Do Firm Credit Constraints Impair Climate Policy?

Matthias Kaldorf **Mengjie Shi**

Deutsche Bundesbank

AEA 2025

Introduction

Research Question:

Do firm credit constraints affect the conduct of climate policy?

- **Micro level**: study the role of credit constraints for the pass-through of climate policy on firm-level climate performance.

$\Rightarrow$ Firms with tighter credit constraints (lower distance-to-default) respond less to carbon tax shocks.

Introduction

Research Question:

Do firm credit constraints affect the conduct of climate policy?

- **Micro level**: study the role of credit constraints for the pass-through of climate policy on firm-level climate performance.

  $\Rightarrow$ Firms with tighter credit constraints (lower distance-to-default) respond less to carbon tax shocks.

- **Macro level**: evaluate macroeconomic relevance in augmented E-DSGE model.

  $\Rightarrow$ Carbon taxes consistent with net zero emissions are 24\$/ToC larger in the economy with endogenous credit constraints than without.

Empirical Analysis

	(1) $\Delta log(Emi)_{j,t}$	(2) $\Delta log(Emi)_{j,t}$
$D2D_{j,t-1} \times \Delta Tax_{c(j),t}$	**-0.002****	-0.008***
	(0.001)	(0.003)
$D2D_{j,t-1}$	0.005**	0.006**
	(0.002)	(0.002)
$\Delta Tax_{c(j),t}$	-0.017	0.061***
	(0.011)	(0.022)
Controls	✓	✓
Observations	40,109	10,215
R-squared	0.024	0.167
Industry-by-year FE	SIC-group	4-digit SIC
Country FE	✓	✓
Sectors	All	Manuf
Capital Intensity	All	Low

- We regress annual emission growth at the firm-level on country-level carbon tax changes interacted with firm-level measure of credit constraint: Merton's distance to default.
- Firms with tighter credit constraints respond less to a carbon tax increase

$\Rightarrow$ 1 std increase of D2D (5.5) corresponds to 1.1% slower emission growth after a 10$ carbon tax increase

Complete Baseline | Data | Summary Statistics

Empirical Results – Baseline

	(1) $\Delta log(Emi)_{j,t}$	(2) $\Delta log(Emi)_{j,t}$
$D2D_{j,t-1} \times \Delta Tax_{c(j),t}$	-0.002**	**-0.008*** **
	(0.001)	(0.003)
$D2D_{j,t-1}$	0.005**	0.006**
	(0.002)	(0.002)
$\Delta Tax_{c(j),t}$	-0.017	0.061***
	(0.011)	(0.022)
Controls	✓	✓
Observations	40,109	10,215
R-squared	0.024	0.167
Industry-by-year FE	SIC-group	**4-digit SIC**
Country FE	✓	✓
Sectors	All	**Manuf**
Capital Intensity	All	**Low**

- This effect is **much stronger** in manufacturing sector after controlling for more granular industry fixed effects.

▸ Complete Baseline ▸ Data ▸ Summary Statistics

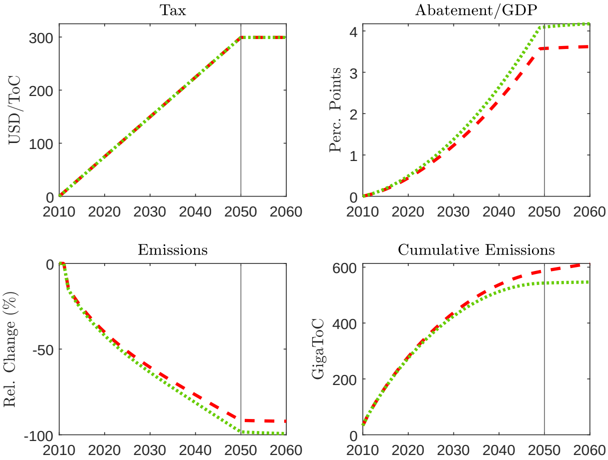
Model Setup and Intuition

- Environmental DSGE model with credit-constrained manufacturing firms and endogenous emission abatement effort.
- Credit constraints are endogenous: firms are
  - more impatient than creditors (households) $\rightarrow$ incentive to issue debt.
  - subject to idiosyncratic productivity shocks $\rightarrow$ debt is risky.
- Emissions are taxed, emission reduction possibly through costly abatement.
- **How do credit constraints impair climate policy?**

  Lower relative impatience $(\beta - \widetilde{\beta})$ $\Rightarrow$ Lower default probability $\Rightarrow$ Higher debt price and higher probability of receiving investment payoffs $\Rightarrow$ More investment in abatement $\Rightarrow$ Greater reduction in emissions.
- Standard macro-finance calibration can reconcile empirical effect of credit constraints on emission reduction.

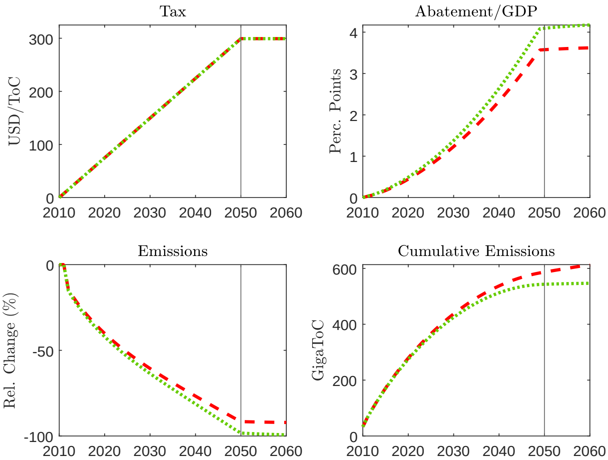
Mechanism: simple model
Mechanism: illustration
Model Validity

Implications for Net Zero Transition



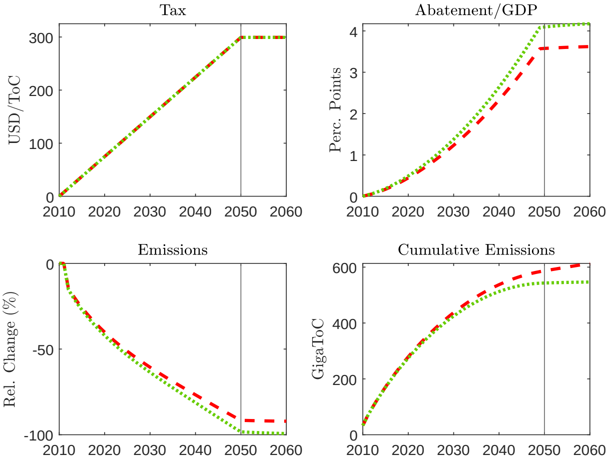
- **upper left**: carbon taxes are increased linearly from zero to 300$/ToC over 40 years

Implications for Net Zero Transition



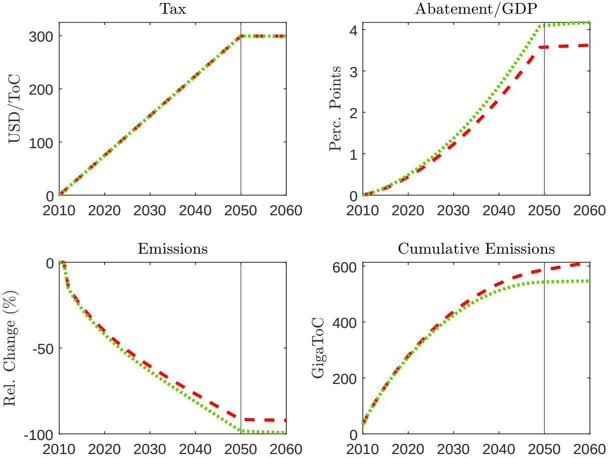
- **upper left**: carbon taxes are increased linearly from zero to 300$/ToC over 40 years
- **lower left**: net zero emissions in the economy **without credit constraints**

Implications for Net Zero Transition



- **upper left**: carbon taxes are increased linearly from zero to 300$/ToC over 40 years
- **lower left**: net zero emissions in the economy **without credit constraints**
- **upper right**: abatement/GDP ratio is **4.0%** in the risk-free economy, while **3.5%** in economy with credit constraints

Implications for Net Zero Transition



- **upper left**: carbon taxes are increased linearly from zero to 300$/ToC over 40 years
- **lower left**: net zero emissions in the economy **without credit constraints**
- **upper right**: abatement/GDP ratio is **4.0%** in the risk-free economy, while **3.5%** in economy with credit constraints
- **lower right**: accumulated CO2 emissions in 2050 are **41 gigatons** larger in the economy with credit constraints (global carbon emissions amount to 33 gigatons in 2022)

Quantitative Analysis: Climate Policy Implications

	Baseline	Risk-Free	$\widetilde{\beta} = 0.98$	$\varphi = 0.15$	$\varsigma_M = 0.2$
Transition					
Leverage Ratio (%)	29	NA	30	30	28
Recovery Rate (%)	69	NA	69	80	69
D2D	3.95	∞	3.87	3.89	3.61
Default Rate (%)	0.82	0	1.22	1.47	0.92
Climate Policy Implications					
Net Zero Tax	324\$/ToC	300\$/ToC	334\$/ToC	324\$/ToC	325\$/ToC
Δ Cum. Emissions (2050, in GigaToC)	41	0	55	40	43

- Full abatement is reached under a 324\$/ToC tax in the economy with credit frictions and a 300\$/ToC in the economy without frictions

Quantitative Analysis: Mechanism

	Baseline	Risk-Free	$\widetilde{\beta} = 0.98$	$\varphi = 0.15$	$\varsigma_M = 0.2$
Transition					
Leverage Ratio (%)	29	NA	30	30	28
Recovery Rate (%)	69	NA	69	80	69
D2D	3.95	∞	3.87	3.89	3.61
Default Rate (%)	0.82	0	1.22	1.47	0.92
Climate Policy Implications					
Net Zero Tax	324\$/ToC	300\$/ToC	334\$/ToC	324\$/ToC	325\$/ToC
Δ Cum. Emissions (2050, in GigaToC)	41	0	55	40	43

- Relative impatience ($\beta - \widetilde{\beta}$) is the driver of credit constraints to impair the efficacy of climate policy

Mechanism: simple model Mechanism: illustration

Conclusion

- Do credit constraints impair the climate policy at the **firm level**?
  - Credit constrained firms (with lower distance to default) **respond less** to a climate policy tightening.
  - The effect is particularly pronounced in low capital intensive firms within the manufacturing sector.

Conclusion

- Do credit constraints impair the climate policy at the **firm level**?
  - Credit constrained firms (with lower distance to default) **respond less** to a climate policy tightening.
  - The effect is particularly pronounced in low capital intensive firms within the manufacturing sector.
- Is this relevant at the **macro level**?
  - Accumulated global emissions in 2050 would be around 40 gigatons larger in an economy with credit frictions.
  - The net zero tax is 24$/tCO2 larger in an economy with credit constraints.

Conclusion

- Do credit constraints impair the climate policy at the **firm level**?
  - Credit constrained firms (with lower distance to default) **respond less** to a climate policy tightening.
  - The effect is particularly pronounced in low capital intensive firms within the manufacturing sector.
- Is this relevant at the **macro level**?
  - Accumulated global emissions in 2050 would be around 40 gigatons larger in an economy with credit frictions.
  - The net zero tax is 24\$/tCO2 larger in an economy with credit constraints.
- **Important**: this impairment is not due to lack of bank credit but due to frictions on **credit demand side**!

Appendix

- Empirical Setup [Data] [Summary Statistics]
- Further Empirical Results:
  - Complete baseline [Results]
  - Anticipation and persistence [Results]
  - Remove endogeneity concern [Results]
  - Add interactions between controls and carbon tax shock [Results]
  - Remove concern of multinational firms [Results]
- Model Setup
  - Households [Details]
  - Final firms [Details]
  - Investment firms [Details]
  - Manufacturing firms: Technology [Details]
  - Manufacturing firms: Credit Frictions [Details]
- Quantitative Analysis
  - Maximization problems [Details]
  - FOCs [Details]
  - Calibrations [Details]
- Mechanism
  - Simplifying the model [Details]
  - Illustration [Details]

Data

Return Return:appendix

- Measuring Climate Policy Shocks
  - Carbon pricing stringency from OECD Statistics (Kruse et al., 2023).
  - Covers all OECD members + Brazil, China, India, Indonesia, Russia, South Africa annually from 1990 to 2020.
  - Indices defined on a scale from 0 to 6, 1 unit increase in carbon pricing stringency corresponds to around 10 $/t$CO_2$.
  - Carbon tax shock defined as change of the carbon pricing stringency; an increase is interpreted as "contractionary" carbon policy.
- Measuring effectiveness of climate policy
  - Emissions (ToC) data from ISS-ESG, available annually from 2012 to 2020.
  - Emission growth utilized to assess the effectiveness of climate policy
- Measuring the credit constraints
  - We use **Merton's distance-to-default** (following Lamont et al (2001)).
  - To calculate D2D, we collect equity and accounting data from Compustat North America and Compusat Global.

⇒ Final sample consists of 18,882 firms from 2012 to 2019.

Empirical Specification

Return

- We estimate

$$\Delta \log(Emi)_{j,t} = \beta_0 + \beta_1 \cdot \mathrm{D2D}_{j,t-1} \times \Delta \mathrm{Tax}_{c(j),t} + \beta_2 \cdot \mathrm{D2D}_{j,t-1} + \beta_3 \cdot \Delta \mathrm{Tax}_{c(j),t} + \beta_4 \cdot X_{j,t-1} + \chi_c + \delta_j \times \delta_t + \epsilon_{j,t} \,. \quad (1)$$

- $log(Emi)_{j,t}$ is log difference of firm j's emission from $t-1$ to t.
- $D2D_{j,t-1}$ is distance-to-default of firm j at $t-1$
- $\Delta Tax_{c(j),t}$ is carbon tax shock in country c from $t-1$ to t
- Control for firm size, age and profitability.
- Include country and industry-by-year FEs.
- The standard errors are clustered at the country level.
- the coefficient of interest is β_1.

⇒ whether and how much firms' credit constraints impair the conduct of climate policy.

Summary Statistics

◂ Return ◂ Return: appendix

Table: **Summary Statistics**

Variables	N	Mean	SD	P25	P50	P75
Emission Gth	74729	0.00	0.91	-31.46	0.03	31.33
D2D	47378	7.86	5.50	3.95	6.01	9.90
Log(Assets)	79068	9.00	2.93	7.06	8.94	11.02
Young	80266	0.56	0.50	0.00	1.00	1.00
EBIT/Revenues	93218	0.02	0.70	0.05	0.10	0.18
Capital Intensity	93267	0.61	1.08	0.12	0.27	0.58
Leverage	84495	0.24	0.24	0.04	0.17	0.38

Complete Baseline

◂ Return ◂ Return: appendix

VARIABLES	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$	$\Delta log(Emi)_{j,t}$
$D2D_{j,t-1} \times \Delta Tax_{c(j),t}$	-0.002**	0.002	-0.004*	-0.005**	0.001	-0.006**	-0.005***	-0.001	-0.008***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
$D2D_{j,t-1}$	0.005**	0.006**	0.005***	0.006**	0.006***	0.005*	0.006***	0.007***	0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
$\Delta Tax_{c(j),t}$	-0.017	-0.078***	0.019	0.020	-0.054*	0.049**	0.018	-0.042*	0.061***
	(0.011)	(0.017)	(0.012)	(0.021)	(0.028)	(0.019)	(0.014)	(0.023)	(0.022)
$Log(Assets)_{j,t-1}$	-0.022*	-0.024	-0.021***	-0.028*	-0.037*	-0.021**	-0.034**	-0.047*	-0.027**
	(0.011)	(0.016)	(0.007)	(0.014)	(0.019)	(0.009)	(0.016)	(0.023)	(0.012)
$Young_{j,t-1}$	-0.021***	-0.030*	-0.015	-0.024***	-0.053**	0.000	-0.019**	-0.053***	0.021
	(0.006)	(0.017)	(0.014)	(0.009)	(0.021)	(0.018)	(0.009)	(0.014)	(0.014)
$EBIT/Revenues_{j,t-1}$	-0.096***	-0.153***	-0.053	-0.060***	-0.081**	-0.041	-0.063***	-0.080**	-0.039
	(0.020)	(0.028)	(0.032)	(0.020)	(0.035)	(0.029)	(0.020)	(0.036)	(0.030)
Constant	0.185*	0.232	0.150**	0.237*	0.357*	0.140**	0.287**	0.449**	0.181*
	(0.096)	(0.154)	(0.057)	(0.120)	(0.186)	(0.068)	(0.140)	(0.219)	(0.100)
Observations	40,109	21,597	18,481	24,125	13,617	10,492	23,984	13,397	10,215
R-squared	0.024	0.033	0.028	0.019	0.031	0.015	0.110	0.157	0.167
Industry-by-year FE	SIC-group	SIC-group	SIC-group	NO	NO	NO	4-digit SIC	4-digit SIC	4-digit SIC
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sectors	All	All	All	Manuf	Manuf	Manuf	Manuf	Manuf	Manuf
Capital Intensity	All	High	Low	All	High	Low	All	High	Low
Year FE	NO	NO	NO	YES	YES	YES	NO	NO	NO

Anticipation and Persistence

Return

VARIABLES	Anticipation			Persistence		
	(1) $\Delta log(Emi)_{j,t}$	(2) $\Delta log(Emi)_{j,t}$	(3) $\Delta log(Emi)_{j,t}$	(4) $\Delta log(Emi)_{j,t+1}$	(5) $\Delta log(Emi)_{j,t+1}$	(6) $\Delta log(Emi)_{j,t+1}$
$D2D_{j,t-1} \times \Delta Tax_{c(j),t+1}$	0.001	0.000	0.000			
	(0.001)	(0.002)	(0.001)			
$D2D_{j,t-1}$	0.005***	0.006***	0.005***			
	(0.001)	(0.001)	(0.001)			
$\Delta Tax_{c(j),t+1}$	0.014	0.034	0.004			
	(0.014)	(0.023)	(0.015)			
$D2D_{j,t-1} \times \Delta Tax_{c(j),t}$				0.000	-0.001	0.000
				(0.001)	(0.002)	(0.001)
$D2D_{j,t-1}$				-0.000	-0.000	-0.001
				(0.001)	(0.001)	(0.001)
$\Delta Tax_{c(j),t}$				0.013	0.028	0.006
				(0.011)	(0.020)	(0.009)
Controls	✓	✓	✓	✓	✓	✓
Observations	40,111	21,597	18,483	35,766	19,094	16,648
R-squared	0.023	0.032	0.027	0.031	0.032	0.040
Industry-by-year FE	Sector	Sector	Sector	Sector	Sector	Sector
Country FE	YES	YES	YES	YES	YES	YES
Sectors	All	All	All	All	All	All
Capital Intensity	All	High	Low	All	High	Low

Endogeneity of Policy Index

◂ Return

VARIABLES	(1) Prob($\text{Tax}_{c,t} \neq \text{Tax}_{c,t-1}$)	(2) Prob($\text{Tax}_{c,t} \neq \text{Tax}_{c,t-1}$)
Mean D2D$(j, t-1)$	-0.015	
	(0.017)	
Median D2D$(j, t-1)$		-0.009
		(0.018)
Country-Controls	✓	✓
Observations	158	158
Pseudo R-squared	0.0544	0.0539

Interaction between Controls and Carbon Tax Shock

Return

VARIABLES	(1) $\Delta log(Emi)_{j,t}$	(2) $\Delta log(Emi)_{j,t}$	(3) $\Delta log(Emi)_{j,t}$	(4) $\Delta log(Emi)_{j,t}$	(5) $\Delta log(Emi)_{j,t}$	(6) $\Delta log(Emi)_{j,t}$	(7) $\Delta log(Emi)_{j,t}$	(8) $\Delta log(Emi)_{j,t}$	(9) $\Delta log(Emi)_{j,t}$
$D2D_{j,t-1} \times \Delta Tax_{c(j),t}$	-0.002**	0.002	-0.003*	-0.006***	-0.000	-0.007***	-0.006***	-0.002	-0.009***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
$D2D_{j,t-1}$	0.005**	0.005**	0.005***	0.006**	0.006***	0.005**	0.006***	0.007**	0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
$\Delta Tax_{c(j),t}$	-0.052**	-0.089**	-0.024	-0.025	-0.101	0.012	-0.022	-0.074	-0.002
	(0.025)	(0.032)	(0.019)	(0.036)	(0.066)	(0.028)	(0.028)	(0.049)	(0.034)
$Log(Assets)_{j,t-1}$	-0.022*	-0.024	-0.021***	-0.028*	-0.037*	-0.021**	-0.034**	-0.048**	-0.026**
	(0.011)	(0.017)	(0.007)	(0.014)	(0.019)	(0.009)	(0.016)	(0.023)	(0.012)
$Young_{j,t-1}$	-0.021***	-0.030*	-0.015	-0.024***	-0.053**	-0.000	-0.019**	-0.053***	0.020
	(0.006)	(0.017)	(0.014)	(0.009)	(0.021)	(0.018)	(0.008)	(0.014)	(0.014)
$EBIT/Revenues_{j,t-1}$	-0.096***	-0.153***	-0.052	-0.060***	-0.083**	-0.041	-0.064***	-0.082**	-0.038
	(0.020)	(0.028)	(0.032)	(0.020)	(0.035)	(0.029)	(0.019)	(0.035)	(0.031)
$Log(Assets)_{j,t-1} \times \Delta Tax_{c(j),t}$	0.003	0.001	0.004**	0.008*	0.009	0.007*	0.008**	0.009	0.012**
	(0.002)	(0.002)	(0.002)	(0.005)	(0.006)	(0.004)	(0.004)	(0.007)	(0.005)
$Young_{j,t-1} \times \Delta Tax_{c(j),t}$	0.029	0.018	0.032	-0.000	0.016	-0.012	-0.016	-0.009	-0.020
	(0.023)	(0.025)	(0.025)	(0.022)	(0.039)	(0.034)	(0.030)	(0.033)	(0.054)
$EBIT/Revenues_{j,t-1} \times \Delta Tax_{c(j),t}$	0.014***	0.010	0.019	0.019***	0.024***	-0.000	0.022***	0.028***	0.002
	(0.003)	(0.010)	(0.030)	(0.006)	(0.008)	(0.011)	(0.008)	(0.008)	(0.017)
Constant	0.185*	0.232	0.149**	0.237*	0.360*	0.138*	0.287**	0.453**	0.177*
	(0.096)	(0.155)	(0.057)	(0.120)	(0.185)	(0.068)	(0.140)	(0.218)	(0.099)
Observations	40,109	21,597	18,481	24,125	13,617	10,492	23,984	13,397	10,215
R-squared	0.024	0.033	0.028	0.020	0.032	0.015	0.111	0.158	0.167
Industry-by-year FE	SIC-group	SIC-group	SIC-group	NO	NO	NO	4-digit SIC	4-digit SIC	4-digit SIC
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sectors	All	All	All	Manuf	Manuf	Manuf	Manuf	Manuf	Manuf
Capital Intensity	All	High	Low	All	High	Low	All	High	Low
Year FE	NO	NO	NO	YES	YES	YES	NO	NO	NO

Remove concern of multinational firms

◂ Return

Table: Carbon Taxes and Credit Constraints: Utility Sector

VARIABLES	(1) $\Delta log(Emi)_{j,t}$	(2) $\Delta log(Emi)_{j,t}$
$D2D_{j,t-1} \times \Delta Tax_{c(j),t}$	-0.004***	-0.003***
	(0.001)	(0.001)
$D2D_{j,t-1}$	0.000	-0.000
	(0.001)	(0.001)
$\Delta Tax_{c(j),t}$	-0.004	-0.023
	(0.022)	(0.023)
Controls	✓	✓
Observations	3,237	3,233
R-squared	0.033	0.076
Industry-by-year FE	NO	YES
Country FE	YES	YES
Year FE	YES	NO
Sample	Transportation & Public Utilities	Transportation & Public Utilities

Model Setup: Households

Return

- **Households**
  - The representative HH has standard preferences over consumption and labor $u(c_t, n_t) = \log(c_t) - \frac{\omega_N}{1+\gamma_N} n_t^{1+\gamma_N}$. The wage is denoted by w_t.
  - Solving their maximization problem yields the standard intra- and inter-temporal optimality conditions

$$w_t = \omega_N n_t^{\gamma_N} c_t \ , \tag{2}$$

$$1 = \mathbb{E}_t \left[\Lambda_{t,t+1}(1 + r_t) \right] \ , \tag{3}$$

where $\Lambda_{t,t+1} \equiv \beta \frac{c_{t+1}^{-1}}{c_t^{-1}}$ is the sdf and β is the time-preference parameter that pins down the (steady state) real interest rate.

Model Setup: Final Good Firms

Return

- **Final Firms**
  - Final good firms are perfectly competitive and use labor n_t and intermediate good z_t to produce the final good $y_t = A_t z_t^{\theta} n_t^{1-\theta}$, where A_t is an exogenous TFP shock.
  - Let the price of the intermediate good be denoted by p_t^Z. Their profit maximization problem yields demand functions for labor and intermediate goods:

$$y_t = z_t^{\theta} n_t^{1-\theta} \ , \tag{4}$$

$$(1-\theta) y_t = p_t^Z z_t \ , \tag{5}$$

$$\theta y_t = w_t n_t \ . \tag{6}$$

Model Setup: Investment Firms

◂ Return

- **Investment Firms**
  - transform $\left(1+\frac{\psi_K}{2}\left(\frac{I_t}{I_{t-1}}\right)\right)$ units of the final good into one unit of capital goods, which they sell at price p_t^K. The profit maximization problem

$$p_t^K = 1+\frac{\psi_K}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2+\psi_K\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}}-\mathbb{E}_t\left[\Lambda_{t,t+1}\psi_K\left(\frac{I_{t+1}}{I_t}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]. \tag{7}$$

yields the FOC for capital good supply

$$p_t^K = 1+\frac{\psi_K}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2+\psi_K\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}}-\mathbb{E}_t\left[\Lambda_{t,t+1}\psi_K\left(\frac{I_{t+1}}{I_t}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]. \tag{8}$$

Model Setup: Manufacturing Firms Technology

Return

- The manufacturing production technology is linear in capital, $z_t = m_t k_t$.
  - The idiosyncratic productivity shock m_t is i.i.d. across firms and time.
  - m_t follows a log-normal distribution with SD (ς_M) and mean ($-\frac{\varsigma_M^2}{2}$), ensuring expected productivity equals one.
  - cdf and partial expectation denoted by $F(m_t)$ and $G(m_t)$.
- Manufacturers generate emissions $e_t = (1 - a_t)z_t$, taxed at rate τ_t.
- Manufacturers can reduce their tax bill by either reducing their investment or by investing in an abatement good (transform $\frac{\alpha_0}{1+\alpha_1} a_{t+1}^{\alpha_1}$ units of the final goods in period t into one unit of the abatement good a_{t+1}).

Model Setup: Manufacturing Firms Credit Frictions

Return

- Firm-owner is more impatient than household ($\widetilde{\beta} < \beta$) and firm owner sdf is $\widetilde{\Lambda}_{t,t+1} \equiv \widetilde{\beta} \frac{c_{t+1}^{-1}}{c_t^{-1}}$.
- Firms finance their investment with long-term debt or equity.
- Debt l_t is long-term and assume that a share χ of all outstanding debt matures each period. The repayment obligation is χl_t.
- The threshold productivity level $\overline{m}_t$ is given by

$$\overline{m}_t \equiv \frac{\chi l_t}{(p_t^Z - \tau_t(1 - a_t))k_t} \tag{9}$$

$\Rightarrow$ carbon tax shock increases firm default probability ($F(\overline{m}_{t+1}) \equiv \int_0^{\overline{m}_{t+1}} dF(m)$).

$\Rightarrow$ the efficacy of carbon taxes depends on a_{t+1}, whose optimal value is determined by τ_{t+1} and $\overline{m}_{t+1}$.

Manufacturing Firms: Maximization Problem

Return

- Assume immediately restructured defaulting firm, dividends in t is

$$div_t = \mathbb{1}\{m_t > \overline{m}_t\} \cdot \Big(\big((p_t^Z - \tau_t(1-a_t)\big) z_t - \chi l_t \Big) - p_t^K i_t - \frac{\alpha_0}{1+\alpha_1} (a_{t+1})^{1+\alpha_1} + q(\overline{m}_{t+1}) \Big(l_{t+1} - (1-\chi) l_t \Big) . \tag{10}$$

- the capital structure choice $\overline{m}_{t+1}$ is linked to the debt price in t via the debt payoff in $t+1$ through the following recursion:

$$q(\overline{m}_{t+1}) = \mathbb{E}_t \left[\Lambda_{t,t+1} \left\{ \chi \left(1 - F(\overline{m}_{t+1}) + \frac{G(\overline{m}_{t+1})}{\overline{m}_{t+1}} - F(\overline{m}_{t+1}) \varphi \right) + (1-\chi) q(\overline{m}_{t+2}) \right\} \right] . \tag{11}$$

- plugging in $i_t = k_{t+1} - (1-\delta_K) k_t$, firm max problem is two-period:

$$\begin{aligned} \max_{a_{t+1}, k_{t+1}, l_{t+1}, \overline{m}_{t+1}} & -p_t^K k_{t+1} - \frac{\alpha_0}{1+\alpha_1} (a_{t+1})^{1+\alpha_1} + q(\overline{m}_{t+1}) \Big(l_{t+1} - (1-\chi) l_t \Big) + \\ & \mathbb{E}_t \left[\widetilde{\Lambda}_{t,t+1} \cdot \left\{ \int_{\overline{m}_{t+1}}^{\infty} \big(p_{t+1}^Z - \tau_{t+1}(1-a_{t+1}) \big) m_{t+1} k_{t+1} - \chi \cdot l_{t+1} dF(m_{t+1}) \right. \right. \\ & \left. \left. + p_{t+1}^K (1-\delta_K) k_{t+1} + q(\overline{m}_{t+2}) \Big(l_{t+2} - (1-\chi) l_{t+1} \Big) \right\} \right] , \\ & \text{s.t. (9) and (11)} \end{aligned} \tag{12}$$

Manufacturing Firms: FOCs in Equilibrium

Return

Solving the firm max problem, we obtain the following FOCs.

$$\alpha_0 a_{t+1}^{\alpha_1} - \mu_t \mathbb{E}_t\left[\frac{\tau_{t+1}\overline{m}_{t+1}}{(p^Z_{t+1} - \tau_{t+1}(1-a_{t+1}))}\right] = \mathbb{E}_t\left[\widetilde{\Lambda}_{t,t+1}\left\{\left(1-G(\overline{m}_{t+1})\right)\tau_{t+1}k_{t+1}\right\}\right], \quad (13)$$

$$p^K_t - \mu_t\frac{\overline{m}_{t+1}}{k_{t+1}} = \mathbb{E}_t\left[\widetilde{\Lambda}_{t,t+1}\left\{(1-\delta_K)p^K_{t+1} + \left(1-G(\overline{m}_{t+1})\right)\left(p^Z_{t+1} - (1-a_{t+1})\tau_{t+1}\right)\right\}\right], \quad (14)$$

$$q(\overline{m}_{t+1}) - \mu_t\frac{\overline{m}_{t+1}}{l_{t+1}} = \mathbb{E}_t\left[\widetilde{\Lambda}_{t,t+1}\left\{\chi(1-F(\overline{m}_{t+1})) + (1-\chi)q(\overline{m}_{t+2})\right\}\right], \quad (15)$$

$$-\mu_t - q'(\overline{m}_{t+1})\Big(l_{t+1} - (1-\chi)l_t\Big) = \mathbb{E}_t\left[\widetilde{\Lambda}_{t,t+1}\left\{\Big(l_{t+2} - (1-\chi)l_{t+1}\Big)q'(\overline{m}_{t+2})\frac{\partial\overline{m}_{t+2}}{\partial\overline{m}_{t+1}}\right\}\right]. \quad (16)$$

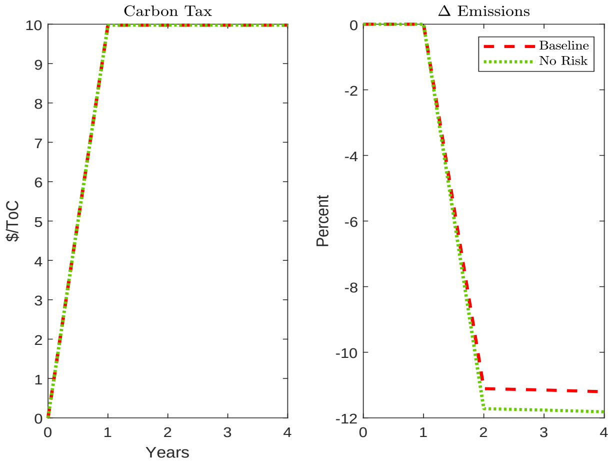
Quantitative Analysis: Calibration

Return

Parameter	Value	Source/Target
Households		
Household discount factor β	0.99	Standard
Labor disutility curvature γ_N	1	Standard
Labor disutility weight ω_N	8	Labor supply $n^{SS} = 0.33$
Technology		
Cobb-Douglas coefficient θ	1/3	Capital share
Inv. adj. parameter ψ_K	10	Standard
Capital depreciation rate δ_K	0.08	Standard
Abatement cost parameter α_1	0.075	Abatement/GDP ratio 4.3%
Abatement cost parameter α_2	1.6	Heutel 2012
Emission decay δ_E	0.99	Heutel 2012
Financial Markets		
Firm owner discount factor $\widetilde{\beta}$	0.983	Distance-to-Default 3.95
St. dev. firm productivity ς_M	0.18	Leverage ratio 30%
Debt maturity parameter χ	0.2	5-year average maturity
Restructuring costs φ	0.25	Recovery rate 69%
Shocks		
Persistence TFP ρ_A	0.95	Standard
TFP shock st. dev. σ_A	0.02	Standard

Model Validity: Permanent Carbon Tax Shocks

Return



- an emission reduction of **11.73%** for the economy without default risk
- an emission reduction of **11.13%** for the economy with severe credit frictions

⇒ credit frictions are macro relevant on the conduct of climate policy

Mechanism: simplifying the model

Return

Return: appendix

- The simple case: no aggregate risk ($\Lambda_{t,t+1} = \beta$), one-period debt ($\chi = 1$), full capital depreciation ($\delta_K = 1$) and no debt restructuring costs ($\varphi = 0$).
  - $\Rightarrow$ the debt price schedule is given by the discounted repayment probability:
  $$q(\overline{m}_{t+1}) = \beta\big(1 - F(\overline{m}_{t+1})\big) \ . \tag{17}$$
  - $\Rightarrow$ The first-order condition for abatement simplifies to
  $$\alpha_0 a_{t+1}^{\alpha_1} + q'(\overline{m}_{t+1})\overline{m}_{t+1}^2 \mathbb{E}_t[\tau_{t+1}]k_{t+1} = \widetilde{\beta}\big(1 - G(\overline{m}_{t+1})\big)\mathbb{E}_t[\tau_{t+1}]k_{t+1} \ . \tag{18}$$
  - $\Rightarrow$ The first-order condition for loans reduces to:
  $$q(\overline{m}_{t+1}) + q'(\overline{m}_{t+1})\overline{m}_{t+1} = \widetilde{\beta}\big(1 - F(\overline{m}_{t+1})\big) \ . \tag{19}$$

Mechanism: simplifying the model

Return Return: appendix

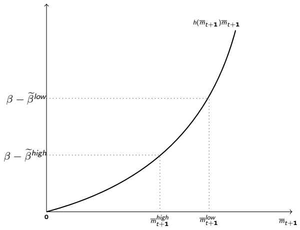
- The simple case: no aggregate risk ($\Lambda_{t,t+1} = \beta$), one-period debt ($\chi = 1$), full capital depreciation ($\delta_K = 1$) and no debt restructuring costs ($\varphi = 0$).
  - $\Rightarrow$ the debt price schedule is given by the discounted repayment probability:
$$q(\overline{m}_{t+1}) = \beta(1 - F(\overline{m}_{t+1})) \ . \tag{17}$$
  - $\Rightarrow$ The first-order condition for abatement simplifies to
$$\alpha_0 a_{t+1}^{\alpha_1} + q'(\overline{m}_{t+1})\overline{m}_{t+1}^2 \mathbb{E}_t[\tau_{t+1}]k_{t+1} = \widetilde{\beta}(1 - G(\overline{m}_{t+1}))\mathbb{E}_t[\tau_{t+1}]k_{t+1} \ . \tag{18}$$
  - $\Rightarrow$ The first-order condition for loans reduces to:
$$q(\overline{m}_{t+1}) + q'(\overline{m}_{t+1})\overline{m}_{t+1} = \widetilde{\beta}(1 - F(\overline{m}_{t+1})) \ . \tag{19}$$
- plugging (17) in (19) yields
$$\left(\beta - \widetilde{\beta}\right)\left(1 - F(\overline{m}_{t+1})\right) = \beta f(\overline{m}_{t+1})\overline{m}_{t+1} \ . \tag{20}$$
- plugging (17) in (18) yields
$$\alpha_0 a_{t+1}^{\alpha_1} = \underbrace{\left(\widetilde{\beta}(1 - G(\overline{m}_{t+1})) + \beta f(\overline{m}_{t+1})\overline{m}_{t+1}^2\right)}_{\equiv \Xi_{t+1}(\textit{impairment})} \mathbb{E}_t[\tau_{t+1}]k_{t+1} \tag{21}$$
- The impairment is particularly strong if Ξ_{t+1} is small, i.e. when $\widetilde{\beta}$ is low.

Mechanism: illustration

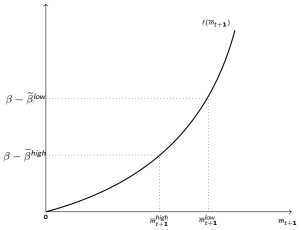
Return

Return: appendix

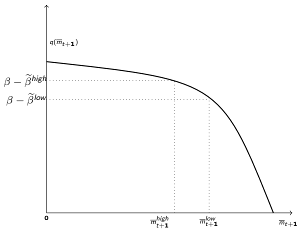
Capital Structure



Revenue Shock PDF



Debt Price



Abatement Effort