The Fiscal Costs of Climate Change

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Introduction

- Climate change's fiscal impacts and policy implications

    i. Costs of existing programs (e.g., healthcare)
    ii. Public adaptation (e.g., coastal infrastructure)
    iii. Revenue impacts (e.g., employment, output effects)

  Growing policy concern (e.g., U.S. GAO "High Risk" List)

- Benchmark Integrated Assessment Models (IAMs, e.g. DICE, Nordhaus, 1992, 2017; FUND, Anthoff and Tol, 2014; Golosov et al., 2014, etc.) typically do not distinguish fiscal costs as such

- However, if gov't raises revenues with *distortionary* taxes:
  - Socially costly to raise, divert public funds
  - Fiscal constraints may limit adaptation → Increase residual climate damages (relative to benchmark predictions)

This Paper

1. Climate impacts on existing programs: 'Damage function'
   - Collect, harmonize existing estimates: disaster assistance etc.
   - Add empirically-based estimate: wildfire healthcare costs

2. Endogenous public adaptation expenditures
   - Build representation based on lit. (e.g., Agrawala et al., 2010)
   - Separate protection of production vs. direct utility impacts

3. Integrate fiscal impacts into COMET (Barrage, 2019) - IAM extending DICE with linear distortionary taxes, gov't spending

   $\Rightarrow$ Optimal policy implications

   $\Rightarrow$ Welfare, fiscal implications of *failure* to price carbon

Literature

- Climate-economy models, IAMs (DICE/RICE, Nordhaus, 1992, 2011, 2017; Manne, Richels, 2005; FUND, Anthoff, Tol, 2014; Golosov et al., 2014; v.d. Ploeg, Withagen, 2014; etc.), Adaptation (e.g., Hope, 2006; Tol, 2007; deBruin et al. 2009; Bosello et al., 2010; Agrawala et al. 2010; Fried 2019)
  - Here: Fiscal constraints, distortionary taxes
- Pollution *mitigation* and distortionary taxes (Sandmo 1975, Bovenberg, de Mooij 1994; Goulder 1995; Bovenberg Goulder, 1996; Williams 2002, Babiker, Metcalf, Reilley 2003; Goulder, Hafstead, Williams 2014, etc.)
  - Here: Integrated assessment, output & public spending impacts
- Fiscal impacts of weather events (Noy, Nualsri, 2011; Deryugina, 2017), climate change (e.g., IMF, 2008; CBO, 2016; OMB, 2016)
  - Here: Integrate into IAM, analyze implications
- Adaptation (Mendelsohn '00; Parry et al. '09; Kane, Shogren '00; Annan, Schlenker '15; Barreca et al. '16; Auffhammer '18; Carleton et al. '18)

Talk Outline

1. Introduction
2. **Climate Change and Public Program Costs**
3. COMET Model and Fiscal Impacts
   - Theory: Optimal Public Adaptation
   - Calibration
4. Quantitative Results
5. Conclusion

Climate Change and Public Program Costs

- Existing estimates:
  - Hurricane-related public disaster spending: CBO (2016)
  - Wildfire suppression: U.S. Forest Service (2015), OMB (2016)
  - Crop insurance subsidies: U.S. Dept. of Agriculture (2016)
  - Air quality, health: Garcia-Menendez et al. (2015), OMB (2016)

- Wildfires and public healthcare: Details
  - Restrospective empirical analysis: BEA, NOAA, Medicare data
  - Wildfire risk changes: McKenzie et al. (2004), Littell et al. (2009), Liu et al. (2009), Lenihan et al. (2003), Rogers et al. (2011)

- Hurricanes and public healthcare costs:
  - Retrospective empirical analysis: Deryugina (2017)
  - Hurricane risk changes: Emanuel et al. (2008), Bakkensen and Barrage (2019)

Climate Change and Public Program Costs

- Harmonize estimates to cost change per $1^\circ C$ warming Linearity

	%ΔCost per $1^\circ C$	
Program(s)	Program	Gov't Cons.
Hurricane response*	+5%	+0.04%
Crop-insurance subsidies	+14%	+0.04%
Wildfire suppression - FS	+52%	+0.04%
Wildfire suppression - DOI	+20%	+0.004%
Fed. healthcare - Air quality		+0.01%
Healthcare - Wildfires	varies by state	+0.008%
Healthcare - Hurricanes	varies by county	+0.19%
Total		**+0.32%**

*Includes FEMA aid, HUD, Army Corps of Engineers, DOD, DOT

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COMET Overview

- Climate Optimization Model of the Economy and Taxes (Barrage, 2019)
- Match key features of seminal DICE model (Nordhaus and Boyer, 2000; Nordhaus, 2008, 2010)

As in DICE	New in COMET	New Here
Carbon cycle	Linear income, input taxes	Gov't consumption effects
Clean energy costs	Government expenditures	Adaptation policy choice
Productivity growth	Endog. labor supply	Gross vs. net climate damages
Population growth	Energy sector	
Total (net) damages	Utility vs. output damages	

Model Overview: Households

- Infinitely-lived, rep. household with well-behaved **preferences** over consumption C_t, labor L_t, climate change T_t:

$$U_0 \equiv \sum_{t=0}^{\infty} \beta^t U(C_t, L_t, (1 - \Lambda_t^u) T_t)$$

- $\Lambda_t^u \sim$ adaptive capacity to reduce climate utility impacts

- **Household Flow Budget Constraints:**

+ After-tax labor & capital income, gov't transfers, gov't bond repayments, energy sector profits
- Consumption, gov't bonds, capital investment

Model Overview: Production

- **Final Good:** Production CRS in L_{1t}, K_{1t} and energy E_t

$$\begin{aligned} Y_t &= F_1(A_{1t}, L_{1t}, K_{1t}, E_t, T_t, \Lambda_t^y,) \\ &= (1 - D(T_t)(1 - \Lambda_t^y)) \cdot A_t \widetilde{F}_1(L_{1t}, K_{1t}, E_t) \end{aligned}$$

  - $D(T_t)$ gross climate damages, Λ_t^y adaptive capacity

- **Energy Input:** CRS extraction technology:

$$E_t = F_2(A_{Et}, L_{2t}, K_{2t})$$

  - Provide fraction μ_t from clean tech. at extra cost $\Theta_t(\mu_t E_t)$

- **Climate** depends on initial conditions $\mathbf{S}_0$, carbon emissions $(1 - \mu_t)E_t$, exog. shifters $\boldsymbol{\eta}_t$:

$$T_t = \mathcal{F}\left(\mathbf{S}_0, (1 - \mu_0)E_0, ..., (1 - \mu_t)E_t, \boldsymbol{\eta}_0, ...\boldsymbol{\eta}_t\right)$$

Model Overview: Government

- **Expenditures:** Must raise revenues to finance
  - Household transfers $\overline{G}_t^T \geq 0$
  - Consumption: $G_t^C(T_t)$
  - Initial debt B_0
- May choose to fund $(\lambda_t^y, \lambda_t^u)$ adaptation:

$$\Lambda_t^i = f^i(\lambda_t^i) \text{ for } i \in \{u, y\}$$

- **Revenues**:
  - Linear taxes on labor income τ_{lt}
  - Linear taxes on net-of-depreciation capital income τ_{kt}
  - Excise taxes on energy inputs τ_{It}
  - Excise taxes on carbon emissions τ_{Et}
  - One-period bonds
- **Marginal Cost of Public Funds** (MCF_t): Welfare cost of raising extra dollar of gov't revenue
  - Ratio of the public / private marginal utility of income

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Production Damages Adaptation

Result 1 *Public adaptation funding to reduce climate impacts on final goods production should remain undistorted (fully provided) regardless of the welfare costs of raising revenues.*

- Intuition: Productivity benefits compensate for fiscal costs
- Optimal tax system maintains production efficiency (Diamond, Mirrlees, 1971); Provides public production inputs fully (Judd, 1999)

Utility Damages Adaptation

Result 2 *Public adaptation to reduce direct utility losses should be less-than-fully provided (distorted) if governments raise revenues with distortionary taxes. That is, the provision and thus consumption of the climate adaptation good should be effectively taxed.*

- Intuition: No productivity benefit to counteract dist. tax costs

- Optimal pollution tax also treats utility damages differently (Bovenberg and van der Ploeg, 1994; Williams, 2002)

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Fiscal Impacts Calibration

- **Government Consumption**:

$$G_t^C(T_t) = \overline{G_t^C}(1 + \alpha_{g,1}(T_t)^{\alpha_{g,2}})$$

→ Benchmark estimates: Set $\alpha_{g,2} = 1$ and $\alpha_{g,1} = 0.0032$

- **Gross Damages, Adaptation** - Set to match:

Moment	Target	Model	Target Source:
Opt. Carbon Tax ($/mtC)	71	73	COMET w/o dist. taxes, adapt.
Opt. Residual Dam.*	1.74	1.72	DICE (2010)
Gross U-Damages*	2.2%	2.2%	Disagg. of Agrawala et. al. (2010)
Gross Y-Damages*	0.7%	0.7%	Disagg. of Agrawala et. al. (2010)
Opt. Resid. Y-Dam.*	1.29	1.24	COMET w/o adaptation
Opt. Resid, U-Dam.*	0.46	0.48	COMET w/o adaptation
Opt. Public Y-adapt.*	0.24%	0.21%	50% of Disagg. Agrawala et. al. (2010)
Opt. Public U-adapt.*	0.08%	0.03%	50% of Disagg. Agrawala et. al. (2010)

*at 2.5C in %GDP

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Fiscal Scenarios

- Income Taxes:

1. "First-Best": Gov't can levy non-distortionary lump-sum taxes
2. "Optimized Distortionary": Gov't can optimize (non-lump sum)
3. "Vary τ_l, BAU $\overline{\tau_k}$": Capital income taxes fixed at baseline ($\overline{\tau_k} = 34.6\%$), gov't can raise labor income taxes
4. "BAU $\overline{\tau_l}$, Vary τ_k": Labor income taxes fixed at baseline ($\overline{\tau_l} = 38.4\%$), gov't can raise capital income taxes

- Carbon & Energy Taxes:

1. "No": Business-as-usual with no carbon tax until 2115
2. "Optimized"

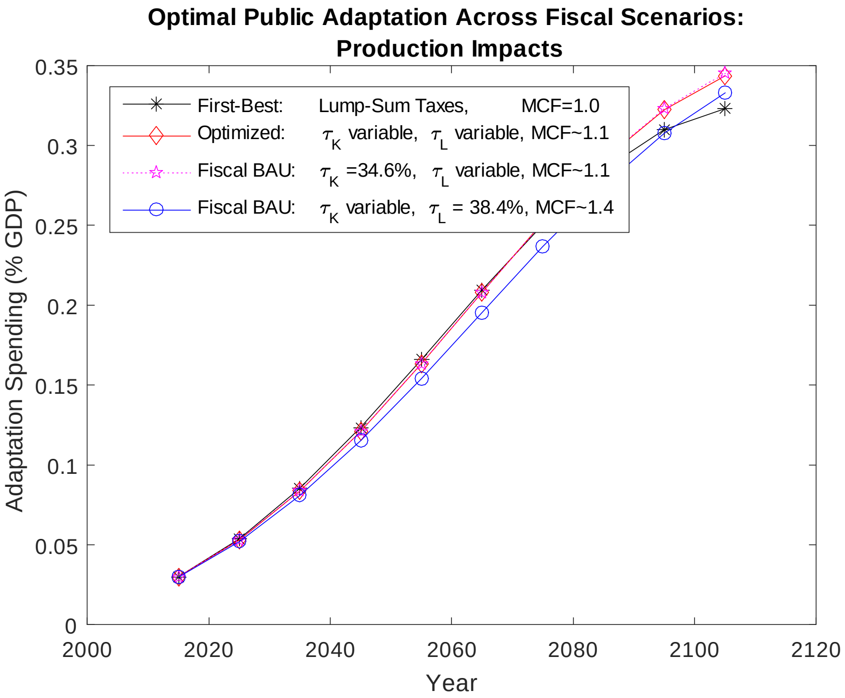
Welfare Impacts of Carbon Pricing

Policy Scenario: Income Taxes:	MCF[2]	Carbon & Energy:	Impacts: Benchmark ΔWelfare[1]	$+G_t^c(T)$ ΔWelfare[1]	Carbon Tax[4] 2015
First-Best	1.0	No[3]			0
	1.0	Opt.	\$20.5 tril.	\$21.3 tril.	74
Optimized	1.1	No			0
	1.1	Opt.	\$22.9 tril.	\$23.9 tril.	61
BAU $\overline{\tau_l}$ (38.4%)	1.4	No			0
vary. τ_k	1.4	Opt.	\$25.8 tril.	\$27.7 tril.	52
Vary τ_l,	1.1	No			0
BAU $\overline{\tau_k}$ (34.6%)	1.1	Opt.	\$22.0 tril.	\$23.0 tril.	61

[1] Equiv. variation change in agg. initial (2015) consumption.

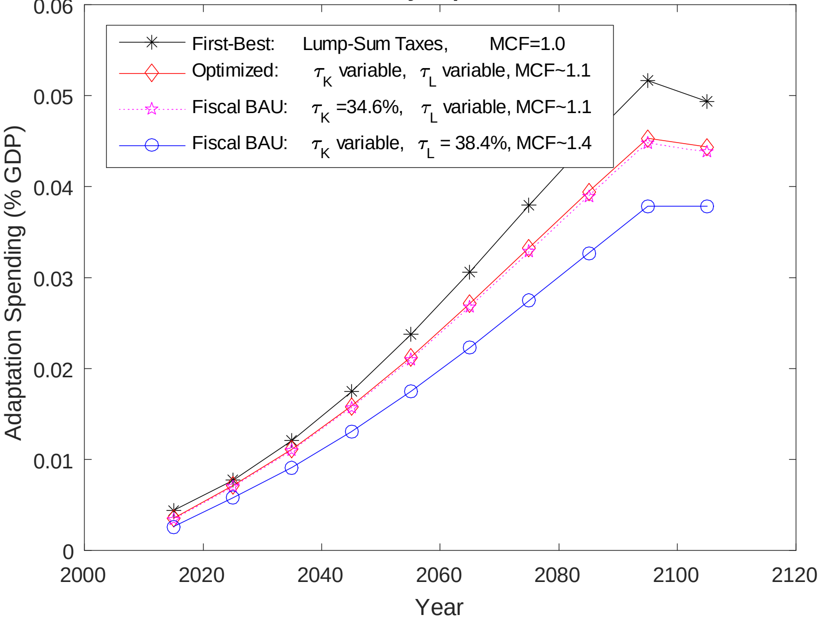
[2] Avg. marginal cost of public funds from 2025-2215.

[3] Until 2115 [4] In \$/mtC



Optimal Public Adaptation Across Fiscal Scenarios:
Production Impacts
First-Best: Lump-Sum Taxes, MCF=1.0
Optimized: τ_K variable, τ_L variable, MCF~1.1
Fiscal BAU: τ_K =34.6%, τ_L variable, MCF~1.1
Fiscal BAU: τ_K variable, τ_L = 38.4%, MCF~1.4
Adaptation Spending (% GDP)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
2000
2020
2040
2060
2080
2100
2120
Year

Optimal Public Adaptation Across Fiscal Scenarios: Utility Impacts



Fiscal Impacts with Public Adaptation

Policy Scenario		Capital Tax	Labor Tax	MCF	Adapt. Spend (%GDP) Avg. 2025-2215	
Income Taxes:	Carbon & Energy:	Avg. 2025-2215			Y	U
First-Best	Opt.	0	0	1.00	0.22%	0.05%
	No	0	0	1.00	0.65%	0.11%
BAU $\overline{\tau_l}$,	Yes	34.3%	38.4%	1.43	0.25%	0.04%
vary τ_k	No	37.5%	38.4%	1.53	0.68%	0.07%
vary τ_l,	Yes	34.6%	38.5%	1.06	0.24%	0.05%
BAU $\overline{\tau_k}$	No	34.6%	38.9%	1.07	0.67%	0.09%

Conclusion

- Consideration of climate change's fiscal impacts may significantly increase welfare gains from carbon pricing
  - +10-30% with distortionary vs. lump-sum taxes
  - *Failure* to price carbon may require non-trivial tax increases
- Optimal public adaptation expenditures w/ dist. taxes:
  - Protection of production: Fully provided
  - Protection of utility: Reduced by 20-40%
- Many caveats! Quantification of fiscal impacts, adaptation even more uncertain than standard damages; Simple model
- Results nonetheless highlight *potential importance* of fiscal impacts $\Rightarrow$ Warrant further empirical, IAM consideration
- Next: Sensitivity, U.S-only model, Rob's suggestions!

	(1)	(2)
	First Stage	Second Stage
	ln(Unhealthy Days)	ln(Outp. Dialysis Events/1000 Ben.)
ln(FireDays)	0.0761***	
	(0.0222)	
ln(UnhealthyDays)		-0.0020
		(0.0057)
Obs.	2,298	2,298
#Counties	233	233
Demo./Inc. Controls:	Yes	Yes
Medicare Controls:	Yes	Yes
County F.E.s:	Yes	Yes
Year F.E.s:	Yes	Yes
State-Trends:	Yes	Yes
S.E. Cluster	County	County
Adj. R-Sq.		0.558
Kleibergen-Paap Wald F. Stat.	11.70	

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Public Program Costs: Linearity Assumption

Crop Insurance Cost Increase by 2080

	RCP 8.5	RCP 4.5	Source
Increase	+40%	+23%	OMB (2016)
Global Temp. Change (by 2075)	2.85 C	1.6 C	IPCC (2014)
Per 1 C impact:	+14.0%	+14.4%	

Wildfire Suppression Cost Increases

	RCP 8.5		Source
	2041-59	2081-99	
Global Temp. Change	2.0 C	3.7 C	IPCC (2014)
Forest Service	+117%	+192%	OMB (2016), USDA FS (2015)
Per 1 C impact:	+58.5%	+51.9%	

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Wildfires and Public Healthcare: Motivation

1) Some areas projected to see substantial wildfire risk increases:

Avg. Projected Change in Wildfire Activity* per 1 C global warming		
State	%Δ	Sources:
AZ	241	McKenzie et al. (2004), Littell et al. (2009), Liu et al. (2009)
UT	240	McKenzie et al. (2004), Littell et al. (2009), Liu et al. (2009)
NM	237	McKenzie et al. (2004), Littell et al. (2009), Liu et al. (2009)
UT	240	McKenzie et al. (2004), Littell et al. (2009), Liu et al. (2009)
NV	98	McKenzie et al. (2004), Littell et al. (2009), Liu et al. (2009)
ID	85	Littell et al. (2010), Liu et al. (2010)
CA	82	Lenihan et al. (2003), McKenzie et al. (2004), Littell et al. (2009)
OR	72	Rogers et al. (2011), Littell et al. (2010), Liu et al. (2010)
WA	72	Rogers et al. (2011), Littell et al. (2010), Liu et al. (2010)

*Acres burned per year or annual wildfire potential (Keetch-Byram Drought Index)

Wildfires and Public Healthcare: Motivation

2) Wildfires have been linked to poor air quality, increased healthcare utilization (e.g., Ahman et al. (2012) on 2012 Colorado fires; Gan et al. (2017) on Washington 2012 fires; Fan et al. (2018) national model)

- Data: County-year panel (1996-2018)
    - Top quartile of wildfire states (National Interagency Fire Center)
- Public medical transfers: BEA "Regional Economic Accounts" (REA); Centers for Medicare & Medicaid Services (CMMS)
- Wildfire and smoke events; other weather events: NOAA
- Air quality ratings: Environmental Protection Agency
- Demographics: REA, National Center for Health Statistics

Dep. Var.:	ln(Public Medical Expenditures)						
	Medicaid plus (Veterans etc.)			Medicare			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(FireDays)	0.0007**	0.0007**	0.0007**	0.0001	0.0006*	0.0001	0.0006*
	(0.0004)	(0.0004)	(0.0004)	(0.0002)	(0.0003)	(0.0002)	(0.0003)
ln(WinterEventDays)			0.0011***			0.0005**	0.0002
			(0.0004)			(0.0002)	(0.0003)
ln(RainThunderDays)			-0.0003			0.0004**	0.0002
			(0.0002)			(0.0002)	(0.0002)
ln(HeatEventDays)			0.0008*			0.0001	-0.0003
			(0.0004)			(0.0002)	(0.0002)
ln(ColdEventDays)			-0.0002			0.0001	0.0002
			(0.0004)			(0.0003)	(0.0003)
Obs.	15,289	15,289	15,289	15,302	15,302	15,302	15,302
Adj. R-Sq.	0.994	0.997	0.994	0.997	0.999	0.997	0.999
#Counties	701	701	701	701	701	701	701
Demo./Inc. Controls:	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pop. Weights:	No	Yes	No	No	Yes	No	Yes
County F.E.s:	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.s:	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Trends:	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S.E. Cluster	County	County	County	County	County	County	County

2SLS Air Quality-Healthcare Dialysis "Placebo" Back

	(1)	(2)	(3)	(4)
	First Stage	Second Stage	First Stage	Second Stage
	ln(Unhealthy Days)	ln(Public Medical Expend.)	ln(Unhealthy Days)	ln(Emergency Dep. Visits/ 1000 Ben.)
ln(FireDays)	0.0728***		0.0798***	
	(0.0166)		(0.0222)	
ln(UnhealthyDays)		0.0082**		0.0069*
		(0.0033)		(0.0041)
Obs.	4,704	4,704	2,320	2,320
#Counties	282	282	237	237
Demo./Inc. Controls:	Yes	Yes	Yes	Yes
Medicare Controls:	-	-	Yes	Yes
County F.E.s:	Yes	Yes	Yes	Yes
Year F.E.s:	Yes	Yes	Yes	Yes
State-Trends:	Yes	Yes	Yes	Yes
S.E. Cluster	County	County	County	County
Adj. R-Sq.		0.973		0.203
Kleibergen-Paap Wald F. Stat.	19.3		12.98	

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