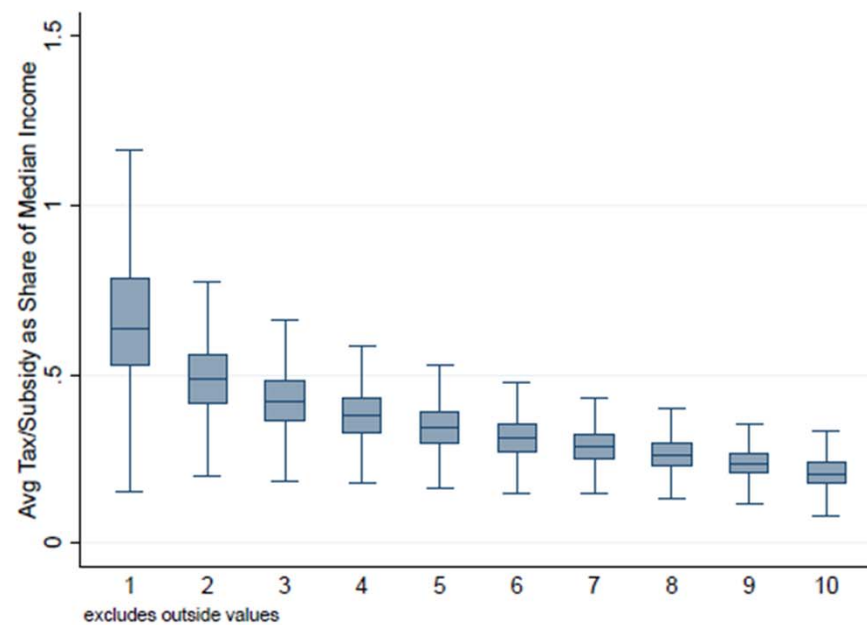
Measuring Distributional Impact

- Measure tax/subsidy per vehicle type for all vehicles produced between 1979 and 2012
- Look at census tract distribution of all vehicles in 2012
- Attribute mean (median) census tract household income to each vehicle in that tract
- Adjust for impact on used cars

Distributional Impact



(a) New Vehicles Only



(b) New and Used Vehicles

Average tax per vehicle as a share of median income, by income decile

Caveats

- Analysis assumes all impact on consumers
- Jacobsen (2013) measures impacts on producers as well as consumers and distinguishes between SR and LR response
- Similar but more nuanced story emerges:

TABLE 8—DISTRIBUTION OF WELFARE EFFECTS OF A 1 MPG INCREMENT IN THE CAFE STANDARD

Income (\$thousand)	Welfare impact		Decomposition		
	EV	EV as percent of income	Producer profit	New car consumer surplus	Used car markets
<i>Year 1</i>					
<25	−60	−0.36	−34	−2	−25
25–50	−195	−0.52	−77	−65	−53
50–75	−293	−0.46	−128	−117	−48
>75	−444	−0.45	−205	−184	−55
All	−177	−0.46	−78	−54	−45
<i>Year 10</i>					
<25	−187	−1.12	−20	−19	−149
25–50	−270	−0.71	−45	−101	−124
50–75	−329	−0.52	−74	−165	−91
>75	−404	−0.41	−124	−218	−63
All	−264	−0.69	−48	−94	−121

Notes: Equivalent variation (EV) expressed in 2001 dollars and as a percentage of income. In Year 10 of the simulation, the CAFE standard becomes regressive across the income distribution, largely due to changes in used car markets.

Distributional Impact of Tax Credits

- Borenstein and Davis (2016) analyze IRS tax data on clean energy tax credits for 2005 – 2012:
 - Nonbusiness energy property tax credit (windows, insulation, furnaces, etc.)
 - Residential energy efficient property tax credit (solar panels, fuel cells, etc.)
 - Alternative motor vehicle credit (hybrids)
 - Qualified plug-in electric drive motor vehicle credit

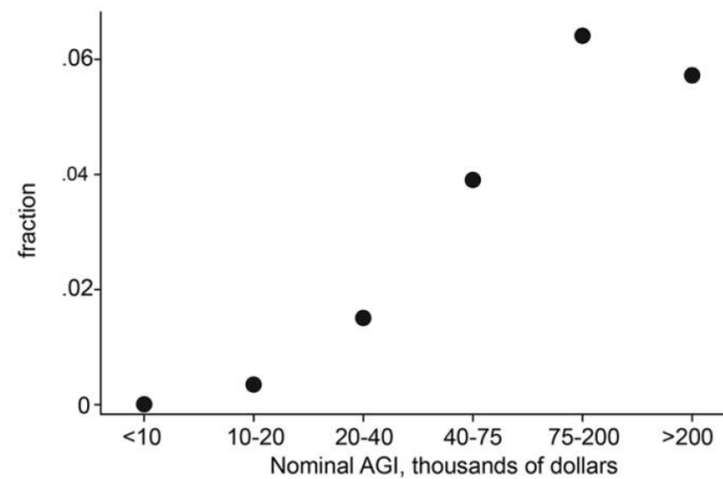
Home Energy Investments Dominate

Annual Expenditures on US Clean Energy Tax Credits, in Millions

Year	Windows and Other Energy-Efficiency Investments (NEPC) (\$)	Solar Panels and Other Residential Renewables (REEPC) (\$)	Hybrids and Other Alternative Fuel Vehicles (AMVC) (\$)	Electric and Plug-In Hybrid Vehicles (PEDVC) (\$)
2005	0	0	0	0
2006	957	43	50	0
2007	938	69	185	0
2008	0	217	49	0
2009	5,177	645	137	129
2010	5,420	754	93	1
2011	755	921	14	76
2012	449	818	20	139
Total	13,696	3,467	549	346

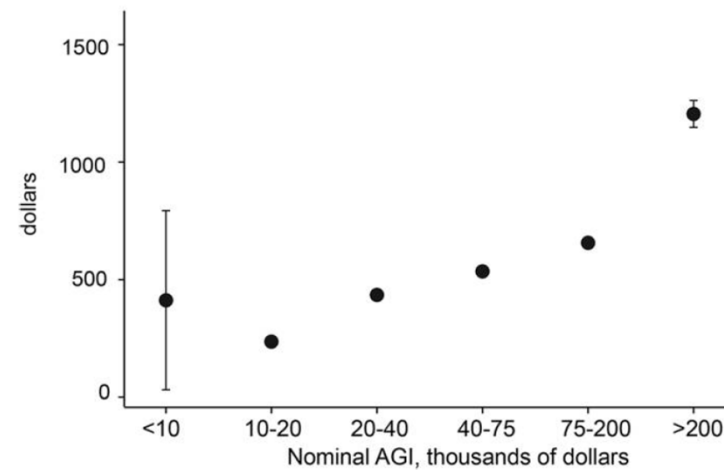
Residential Credits

A: Share Claiming Credit 2006-2012, by Adjusted Gross Income



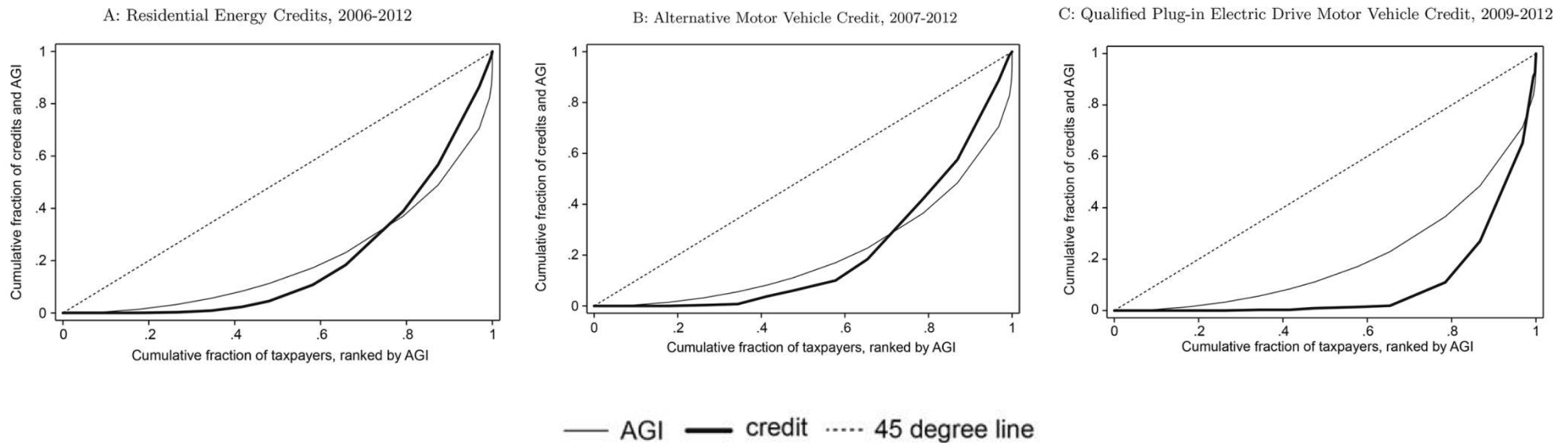
Credit use rises with income

B: Average Credit Amount Claimed 2006-2012, by Adjusted Gross Income



Credit amount rises with income

Credit Use Skews to High Income Households



Comparing to Other Credits

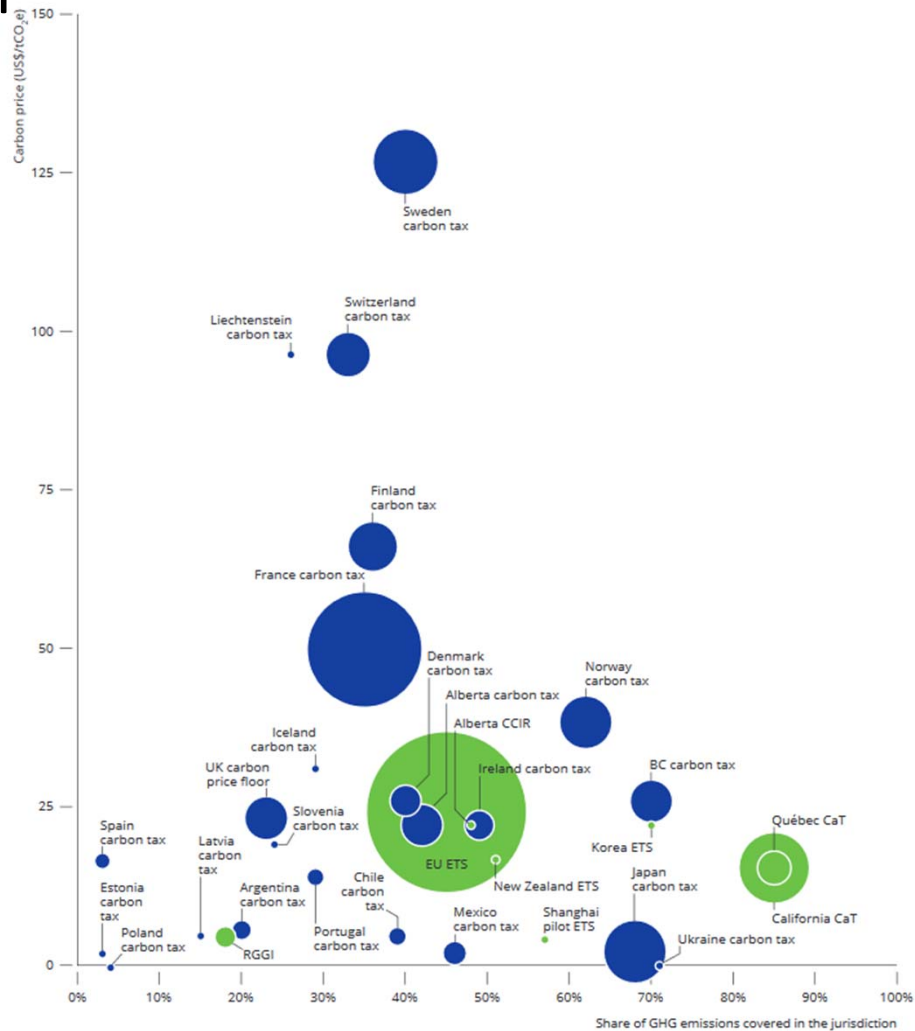
Distributional Effects of Selected Tax Credits

	Percent of Credit Received by Income Category (in Thousands)						Concentration Index
	\$0–\$10	\$10–\$20	\$20–\$40	\$40–\$75	\$75–\$200	\$200+	
A. Clean Energy Tax Credits							
Residential Energy Credits	0	1	10	28	48	14	0.606
Alternative Motor Vehicle Credit	0	1	9	32	47	11	0.584
Plug-in Electric Drive Vehicle Credit	0	0	1	10	54	35	0.801
B. Other Major Tax Credits							
Earned Income Tax Credit	18	49	32	1	0	0	–0.415
Making Work Pay Credit	7	14	25	28	26	0	0.163
Child Tax Credit	2	13	31	31	23	0	0.185
First-Time Home Buyer Credit	7	6	23	40	24	1	0.222
Foreign Tax Credit	0	0	1	2	9	88	0.954

Outline of Lecture

- Market-based approaches to pollution problems
- Other approaches
- **Assessing instruments**
 - Distributional Impacts
 - Carbon pricing economic impacts
 - Emissions
 - Employment and GDP
- Political economy
- Second-best considerations

Global Experience With Carbon Pricing



World Bank (2019)

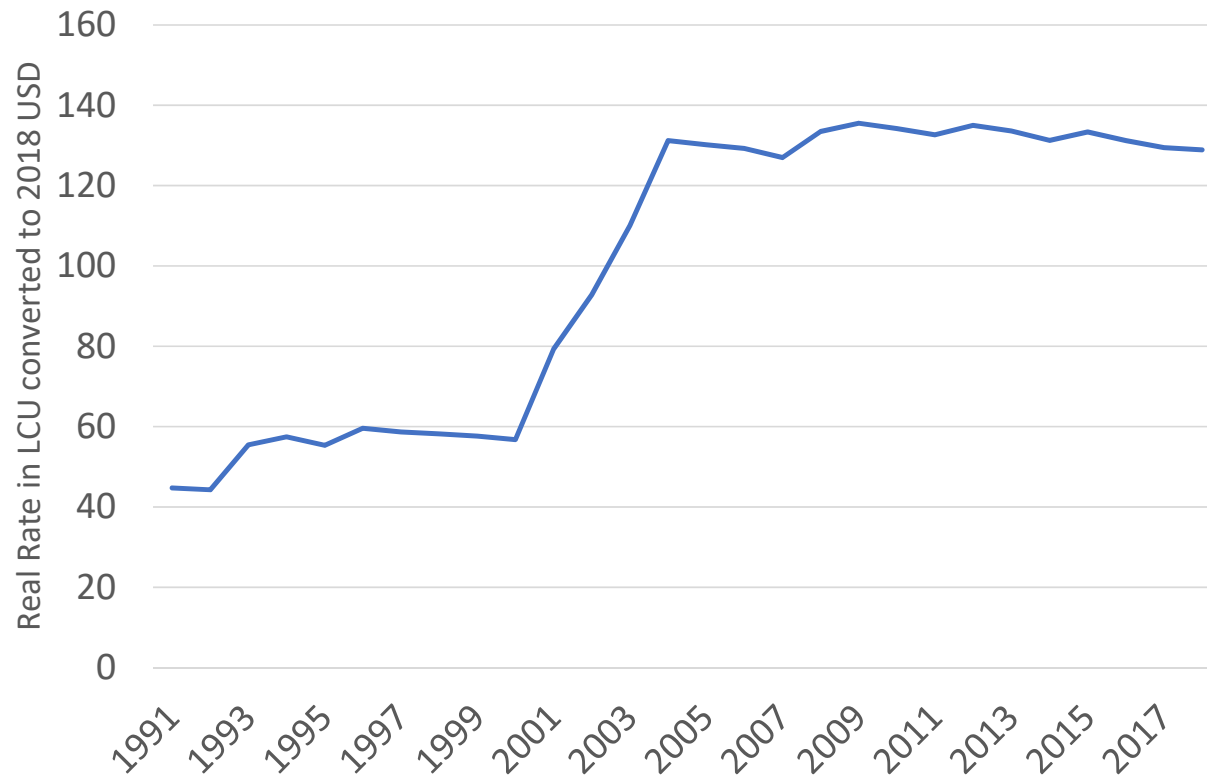
Empirical Impacts of Carbon Taxation

- How much do emissions fall?
- What is the impact on employment?
- What is the impact on GDP?

Impact on Emissions

- Various studies of carbon tax impact on emissions (summarized in Metcalf, 2019)
 - Studies of BC find zero to modest reductions in emissions
 - Studies of EU find modest reductions
- Andersson (2019) focuses on transport emissions in Sweden
 - Transport emissions the largest single source in Sweden
 - Transport fully taxed by carbon tax
 - Theory and evidence suggest tax fully passed forward to consumers

Sweden's Carbon Tax



Sweden's Carbon Tax: Transport

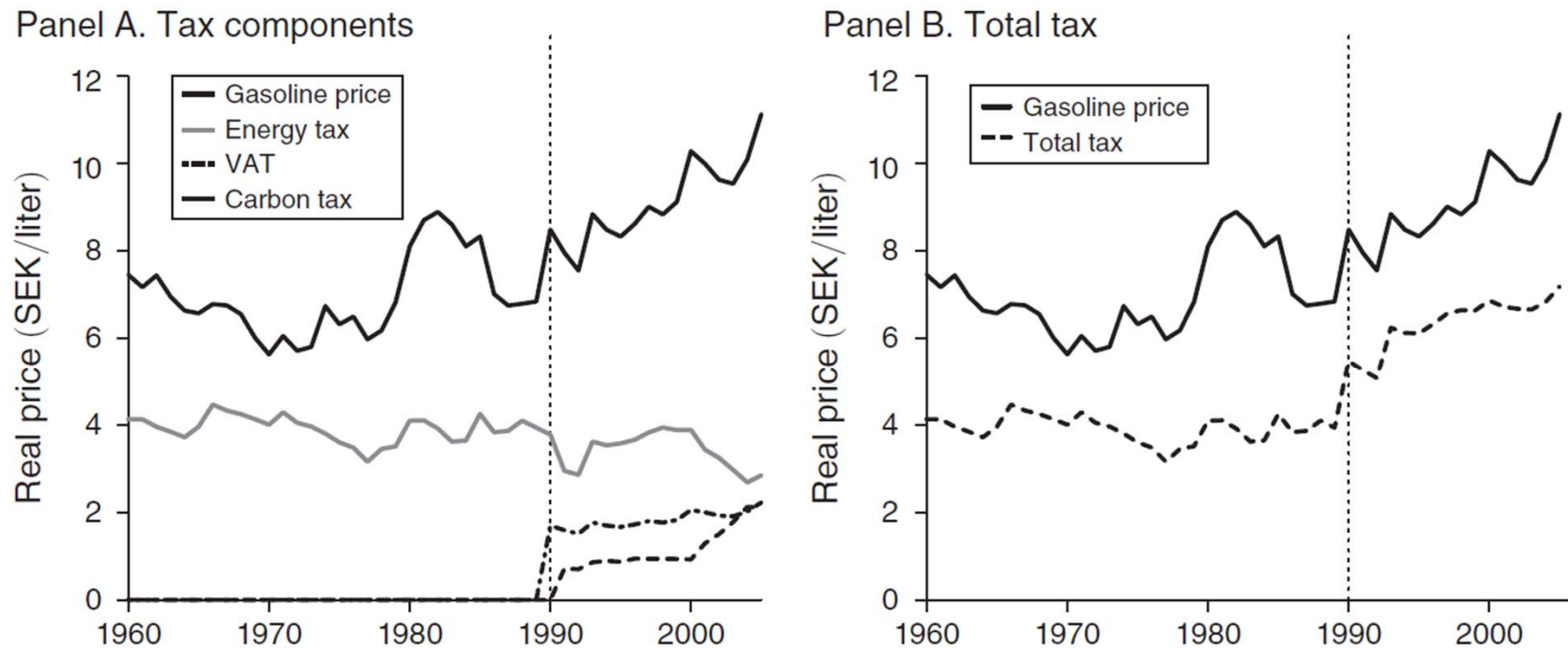


FIGURE 1. GASOLINE PRICE COMPONENTS IN SWEDEN 1960–2005

Empirical Strategy

- Synthetic control approach using a sample of OECD countries
- Controls chosen to match on key variables in pre-treatment period

TABLE 1—CO₂ EMISSIONS FROM TRANSPORT PREDICTOR MEANS BEFORE TAX REFORM

Variables	Sweden	Synth. Sweden	OECD sample
GDP per capita	20,121.5	20,121.2	21,277.8
Motor vehicles (per 1,000 people)	405.6	406.2	517.5
Gasoline consumption per capita	456.2	406.8	678.9
Urban population	83.1	83.1	74.1
CO ₂ from transport per capita 1989	2.5	2.5	3.5
CO ₂ from transport per capita 1980	2.0	2.0	3.2
CO ₂ from transport per capita 1970	1.7	1.7	2.8

Emission Trend in Sample

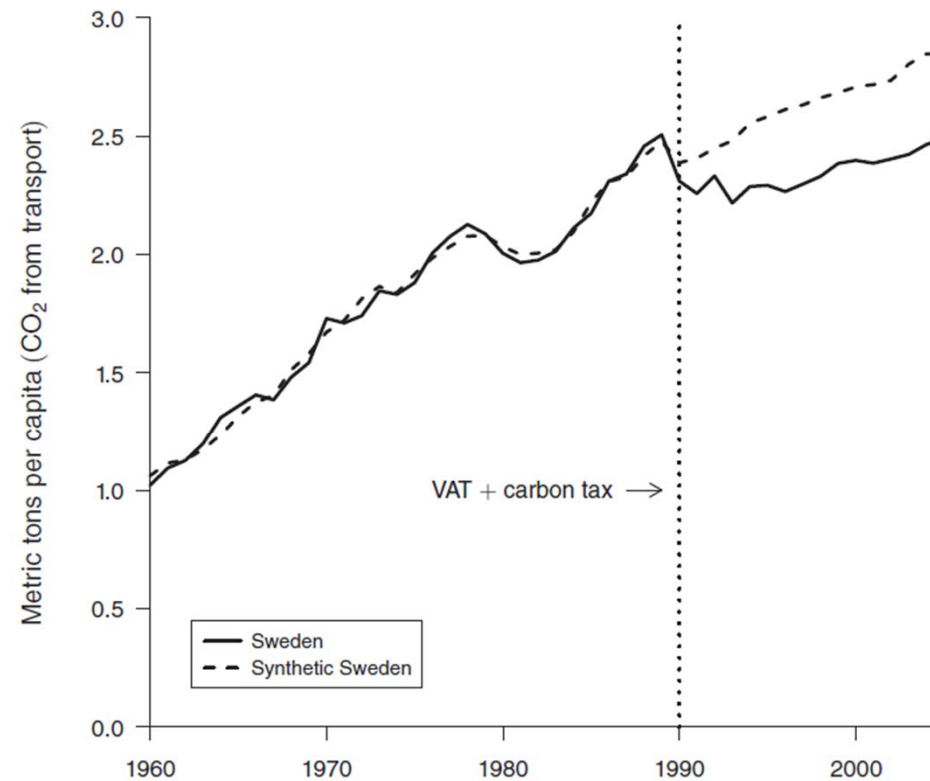


FIGURE 4. PATH PLOT OF PER CAPITA CO₂ EMISSIONS FROM TRANSPORT DURING 1960–2005:
SWEDEN VERSUS SYNTHETIC SWEDEN

Impact of VAT and Carbon Tax

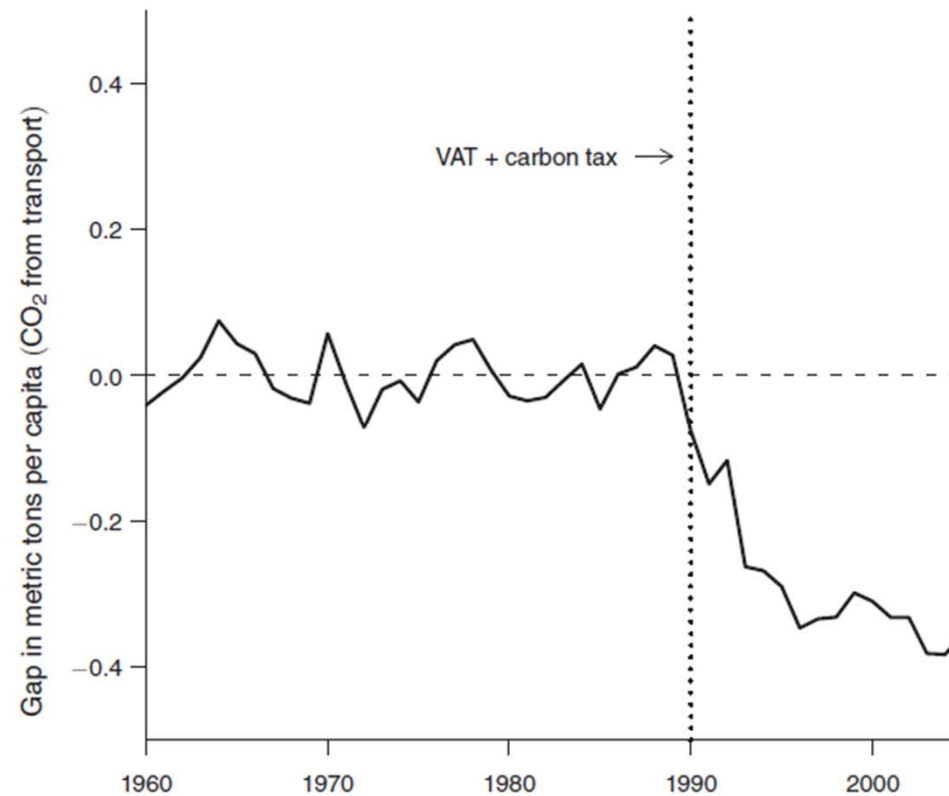


FIGURE 5. GAP IN PER CAPITA CO₂ EMISSIONS FROM TRANSPORT BETWEEN SWEDEN AND SYNTHETIC SWEDEN

Decomposing VAT and Carbon Tax Impacts

$$p_t^* = (p_t + \tau_{t,energy} + \tau_{t,CO_2}) VAT_t$$

Gasoline
consumption

$$p_t^v = (p_t + \tau_{t,energy}) VAT_t$$

$$\tau_{t,CO_2}^v = (\tau_{t,CO_2}) VAT_t$$

1+VAT rate

$$\ln(x_t) = \alpha + \beta_1 p_t^v + \beta_2 \tau_{t,CO_2}^v + \beta_3 D_{t,CO_2} + X_t \gamma + \epsilon_t$$

- Regression allows for differential price and carbon tax impacts
- Can simulate VAT and carbon tax effects on consumption separately

Decomposing VAT and Carbon Tax Impacts

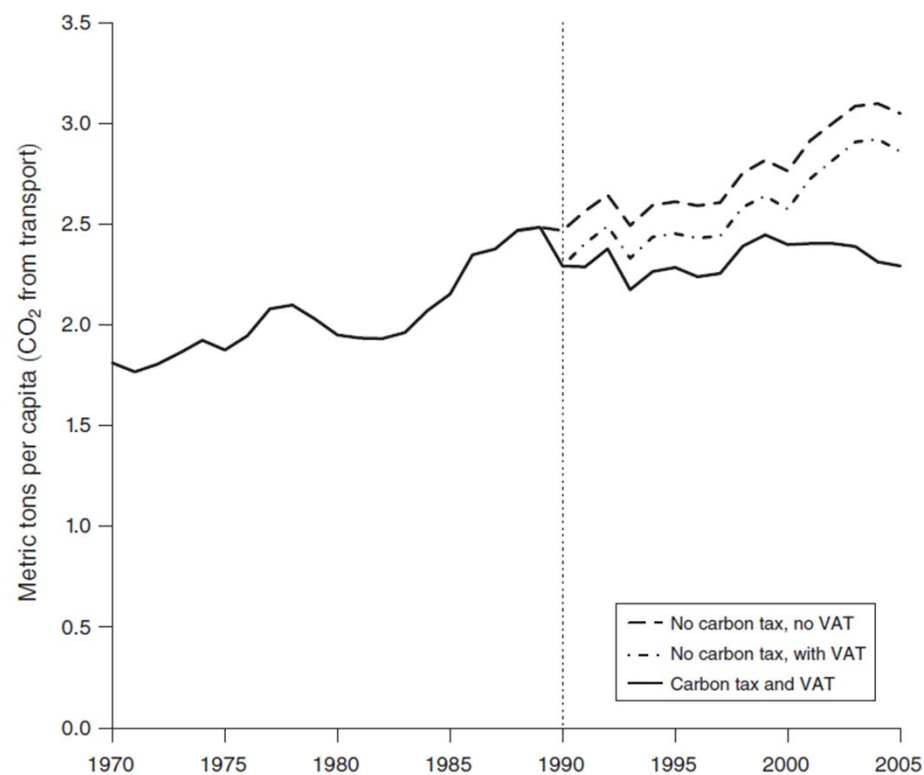


FIGURE 13. DISENTANGLING THE CARBON TAX AND VAT

Summary of Andersson

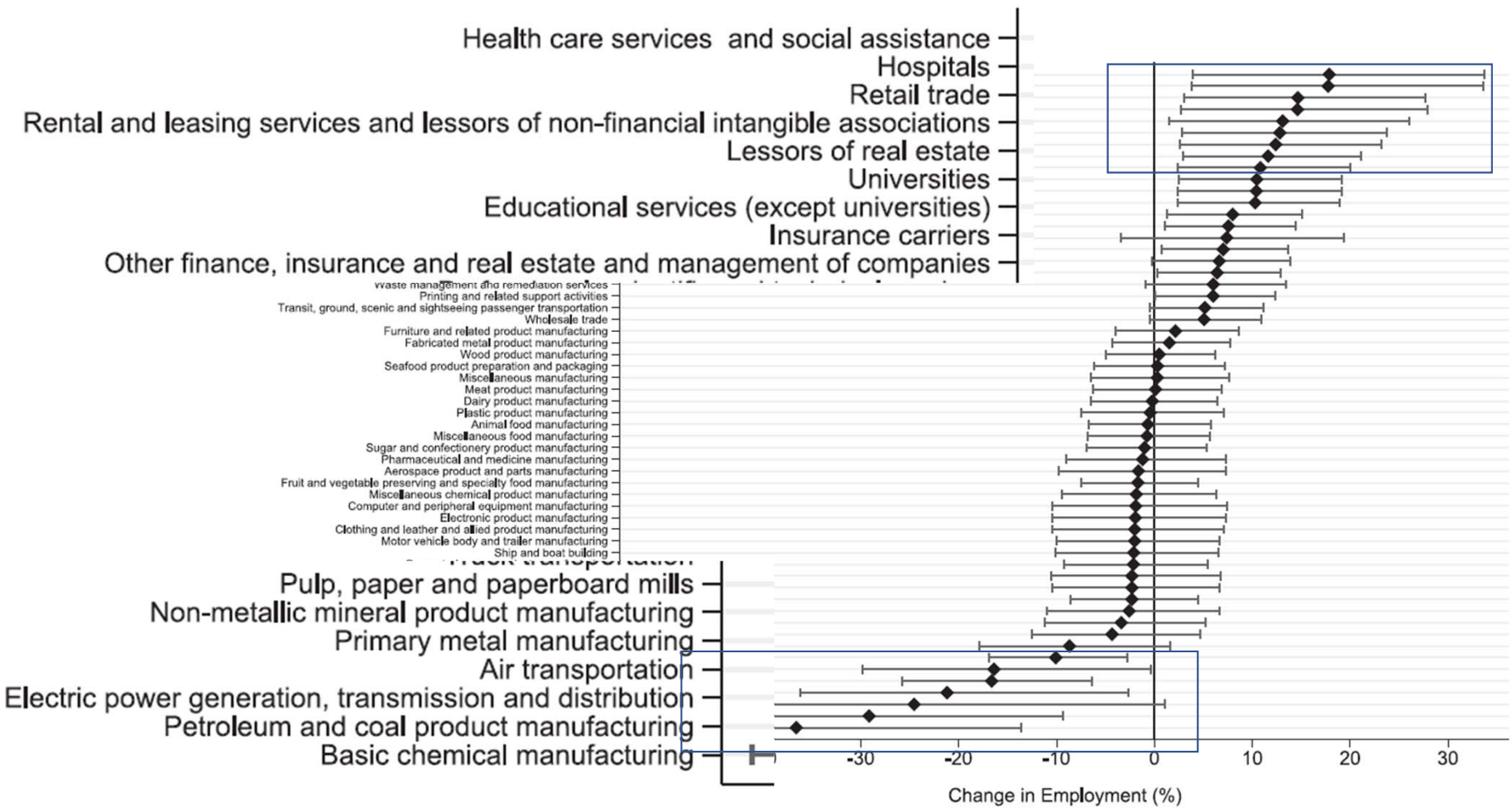
- Per capita transport emissions 12.5 percent lower in 2005 relative to counterfactual and 11 percent over 1990-2005 period
- Carbon tax responsible for largest share of reduction
- Carbon tax elasticity 3x the magnitude of price elasticity of demand
 - Price elasticity: -0.51
 - Carbon tax elasticity: -1.57
- Carbon tax on transport fully passed forward to consumers

Impact on Employment

- Evidence suggests little to no impact on aggregate employment
 - Yamazaki (2017) analysis of British Columbia carbon tax
 - Metcalf and Stock (2020) analysis of EU carbon taxes
- Yamazaki undertakes a sectoral analysis in British Columbia
- BC carbon tax is revenue neutral
 - Cuts in existing personal and business income taxes
 - Targeted lump-sum grants to groups
 - C\$10 per ton CO₂ in 2008 increasing by C\$5 annually
 - Current rate is C\$40
- Tax could reduce activity (and employment) in carbon and trade intensive sectors
- Tax rebate could increase activity (and employment) in low-carbon sectors

Yamazaki Analysis

- Sector by province by year analysis
 - 68 industry sectors
 - Time frame: 2001 – 2013
- DID analysis finds zero to modest positive (+0.09%) impact on aggregate employment
- Sectoral shifts in employment...

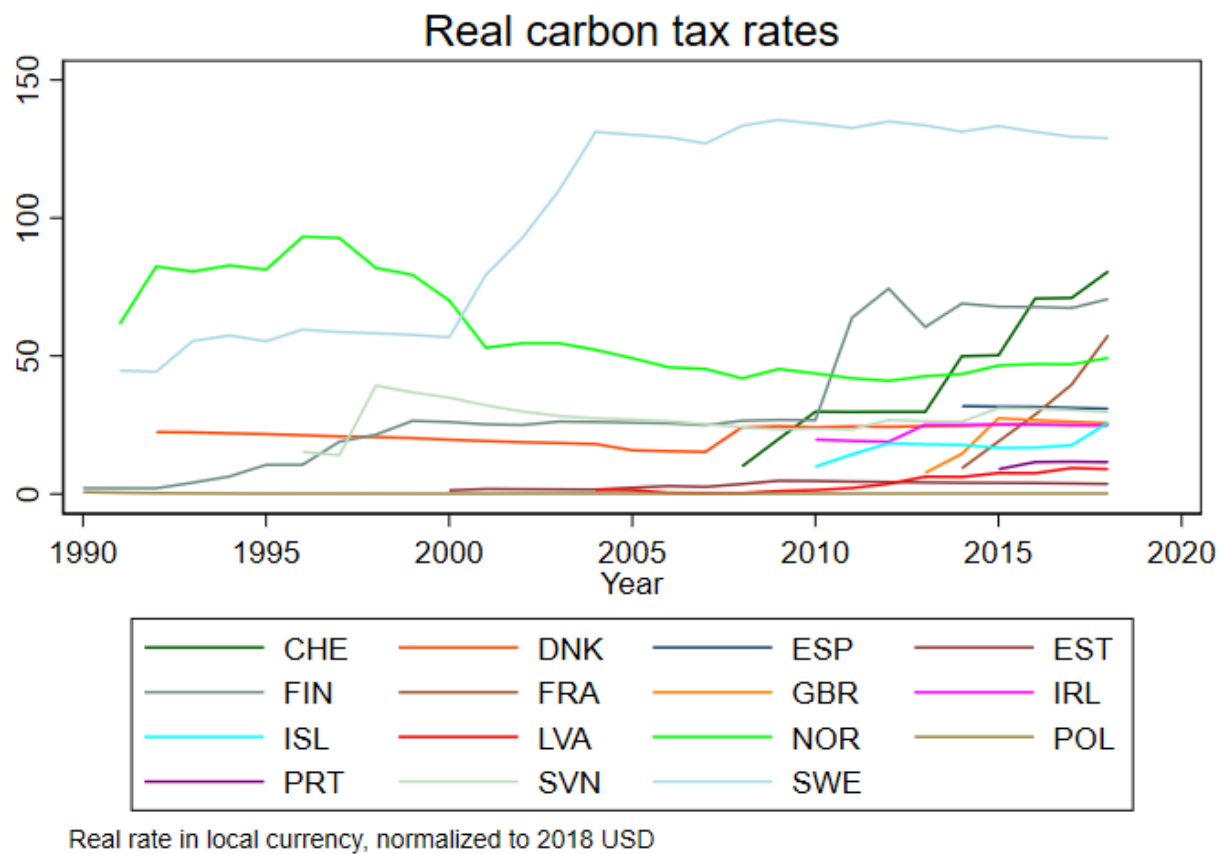


Impact on GDP

- Elgie and McClay (2013) – BC income (+)
- Metcalf (2016, 2019) – BC and EU (0/+)
- Bernard et. al. (2018) – BC carbon tax and provincial income (VAR on with-tax fuel price) (0/+)
- Metcalf and Stock (2020) – EU carbon taxes (0/+)

Metcalf and Stock Analysis

Data set:
EU + Iceland +
Norway + Switzerland
(n = 31)



Empirical Approach

- Estimand: cumulative dynamic causal effect of change in tax rate on real variables
- Method depends on exogeneity conditions

Distributed lag

$$100\Delta\ln(GDP_{it}) = \alpha_i + \beta(L)\tau_{it} + W_{it} + u_{it}.$$

Exogeneity condition:

$$E(u_t | \tau_t, \tau_{t-1}, \dots, W_t, W_{t-1}, \dots) = E(u_t | W_t, W_{t-1}, \dots)$$

Local projections

$$100\Delta\ln(GDP_{it+h}) = \alpha_i + \Theta_{yx,h}\tau_{it} + \beta(L)\tau_{it-1} + \delta(L)\Delta\ln(GDP_{it-1}) + W_{it} + u_{it}.$$

Exogeneity condition:

$$\begin{aligned} E(u_t | \tau_t, \tau_{t-1}, \dots, \Delta\ln(GDP_{t-1}), W_t, W_{t-1}, \dots) \\ = E(u_t | \tau_{t-1}, \tau_{t-2}, \dots, \Delta\ln(GDP_{t-1}), W_t, W_{t-1}, \dots) \end{aligned}$$

Note: $\Theta_{yx,h}$ is h -period ahead cumulative impulse response function

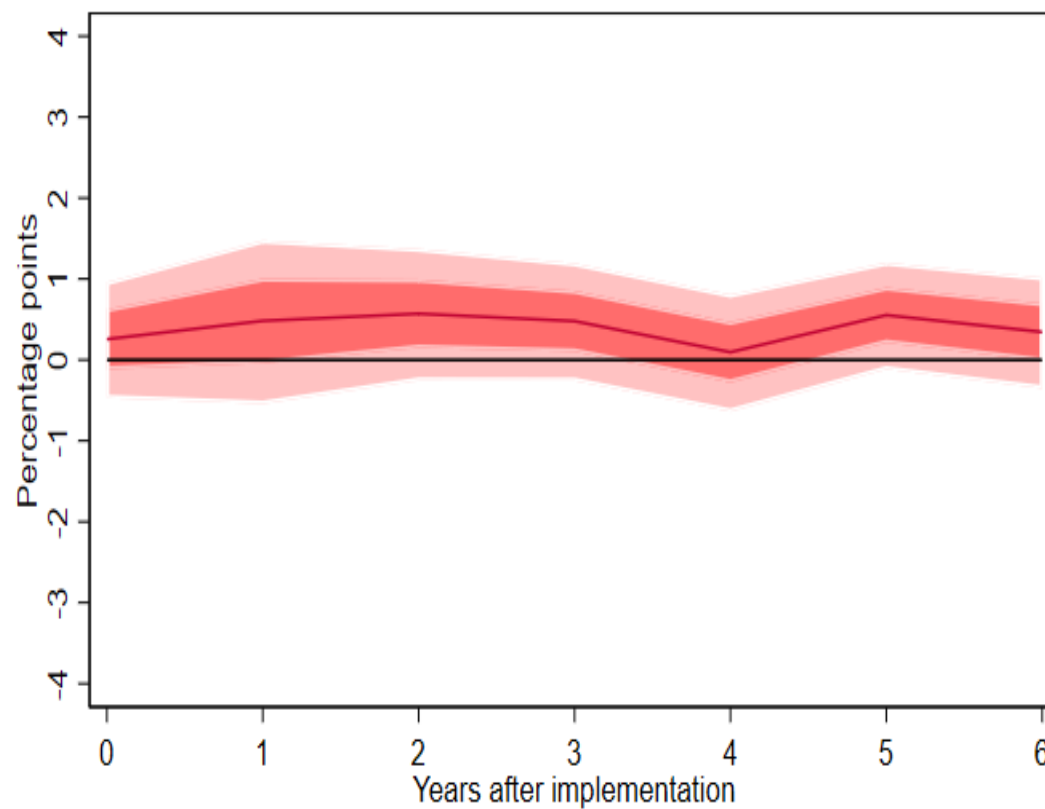
Results: GDP growth

Method: Linear Projection

Sample: EU+

Tax variable: Real carbon tax, share wtd

Controls: Year Effects



67% and 95% confidence bands. Includes 2 lags of all regressors.

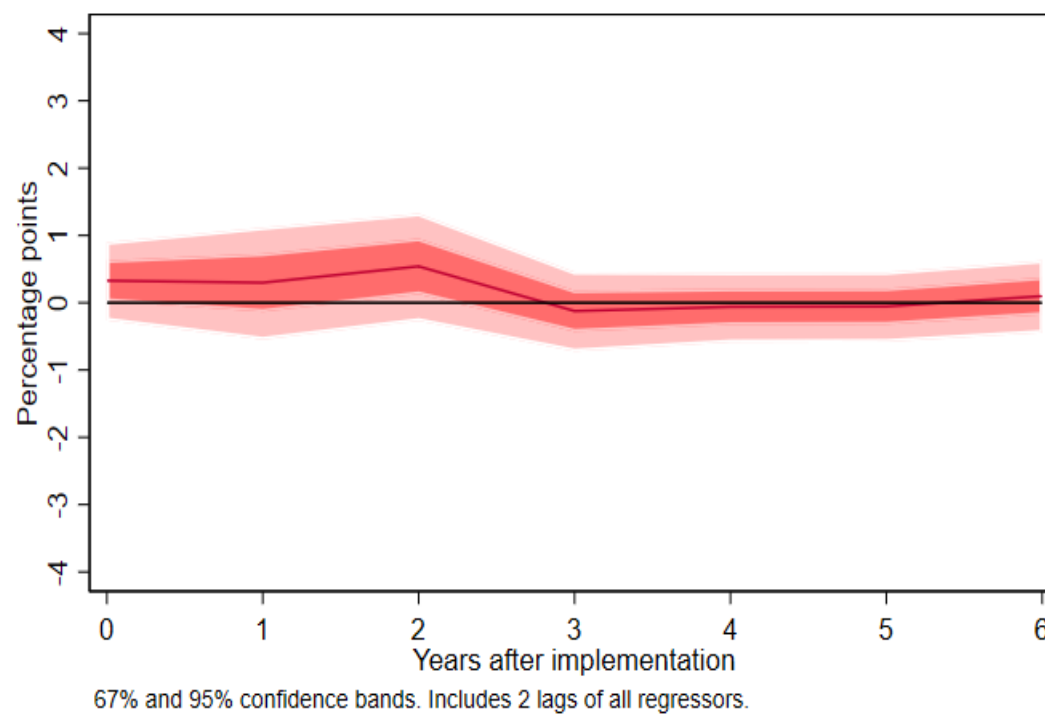
Results: Total employment growth

Method: [Linear Projection](#)

Sample: [EU+](#)

Tax variable: [Real carbon tax, share wtd](#)

Controls: [Year Effects](#)



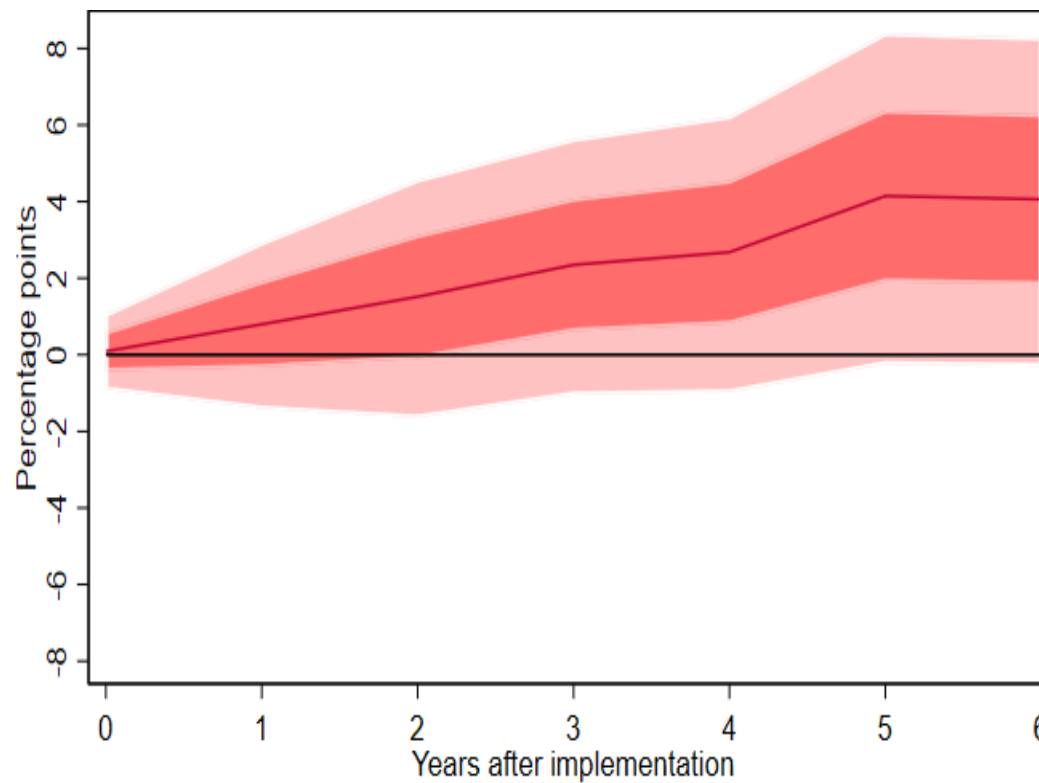
Results: GDP growth: Cumulative Impact

Method: Linear Projection

Sample: EU+

Tax variable: Real carbon tax, share wtd

Controls: Year Effects



67% and 95% confidence bands. Includes 2 lags of all regressors.

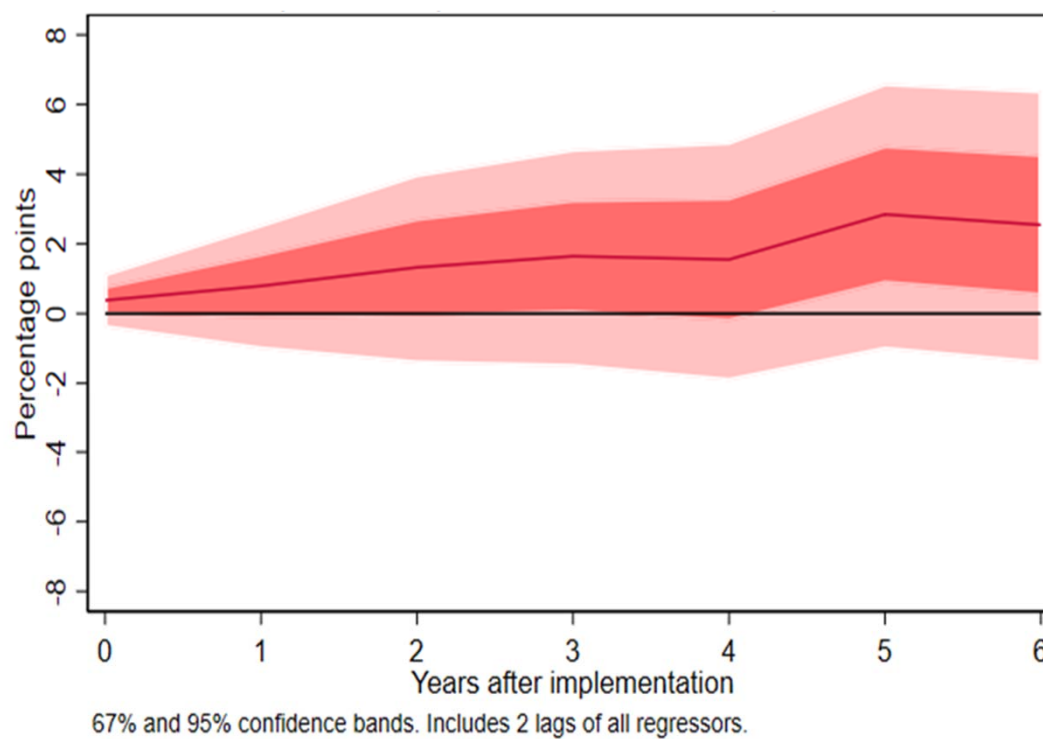
Results: Total Employment: Cumulative Impact

Method: Linear Projection

Sample: EU+

Tax variable: Real carbon tax, share wtd

Controls: Year Effects



Summary

- No evidence of damaging impacts on GDP or employment in EU+ countries from carbon tax
 - If anything, point estimates suggest positive impacts
 - Mechanism unclear but revenue neutral nature of reforms may play a role

Outline of Lecture

- Market-based approaches to pollution problems
- Other approaches
- Assessing instruments
- **Political economy**
- Second-best considerations

Political Economy

- Carbon taxes are efficient and can be tailored to desirable distributional or efficiency outcomes
- So, why hasn't Congress passed one yet?
- Like any other policy, carbon tax generates winners and losers
 - Immediate costs coupled with delayed benefits important
 - Free rider problem also important
- Mancur Olson's *Logic of Collective Choice* relevant
- Role of lobbying
 - Example from failed effort to enact Waxman-Markey cap and trade bill (2009)

Meng and Rode (2019)

- How did lobbying expenditures affect probability of passage of Waxman-Markey (WM) bill?
- Could alternative allowance allocation schemes improved the probability of passage?
- Takes advantage of a prediction market that traded in contracts on bets that WM would pass or not in 2009-2010.

θ_t - prediction market probability that WM will pass on date t

Stock Performance and WM

- Event study on firms (indexed by i) over time (t)
- Stock return for firm i at time t regressed on change in predicted probability of WM passage and a measure of normal market return

$$r_{it} = \kappa_i \Delta \theta_t + \Delta \ln \rho_{it} + \varepsilon_{it}$$

$$\kappa_i = \frac{\pi_i^* - \pi_i^0}{\pi_i^0}$$

Value of Lobbying

- Regress gain from passage (or failure) of WM on lobbying expenditures by firms to estimate marginal value of lobbying
 - Run separate regressions for winners and losers:

$$\ln|\pi_i^* - \pi_i^0| = \alpha_k + \beta_k \ln s_i + v_i$$

- k indexes winners and losers

Fitted Relationship

- For gaining firms, a 1 percent increase in lobbying leads to a 0.49% increase in firm value
- For losing firms, a 1 percent increase in lobbying leads to a 0.25% loss in firm value

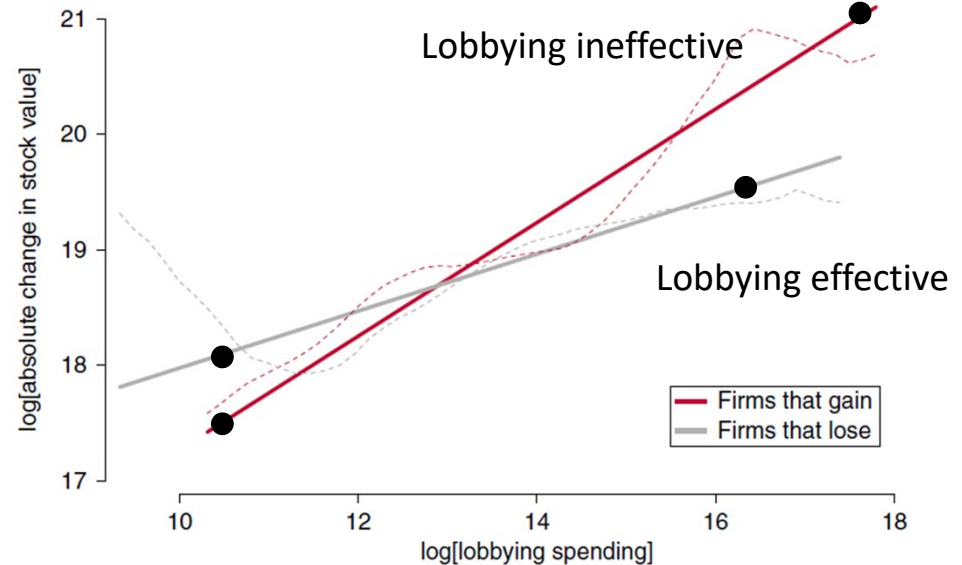


Fig. 3 | Differential statistical relationships for gaining and losing firms. Horizontal axis shows firm-level log lobbying spending on the Waxman-Markey bill. Vertical axis shows log absolute change in firm-level stock value had Waxman-Markey been implemented, obtained from a prediction market event study using an aggregate market index (see statistical analysis section of Methods). Solid line shows a linear fit. Dashed line shows a local polynomial fit using an Epanechnikov kernel with a rule-of-thumb bandwidth⁴⁴. Model fitted separately for firms that gain (in red, $n=116$) and lose (in grey, $n=104$) stock value under Waxman-Markey.

Implication for Lobbying Effectiveness

“The amount a firm spends on lobbying depends on how much is at stake. This relationship depends on how effective lobbying is at altering the likelihood of enacting the policy. Intuitively, if lobbying were not effective, only firms that have a lot at stake will lobby intensively, while firms with less at stake lobby far less. This implies a steeper slope in the relationship between change in firm value and lobbying. Conversely, if lobbying were more effective at changing the likelihood of policy enactment, lobbying would be less sensitive to the consequences of the policy.”

Formalized in a game-theoretic framework of lobbying

Model

- WM passes if

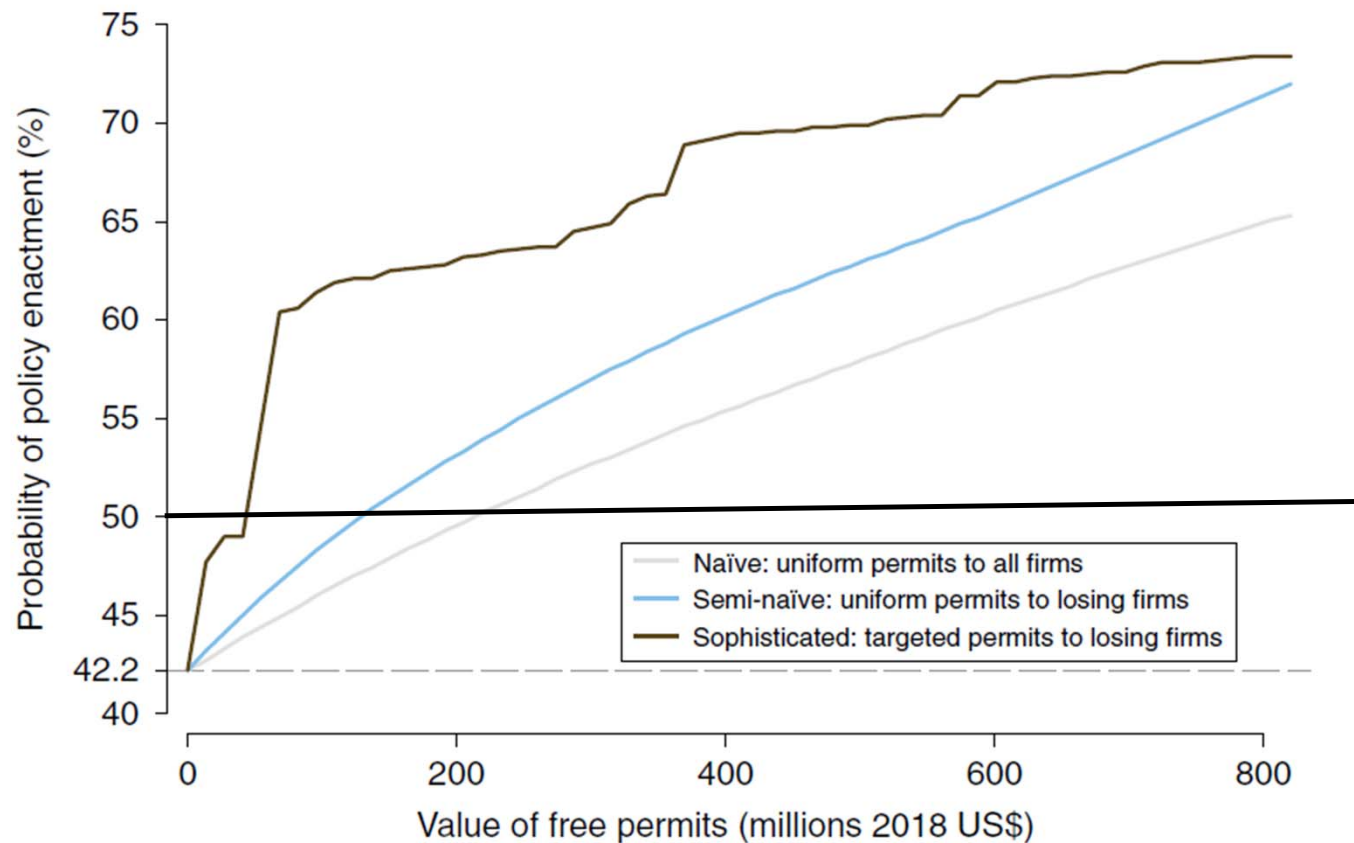
$$P_0 + \mu_F \sum_{j \in F} s_j^{\gamma_F} - \mu_A \sum_{j \in A} s_j^{\gamma_A} > \eta$$

Relates to probability of passage in absence of lobbying

Random variable with mean zero

- Meng and Rode develop a model to estimate μ_F , μ_A , γ_F , and γ_A based on firm decision to lobby for (F) or against (A) as well as lobbying amount.
- Compute change in probability of enactment given lobbying
- Consider counterfactual allowance allocations that affect market value and firm lobbying choice variables

Counterfactual Analysis of Allowance Allocation



Implication for Policy Design

- Meng and Rode (2019) illustrates an additional role for carbon tax revenue use
 - Use revenue to enhance efficiency (double-dividend literature)
 - Use revenue to achieve desired distributional outcomes (Climate Leadership Council Tax and Dividend scheme)
 - Use revenue to increase likelihood of passage
- Klenert et al. (2018) flesh this theme out in a heuristic way...

Efficiency, Equity, or Acceptability?

“We argue that traditional economic lessons on efficiency and equity are subsidiary to the primary challenge of garnering greater political acceptability”

- Klenert et al. (2018)

Recycling mechanism	efficiency	equity	acceptability
labor tax (initial tax system non-optimal)	+	+	0
labor tax (initial tax system optimal)	0	0	0
capital/corporate tax (initial tax system non-optimal)	+	-	0
capital/corporate tax (initial tax system optimal)	0	-	0
directed transfers	0	+	+
uniform transfers (initial tax system non-optimal)	0	+	+
uniform transfers (initial tax system optimal)	+	+	+

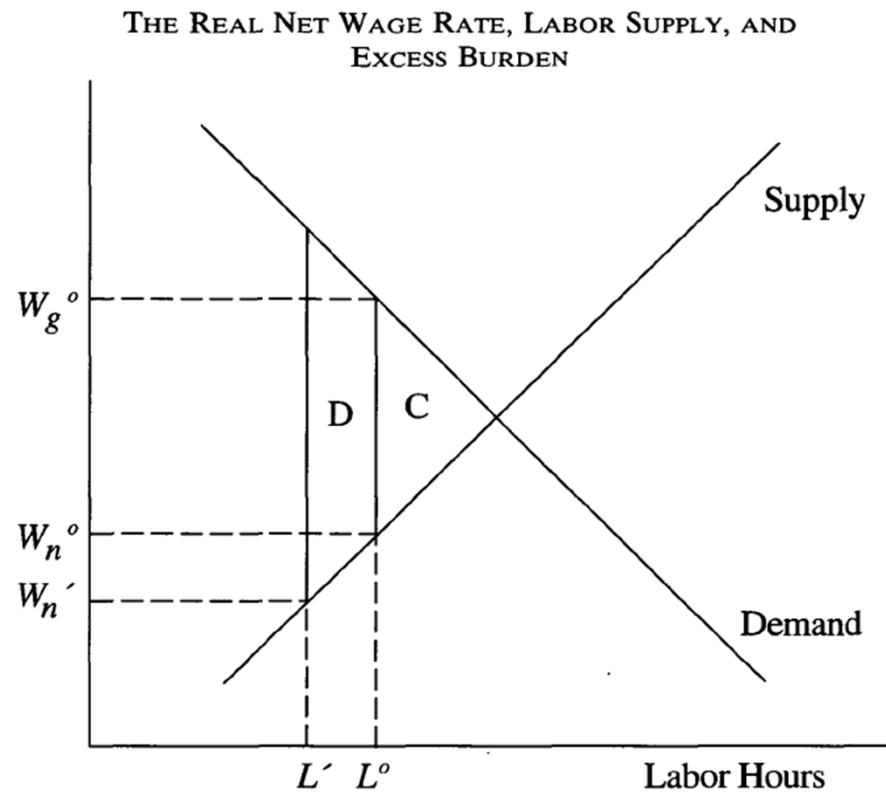
Outline of Lecture

- Market-based approaches to pollution problems
- Other approaches
- Assessing instruments
- Political economy
- **Second-best considerations**

Second-Best Considerations

- Pigouvian prescription is to set carbon price equal to the social marginal damages from GHG emissions: $\tau^* = SMD$
- Second-best considerations can create departures from that policy prescription:
 - Double-dividend literature focuses on first-order deadweight loss of pollution taxes in presence of existing distortionary taxation (e.g. Bovenberg and de Mooij, 1994): $\tau^* < SMD$

Pigouvian Taxes w/ Distortionary Taxation



Second-Best Considerations

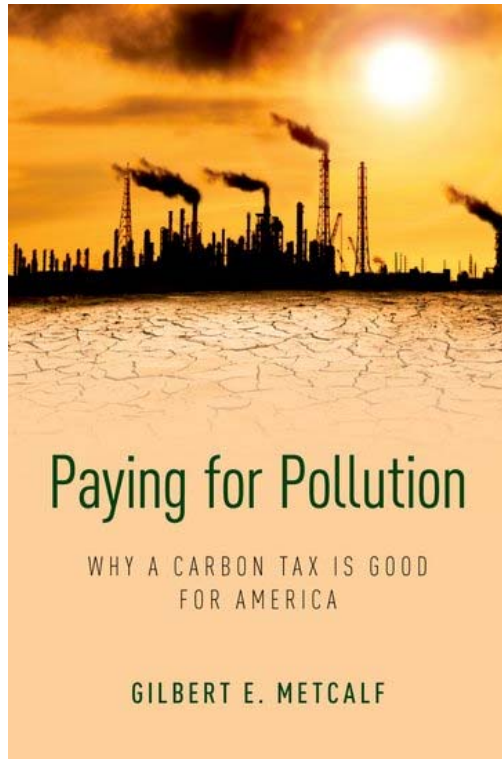
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- Second-best considerations can create departures from that policy prescription:
 - Double-dividend literature focuses on first-order deadweight loss of pollution taxes in presence of existing distortionary taxation (e.g. Bovenberg and de Mooij, 1994): $\tau^* < SMD$
 - R&D externality and market power combined with pollution (Acemoglu et al., 2012): $\tau^* < SMD$, subsidy to clean R&D, subsidy to offset market power
 - Credit constraints inhibiting take-up of energy-efficient investments creates a second margin (Berkouwer and Dean, 2019): $\tau^* < SMD$ and $s^* > 0$

Bottom Line

- Carbon tax efficient
 - Revenue can be used in a variety of ways
 - Distributional concerns are overblown (if not wrong)
 - Political obstacles to passage
- Optimal tax rate depends on
 - Social marginal damages from emissions
 - Interaction with other market failures
- Additional policies needed
 - Other market failures (e.g. R&D externality)
- Different countries will want to use different policies

Paying for Pollution

Why a Carbon Tax is Good for America



**Brookings Papers on Economic Activity, Spring 2019 Edition**

On the economics of a carbon tax for the United States

Gilbert E. Metcalf John DiBiaggio Professor of Citizenship and Public Service and Professor of Economics, Tufts University Research Associate - National Bureau of Economic Research

A photograph showing a man in a dark jacket holding an American flag. To his right is a large sign that reads 'SMOG INSPECTION \$35.80 MOST CARS + CERTIFICATE'. The sign also includes smaller text: 'SMOG INSPECTION & CERTIFICATE', 'SMOG INSPECTION & CERTIFICATE', and 'SMOG INSPECTION & CERTIFICATE'.

The ever-rising accumulation of greenhouse gases in the Earth's atmosphere—the most prominent of which is carbon dioxide—is

What Have We Ignored?

- Climate finance
- International negotiations
- Stranded assets and other transitional impacts
- Lots more...

Thank You

Lint Barrage

Michael Greenstone

Gilbert Metcalf