Mechanisms to Reduce Emissions Uncertainty under a Carbon Tax

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RESOURCES FOR THE FUTURE

Carbon Taxes and Emissions Uncertainty

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- If we care about emissions levels, why not just implement a cap-and-trade?
  - US federal cap-and-trade is (currently) politically unviable
- Some policymakers are considering a hybrid carbon tax policy solution

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    - Simulation modeling with "Price Updating in Expectation"

Key Research Questions

- How uncertain are emissions under a carbon tax?
  - What are the drivers of emissions uncertainty?

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- How uncertain are emissions under a carbon tax?
  - What are the drivers of emissions uncertainty?
- What are the costs of providing emissions certainty under a carbon tax?
  - How do the costs vary by mechanism design?
  - What are the trade-offs across different designs?

Preview of Results

- How uncertain are emissions under a carbon tax?
  - The confidence interval for cumulative emissions is quite large
    - $+/-$ 24 percent of expected cumulative emissions
  - Uncertainty in the price elasticity drives emissions uncertainty
- What are the additional expected costs of providing emissions certainty under a carbon tax?
  - Depends on how we define certainty
  - Depends on key design choices
    - 5 - 80% of primary cost

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- Intro
- Emissions Certainty Mechanisms Examples
- Reduced-Form Model of Emissions with Uncertainty
- Quantifying Emissions Uncertainty
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Theoretical: REACT example

From Metcalf (2009),

"REACT takes the following approach:

- An initial tax and standard growth rate for the tax is set for the first year of a control period
- Benchmark targets for cumulative emissions are set for the control period. The law could require that the targets be met at annual, five-year, ten-year or some other time interval
- If cumulative emissions exceed the target in the given years, the growth rate of the tax would rise from its standard growth rate to a higher catch-up rate until cumulative emissions fall below the target again"

Real World: Swiss Carbon Tax on Thermal Fuels

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- from 1 January 2016:
  - at 72 francs per tonne CO_2 if the CO_2 emissions from thermal fuels in 2014 exceed 76 percent of 1990 emissions,
  - at 84 francs per tonne CO_2 if the CO_2 emissions from thermal fuels in 2014 exceed 78 percent of 1990 emissions;

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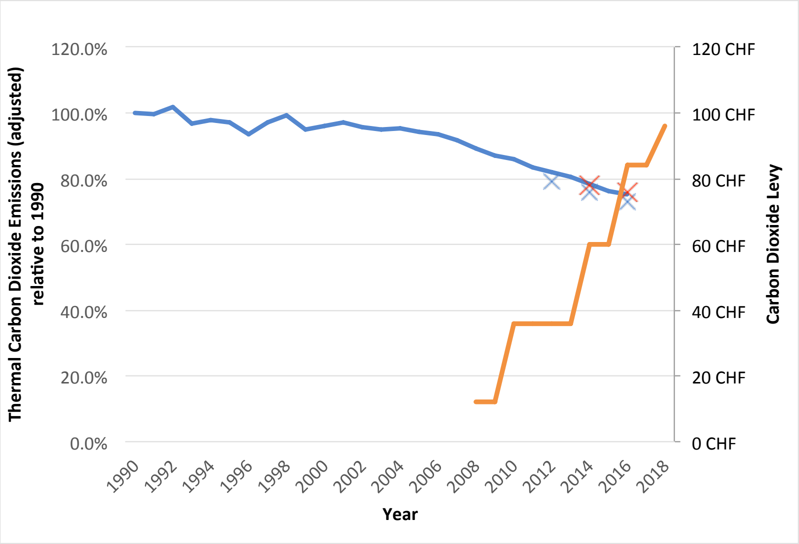
  - at 84 francs per tonne CO_2 if the CO_2 emissions from thermal fuels in 2014 exceed 78 percent of 1990 emissions;
- from 1 January 2018:
  - at 96 francs per tonne CO_2 if the CO_2 emissions from thermal fuels in 2016 exceed 73 percent of 1990 emissions,
  - at 120 francs per tonne CO_2 if the CO_2 emissions from thermal fuels in 2016 exceed 76 percent of 1990 emissions."

Real World: Swiss Carbon Tax on Thermal Fuels



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Reduced-Form Model

Extension of basic model in Metcalf (2009):

Projections of GDP and emissions intensity

Log-linear time trend for elasticity; scaling parameter

$$\bar{Y}_t = (1+\gamma)^t \bar{Y}_0 \tag{1}$$

$$\log Y_t - \log \bar{Y}_t = \rho_y (\log Y_{t-1} - \log \bar{Y}_{t-1}) + \varepsilon_t^y \tag{2}$$

$$\log(E_t/Y_t) = E_0/Y_0 + \beta_1 t + (\beta_2 + \beta_3 \log(t)) \log(1 + P_t/c) + u_t \tag{3}$$

$$u_t = \rho^u u_{t-1} + \varepsilon_t^u \tag{4}$$

$$P_t = (1+\alpha)^{t-1} P_1 + f(E_t) \tag{5}$$

Reduced-Form Model

Trend Uncertainty

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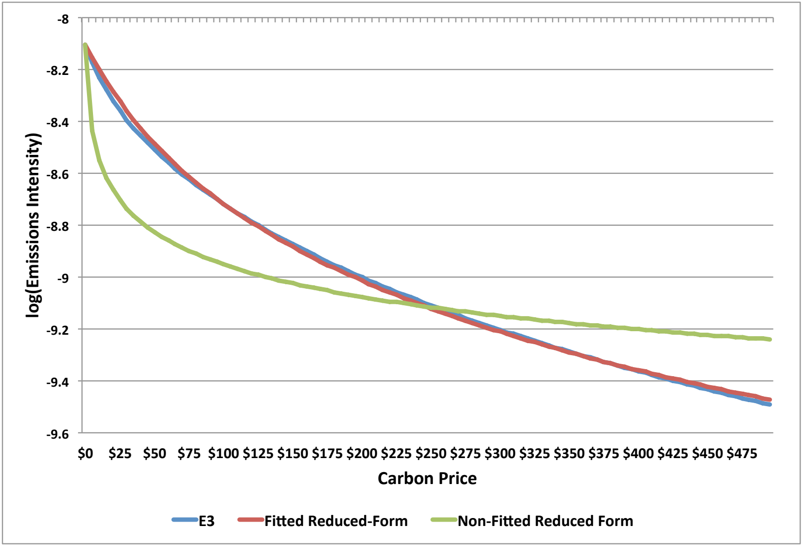
Reduced-Form Model: Central-Case Calibration

- Trend parameters β_1 and γ
  - EIA AEO 2017 estimates for 2017-2050
- Price elasticities β_2 and β_3 and constant term c
  - Fit long-run elasticity and constant term to steady-state output from E3 CGE model
  - Fit short-run elasticity, holding constant term fixed, to transition output from Goulder-Hafstead E3 CGE model

Reduced-Form Model: Evaluating Price Elasticity Fit



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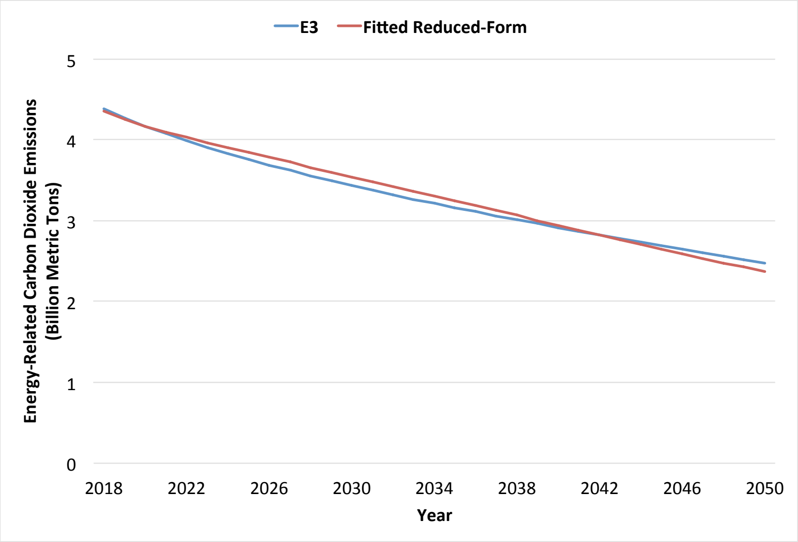

Reduced-Form Model: Calibrating Uncertainty

- Trend Uncertainty
  - Normal distribution
  - Choose std. dev. such that confidence interval matches AEO confidence intervals
- Cyclical Uncertainty
  - Calibrate to match historical ()1973-2017) fluctuations
- Price Elasticity Uncertainty
  - Log-normal distribution (β_2 and β_3)
  - Choose std. dev. to generate plausible confidence intervals
  - Alternatives include: Abrell and Rausch (2017), EMF32, others?

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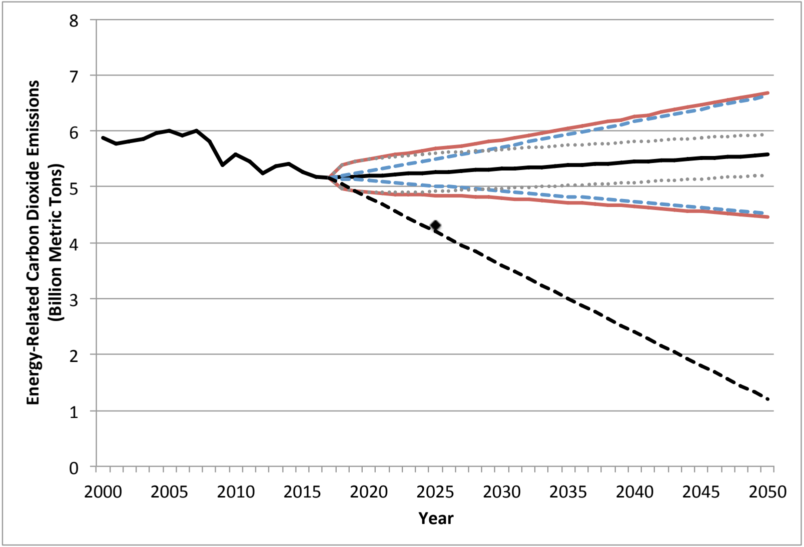
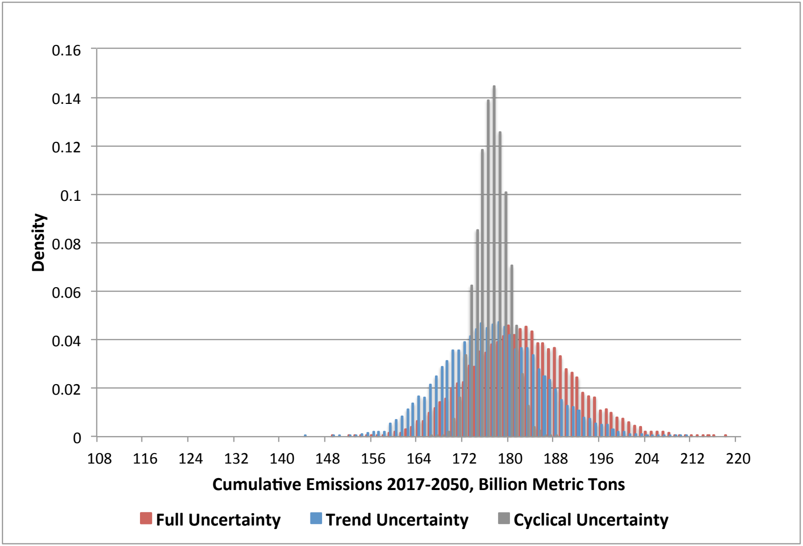
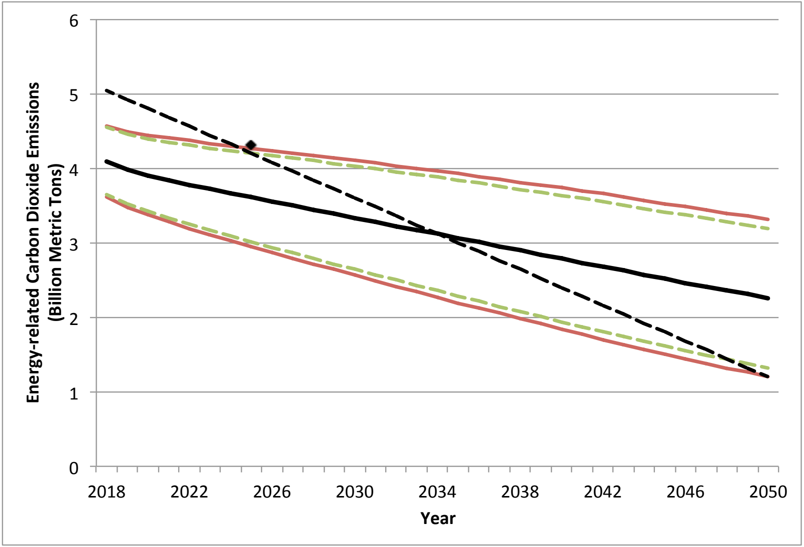
$0 Carbon Tax Case: Annual US Emissions



$0 Carbon Tax Case: Cumulative US Emissions



$44 @ 5% Carbon Tax Case: Annual US Emissions



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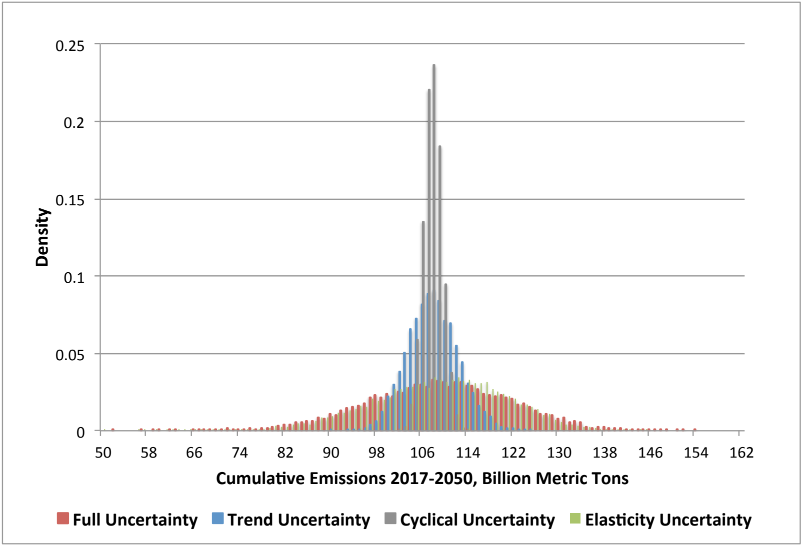

Quantifying Emissions Uncertainty: Summary

- Without a carbon tax
  - Cyclical variation drives short-term uncertainty
  - Trends drive long-term uncertainty
- With a carbon tax
  - Uncertainty in the elasticity of emissions intensity with respect to the price dominates other sources of uncertainty

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Defining Emissions Certainty

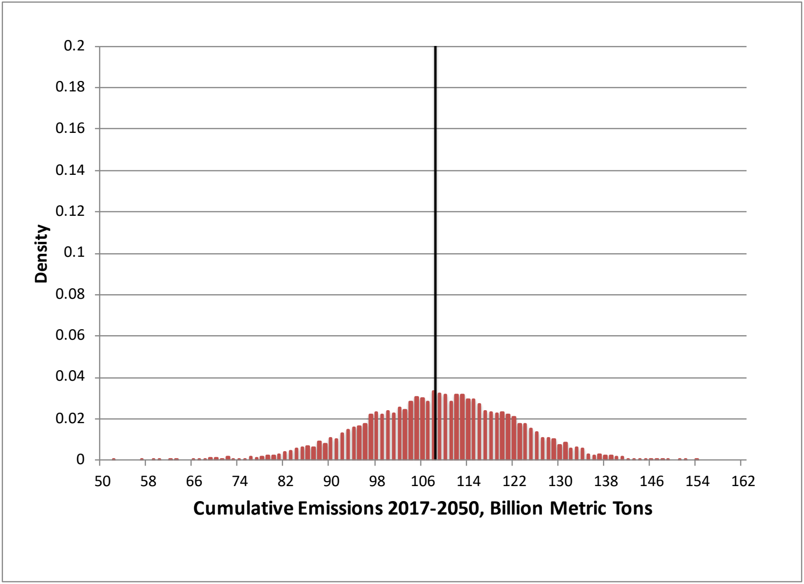
Philosophical Questions

- What do the environmentalists want to be certain about?
- Should we take into consideration the damage function?

Practical Questions

- Annual emissions or cumulative emissions?
- What moment(s) of the distribution do we compare?

Cumulative Emissions Distribution: Examples



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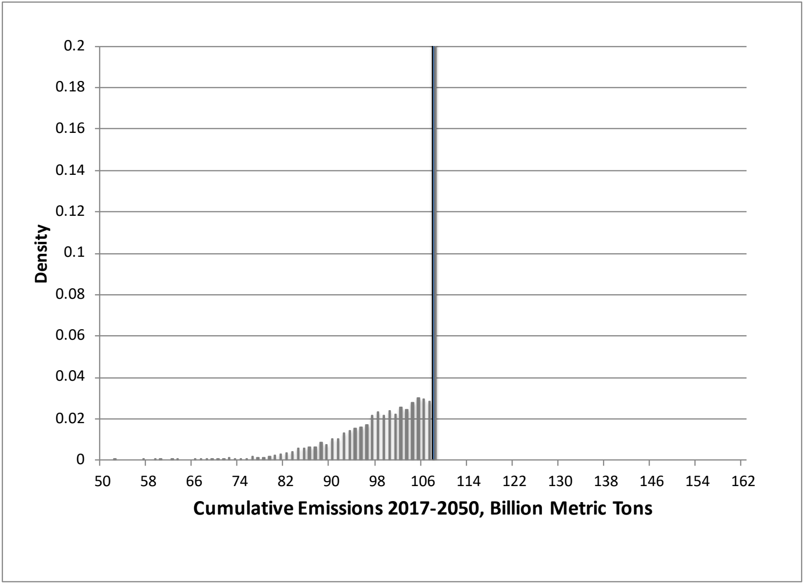

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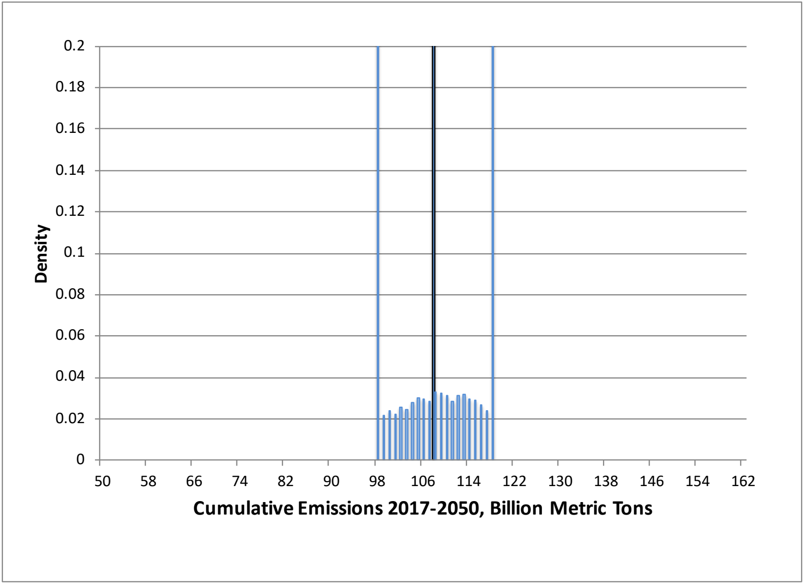
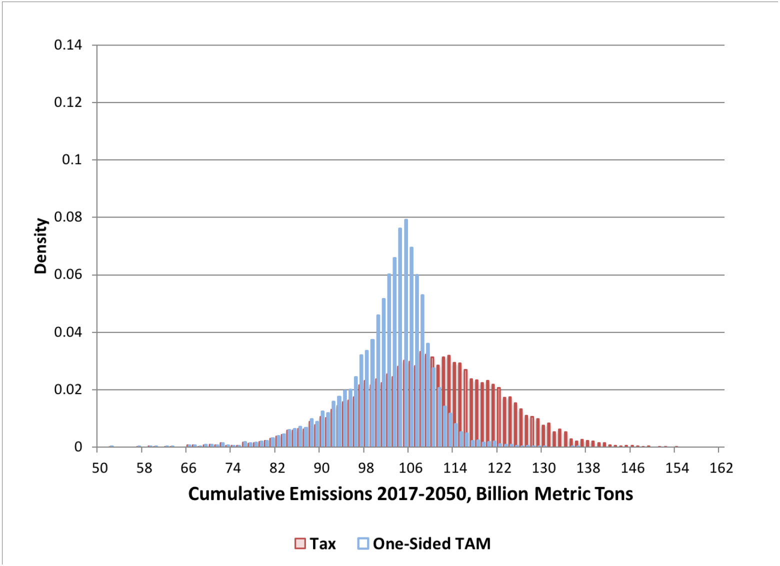


Cumulative Emissions Distribution and TAM



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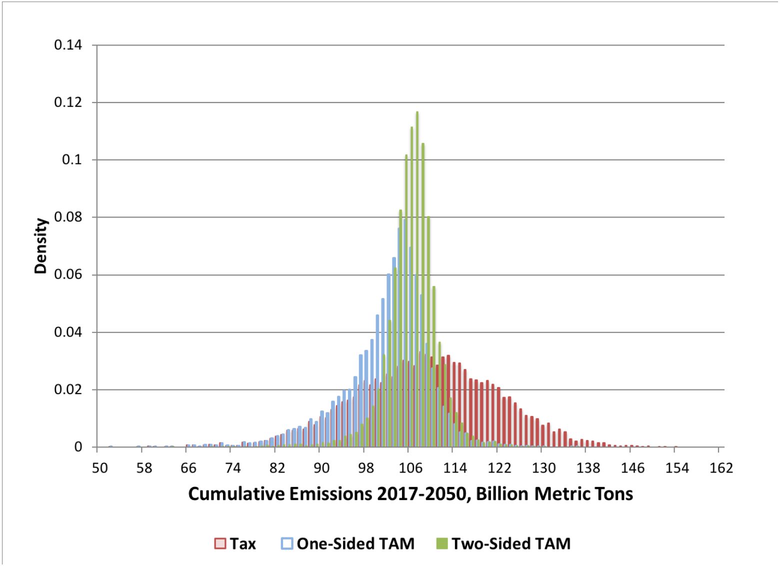

Defining Emissions Certainty

Philosophical Questions

- What do the environmentalists want to be certain about?
  - Avoid high emissions outcomes
- Should we take into consideration the damage function?
  - Yes we should, but we need more info on shape of damage curves

Practical Questions

- Annual emissions or cumulative emissions?
- What moment(s) of the distribution do we compare?
  - Normalize the 97.5th percentile to be within x% of goal using size of adjustment
  - Compare various moments

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Comparing Tax Adjustment Mechanisms

- Alternative mechanism design
- Examples of TAM's in practice
- Comparison across mechanisms: A Monte Carlo experiment

Alternative Mechanism Design from Hafstead et al.

- Rules vs. Discretion
- Control Period
- Targets and Benchmarks
- Types of Adjustments
- Frequency and Size of Adjustments
- Adjustment Trigger

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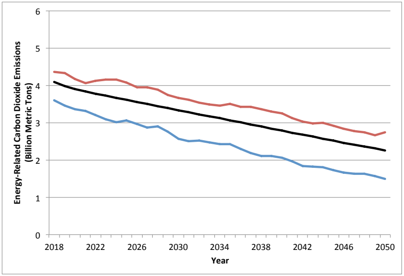
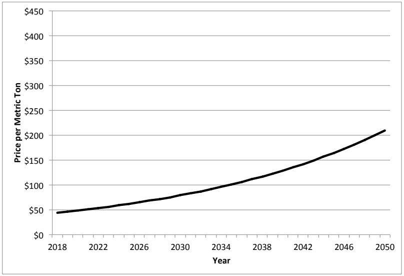
  - One Sided vs. Two Sided
  - Alternative Thresholds

Example: $44 @ 5% Carbon Tax, No TAM



(a) Emissions



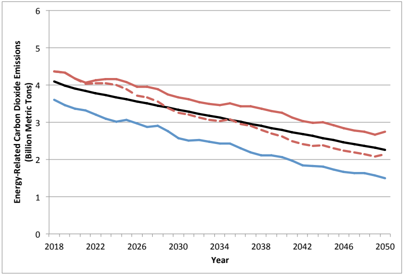
(b) Price

Bad Draw

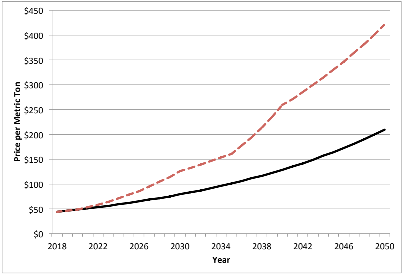
Good Draw

Example: \$44 @ 5% Carbon Tax, TAM

Central case benchmark path (annual emissions), growth rate penalty (5%), 5 years, One-Sided



(a) Emissions



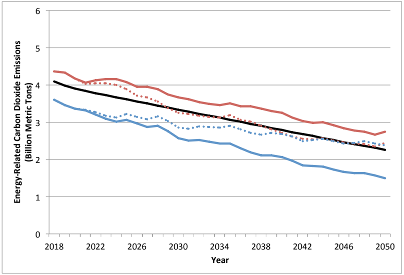
(b) Price

Bad Draw

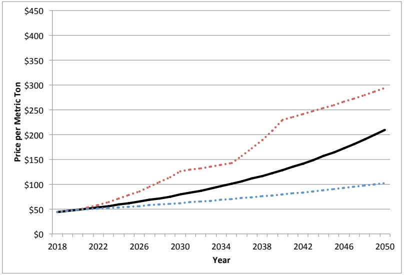
Good Draw

Example: $44 @ 5% Carbon Tax, TAM

Central case benchmark path (annual emissions), growth rate penalty (5%), 5 years, Two-Sided



(a) Emissions



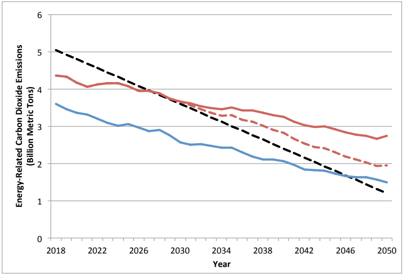
(b) Price

Bad Draw

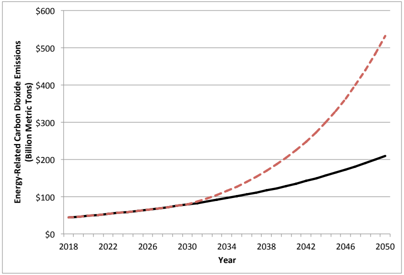
Good Draw

Example: $44 @ 5% Carbon Tax, TAM

Straight-line benchmark path (annual emissions), growth rate penalty (5%), 5 years, One-Sided



(a) Emissions



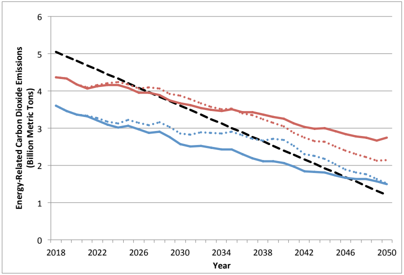
(b) Price

Bad Draw

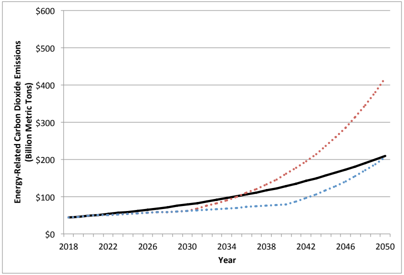
Good Draw

Example: $44 @ 5% Carbon Tax, TAM

Straight-line benchmark path (annual emissions), growth rate penalty (5%), 5 years, Two-Sided



(a) Emissions



(b) Price

Bad Draw

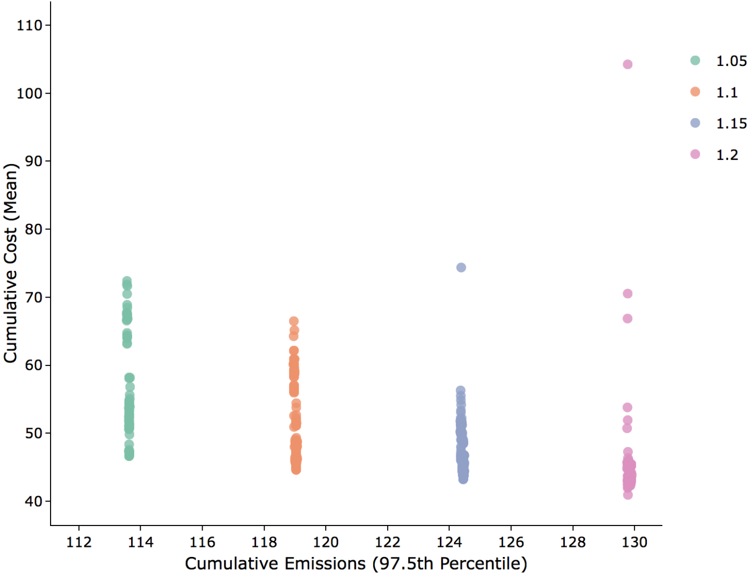
Good Draw

Mechanism Comparison

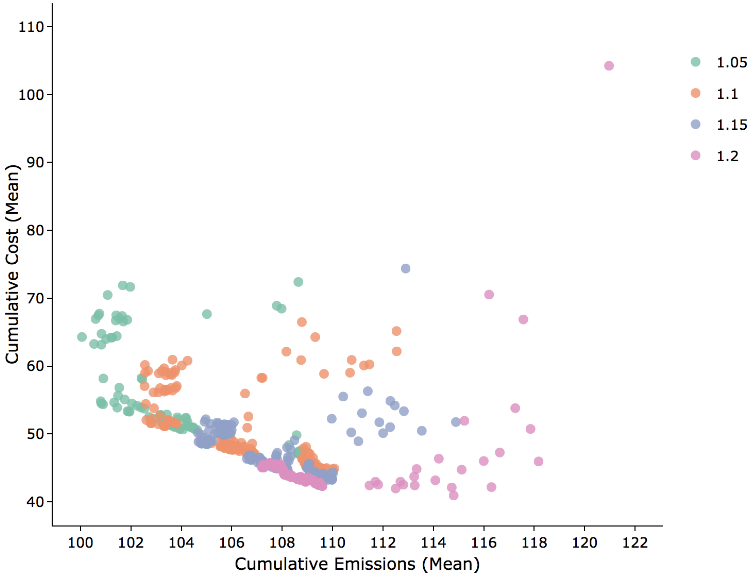
Key questions

- How do the additional expected costs vary across mechanisms?
- What are the trade-offs across mechanisms?
- Do some mechanisms Pareto dominate others?

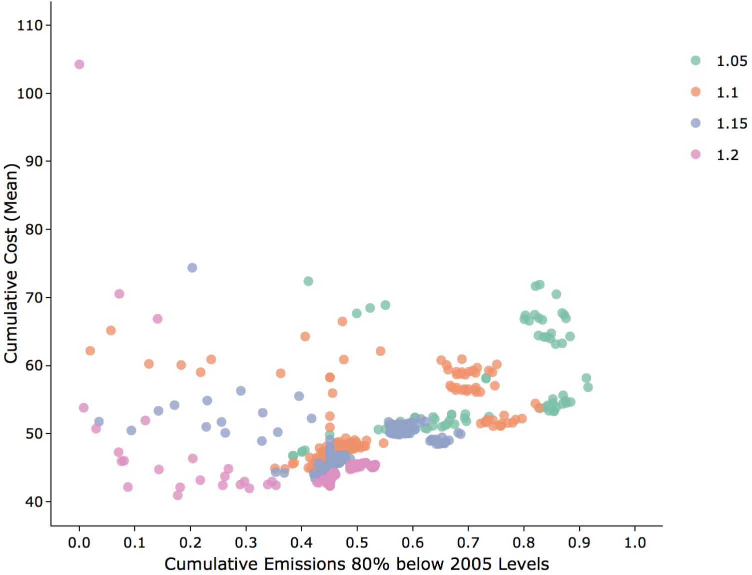
Cost vs Emissions (97.5th percentile)



Cost vs Emissions (mean)



Cost vs Emissions (target)



Mechanism Comparison

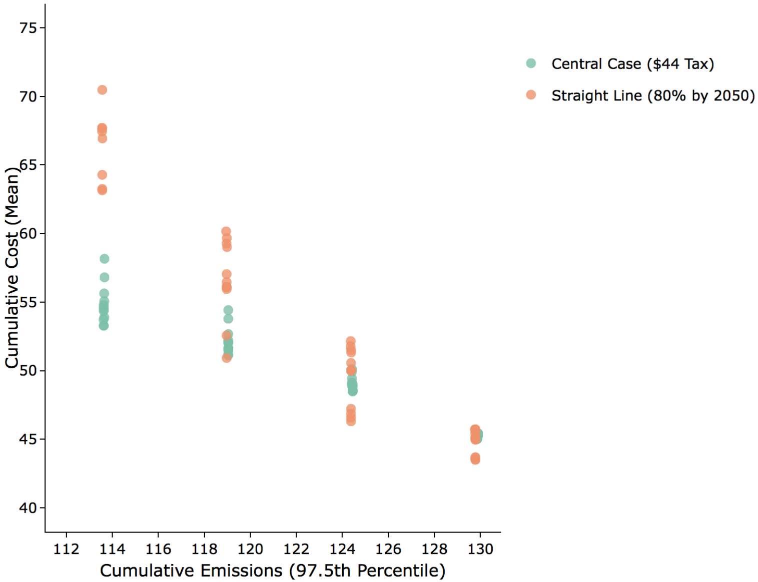
Key questions

- How do the additional expected costs vary across mechanisms?
  - Considerably
- What are the trade-offs across mechanisms?
  - Mechanisms that are more costly at reducing "right-side" risk may have lower average emissions (or higher probability of meeting projected cumulative emissions goal)
- Do some mechanisms Pareto dominate others?

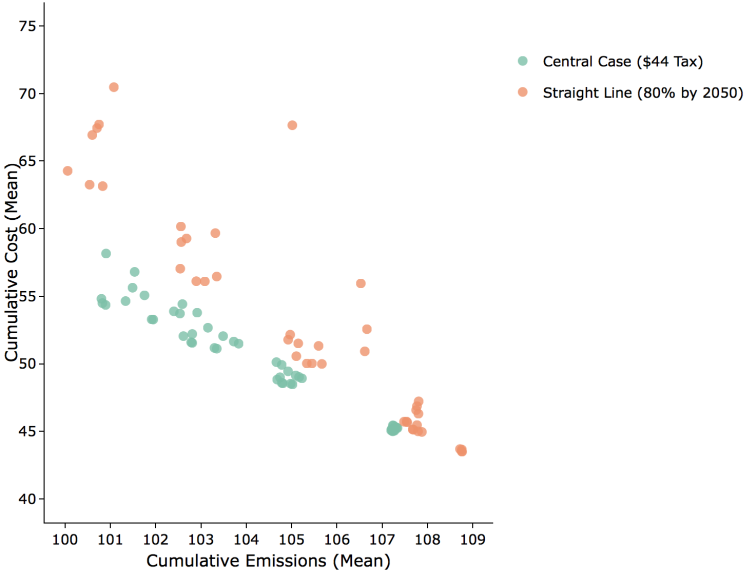
Mechanism Comparison: Details

- Alternative benchmark paths
- Type of Adjustment
- Frequency of Adjustment
- One-side vs Two-sided

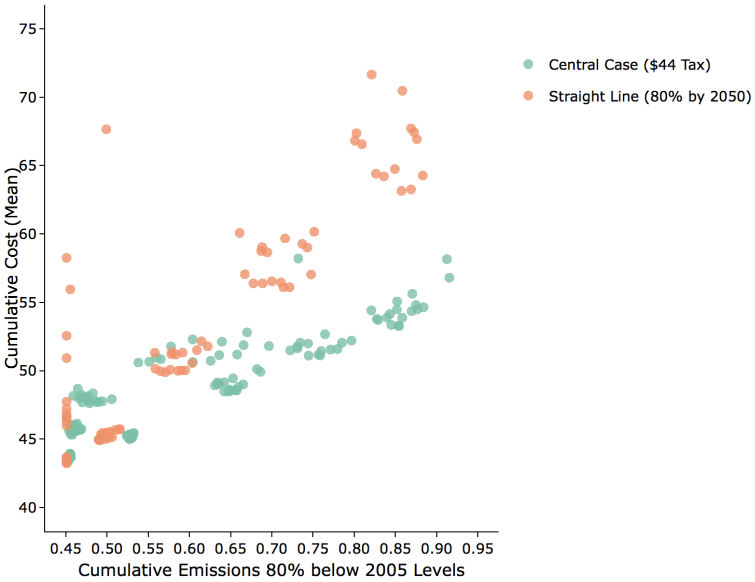
Cost vs Emissions (97.5th percentile): Adj. Path



Cost vs Emissions (mean): Adj. Path



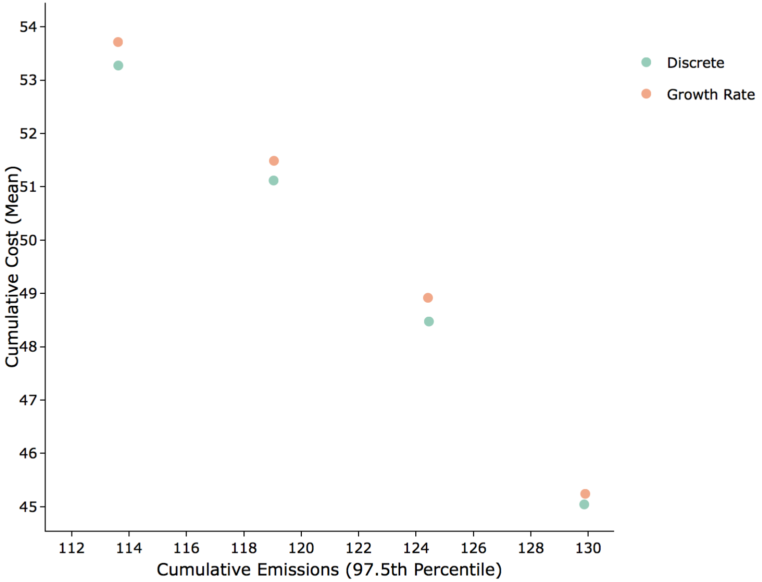
Cost vs Emissions (target): Adj. Path



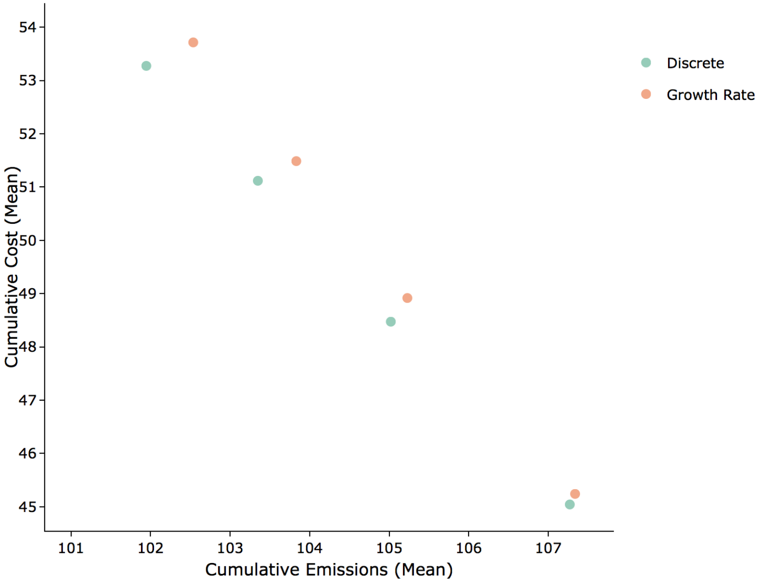
Mechanism Comparison: Details

- Alternative benchmark paths
  - Central case path Pareto dominates straight-line path
- Type of Adjustment
- Frequency of Adjustment
- One-side vs Two-sided

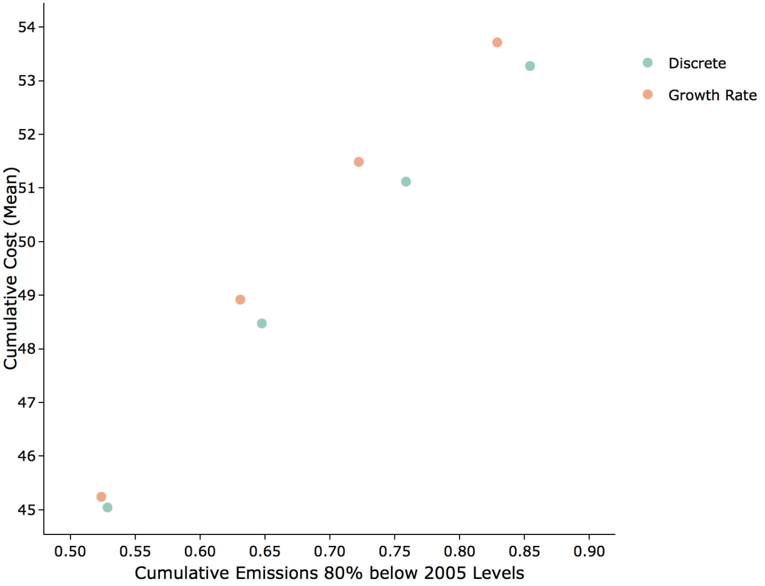
Cost vs Emissions (97.5th percentile): Type of Adj.



Cost vs Emissions (mean): Type of Adj.



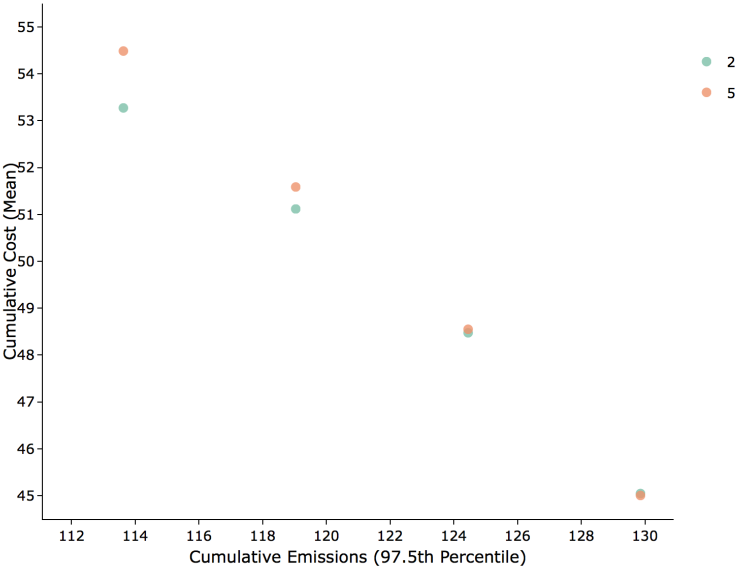
Cost vs Emissions (target): Type of Adj.



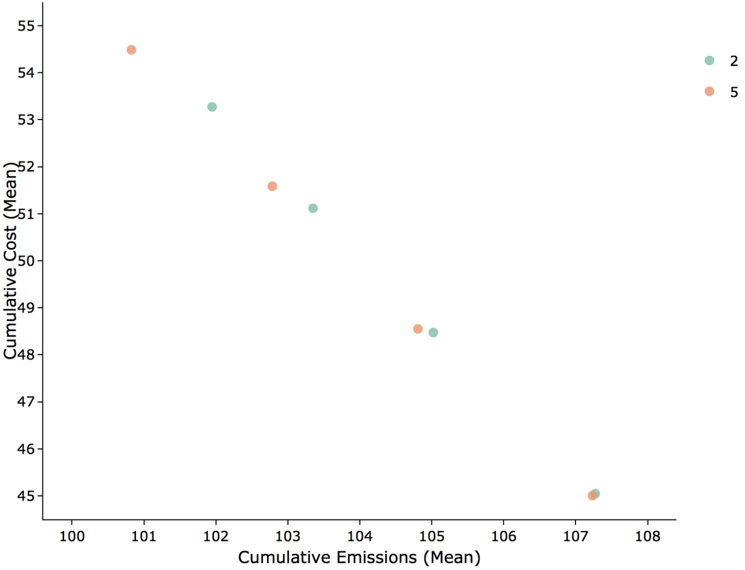
Mechanism Comparison: Details

- Alternative benchmark paths
  - Central case path Pareto dominates straight-line path
- Type of Adjustment
  - Discrete adjustments seem to dominate growth rate penalties
- Frequency of Adjustment
- One-side vs Two-sided

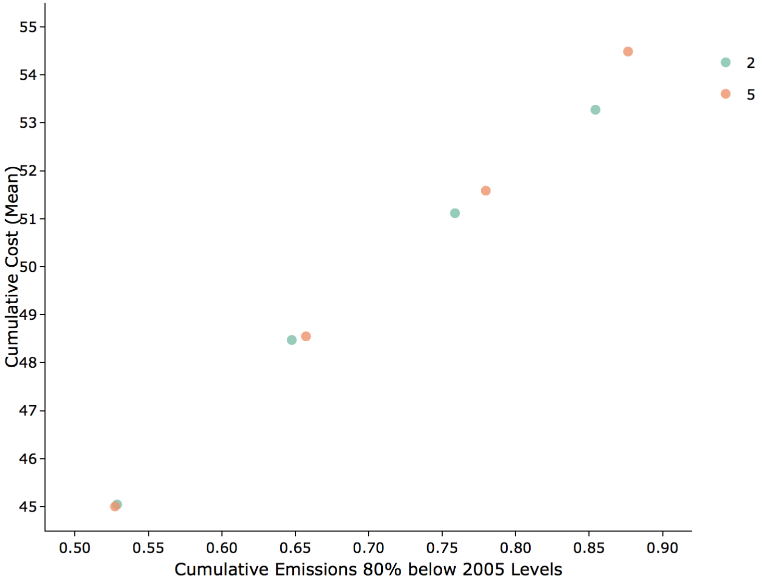
Cost vs Emissions (97.5th percentile): Frequency



Cost vs Emissions (mean): Frequency



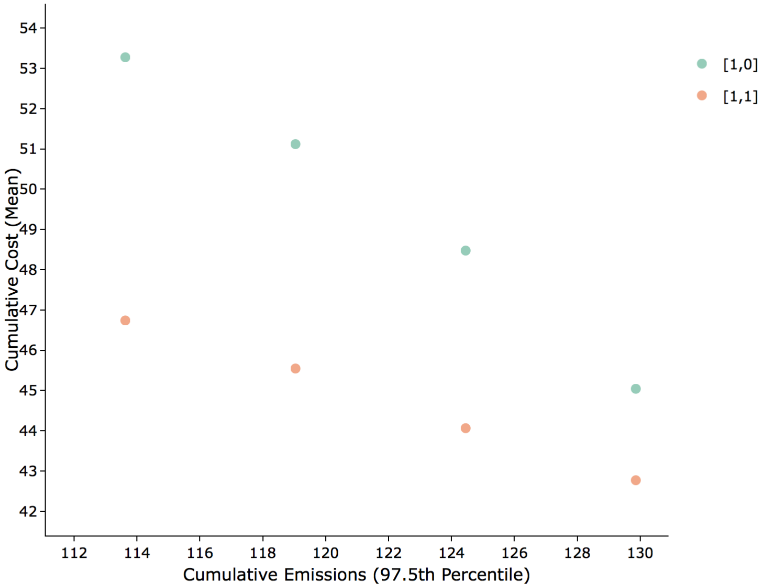
Cost vs Emissions (target): Frequency



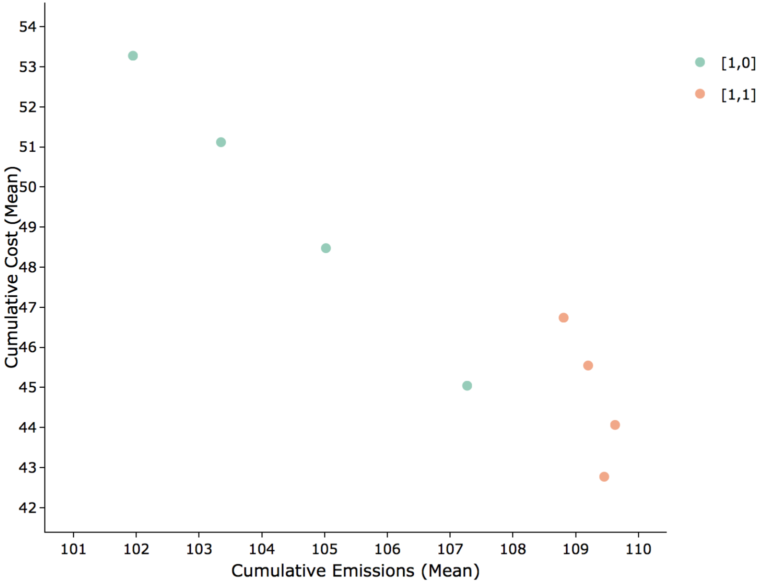
Mechanism Comparison: Details

- Alternative benchmark paths
  - Central case path Pareto dominates straight-line path
- Type of Adjustment
  - Discrete adjustments seem to Pareto dominate growth rate penalties
- Frequency of Adjustment
  - More frequent adjustments are more cost-effective given 97.5 percentile target
  - Less frequent adjustments may lead to lower emissions
  - Unclear if there is Pareto dominance
- One-side vs Two-sided

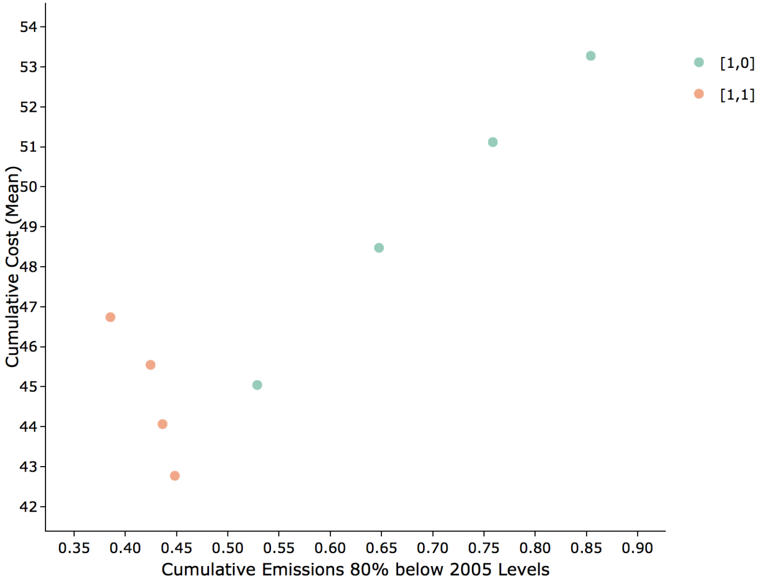
Cost vs Emissions (97.5th percentile): One vs. Two Sided



Cost vs Emissions (mean): One vs Two Sided



Cost vs Emissions (target): One vs Two Sided



Mechanism Comparison: Details

- Alternative benchmark paths
  - Central case path Pareto dominates straight-line path
- Type of Adjustment
  - Discrete adjustments seem to Pareto dominate growth rate penalties
- Frequency of Adjustment
  - More frequent adjustments are more cost-effective given 97.5 percentile target
  - Less frequent adjustments may lead to lower emissions
  - Unclear if there is Pareto dominance
- One-side vs Two-sided
  - Two-sided adjustments are far more cost-effective given 97.5 percentile target
  - Two-sided adjustments are much less likely to hit projected emissions target

Conclusion

Using a new reduced-form model, we

- quantify emissions uncertainty under a carbon tax
- perform a comprehensive quantitative analysis of tax adjustment mechanisms

We find

- emissions uncertainty is potentially large
- tax adjustment mechanisms can reduce right-side risk at a moderate expected cost
- trade-offs exist across mechanisms