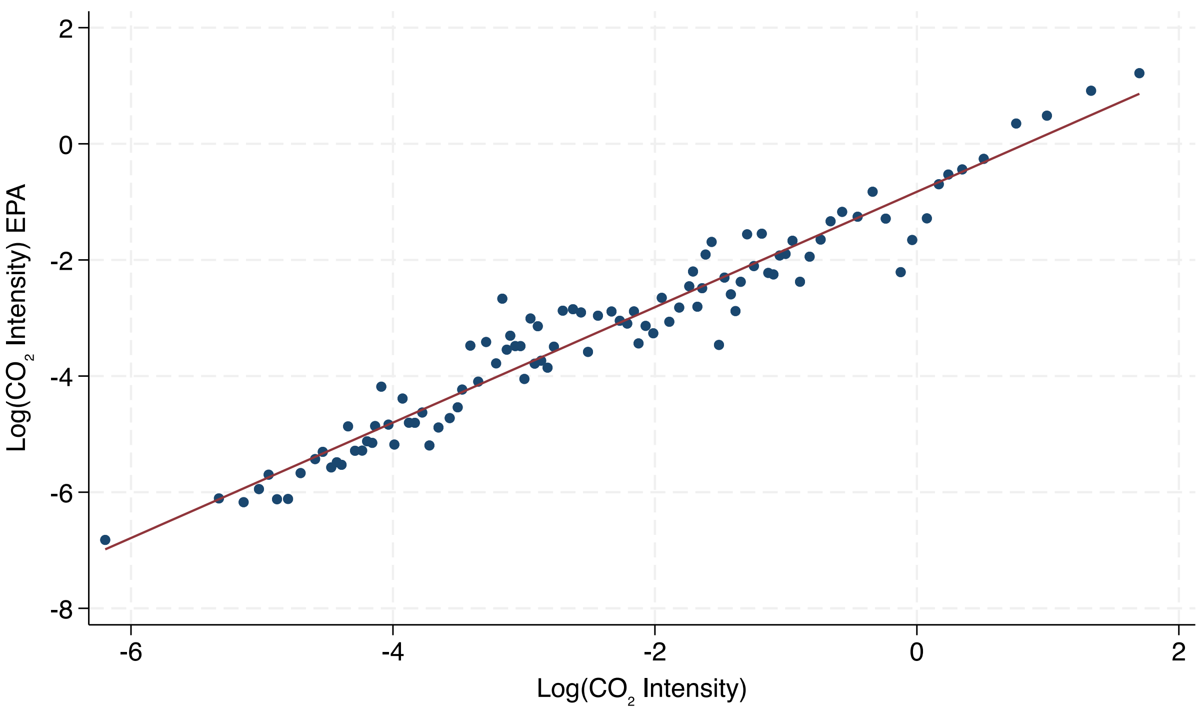
Supplemental Appendix

The Environmental Bias of Corporate Income Taxation

Luigi Iovino, Thorsten Martin, and Julien Sauvagnat

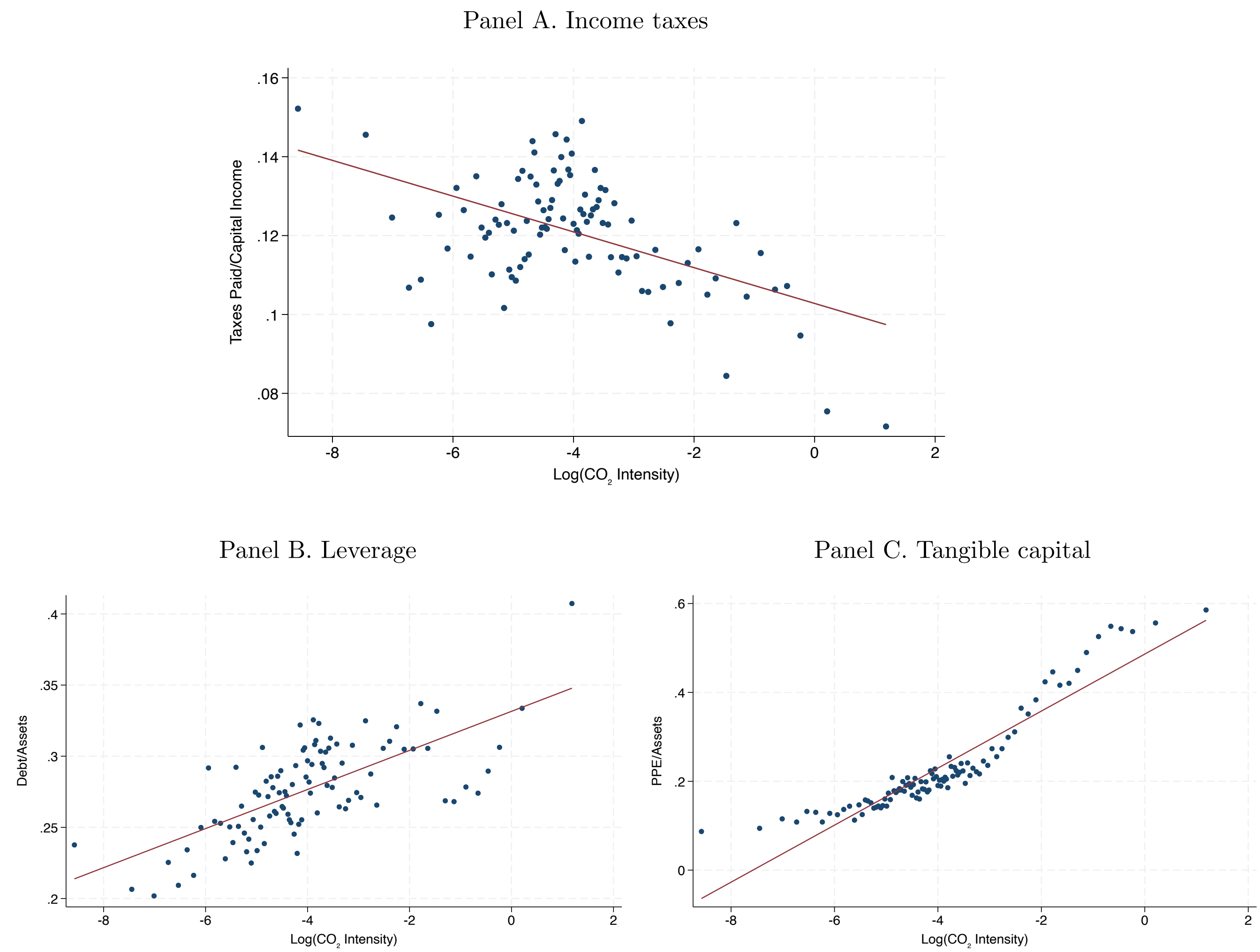
A Additional Figures and Tables

Figure A.1. EPA vs. Trucost emissions



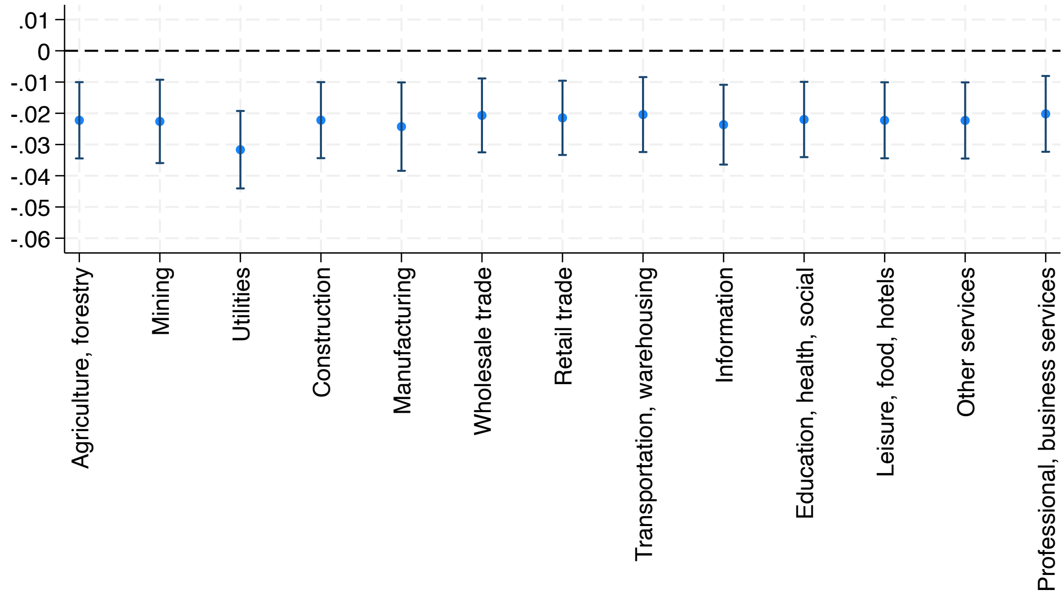
Note: This scatter plot shows the relationship between the logarithm of firms' CO_2 emissions from Trucost scaled by sales and the logarithm of firms' CO_2 emissions from stationary sources reported to the EPA scaled by sales over the period 2010-2021, after absorbing year fixed effects. Each dot represents an equal-size bin of firms' CO_2 emissions over sales (100 bins). The corresponding regression yields a slope of 0.99 and a standard error clustered by firm of 0.04.

Figure A.2. CO_2 intensity, income taxes, leverage, and tangible capital



Note: This scatter plot reports the relationship between income taxes over capital income (Panel A), debt over assets (Panel B) and property, plant, and equipment over assets (Panel C) on the logarithm of CO_2 intensity over the sample period 2003-2021, after absorbing year fixed effects and controlling for firm size, age, profitability, foreign profit share, and statutory income tax rate. Each dot represents an equal-size bin of firms' CO_2 intensity (100 bins). Data on CO_2 emissions are from Trucost. Financial data are from Compustat.

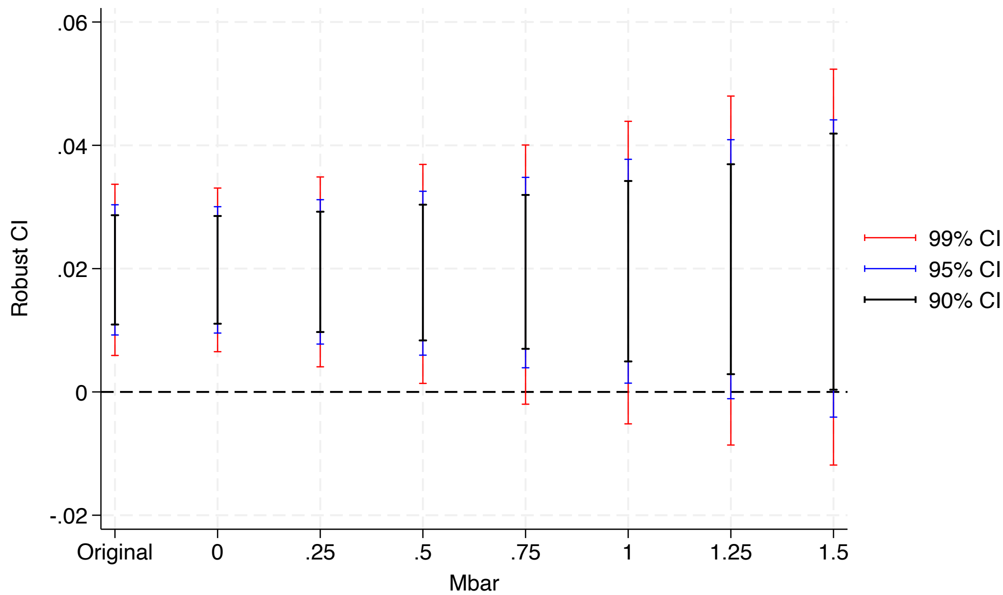
Figure A.3. CO_2-intensive firms and corporate income taxes—leave-one-industry-out



Note: This figure displays estimates of pooled OLS regressions of income taxes over capital income on CO_2 intensity for the sample period 2003-2021 in leave-one-out specifications in which we exclude observations for firms in a given BEA sector, after absorbing year fixed effects and controlling for firm size, age, profitability, foreign profit share, and statutory income tax rate. Standard errors are clustered at the firm level. Data on CO_2 emissions are from Trucost. Financial data are from Compustat.

Figure A.4. Sensitivity analysis for treatment confidence intervals

Panel A. Federal income taxes



Panel B. Log capital

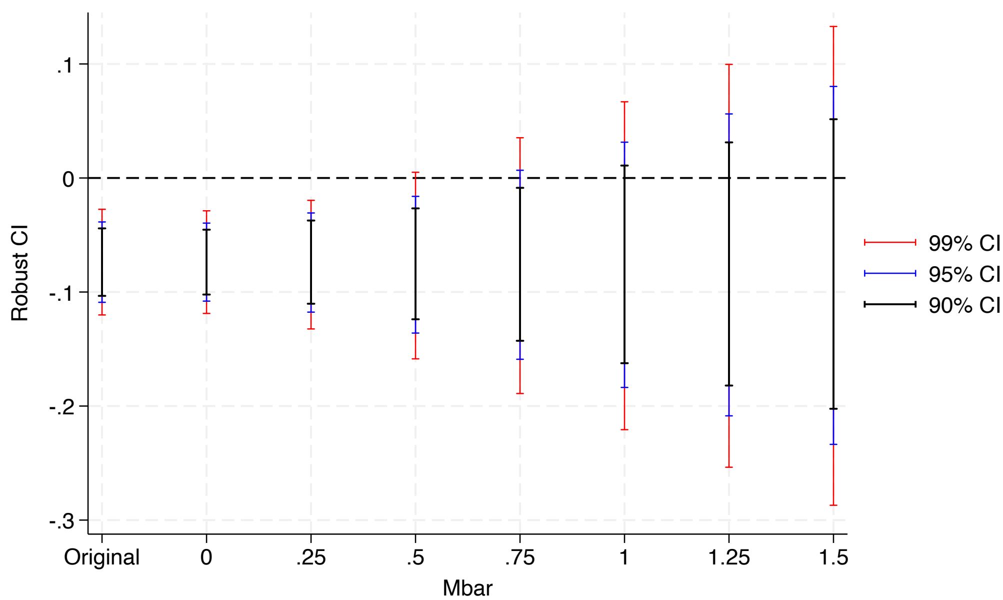
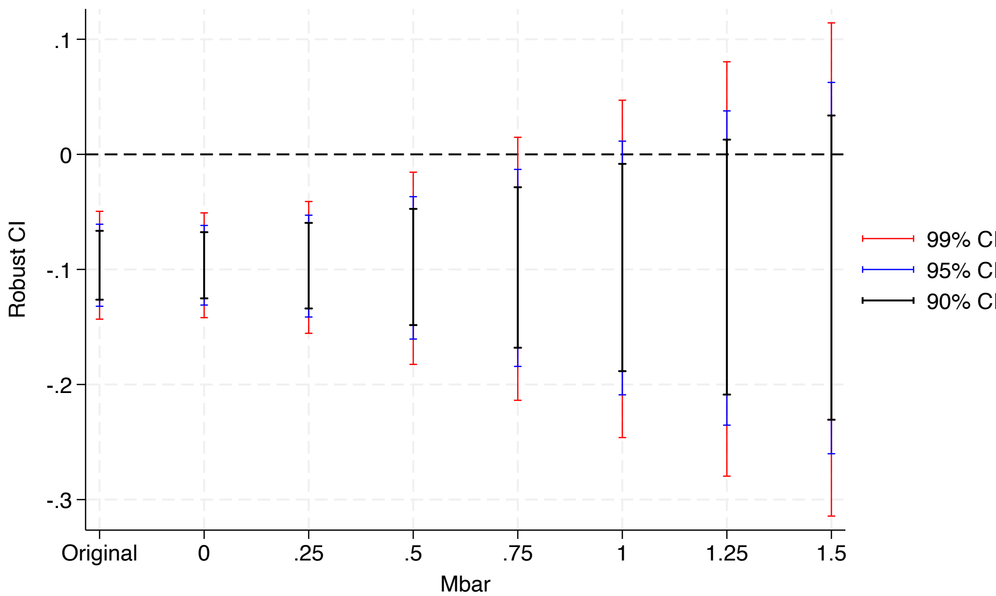


Figure A.4. Sensitivity analysis for treatment confidence intervals (continued)

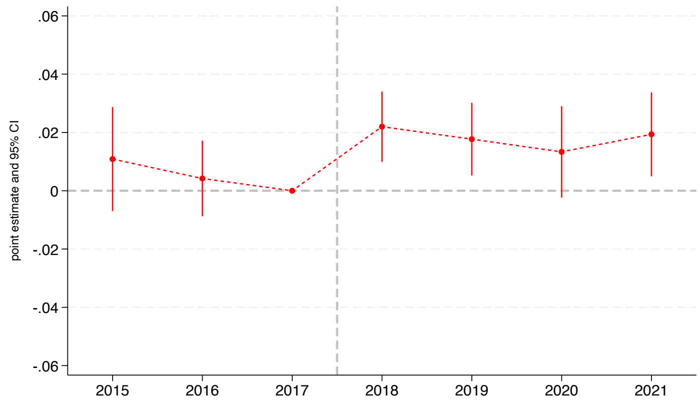
Panel C. Log assets



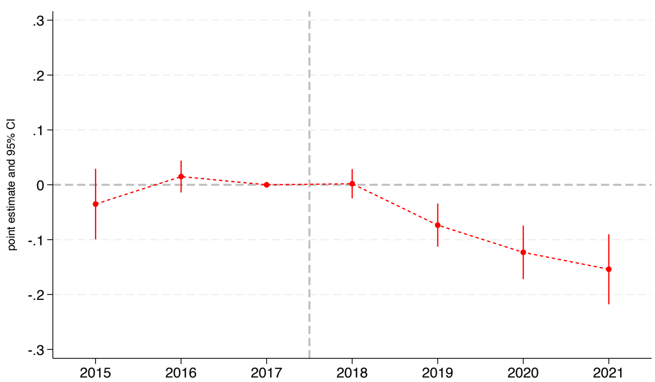
Note: This figure presents sensitivity analyses for treatment confidence intervals following Rambachan and Roth (2023) for the three main outcomes of the event-study specifications presented in the main text, namely federal income taxes over capital income (in 2018), the logarithm of firm capital and the logarithm of firm assets (in 2019, the first year effects on capital and assets are observed) following the federal tax rate cut implemented in 2018. We bound treatment effects using the following formula (see equation in Rambachan and Roth, 2023): $\Delta^{RM}(\overline{M}) = \{\delta : \forall t \geq 0, |\delta_{t+1} - \delta_t| \leq \overline{M}. \max_{s<0} |\delta_{s+1} - \delta_s|\}$, where $\Delta^{RM}(\overline{M})$ bounds the maximum post-treatment violation of parallel trends between consecutive periods by $\overline{M}$ times the maximum pre-treatment violation of parallel trends. The sample period is 2015-2021.

Figure A.5. Federal tax rate cut, effective income taxes, and growth of dirty vs. clean firms
Triple-differences specification, U.S. vs. foreign

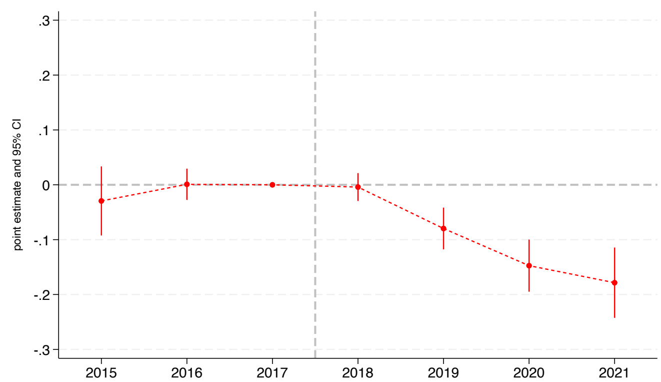
Panel A. Income taxes



Panel B. Log capital



Panel C. Log assets

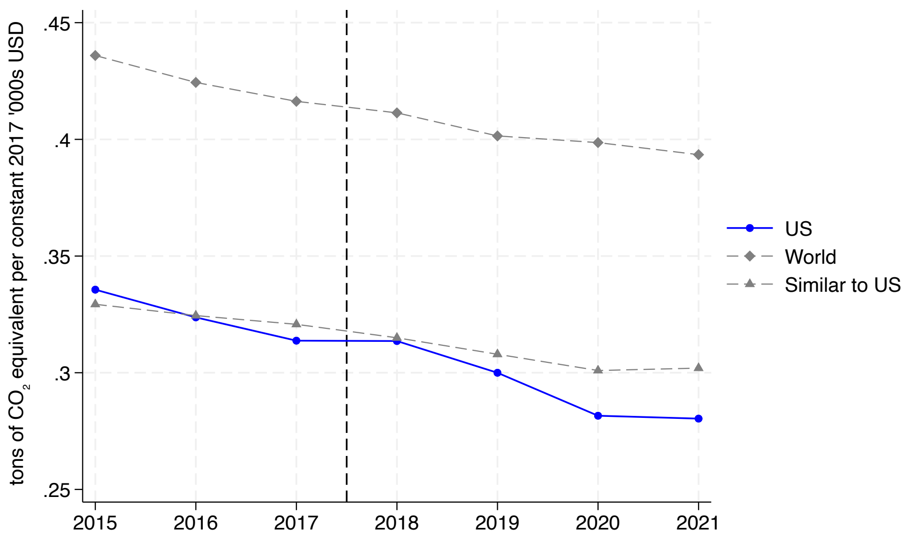


Note: This figure presents estimates from panel regressions of income taxes scaled by capital income (in Panel A), the logarithm of capital (in Panel B), and the logarithm of assets (in Panel C) in a triple-differences specification, comparing dirty and clean firms, pre- and post-2018, in the U.S. versus a set of foreign countries where statutory corporate income tax rates remained constant over the sample period. Specifically, the graphs plot estimated coefficients for the interaction of year dummies with a dummy for dirty firms based in the U.S., $\beta_{\tau,c=US}$, with 95% confidence intervals, from the following regression:

$$Y_{f,c,t} = \sum_{\tau=2015}^{2021} \beta_{\tau,c=US} \times CO_2Intensive_{f,2017} \times \mathbb{1}_{c=US} \times \mathbb{1}_{\tau=t} + \alpha_f + \gamma_{CO_2Intensive,t} + \gamma_{c,t} + \epsilon_{f,c,t},$$

where $CO_2Intensive_{f,2017}$ is a dummy for dirty firms, defined as those in the top quartile of the 2017 CO_2-intensity distribution, $\mathbb{1}_{c=US}$ is an indicator that equals one for U.S. firms, $\mathbb{1}_{\tau=t}$ is an indicator that equals one in year t and zero otherwise, α_f are firm fixed effects, $\gamma_{CO_2Intensive,t}$ denote the interaction of year dummies with a dummy for dirty firms, and $\gamma_{c,t}$ denote country $\times$ year fixed effects. Given that the tax cut affects firms starting in 2018, we identify the differential effects of the policy relative to the baseline year 2017. The sample period is 2015-2021. Standard errors are clustered at the firm level.

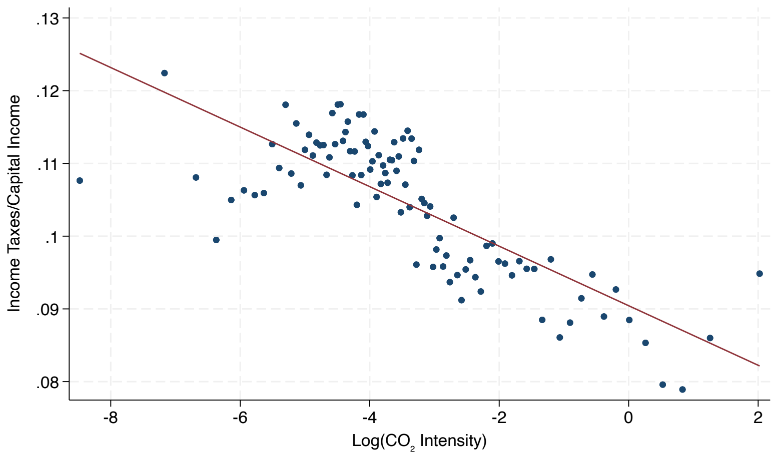
Figure A.6. Aggregate CO_2 intensity of U.S. economy



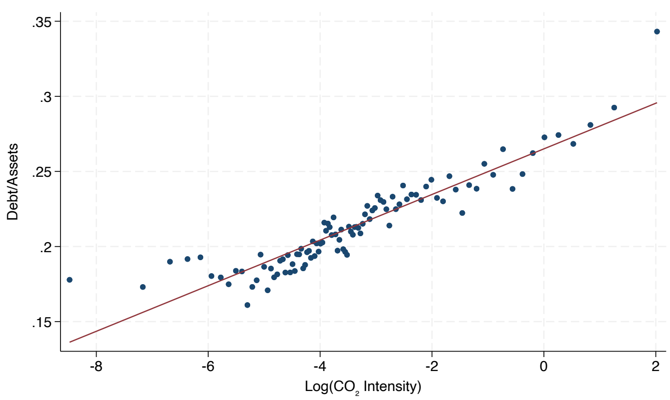
Note: This figure presents aggregate CO_2 intensity (CO_2/GDP) from 2015 to 2021 for the U.S., the World, and a group of countries with emission intensity similar to the U.S. prior to the reform. CO_2/GDP for this group is calculated as the average across countries within a 10% range of U.S. CO_2 intensity in 2017. CO_2 intensity is expressed in tons of CO_2 equivalent per 1,000 constant 2017 USD of GDP. Data are from the Emissions Database for Global Atmospheric Research (Crippa et al., 2023).

Figure A.7. CO_2 intensity, income taxes, leverage, and tangible capital—Foreign firms

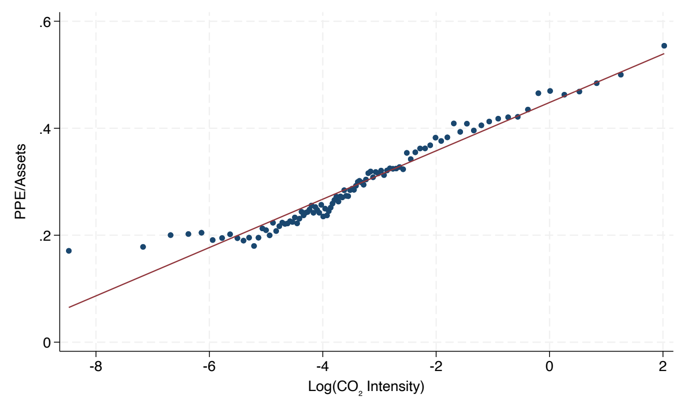
Panel A. Income taxes



Panel B. Leverage



Panel C. Tangible capital



Note: This scatter plot reports the relationship between income taxes over capital income (Panel A), debt over assets (Panel B) and property, plant, and equipment over assets (Panel C) on the logarithm of CO_2 intensity for firms headquartered outside the U.S. over the sample period 2003-2021, after absorbing headquarter country × year fixed effects and controlling for firm size, age, profitability, foreign profit share, and statutory income tax rate. Each dot represents an equal-size bin of firms' CO_2 intensity (100 bins). Data on CO_2 emissions are from Trucost. Financial data are from Compustat Global and North America Fundamentals.

Table A.1. CO_2-intensive firms and corporate income taxes—Robustness

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Alternative Measures of CO_2 emissions				Inc. Neg. Profit Firms		
	Estimated	EPA Emissions	Scope 1+2	Scope 1+2+3	Scaled Sales	Scaled Assets	Log Spec
CO_2 Intensity	-0.032	-0.032	-0.021	-0.017	-0.004	-0.005	
	(0.008)	(0.009)	(0.006)	(0.004)	(0.001)	(0.001)	
Log(CO_2 Intensity)							-0.005
							(0.001)
Year FE	Y	Y	Y	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y	Y	Y	Y
R^2	0.100	0.083	0.099	0.098	0.069	0.122	0.097
N	6884	8509	11223	11223	13394	13394	11217

Note: This table presents variants of the specification presented in column (2) of Table 2. All columns include year fixed effects and controls for firm size, age, profitability, foreign profit share, and statutory income tax rate. In column (1), we restrict the sample to firms for which CO_2 emissions are estimated by Trucost. In column (2), we use CO_2 emissions of stationary sources, reported to the EPA's Greenhouse Gas Reporting Program since 2010. In columns (3) and (4), we use, respectively, the sum of scope 1 and scope 2 emissions, and the sum of scope 1, scope 2, and scope 3 emissions. In columns (5) and (6), we scale taxes paid by respectively sales and assets, instead of capital income, and include firms with negative profits in the sample. In column (7), we use the logarithm of CO_2 intensity as independent variable. The sample period is 2010-2021 in column (2) and 2003-2021 in all other columns. Standard errors clustered at the firm level are reported in parentheses.

Table A.2. Decomposing the relationship between CO_2 intensity and tangible capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent Variables Scaled by Assets						
	Gross PPE	Machinery	Buildings	Leases	Land	ConstrProg	Other
CO_2 Intensity	0.395	0.354	0.007	-0.021	0.009	0.016	0.001
	(0.060)	(0.050)	(0.009)	(0.004)	(0.005)	(0.004)	(0.004)
Year FE	Y	Y	Y	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y	Y	Y	Y
R^2	0.133	0.174	0.037	0.114	0.038	0.065	0.019
N	7418	7418	7418	7418	7418	7418	7418
Dep Var Mean	0.455	0.277	0.093	0.029	0.017	0.013	0.017

Note: This table presents estimates from pooled OLS specifications where the dependent variables correspond to the different components of property, plant, and equipment (PPE) scaled by assets, namely "machinery and equipment," "buildings," "leases," "land and improvements," "construction in progress," "natural resources," and "other". We combine "natural resources" and "other" into a single category labeled "other", as "natural resources" represents only a negligible fraction of PPE. The data are reported before subtracting accumulated depreciation. Information on the different components of PPE is not available for utilities. We exclude observations for which the sum of the components differs from total PPE by more than 10%. All columns include year fixed effects and controls for firm size, age, profitability, foreign profit share, and statutory income tax rate. The sample period is 2003-2021. Standard errors clustered at the firm level are reported in parentheses. The last row presents the sample average of the dependent variable for each column.

Table A.3. CO_2 intensity and intangible capital

	(1)	(2)	(3)	(4)
	Dependent Variables Scaled by Assets			
	Total Intangibles	Balance-Sheet Intangibles	Knowledge Capital	Organization Capital
CO_2 Intensity	-0.269	-0.100	-0.077	-0.090
	(0.044)	(0.017)	(0.014)	(0.017)
Year FE	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y
R^2	0.123	0.068	0.297	0.144
N	10997	10997	10997	10997

Note: This table presents estimates from pooled OLS specifications of measures of intangible capital, all scaled by firm assets, on CO_2 intensity. All columns include year fixed effects and controls for firm size, age, profitability, foreign profit share, and statutory income tax rate. Total intangible capital is the sum of balance-sheet intangibles (Compustat item INTAN), Knowledge Capital and Organization Capital, measured as in Peters and Taylor (2017a). Knowledge Capital is the cumulative stock of research and development expenses (Compustat item XRD) depreciated at 15% per year. Organization Capital is the cumulative stock of 30% of selling, general, and administrative expenses (Compustat item XSGA less XRD) depreciated at 20% per year. The sample period is 2003-2021. Standard errors clustered at the firm level are reported in parentheses.

Table A.4. CO_2 intensity, tangible capital, debt, pretax income, and income taxes—Industry effects

	(1)	(2)	(3)	(4)
	Dependent Variables Scaled by Capital Income			
	PPE	Debt	Pretax Income	Income Taxes Paid
Implied Industry CO_2 Intensity	2.406	0.733	-0.056	-0.026
	(0.232)	(0.110)	(0.012)	(0.006)
Firm Residual CO_2 Intensity	1.118	0.589	-0.039	-0.015
	(0.267)	(0.116)	(0.011)	(0.007)
Year FE	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y
R^2	0.224	0.150	0.103	0.100
N	11205	11205	11205	11205

Note: This table presents estimates from pooled OLS specifications of property, plant, and equipment, total debt, pretax income, and income taxes paid, all scaled by capital income, on the industry CO_2 intensity implied by firms' sales across industries and firms' residual CO_2 intensity. Implied industry CO_2 intensity is computed as the weighted-average industry CO_2 intensity across firms' business units. Industry CO_2 intensity is computed as the average CO_2 intensity across firms operating only in one industry. Firm residual CO_2 intensity are the residuals of regressing firm-level CO_2 intensity on implied industry CO_2 intensity. All columns include year fixed effects and controls for firm size, age, profitability, foreign profit share, and statutory income tax rate. The sample period is 2003-2021. Standard errors clustered at the firm level are reported in parentheses.

Table A.5. CO_2 intensity, tangible capital, debt, pretax income, and income taxes—Energy sector

	(1)	(2)	(3)	(4)	(5)
		Dependent Variables Scaled by Capital Income			
	CO_2 Intensity	PPE	Debt	Pretax Income	Income Taxes Paid
Fossil Fuel Capacity	2.035	2.097	1.967	-0.115	-0.026
	(0.431)	(0.325)	(0.328)	(0.016)	(0.006)
Year FE	Y	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y	Y
R^2	0.442	0.355	0.405	0.242	0.281
N	592	592	592	592	592

Note: This table presents estimates from pooled OLS specifications of CO_2 intensity as well as property, plant, and equipment, total debt, pretax income, and income taxes paid, all scaled by capital income, on fossil fuel production capacity within the energy sector. Fossil fuel capacity is measured in gigawatts using EIA data on energy generators reported under form 860, scaled by sales. We aggregate the nameplate capacity of operating generators with main energy source coal, petroleum or natural gas to the firm owning the generator. We restrict the sample to firms operating energy generators reporting to the EIA. All columns include year fixed effects and controls for firm size, age, profitability, foreign profit share, and statutory income tax rate. The sample period is 2003-2021. Standard errors clustered at the firm level are reported in parentheses.

Table A.6. Summary statistics for clean and dirty firms—2015-2017

	(1) Clean Firms Mean	(2) Dirty Firms Mean	(3) Equality Test P-value
CO_2 Intensity (tCO_2/k$)	0.013	0.370	0.000
Income Taxes/Capital Income	0.116	0.094	0.003
Pretax Income/Capital Income	0.544	0.496	0.003
Income Taxes/Pretax Income	0.246	0.230	0.226
Sales (in USD Million)	9089	8749	0.865
Assets (in USD Million)	11575	13357	0.537
Capital (in USD Million)	9688	11024	0.585
Firm Age	39.465	47.611	0.000
Capital Income/Sales	0.222	0.210	0.209
Share Foreign Profits	0.297	0.336	0.184
Tax Rate	0.349	0.342	0.008
Debt/Assets	0.291	0.332	0.003
Interest/Capital Income	0.131	0.199	0.000
PPE/Assets	0.165	0.394	0.000

Note: This table presents summary statistics for U.S. firms, separately for clean and dirty firms (top quartile of the 2017 CO_2-intensity distribution) for the pre-TCJA period 2015-2017. Data on CO_2 emissions are from Trucost. Financial data are from Compustat North America Fundamentals. CO_2 intensity is expressed in metric tons of CO_2 equivalent per USD 1,000 of sales, in 2019 USD. Income Taxes are Compustat item TXPD. Capital Income is sales (Compustat item SALE) minus cost of goods sold (Compustat item COGS) minus selling, general, and administrative expenses (Compustat item XSGA less XRD). Pretax Income is measured net of special items (Compustat item PI less SPI). Assets are Compustat item AT. Firm Age is measured relative to the founding year. Capital is the sum of property, plant, and equipment (Compustat item PPENT), and total intangible capital, measured as in Peters and Taylor (2017a). Share Foreign Profits is the ratio of foreign pretax income over total pretax income. The statutory income tax rate is $\tau_{f,t}$ defined in Supplemental Appendix B. Debt is the sum of short term debt (Compustat item DLC) and long term debt (Compustat item DLTT). Interest payments are Compustat item XINT. Property, plant, and equipment (PPE) is Compustat item PPENT. The sample is restricted to firms with positive capital income.

Table A.7. Summary statistics for foreign firms—2015-2017

	Obs.	Mean	SD	p1	p50	p99
CO_2 Intensity (tCO_2/k$)	9797	0.244	0.787	0.001	0.021	5.128
Income Taxes/Capital Income	8841	0.149	0.109	-0.101	0.134	0.571
Sales (in USD Million)	9797	4389	14586	27	989	59781
Assets (in USD Million)	9797	6327	21448	40	1417	86777
Capital (in USD Million)	9388	4388	15059	24	845	60429
Firm Age	9797	53.556	41.460	5	40	181
Capital Income/Sales	9797	0.201	0.151	0.013	0.161	0.769
Tax Rate	9797	0.282	0.031	0.200	0.292	0.353
Debt/Assets	9791	0.203	0.169	0.000	0.179	0.665
Interest/Capital Income	9582	0.116	0.217	0.000	0.038	1.343
PPE/Assets	9796	0.288	0.216	0.005	0.245	0.880

Note: This table presents summary statistics for foreign firms for the pre-TCJA period 2015-2017. Data on CO_2 emissions are from Trucost. Financial data are from Compustat Global and North America Fundamentals (S&P Global, 2024a,b). CO_2 intensity is expressed in metric tons of CO_2 equivalent per USD 1,000 of sales, in 2019 USD. Income Taxes are Compustat item TXPD. Capital Income is sales (Compustat item SALE) minus cost of goods sold (Compustat item COGS) minus selling, general, and administrative expenses (Compustat item XSGA less XRD). Assets are Compustat item AT. Firm Age is measured relative to the founding year. Capital is the sum of property, plant, and equipment (Compustat item PPENT), and total intangible capital, measured as in Peters and Taylor (2017a). The statutory income tax rate is $\tau_{f,t}$ defined in Supplemental Appendix B. Debt is the sum of short term debt (Compustat item DLC) and long term debt (Compustat item DLTT). Interest payments are Compustat item XINT. Property, plant, and equipment (PPE) is Compustat item PPENT. The sample includes firms based outside the U.S. in countries with at least 50 firms observed in the pre-event year 2017, namely Australia, Brazil, Canada, China, Finland, Germany, Japan, Mexico, the Netherlands, Singapore, Switzerland, Thailand, and South Africa. The sample is restricted to firms with positive capital income.

Table A.8. Federal tax rate cut, income taxes, and growth of dirty vs. clean firms—Constrained vs. Unconstrained Triple-differences specification, U.S. vs. foreign

	(1)	(2)	(3)	(4)	(5)	(6)
	Dividend		Firm Size		Profitability	
	Low	High	Small	Large	Low	High
	Income Taxes/Capital Income					
Post Tax Cut × CO_2 Intensive$_{17}$ × US	0.017	0.015	0.017	0.017	0.017	0.017
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.006)
Test "Const. = Unconst."		(-0.21)		(0.04)		(0.06)
R^2	0.687	0.704	0.706	0.693	0.682	0.698
N	17157	16664	17306	16520	17325	16501
	Log Capital					
Post Tax Cut × CO_2 Intensive$_{17}$ × US	-0.096	-0.100	-0.139	-0.074	-0.084	-0.122
	(0.042)	(0.028)	(0.037)	(0.029)	(0.033)	(0.034)
Test "Const. = Unconst."		(-0.07)		(1.37)		(-0.79)
R^2	0.981	0.989	0.957	0.984	0.986	0.984
N	17706	17531	17572	17670	17615	17627
	Log Assets					
Post Tax Cut × CO_2 Intensive$_{17}$ × US	-0.077	-0.088	-0.113	-0.064	-0.063	-0.114
	(0.040)	(0.026)	(0.034)	(0.029)	(0.031)	(0.032)
Test "Const. = Unconst."		(-0.24)		(1.08)		(-1.14)
R^2	0.980	0.989	0.956	0.979	0.985	0.984
N	18364	18350	18356	18362	18361	18357
Firm FE	Y	Y	Y	Y	Y	Y
Dirty Dummy-Year FE	Y	Y	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y	Y	Y
Multi, Deduc, Loss, Manuf, Bonus × US-Year FE	Y	Y	Y	Y	Y	Y
Size, Age, Prof, Tax Rates-Year FE	Y	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y	Y

Note: This table presents the same estimates as in column (4) of Table 6 for sub-samples of firms split along proxies for financial constraints. The dependent variables are respectively income taxes scaled by capital income (Panel A), the logarithm of capital (Panel B), and the logarithm of assets (Panel C). Columns (1-2) split the full sample by dividends scaled by assets, columns (3-4) by firm size, and columns (5-6) by profitability. The cutoffs correspond to the medians of the respective distributions within the U.S. and foreign subsamples in 2017. Test "Const. = Unconst." is a t-test of equality of the main coefficient of interest between the constrained and the unconstrained firms. The sample period is 2015-2021. Standard errors clustered at the firm level are reported in parentheses.

Table A.9. Federal tax rate cut, income taxes, and growth of dirty vs. clean firms—Robustness
Triple-differences specification, U.S. vs. foreign

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Subsamples—Excluding:											
	Multinat.	Above Interest Deduct	Tax-Loss Forward	Manuf.	Long Duration Industries	Estimated Only	EPA	Scope 1+2	. Scope 1+2+3	High Inc. Only	1-to-1 Match	Carbon Taxes & Tariffs
	Federal Income Taxes/Capital Income											
Post Tax Cut x CO_2 intensive x US	0.023	0.015	0.026	0.026	0.014	0.019	0.010	0.010	0.018	0.018	0.016	0.017
	(0.006)	(0.005)	(0.006)	(0.007)	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.005)
R^2	0.709	0.689	0.692	0.706	0.693	0.717	0.693	0.693	0.693	0.719	0.706	0.693
N	29268	32138	28453	29201	30548	23927	33826	33826	33826	24967	13177	33826
	Log Capital											
Post Tax Cut x CO_2 intensive x US	-0.101	-0.085	-0.098	-0.087	-0.123	-0.123	-0.097	-0.089	-0.096	-0.087	-0.088	-0.099
	(0.031)	(0.024)	(0.030)	(0.033)	(0.032)	(0.031)	(0.024)	(0.024)	(0.023)	(0.024)	(0.033)	(0.023)
R^2	0.985	0.986	0.986	0.985	0.985	0.977	0.985	0.985	0.985	0.989	0.986	0.985
N	30437	33515	29699	30333	31863	24163	35242	35242	35242	26301	13862	35242
	Log Assets											
Post Tax Cut x CO_2 intensive x US	-0.091	-0.072	-0.086	-0.075	-0.108	-0.098	-0.099	-0.074	-0.098	-0.070	-0.073	-0.087
	(0.028)	(0.023)	(0.028)	(0.029)	(0.030)	(0.028)	(0.024)	(0.023)	(0.022)	(0.023)	(0.031)	(0.022)
R^2	0.984	0.985	0.986	0.985	0.984	0.977	0.984	0.984	0.984	0.987	0.984	0.984
N	31792	34935	30989	31695	33238	25154	36718	36718	36718	27556	14429	36718
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dirty Dummy-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi, Deduc, Loss, Manuf, Bonus × US-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Size, Age, Prof, Tax Rates-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Carbon Taxes & Tariffs												Y

Note: This table presents variants of the specification presented in column (4) of Table 6. In columns (1-5), we exclude from the sample U.S. firms that, in 2017, are multinationals, exceed the interest-deductibility limit, have a tax-loss carryforward exceeding 2% of assets, are in manufacturing industries, and are exposed to long-duration industries. In column (6), we restrict the sample to firms for which CO_2 emissions are estimated by Trucost. In column (7) we construct the dirty dummy for U.S. firms based on EPA rather than Trucost emission data, while in columns (8) and (9), we use respectively the sum of scope 1 and 2 emissions, and the sum of scope 1, 2, and 3 emissions, for defining the group of dirty firms, those in the top quartile of the 2017 CO_2-intensity distribution. In column (10), we restrict the control group to firms located in high-income countries (where statutory corporate income tax rates remained constant), namely excluding Brazil, China, Mexico, Thailand and South Africa. In column (11), we use a one-to-one exact matching procedure to match each U.S. firm with a control firm in control countries that is in the same decile of CO_2 intensity, firm size, and in the same 2-digit industry. The match is conducted in the pre-event year 2017. The firms that match are then taken out of the sample of potential matches. When there is no exact match, the U.S. firm is removed from the estimation. When there is more than one exact match, the ties are broken at random. In column (12), we control for firm-level exposure to changes in tariff policies and carbon taxes. The sample period is 2015-2021. Standard errors clustered at the firm level are reported in parentheses.

Table A.10. Federal tax rate cut, income taxes, and growth of dirty vs. clean industries
IRS data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	C corporations						S corporations		
	Income Taxes/Capital Income			Log Capital			Log Capital		
Post Tax Cut × CO_2 Intensive$_{17}$	0.024	0.021	0.020	-0.077	-0.078	-0.084	-0.007	-0.009	-0.027
	(0.008)	(0.007)	(0.008)	(0.037)	(0.036)	(0.036)	(0.056)	(0.032)	(0.034)
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi, Deduc, Loss, Manuf, Bonus-Year FE	N	Y	Y	N	Y	Y	N	Y	Y
Size, Age, Prof, Tax Rates-Year FE	N	N	Y	N	N	Y	N	N	Y
R^2	0.925	0.944	0.971	0.988	0.989	0.990	0.993	0.994	0.995
N	396	396	396	1022	1022	1022	1019	1019	1019

Note: This table presents estimates from panel regressions of income taxes scaled by capital income (columns 1-3) and the logarithm of the sum of depreciable and intangible assets (columns 4-9) respectively, on the interaction of a dummy for dirty industries, defined as those in the top quartile of the 2017 CO_2-intensity distribution, with a dummy equal to one for years following the federal tax rate cut. CO_2 intensity is the 2017 industry median CO_2 intensity computed from Trucost data. Columns (1-6) show the results for C corporations, while columns (7-9) show the results for S corporations. The IRS data are from the SOI Tax Stats - Corporation Income Tax Returns Complete Report, Table 5.1 (Returns of Active Corporations) and 5.3 (Returns of Active Corporations, other than Forms 1120S, 1120-REIT, and 1120-RIC) at the 'Minor Industry' level. We map these industries to NAICS codes (Iovino et al., 2026). Columns (1-6) use data from Table 5.3 (C corporations), while in columns (7-9) we proxy for S corporations by subtracting Table 5.3 from 5.1. We exclude financial industries (removing RICs) and industries including REITs ('Lessors of buildings (including equity REITs)', 'Lessors of miniwarehouses, self-storage units, and other real estate (including equity REITs)'). The IRS data are at the tax-year level. Tax year t covers accounting periods ending July t–June $t+1$. The sample covers tax years 2014-2021, thus covering July 2014 until June 2022. All columns include industry and (tax-)year fixed effects. Industry cells are weighted by pre-event sales (tax year 2016). In columns (2), (5), and (8) we add pre-TCJA controls for industry exposure to foreign income taxation, the interest-deductibility threshold, tax-loss carryforwards, the domestic production activities deduction, and bonus depreciation generosity, interacted with year fixed effects. In columns (3), (6) and (9), we add terciles of industry measures to capture firm size, age, profitability, and statutory income tax rates, all measured in 2017, interacted with year fixed effects. Income Taxes is IRS item 'total income tax after credits' scaled by capital income. We compute capital income as 'net income (less deficit)'+'interest paid'+'depreciation'+'amortization'. Capital is the sum of 'depreciable assets' and 'intangible assets'. We construct dummy variables for industries with net interest expense above 0.3 × EBITDA, negative net income, in the bottom tercile of z_0 (Zwick and Mahon, 2017a), top tercile of domestic production activities deduction scaled by capital income, and top tercile of foreign income scaled by capital income. We proxy for firm size with sales scaled by the number of active firms in the industry, firm age with the share of employment in young firms (below 10 years old) in the industry based on Census Business Dynamics Statistics data (U.S. Census Bureau, 2022), industry statutory income tax rates based on the data described in Appendix B, and profitability as capital income scaled by sales. Note that disclosure rules lead to missing observations. This affects in particular 'total income tax after credits' and 'net income', leading to fewer observations in columns (1-3). We replace net income with 'total receipts less total deductions'+'constructive taxable income from related foreign corporations' in the denominator if net income is missing and we restrict the sample to industries with positive capital income in these columns. Standard errors clustered at the (3-digit NAICS) industry level are reported in parentheses.

Table A.11. Federal tax rate cut and firm leverage
Triple-differences specification, U.S. vs. foreign

	(1)	(2)	(3)	(4)
	Leverage (Debt/Assets)			
Post Tax Cut × CO_2 Intensive$_{17}$ × US	-0.011	-0.017	-0.017	-0.018
	(0.006)	(0.007)	(0.007)	(0.006)
Firm FE	Y	Y	Y	Y
Dirty Dummy-Year FE	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y
Multi, Deduc, Loss, Manuf, Bonus × US-Year FE	N	Y	Y	Y
Size, Age, Prof, Tax Rates-Year FE	N	N	Y	Y
Industry-Year FE	N	N	N	Y
R^2	0.882	0.883	0.884	0.890
N	36663	36663	36663	36663

Note: This table presents estimates from panel regressions of a triple-differences specification, comparing dirty and clean firms, pre- and post-2018, in the U.S. versus foreign countries where statutory corporate income tax rates remained constant, where the dependent variable is firm leverage, regressed on the interaction of a dummy for firms in the top quartile of the 2017 CO_2-intensity distribution with a U.S. dummy for US-based firms and a post dummy for years following the federal tax rate cut. All columns include firm fixed effects, the interaction of the dummy for dirty firms with year fixed effects, and country × year fixed effects. In columns (2-4), we add for US-based firms interactions of year fixed effects with the following pre-TCJA (2017) characteristics: indicators for being a multinational, exceeding the interest-deductibility threshold, having tax-loss carryforwards, being a manufacturing firm, as well as exposure to long-duration industries. In column (3-4), we add terciles of firm size, age, profitability, and statutory income tax rates, all measured in 2017, interacted with year fixed effects. In column (4), we add 2-digit industry × year fixed effects. The sample period is 2015-2021. Standard errors clustered at the firm level are reported in parentheses. The sample is restricted to firms with positive capital income. We keep countries for which we observe at least 50 firms in the pre-event year 2017, namely Australia, Brazil, Canada, China, Germany, Finland, Japan, Mexico, the Netherlands, Singapore, Switzerland, Thailand, USA, and South Africa.

Table A.12. Model-generated data: tax cut, income taxes, and growth of dirty vs. clean firms
Lower corporate income tax & higher bonus depreciation

	(1)	(2)	(3)	(4)
	Lower Corporate Income Tax (from 35% to 21%) & Higher Bonus Depreciation Rate of Equipment (from 50% to 100%)			
	ΔTaxes/Capital Income		ΔLog Capital	
CO_2 Intensive	0.015	0.015	-0.043	-0.041
	(0.002)	(0.002)	(0.004)	(0.004)
ρ	1	0.2	1	0.2
N	378	378	378	378

Note: This table replicates the analysis presented in Panels A and C of Table 5 using model-generated data across 378 BEA sectors. Specifically, we estimate $\Delta Y_i = \beta \times CO_2\text{-Intensive}_i + \epsilon_i$, where ΔY_i denotes, for sector i, the change in the ratio of income taxes to capital income in columns (1)–(2), and the change in log capital in columns (3)–(4), as the economy moves from a steady state with a corporate income tax rate of 35% to one with a rate of 21%, and the bonus-depreciation rate moves from 50% to 100%. $CO_2\text{-Intensive}_i$ is a dummy for sectors in the top quartile of the 2017 CO_2-intensity distribution. We report the results for different values of ρ, i.e., the elasticity of substitution between equipment and the fuel bundle. Columns (1) and (3) report the results for $\rho = 1$, columns (2) and (4) for $\rho = 0.2$.

Table A.13. Policy counterfactual
Lower corporate income tax & higher bonus depreciation

	Lower Corporate Income Tax (from 35% to 21%) & Higher Bonus Depreciation Rate of Equipment (from 50% to 100%)				
	ρ				
	1	0.8	0.6	0.4	0.2
Change GDP (%)	5.01	5.01	5.01	5.00	5.00
Change Consumption (%)	3.70	3.70	3.70	3.70	3.70
Change CO_2 Emissions (%)	3.87	3.51	3.15	2.80	2.44
Scale	5.38	5.37	5.37	5.36	5.36
Composition	-1.58	-1.61	-1.64	-1.67	-1.70
Technique	0.07	-0.25	-0.58	-0.90	-1.22

Note: This table presents the results of the first counterfactual in which the cut in the corporate income tax rate is accompanied by an increase in bonus depreciation from 50% to 100%. The effect on CO_2 emissions is decomposed as the sum of three components: (i) the change in aggregate output ("Scale"), (ii) the change in the sectoral composition of output for given aggregate production ("Composition"), and (iii) the change in sectors' CO_2 intensities ("Technique"). We report the results for different values of ρ, i.e., the elasticity of substitution between equipment and the fuel bundle.

B Construction of Firm-level Statutory Income Tax Rates

The statutory income tax rate that each U.S. firm f faces in year t is computed as follows:

$$\tau_{f,t} = \omega^{f}_{US,t}\big[\tau_{fed,t} + (1-\tau_{fed,t})\sum_{s}\omega^{f,Domestic}_{s,t}\tau_{s,t}\big] + (1-\omega^{f}_{US,t})\big[\sum_{c}\omega^{f,Foreign}_{c,t}\tau_{c,t}\big],$$

where $\omega^{f}_{US,t}$ is the share of firm f's domestic sales, $\tau_{fed,t}$ is the U.S. federal income tax rate in year t, $\omega^{f,Domestic}_{s,t}$ is the domestic tax weight of firm f in U.S. state s and year t, $\tau_{s,t}$ is the corporate income tax rate in U.S. state s in year t, $\omega^{f,Foreign}_{c,t}$ is the tax weight of firm f in foreign country c and year t, and $\tau_{c,t}$ is the corporate income tax rate in foreign country c in year t.

For the domestic tax weight $\omega^{f,Domestic}_{s,t}$, we follow Giroud and Rauh (2019b) and use information on the distribution of firms' sales and employment across U.S. states, and apportionment factors on sales, employment, and property in each U.S. state, and define it as $\alpha^{Sales}_{s,t}\frac{Sales^{f,US}_{s,t}}{\sum_{s\in US} Sales^{f,US}_{s,t}} + (1 - \alpha^{Sales}_{s,t})\frac{Emp^{f,US}_{s,t}}{\sum_{s\in US} Emp^{f,US}_{s,t}}$, where $\alpha^{Sales}_{s,t}$ represents the apportionment factors on sales in U.S. state s and year t, and $Sales^{f,US}_{s,t}$ and $Emp^{f,US}_{s,t}$ are total sales and total employment of firm f in U.S. state s and year t, respectively. This equation implicitly assumes that the distribution of firm employment across U.S. states is a good proxy for the distribution of both firms' properties and payroll expenses, which we do not observe. States generally set the payroll and property apportionment factors equal to each other. We use the data shared by Giroud and Rauh (2019a,b) on apportionment factors, which we extend until 2021 using data from the Federation of Tax Administrators (2021). We use information gathered by Infogroup (2024) to identify firms' employment and sales for each of their domestic establishments.

Note that we compute the combined domestic tax rate as $\tau_{fed,t} + (1-\tau_{fed,t})\sum_{s}\omega^{f,Domestic}_{s,t}\tau_{s,t}$ to account for the deductibility of state taxes for federal income tax purposes. We set $\tau_{s,t}$ to 0 for states with a gross receipts tax in year t. For state-level corporate income tax rates, we take the data shared by Giroud and Rauh (2019a,b), which we extend until 2021 using data from the Federation of Tax Administrators (2014) and the Tax Foundation (2021). Details on the construction of the state panel of corporate income tax rates and apportionment factors are provided in Iovino et al. (2026). Finally, we use FactSet (2021) data on the distribution of U.S. multinationals' foreign sales across countries. We obtain data on corporate income tax rates for each foreign country and year from OECD (2024) and Tax Foundation (2023).

C Accelerated Depreciation and Property Taxes

In this section, we discuss two features of U.S. corporate taxation that lead to differential tax burdens based on the nature of firms' capital: accelerated depreciation and property taxes.

Besides standard accelerated depreciation methods, such as the Modified Accelerated Cost Recovery System (MACRS), bonus depreciation provisions on eligible capital reduce current taxes and increase deferred taxes, benefiting firms by delaying tax payments.[1] Since investments in equipment are typically eligible for bonus depreciation, this provision can also act as an implicit subsidy for CO_2-intensive firms.[2] As discussed in more detail in Zwick and Mahon (2017b), firms that benefit the most from bonus depreciation are those that would depreciate assets over a longer time horizon in the absence of the incentive. Let z_0 denote the present value of depreciation deductions per dollar of investment under MACRS and let b denote the bonus-depreciation rate. Under bonus depreciation, the present value of depreciation deductions becomes $z = b + (1 - b)z_0$. This formula shows that bonus depreciation provides a larger subsidy to capital that is depreciated more slowly according to IRS rules. We construct a firm-level measure of z_0 by weighting 4-digit NAICS industry-level z_0 values from Zwick and Mahon (2017a) with each firm's 2017 sales shares across 4-digit NAICS segments in Compustat. A lower z_0 for a given firm reflects a longer depreciation horizon in the absence of bonus depreciation and, correspondingly, means that bonus depreciation is associated with more deferred taxes.

In Supplemental Appendix Table C.1, column (1), we confirm the positive and statistically significant relationship between CO_2 intensity and the ratio of deferred income taxes to capital income. In column (2), we then control for the firm-level z_0. The coefficient on CO_2 intensity becomes small and statistically insignificant, whereas the coefficient on z_0 is negative and statistically significant at the 1% level. This pattern confirms that firms with a lower z_0 accumulate more deferred taxes under bonus depreciation, and that there is no robust relationship between CO_2 intensity and deferred income taxes, once we control for differences in asset duration across firms. Column (3) shows that z_0 has no significant effect on income taxes paid scaled by capital income, consistent with bonus depreciation affecting the timing rather than the level of tax payments. Importantly, the negative association between CO_2 intensity and income taxes paid remains essentially unchanged when we control for z_0: the coefficient is -0.021 (and statistically significant at the 1% level), virtually unchanged compared to the baseline estimate reported in Table 2. Taken together, these results indicate that differences in the generosity of bonus depreciation allowances across firms explain why CO_2-intensive firms have higher deferred income taxes, while not driving our central finding on income taxes paid.

Finally, note that the present value of these tax deferrals is much smaller than the baseline

[1] In later years of an asset's life, straight-line accounting depreciation exceeds tax depreciation, as the benefits of accelerated or bonus depreciation are concentrated in the earlier years. Thus, while accelerated and bonus depreciation affect the timing of tax payments, they do not alter the cumulative taxes paid over the asset's life.

[2] The Job Creation and Worker Assistance Act of 2002 introduced a 30% bonus depreciation for 2002–2003, which then fluctuated in generosity over time. The TCJA raised bonus depreciation to 100% for 2018–2022.

effect on the level of taxes paid reported in Table 2. The coefficient of 0.009 implies that 1 ton of CO_2 per USD 1,000 in sales is associated with a deferral of 0.009 in taxes, compared with a reduction of 0.022 in taxes in our main result. To compare these magnitudes, one must compute the present value of deferring 0.009 in taxes, which depends on the discount rate and the duration of the deferral. For example, using a 7% discount rate, deferring USD 1 in taxes over five years yields a present value benefit of about 30 cents, implying that the deferral benefit is roughly eight times smaller than the direct tax-reduction effect.

Property taxes paid by corporations account for the largest share of total state and local business tax revenue, around 40% in 2019. However, given that there is virtually no relationship between CO_2 intensity and the stock of buildings on firms' balance sheets (see column (3) of Supplemental Appendix Table A.2), we do not expect property taxes to disproportionately affect CO_2-intensive firms.[3]

Table C.1. CO_2-intensive firms, bonus depreciation, and deferred income taxes

	(1)	(2)	(3)
	Dependent Variables Scaled by Capital Income		
	Deferred Income Taxes		Income Taxes Paid
CO_2 Intensity	0.009	0.005	-0.021
	(0.003)	(0.004)	(0.006)
z_0 (Zwick and Mahon, 2017b)		-0.273	0.071
		(0.102)	(0.194)
Year FE	Y	Y	Y
Firm Controls	Y	Y	Y
R^2	0.028	0.029	0.097
N	11144	9992	10065

Note: This table presents estimates from pooled OLS specifications of deferred income taxes (columns 1 and 2) and income taxes paid (column 3) over capital income on CO_2 intensity and other control variables. All columns include year fixed effects and controls for capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory income tax rate. Columns (2-3) also include z_0, the present value of depreciation allowances per dollar of investment in the absence of bonus depreciation. We construct a firm-level measure of z_0 using each firm's sales distribution across (4-digit NAICS) industries using Compustat Segment data and industry-level measures of z_0 based on administrative tax return data from Zwick and Mahon (2017a). Deferred income taxes are Compustat item TXDI. The sample period is 2003-2021. Standard errors clustered at the firm level are reported in parentheses.

[3] Estimating precisely the relative tax burden at the firm level associated with property taxes is not feasible in practice, as property tax rates vary strongly across local governments, and we lack precise information on the location and eligibility of firms' properties across the U.S.

D The Model

Time is discrete and infinite. There is a representative household who consumes, supplies labor elastically and makes portfolio decisions. The economy features N different non-fuel sectors, indexed by $i \in \mathcal{N} = \{1, ..., N\}$, and three (fossil) fuel sectors, which we denote with c, o, and g, for "coal", "oil", and "gas", respectively. We define $\overline{\mathcal{N}}$ as the set of all sectors: $\overline{\mathcal{N}} = \{1, ..., N\} \cup \{c, o, g\}$. In each sector, there is a unit measure of firms selling a differentiated good. Goods are sold to final consumers and to other firms, which use them both as intermediate inputs and as investment goods for the production of capital.

The representative household purchases goods from firm f in sector i at price $p^f_{i,t}$, and pays a consumption tax τ_c. The household supplies labor for a wage w_t, which is taxed at rate τ_h. The household can save through risk-free government debt $B_{g,t+1}$, and firms' risky debt $B^f_{i,t+1}$ and equity shares $s^f_{i,t+1}$, for each firm f and sector i. Government debt pays an interest rate of r_t. Firms' debt pays an interest rate of $r^b_{i,t}$, unless default occurs and the firm is liquidated.[4] Finally, equity trades at price $Q^f_{i,t}$ and entitles the owner to dividends $d^f_{i,t}$, unless default occurs. We describe liquidation and default below, for now we let $\mathcal{L}^f_{i,t}$ and $\mathcal{D}^f_{i,t}$ be the indicator functions of, respectively, the events of liquidation and default for firm f, in sector i, at time t. We assume that interest income is taxed as regular labor income, dividends and capital gains are, instead, taxed at rate τ_d. Finally, the representative household receives lump-sum transfers T_t. All variables are real, the consumption bundle is the numeraire.

The household maximizes

$$\mathbb{E} \sum_{t=0}^{\infty} \beta^t \left(U(C_t) - V(L_t) \right),$$

subject to the budget constraint

$$\begin{aligned}
(1+\tau_c) \sum_{i \in \overline{\mathcal{N}}} \int p^f_{i,t} c^f_{i,t} df &= (1-\tau_h) w_t L_t + T_t + (1 + (1-\tau_h) r_{t-1}) B_{g,t} - B_{g,t+1} \\
&+ \sum_{i \in \overline{\mathcal{N}}} \int \left\{ [1 + (1-\tau_h)((1-\mathcal{L}^f_{i,t}) r^b_{i,t} - \mathcal{L}^f_{i,t})] B^f_{i,t} - B^f_{i,t+1} \right\} df \\
&+ \sum_{i \in \overline{\mathcal{N}}} \int \left\{ [(1-\mathcal{D}^f_{i,t})(1-\tau_d)(d^f_{i,t} + Q^f_{i,t}) + \tau_d Q^f_{i,t-1}] s^f_{i,t} - Q^f_{i,t} s^f_{i,t+1} \right\} df,
\end{aligned}$$

and a no-Ponzi condition requiring the discounted value of bond holdings to be non-negative in the limit as $t \to \infty$. We assume a nested Dixit-Stiglitz structure:

$$C_t \equiv \prod_{i \in \overline{\mathcal{N}}} \left(\frac{c_{i,t}}{\theta_i} \right)^{\theta_i}, \tag{D.1}$$

[4] To simplify notation, we anticipate that the interest rate will be sector-specific, but not firm-specific.

with

$$c_{i,t} \equiv \left(\int (c^f_{i,t})^{\frac{\sigma-1}{\sigma}} df \right)^{\frac{\sigma}{\sigma-1}},$$

and $\sum_i \theta_i = 1$, where $\sigma > 1$ parameterizes the elasticity of substitution across goods within a sector.

Firms within sectors are perfectly symmetric. We can thus solve the problem of the representative firm in each sector and simplify notation by replacing the firm's identifier f. We will refer to the representative firm in sector i as "firm i". Firms produce output by combining labor, capital, fuel and other intermediates. Capital can be of different types, which we index with $s \in \mathcal{S}$. Output $y_{i,t}$ is produced through a constant-returns-to-scale production function

$$y_{i,t} = \mathcal{Y}_i \left(\ell_{i,t}, \{k^s_{i,t}\}_s, F_{i,t}, \{x_{i,j,t}\}_j \right), \tag{D.2}$$

where $\ell_{i,t}$ is labor, $k^s_{i,t}$ is the amount of type-s capital owned by the firm, $F_{i,t} = \mathcal{F}_i(x_{i,c,t}, x_{i,o,t}, x_{i,g,t})$ is the fuel bundle, and $x_{i,j,t}$ is intermediate input from non-fuel sector j.

Investment. Firms can vary the amount of capital by combining inputs from different sectors. We allow such combinations of inputs to be sector specific. Formally, capital of type s in sector i follows the law of motion:

$$k^s_{i,t+1} = (1-\delta^s)k^s_{i,t} + I^s_{i,t},$$

where $\delta^s \in (0,1)$ is type-s capital's depreciation rate, and investment $I^s_{i,t}$ is a composite of different inputs $I^s_{i,t} \equiv \prod_j (i^s_{i,j,t}/\omega^s_{ij})^{\omega^s_{ij}}$, $\omega^s_{ij} \in [0,1]$, $\sum_j \omega_{ij} = 1$. We let $q^s_{i,t}$ denote the price of capital of type s, in sector i, at time t. In addition to creating new capital through investment, firms can also trade capital in a secondary market, which we describe below.

Default. Each firm is subject to an idiosyncratic default shock. We propose a default process that remains tractable while offering sufficient flexibility for calibration. In particular, the default process will imply that equilibrium leverage (and the interest rate on firms' debt) will be sector specific and will depend on the firm's holdings of certain types of capital, consistent with the empirical evidence in Section IID.

We assume that both default and liquidation shocks are exogenous. More specifically, at the beginning of every period, before production takes place, a firm can be hit by an idiosyncratic default shock with probability $(\rho_i + \lambda_i)$, with $\rho_i, \lambda_i > 0$. When default occurs, firm's equity becomes worthless. There are two types of default: restructuring and liquidation. Conditional on default, with probability $\rho_i/(\lambda_i + \rho_i)$ the firm must be restructured to continue production. A firm that undergoes restructuring keeps a (sector-specific and capital-specific) share ψ_s of its capital; the remaining capital is seized and transferred lump-sum to households. The capital retained by the firm is sold in the secondary market to repay bondholders. A restructured firm can issue new debt and equity, and restart production.

Firms in default that cannot be restructured must be liquidated, which occurs with probability $\lambda_i/(\lambda_i+\rho_i)$. Firms in liquidation lose all their capital (which is transferred lump-sum to households) and exit the economy permanently. To keep the total mass of firms unchanged, we assume that liquidated firms are immediately replaced with new firms with the same technology.

Finally, we assume the existence of a secondary market where households can sell the capital that was transferred to them to restructured and newly-born firms.

Leverage. Since firms in liquidation lose all of their capital, firms in our model cannot issue risk-free debt. More specifically, lenders can recover up to a fraction ψ_s of type-s capital from firm i in default, unless the firm is liquidated. Debt is thus risky and will carry a compensation for credit risk in equilibrium, i.e., $r^b_{i,t+1} > r_t$. Finally, note that any borrowing above the threshold ψ_s will not be repaid once the firm defaults, even in the event of a restructuring. We treat this additional borrowing as equity. Formally, we require debt $b_{i,t+1}$ to be such that

$$b_{i,t+1} \leq \frac{1}{1+r^b_{i,t+1}} \sum_{s\in\mathcal{S}} \psi_s q^s_{i,t+1} k^s_{i,t+1}. \tag{D.3}$$

Our default process assumes restructuring and liquidation probabilities that are independent of the quantity of debt. Below, we make an assumption on model parameters ensuring that equity is more expensive than debt, consistent with empirical evidence. Together, these assumptions simplify the leverage decision by implying that it is always optimal to issue the maximum amount of debt possible, that is, condition (D.3) will hold with equality. Then, using the definition of leverage $lev_{i,t} \equiv b_{i,t+1}/\sum_s q^s_{i,t+1} k^s_{i,t+1}$, constraint (D.3) becomes (6) in the main text.[5]

Emissions. We assume that production generates CO_2 emissions as a byproduct of fuel usage. More specifically, firm i's emissions are $E_{i,t} \equiv \sum_j e_j x_{i,j,t}$, where e_j is the emission rate of fuel $j = c, o, g$. Total emissions in the economy are thus $E_t = \sum_i E_{i,t}$.

Firms pay income taxes on their taxable income. The U.S. tax code allows firms to deduct expenditures on intermediate inputs, labor compensation, interest, and depreciation or amortization of capital. In addition, firms may be permitted to accelerate depreciation or amortization for certain types of capital. Let z^s_i denote the present discounted value of tax allowances for investment in type-s capital.

In every period, firms choose labor, intermediate inputs, investment, leverage, final-good price and production to maximize

$$\mathbb{E} \sum_{t=0}^{\infty} \varphi_t \Pi_{i,t},$$

[5] The default process implies that leverage increases with the share of certain types of capital, but the interest rate is independent of capital. It is straightforward to generalize the default process so that both the amount of borrowing and the cost of debt depend on capital: this can be achieved by assuming that lenders recover a fraction of tangible capital in the event of liquidation.

where

$$\Pi_{i,t} = (1-\tau)\Big(p_{i,t}y_{i,t} - \sum_{j\in\mathcal{N}} p_{j,t}x_{i,j,t} - P^F_{i,t}F_{i,t} - w_t\ell_{i,t} - r^b_{i,t}b_{i,t}\Big) - \sum_{s\in\mathcal{S}}(1-z^s_i\tau)q^s_{i,t}I^s_{i,t} + b_{i,t+1} - b_{i,t}$$

and where φ_t is the economy's stochastic discount factor, τ is the corporate income tax, and $P^F_{i,t}$ is the price of the fuel bundle for sector i.

Government and equilibrium definition. In every period, the government collects taxes, issues risk-free debt and sets lump-sum taxes to satisfy its budget constraint.

An equilibrium consists of a set of choices by households and firms, prices, and government policies, such that each agent optimizes, the government budget constraint is satisfied, and all markets clear. In particular, the goods-market in each sector and the aggregate labor market must clear:

$$y_{i,t} = c_{i,t} + \sum_{j\in\overline{\mathcal{N}}} x_{j,i,t} + \sum_{s\in\mathcal{S}}\sum_{j\in\overline{\mathcal{N}}} i^s_{j,i,t} \quad \text{and} \quad L_t = \sum_{i\in\overline{\mathcal{N}}} \ell_{i,t}. \tag{D.4}$$

In addition, the market for risk-free debt, firms' debt and equity, and used capital in each sector must all clear.

D.1 Proofs

Household. We begin with the household's problem. We first minimize total expenditures

$$\sum_{i\in\overline{\mathcal{N}}} \int p^f_{i,t} c^f_{i,t} df,$$

subject to achieving some level of aggregate consumption $C_t \equiv \prod_i (c_{i,t}/\theta_i)^{\theta_i}$, where consumption on goods from sector i is $c_{i,t} \equiv \left(\int (c^f_{i,t})^{\frac{\sigma-1}{\sigma}} df\right)^{\frac{\sigma}{\sigma-1}}$. We obtain the standard demand schedule

$$c^f_{i,t} = \left(\frac{p^f_{i,t}}{p_{i,t}}\right)^{-\sigma} c_{i,t}, \tag{D.5}$$

where $p_{i,t} \equiv \left(\int (p^f_{i,t})^{1-\sigma} df\right)^{\frac{1}{1-\sigma}}$ is the appropriate price index for sector i. In addition, the Cobb-Douglas specification implies

$$p_{i,t}c_{i,t} = \theta_i C_t, \tag{D.6}$$

where we have used the normalization $P_t \equiv \prod_i p^{\theta_i}_{i,t} = 1$.

Next, we choose C_t. Letting φ_t be the Lagrange multiplier on the household's budget constraint, we obtain

$$U'(C_t) = (1+\tau_c)\varphi_t. \tag{D.7}$$

Similarly, the optimal choice of L_t satisfies the first-order condition

$$V'(L_t) = (1-\tau_h)\varphi_t w_t. \tag{D.8}$$

Finally, we consider the portfolio problem. Since default and liquidation shocks are i.i.d. across firms, in every period there will be exactly a fraction $\rho_i + \lambda_i$ of firms in default and a fraction λ_i of firms in liquidation. The first-order conditions for the optimal choices of risk-free bonds, corporate bonds and equity are, respectively,

$$\varphi_t = \varphi_{t+1}(1+(1-\tau_h)r_t),$$

$$\varphi_t = \varphi_{t+1} + \varphi_{t+1}(1-\lambda_i)(1-\tau_h)r^b_{i,t+1} - \varphi_{t+1}\lambda_i(1-\tau_h),$$

and

$$\varphi_t Q^f_{i,t} = \varphi_{t+1}(1-\rho_i-\lambda_i)(1-\tau_d)(d^f_{i,t+1} + Q^f_{i,t+1}) + \varphi_{t+1}\tau_d Q^f_{i,t}.$$

Combining the first two conditions, we obtain

$$r^b_{i,t+1} = \frac{\lambda_i + r_t}{1-\lambda_i}.$$

Similarly, the first and third conditions together give

$$r^e_{i,t+1} \equiv \frac{d^f_{i,t+1} + Q^f_{i,t+1}}{Q^f_{i,t}} - 1 = \frac{(\rho_i+\lambda_i)(1-\tau_d) + (1-\tau_h)r_t}{(1-\rho_i-\lambda_i)(1-\tau_d)}. \tag{D.9}$$

Note that the expected net return on equity is equal to the net risk-free rate because there is no aggregate risk:

$$(1-\rho_i-\lambda_i)(1-\tau_d)r^e_{i,t+1} + (\rho_i+\lambda_i)(-1)(1-\tau_d) = (1-\tau_h)r_t.$$

The same property holds for corporate bonds.

Firms. We now turn to the firm's problem. In the main text, we simplified notation by focusing on a representative firm in each sector; here, instead, we solve the problem of a generic firm f in sector i. In addition, to study both scenarios—with and without the tax shield—we introduce the parameter ω_r in equation (D.10). This parameter is set to 1 when the tax shield is present and to $1/(1-\tau)$ when the tax shield is absent.

The firm maximizes

$$\mathbb{E}\sum_{t=0}^{\infty} \varphi_t \Pi^f_{i,t},$$

subject to

(i) the cash-flow process

$$\Pi_{i,t} =(1-\tau)\Big(p^f_{i,t}y^f_{i,t} - \sum_{j\in\mathcal{N}} p_{j,t}x^f_{i,j,t} - P^F_{i,t}F^f_{i,t} - w_t\ell^f_{i,t} - \omega_r r^b_{i,t}b^f_{i,t}\Big) \tag{D.10}$$
$$- \sum_{s\in\mathcal{S}}(1-z^s_i\tau)q^s_{i,t}I^{s,f}_{i,t} + b^f_{i,t+1} - b^f_{i,t},$$

where $q^s_{i,t}$ is the price of the investment bundle for type-s capital and sector i (which we define below);

(ii) the production function

$$y^f_{i,t} = z_i\Big((\ell^f_{i,t})^{\phi^\ell_i}(K^f_{i,t})^{\phi^K_i}(k^{o,f}_{i,t})^{\phi^o_i}\Big)^{\gamma_i}\Big(\prod_{j\in\mathcal{N}}(x^f_{i,j,t})^{\alpha_{ij}}\Big)^{1-\gamma_i}, \tag{D.11}$$

where

$$K^f_{i,t} \equiv \Big(\phi^F_i(F^f_{i,t})^{\frac{\rho-1}{\rho}} + (1-\phi^F_i)(k^{e,f}_{i,t})^{\frac{\rho-1}{\rho}}\Big)^{\frac{\rho}{\rho-1}}, \quad F^f_{i,t} \equiv \prod_{j=c,o,g}(x^f_{i,j,t})^{\eta^{F,j}_i}; \tag{D.12}$$

(iii) the law of motion for capital

$$k^{s,f}_{i,t+1} = (1-\delta^s)k^{s,f}_{i,t} + I^{s,f}_{i,t}, \tag{D.13}$$

where the investment bundle is

$$I^{s,f}_{i,t} \equiv \prod_{j\in\overline{\mathcal{N}}}\left(\frac{i^{s,f}_{i,j,t}}{\omega^s_{ij}}\right)^{\omega^s_{ij}}; \tag{D.14}$$

(iv) the borrowing constraint

$$b^f_{i,t+1} \leq \frac{1}{1+r^b_{i,t+1}}\sum_{s\in\mathcal{S}}\psi_s q^s_{i,t+1}k^{s,f}_{i,t+1}; \tag{D.15}$$

(v) and the demand schedule

$$y^f_{i,t} = \left(\frac{p^f_{i,t}}{p_{i,t}}\right)^{-\sigma} y_{i,t}. \tag{D.16}$$

Note that monopolistically competitive firms take demand into account when choosing production, this is why (D.16)—which follows from (D.5) and goods-market clearing—enters the maximization problem. We let $\mu_i \equiv (\sigma-1)/\sigma$ denote the inverse of the gross markup.

We begin with the choice of labor. Substituting $p^f_{i,t}$ from (D.16) and $y^f_{i,t}$ from (D.11) into (D.10) and taking the first-order condition with respect to $\ell^f_{i,t}$, we obtain

$$\mu_i \gamma_i \phi^\ell_i = \frac{w_t \ell^f_{i,t}}{p^f_{i,t} y^f_{i,t}}. \tag{D.17}$$

Similarly, the choice of any input $x^f_{i,j,t}$, $j \in \mathcal{N}$, satisfies

$$\mu_i (1-\gamma_i) \alpha_{ij} = \frac{p_{j,t} x^f_{i,j,t}}{p^f_{i,t} y^f_{i,t}}. \tag{D.18}$$

The first-order condition for the choice of fuel input $x^f_{i,j,t}$, $j = c, o, g$, is given by

$$\mu_i \gamma_i \phi^K_i \phi^F_i \eta^{F,j}_i = \frac{p_{j,t} x^f_{i,j,t}}{p^f_{i,t} y^f_{i,t}} \left(\frac{F^f_{i,t}}{K^f_{i,t}} \right)^{\frac{1}{\rho}-1}. \tag{D.19}$$

Finally, conditional on total investment $I^{s,f}_{i,t}$, the choice of $i^{s,f}_{i,j,t}$ is static and satisfies the first-order condition

$$p_{j,t} i^{s,f}_{i,j,t} - \lambda^{s,f}_{i,t} \omega_{ij} I^{s,f}_{i,t} = 0,$$

where $\lambda^{s,f}_{i,t}$ is the Lagrange multiplier on (D.14). As a result,

$$\sum_{j \in \mathcal{N}} p_{j,t} i^{s,f}_{i,j,t} = q^s_{i,t} I^{s,f}_{i,t},$$

where $q^s_{i,t} \equiv \prod_j p_{j,t}^{\omega^s_{ij}}$ is the price index for sector i's investment bundle. Therefore,

$$i^{s,f}_{i,j,t} = \frac{1}{p_{j,t}} \omega^s_{ij} q^s_{i,t} I^{s,f}_{i,t}. \tag{D.20}$$

In a symmetric equilibrium all firms in a sector make the same choices, therefore, we can drop the superscript f from the notation.

Consider now the choice of debt and investment. The assumption that $r^e_{i,t+1} \geq r^b_{i,t+1}$, for all i, together with the fact that debt enjoys a tax advantage, imply that firms always prefer borrowing through debt rather than equity. It follows that the borrowing constraint (D.15) will hold with equality, pinning down the optimal choice of debt. Using (D.13) to replace $I^{s,f}_{i,t}$ into (D.10), the optimal choice of $k^{s,f}_{i,t+1}$ satisfies the first-order condition

$$-(1-z^s_i\tau)q^s_{i,t}+\frac{1}{1+r^b_{i,t+1}}\psi_s q^s_{i,t+1}+\frac{1}{1+r^e_{i,t+1}}(1-\tau)\mu_i p^f_{i,t+1}\frac{\partial y^f_{i,t+1}}{\partial k^{s,f}_{i,t+1}}$$
$$+\frac{1}{1+r^e_{i,t+1}}\Big\{-(1-\tau)\omega_r\frac{r^b_{i,t+1}}{1+r^b_{i,t+1}}\psi_s q^s_{i,t+1}+(1-z^s_i\tau)(1-\delta^s)q^s_{i,t+1}-\frac{1}{1+r^b_{i,t+1}}\psi_s q^s_{i,t+1}\Big\}=0,$$

where we have used (D.9). In the symmetric equilibrium, this equation can be rewritten as

$$\mu_i=R^s_{i,t}\frac{q^s_{i,t}}{p_{i,t}\frac{\partial y_{i,t}}{\partial k^s_{i,t}}},\tag{D.21}$$

where

$$\begin{aligned}R^s_{i,t}\equiv&\frac{1-(1-z^s_i\tau)(1-\delta^s)}{1-\tau}+\omega_r r^b_{i,t}\frac{\psi_s}{1+r^b_{i,t}}+\frac{1}{1-\tau}r^e_{i,t}\Big(1-\frac{\psi_s}{1+r^b_{i,t}}\Big)\\&+\frac{1}{1-\tau}(1+r^e_{i,t})\Big((1-z^s_i\tau)\frac{q^s_{i,t-1}}{q^s_{i,t}}-1\Big)\end{aligned}\tag{D.22}$$

is the user cost of type-s capital. For $s=o$, (D.21) becomes

$$\mu_i\gamma_i\phi^o_i=R^o_{i,t}\frac{q^o_{i,t}k^o_{i,t}}{p_{i,t}y_{i,t}};\tag{D.23}$$

for $s=e$, it becomes

$$\mu_i\gamma_i\phi^K_i(1-\phi^F_i)=R^e_{i,t}\frac{q^e_{i,t}k^e_{i,t}}{p_{i,t}y_{i,t}}\left(\frac{k^e_{i,t}}{K_{i,t}}\right)^{\frac{1}{\rho}-1}.\tag{D.24}$$

Steady state. We now focus on the steady state prior to any counterfactual policy. Since we will use "exact hat algebra", it is not necessary to solve for the entire equilibrium. Steady-state variables do not bear a time subscript. From (D.19),

$$x_{i,j}=\mu_i\gamma_i\phi^K_i\phi^F_i\eta^{F,j}_i\frac{p_iy_i}{p_j}\left(\frac{F_i}{K_i}\right)^{1-\frac{1}{\rho}}$$

or, letting $\eta^F_i\equiv\phi^F_i(F_i/K_i)^{1-\frac{1}{\rho}}$,

$$x_{i,j}=\mu_i\gamma_i\phi^K_i\eta^F_i\eta^{F,j}_i\frac{p_iy_i}{p_j}.\tag{D.25}$$

Combining (D.6) and (D.25) gives

$$\frac{\theta_j/c_j}{\theta_i/c_i}=\frac{p_j}{p_i}=\mu_i\gamma_i\phi^K_i\eta^F_i\eta^{F,j}_i\frac{y_i}{x_{i,j}}$$

or

$$x_{j,i} = \mu_j y_j \gamma_j \phi_j^K \eta_j^F \eta_j^{F,i} \frac{\theta_j c_i}{c_j \theta_i}. \tag{D.26}$$

Similarly, from (D.18),

$$x_{i,j} = \mu_i (1 - \gamma_i) \alpha_{ij} \frac{p_i y_i}{p_j}, \tag{D.27}$$

thus,

$$\frac{\theta_j / c_j}{\theta_i / c_i} = \frac{p_j}{p_i} = \mu_i (1 - \gamma_i) \alpha_{ij} \frac{y_i}{x_{i,j}}$$

or

$$x_{j,i} = \mu_j y_j (1 - \gamma_j) \alpha_{ji} \frac{\theta_j c_i}{c_j \theta_i}. \tag{D.28}$$

Summing across fuel and non-fuel inputs yields

$$\sum_{j=c,o,g} x_{j,i} = \frac{c_i}{\theta_i} \sum_{j=c,o,g} \mu_j y_j \gamma_j \phi_j^K \eta_j^F \eta_j^{F,i} \frac{\theta_j}{c_j} \quad \text{and} \quad \sum_{j \in \mathcal{N}} x_{j,i} = \frac{c_i}{\theta_i} \sum_{j \in \mathcal{N}} \mu_j y_j (1 - \gamma_j) \alpha_{ji} \frac{\theta_j}{c_j}.$$

Also, from the definition of η_i^F and K_i, $1 - \eta_i^F = (1 - \phi_i^F)(k_i^e / K_i)^{1 - \frac{1}{\rho}}$, hence, in steady state (D.23) and (D.24) simplify to

$$\mu_i \gamma_i \phi_i^o = R_i^o \frac{q_i^o k_i^o}{p_i y_i}, \quad \text{and} \quad \mu_i \gamma_i \phi_i^K (1 - \eta_i^F) = R_i^e \frac{q_i^e k_i^e}{p_i y_i}, \tag{D.29}$$

respectively, where the steady-state user cost is

$$R_i^s \equiv \frac{1 - z_i^s \tau}{1 - \tau} (\delta^s + r_i^e) - \left(\frac{1}{1 - \tau} r_i^e - \omega_r r_i^b \right) \frac{\psi_s}{1 + r_i^b}, \quad s = o, e.$$

The latter coincides with (7) when $\omega_r = 1$, that is, when the tax shield is present. In steady state, $I_i^s = \delta^s k_i^s$, and we can rewrite (D.20) as

$$p_j i_{i,j}^s = \omega_{ij}^s \delta^s q_i^s k_i^s.$$

Combining the latter expression with (D.29) yields, for $s = o$,

$$\frac{p_j i_{i,j}^o}{p_i y_i} = \mu_i \gamma_i \phi_i^o \omega_{ij}^o \frac{\delta^o}{R_i^o}. \tag{D.30}$$

Using equation (D.6) with (D.30) we then obtain

$$\frac{\theta_j / c_j}{\theta_i / c_i} = \frac{p_j}{p_i} = \mu_i \gamma_i \phi_i^o \omega_{ij}^o \frac{\delta^o}{R_i^o} \cdot \frac{y_i}{i_{i,j}^o}$$

or

$$i^o_{j,i} = \mu_j \gamma_j \phi^o_j \omega^o_{ji} \frac{\delta^o}{R^o_j} y_j \frac{\theta_j c_i}{c_j \theta_i}. \tag{D.31}$$

The expression for $s = e$ is analogous.

Summing across sectors and types of capital, we obtain

$$\sum_{s\in\mathcal{S}} \sum_{j\in\overline{\mathcal{N}}} i^s_{j,i} = \frac{c_i}{\theta_i} \sum_{j\in\overline{\mathcal{N}}} \mu_j y_j \gamma_j \phi^K_j (1-\eta^F_j) \omega^e_{ji} \frac{\delta^e}{R^e_j} \cdot \frac{\theta_j}{c_j} + \frac{c_i}{\theta_i} \sum_{j\in\overline{\mathcal{N}}} \mu_j y_j \gamma_j \phi^o_j \omega^o_{ji} \frac{\delta^o}{R^o_j} \cdot \frac{\theta_j}{c_j}.$$

Therefore, the resource constraint (D.4) can be rewritten as

$$\begin{aligned} y_i =& c_i + \frac{c_i}{\theta_i} \sum_{j=c,o,g} \mu_j y_j \gamma_j \phi^K_j \eta^F_j \eta^{F,i}_j \frac{\theta_j}{c_j} + \frac{c_i}{\theta_i} \sum_{j\in\mathcal{N}} \mu_j y_j (1-\gamma_j) \alpha_{ji} \frac{\theta_j}{c_j} \\ &+ \frac{c_i}{\theta_i} \sum_{j\in\overline{\mathcal{N}}} \mu_j y_j \gamma_j \phi^K_j (1-\eta^F_j) \omega^e_{ji} \frac{\delta^e}{R^e_j} \cdot \frac{\theta_j}{c_j} + \frac{c_i}{\theta_i} \sum_{j\in\overline{\mathcal{N}}} \mu_j y_j \gamma_j \phi^o_j \omega^o_{ji} \frac{\delta^o}{R^o_j} \cdot \frac{\theta_j}{c_j}. \end{aligned} \tag{D.32}$$

It is convenient to work with matrix notation. Given a vector $\boldsymbol{x}$, we let $\operatorname{diag}(\boldsymbol{x})$ denote the diagonal matrix whose main diagonal is given by $\boldsymbol{x}$. Equation (D.32) can then be rewritten as

$$\boldsymbol{y} = \boldsymbol{c} + \operatorname{diag}(\boldsymbol{c}) \operatorname{diag}(\boldsymbol{\theta})^{-1} \Delta \operatorname{diag}(\boldsymbol{\theta}) \operatorname{diag}(\boldsymbol{c})^{-1} \boldsymbol{y},$$

where

$$\begin{aligned} \Delta \equiv& H' \operatorname{diag}(\boldsymbol{\mu}) \operatorname{diag}(\boldsymbol{\gamma}) \operatorname{diag}(\boldsymbol{\phi^K}) \operatorname{diag}(\boldsymbol{\eta^F}) + A' \operatorname{diag}(\boldsymbol{\mu}) \operatorname{diag}(\boldsymbol{1}-\boldsymbol{\gamma}) \\ &+ (\Omega^e)' \operatorname{diag}(\boldsymbol{\mu}) \operatorname{diag}((\boldsymbol{R}^e)^{-1}) \operatorname{diag}(\boldsymbol{\delta}^e) \operatorname{diag}(\boldsymbol{\phi^K}) \operatorname{diag}(\boldsymbol{1}-\boldsymbol{\eta^F}) \operatorname{diag}(\boldsymbol{\gamma}) \\ &+ (\Omega^o)' \operatorname{diag}(\boldsymbol{\mu}) \operatorname{diag}((\boldsymbol{R}^o)^{-1}) \operatorname{diag}(\boldsymbol{\delta}^o) \operatorname{diag}(\boldsymbol{\phi}^o) \operatorname{diag}(\boldsymbol{\gamma}), \end{aligned}$$

and where H and A denote the matrices whose (i,j) entries equal $\eta^{F,j}_i$ and α_{ij}, respectively. Letting $I_{\mathcal{N}}$ denote the identity matrix of dimension $N \times N$, we have

$$\boldsymbol{y} = (I_{\mathcal{N}} - \operatorname{diag}(\boldsymbol{c}) \operatorname{diag}(\boldsymbol{\theta})^{-1} \Delta \operatorname{diag}(\boldsymbol{\theta}) \operatorname{diag}(\boldsymbol{c})^{-1})^{-1} \boldsymbol{c}$$

or, since $(A^{-1}BA)^{-1} = A^{-1}B^{-1}A$,

$$\boldsymbol{y} = \operatorname{diag}(\boldsymbol{c}) \operatorname{diag}(\boldsymbol{\theta})^{-1} (I_{\mathcal{N}} - \Delta)^{-1} \operatorname{diag}(\boldsymbol{\theta}) \operatorname{diag}(\boldsymbol{c})^{-1} \boldsymbol{c}.$$

Finally, using $\operatorname{diag}(\boldsymbol{c})^{-1}\boldsymbol{c} = \boldsymbol{1}$, we obtain

$$\operatorname{diag}(\boldsymbol{\theta}) \operatorname{diag}(\boldsymbol{c})^{-1} \boldsymbol{y} = (I_{\mathcal{N}} - \Delta)^{-1} \boldsymbol{\theta} \tag{D.33}$$

or, using (D.6),

$$\text{diag}(\boldsymbol{p})\boldsymbol{y} = (I_{\mathcal{N}} - \Delta)^{-1}\boldsymbol{\theta}. \tag{D.34}$$

Counterfactuals with "exact-hat algebra". To study policy counterfactuals, we adopt the "exact hat algebra" approach (Dekle et al., 2008; Costinot and Rodríguez-Clare, 2014), in which equilibrium relations are expressed as deviations from the initial equilibrium (i.e., prior to the policy change). Since we will be comparing steady states, we drop the time subscript from the notation. Specifically, letting X_i and X_i' denote the value of a variable before and after the policy change, respectively, we write equilibrium relations in terms of $\hat{X}_i \equiv X_i'/X_i$. For convenience, we then define the production function in deviation from the initial equilibrium.

The tax shield impacts the economy by changing the user cost of the different types of capital. Let $(R_i^s)'$ be the user cost of type-s capital in sector i in the new equilibrium and let $\hat{R}_i^s \equiv (R_i^s)'/R_i^s$ be the change relative to the original equilibrium. We also assume $U(C) = C^{1-\nu}/(1-\nu)$ and $V(L) = L^{1+1/\epsilon}/(1+1/\epsilon)$.

We begin with the labor market. Combining conditions (D.7) and (D.8) yields

$$\frac{L^{1/\epsilon}}{C^{-\nu}} = \frac{1-\tau_h}{1+\tau_c} w, \tag{D.35}$$

which, together with (D.6) and (D.17), gives

$$\ell_i = \frac{1-\tau_h}{1+\tau_c} \cdot \frac{C^{1-\nu}}{L^{1/\epsilon}} \theta_i \phi_i^\ell \gamma_i \mu_i \frac{y_i}{c_i} \tag{D.36}$$

Using the "hat" notation we can rewrite (D.35) and (D.36) as

$$\frac{\hat{L}^{1/\epsilon}}{\hat{C}^{-\nu}} = \hat{w} \tag{D.37}$$

and

$$\hat{\ell}_i = \frac{\hat{C}^{1-\nu}}{\hat{L}^{1/\epsilon}} \cdot \frac{\hat{y}_i}{\hat{c}_i}, \tag{D.38}$$

respectively. From labor-market clearing,

$$\hat{L} = \sum_{i \in \mathcal{N}} \frac{w\ell_i}{wL} \hat{\ell}_i$$

or, using (D.38),

$$\hat{L}^{1+1/\epsilon} = \hat{C}^{1-\nu} \sum_{i \in \mathcal{N}} \vartheta_i^L \frac{\hat{y}_i}{\hat{c}_i}, \tag{D.39}$$

where $\vartheta_i^L \equiv w\ell_i/wL$.

Similarly, (D.18) and (D.19) become

$$\frac{\hat{p}_j \hat{x}_{i,j}}{\hat{p}_i \hat{y}_i} = 1 \tag{D.40}$$

and

$$\frac{\hat{p}_j \hat{x}_{i,j}}{\hat{p}_i \hat{y}_i} \left(\frac{\hat{F}_i}{\hat{K}_i} \right)^{\frac{1}{\rho}-1} = 1, \tag{D.41}$$

respectively.

The optimal choice of labor (D.17), and the optimal choice of capital (D.23) and (D.24) become, respectively,

$$\frac{\hat{w}\hat{\ell}_i}{\hat{p}_i \hat{y}_i} = 1, \quad \hat{R}_i^o \frac{\hat{q}_i^o \hat{k}_i^o}{\hat{p}_i \hat{y}_i} = 1 \quad \text{and} \quad \hat{R}_i^e \frac{\hat{q}_i^e \hat{k}_i^e}{\hat{p}_i \hat{y}_i} \left(\frac{\hat{k}_i^e}{\hat{K}_i} \right)^{\frac{1}{\rho}-1} = 1. \tag{D.42}$$

From the definition of the fuel bundle (D.12), we have

$$\hat{F}_i = \prod_{j=c,o,g} \hat{x}_{i,j}^{\eta_i^{F,j}}.$$

Also, from (D.41), we obtain demand for fuel j:

$$\hat{x}_{i,j} = \hat{p}_i \hat{y}_i \left(\frac{\hat{F}_i}{\hat{K}_i} \right)^{1-\frac{1}{\rho}} \hat{p}_j^{-1}. \tag{D.43}$$

Raising the latter to the power of $\eta_i^{F,j}$, multiplying over $j = c, o, g$, and combining it with $\hat{F}_i$ gives

$$\hat{F}_i = (\hat{p}_i \hat{y}_i)^\rho \hat{K}_i^{1-\rho} (\hat{P}_i^F)^{-\rho}, \tag{D.44}$$

where we let $\hat{P}_i^F \equiv \prod_{j=c,o,g} \hat{p}_j^{\eta_i^{F,j}}$.

From (D.12) and the definition of η_i^F, we have

$$\hat{K}_i = (\eta_i^F (\hat{F}_i)^{\frac{\rho-1}{\rho}} + (1-\eta_i^F)(\hat{k}_i^e)^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}}.$$

Also, from (D.42),

$$\hat{k}_i^e = \hat{p}_i \hat{y}_i \left(\frac{\hat{k}_i^e}{\hat{K}_i} \right)^{1-\frac{1}{\rho}} (\hat{R}_i^e)^{-1} (\hat{q}_i^e)^{-1}. \tag{D.45}$$

Raising both this equation and (D.44) to the power of $(\rho-1)/\rho$, taking a weighted average of the two resulting expressions (with weights η_i^F and $(1-\eta_i^F)$, respectively), and substituting them into the expression for $\hat{K}_i$ yields

$$\hat{K}_i = \hat{p}_i \hat{y}_i (\hat{P}_i^K)^{-1}, \tag{D.46}$$

where we let $\hat{P}_i^K \equiv \left(\eta_i^F(\hat{P}_i^F)^{1-\rho} + (1-\eta_i^F)(\hat{R}_i^e\hat{q}_i^e)^{1-\rho}\right)^{\frac{1}{1-\rho}}$. Substituting (D.44) and (D.46) into (D.43) yields

$$\hat{x}_{i,j} = \hat{p}_i\hat{y}_i(\hat{P}_i^K)^{\rho-1}(\hat{P}_i^F)^{1-\rho}\hat{p}_j^{-1}. \tag{D.47}$$

From (D.40), we obtain the demand for any non-fuel input:

$$\hat{x}_{i,j} = \hat{p}_i\hat{y}_i\hat{p}_j^{-1}, \tag{D.48}$$

which we raise to the power of α_{ij} and multiplying over $j \in \mathcal{N}$ to get

$$\prod_{j\in\mathcal{N}} \hat{x}_{i,j}^{\alpha_{ij}} = \hat{p}_i\hat{y}_i \prod_{j\in\mathcal{N}} (\hat{p}_j)^{-\alpha_{ij}}. \tag{D.49}$$

From (D.42), we obtain the demand for labor and capital of type $s = o$:

$$\hat{\ell}_i = \hat{p}_i\hat{y}_i\hat{w}^{-1}, \tag{D.50}$$

$$\hat{k}_i^o = \hat{p}_i\hat{y}_i(\hat{R}_i^o)^{-1}(\hat{q}_i^o)^{-1}, \tag{D.51}$$

respectively.

Finally, if we raise (D.50) to the power of $\gamma_i\phi_i^\ell$, (D.46) to the power of $\gamma_i\phi_i^K$, (D.51) to the power of $\gamma_i\phi_i^o$, and (D.49) to the power of $(1-\gamma_i)$, and substitute the resulting expressions into the production function (D.11), we obtain

$$\hat{p}_i = \hat{w}^{\gamma_i\phi_i^\ell}(\hat{P}_i^K)^{\gamma_i\phi_i^K}(\hat{R}_i^o\hat{q}_i^o)^{\gamma_i\phi_i^I}\prod_{j\in\mathcal{N}}\hat{p}_j^{(1-\gamma_i)\alpha_{ij}}. \tag{D.52}$$

We now rewrite the resource constraint (D.4) as

$$\hat{y}_i = \frac{p_ic_i}{p_iy_i}\hat{c}_i + \sum_{j=c,o,g}\frac{p_ix_{j,i}}{p_iy_i}\hat{x}_{j,i} + \sum_{j\in\mathcal{N}}\frac{p_ix_{j,i}}{p_iy_i}\hat{x}_{j,i} + \sum_{s\in\mathcal{S}}\sum_{j\in\overline{\mathcal{N}}}\frac{p_ii_{j,i}^s}{p_iy_i}\hat{i}_{j,i}^s. \tag{D.53}$$

From (D.6), we have

$$\hat{c}_i = \hat{p}_i^{-1}\hat{C}. \tag{D.54}$$

Similarly, from (D.30), we obtain

$$\hat{i}_{i,j}^o = \frac{1}{\hat{R}_i^o}\hat{p}_i\hat{y}_i\hat{p}_j^{-1}. \tag{D.55}$$

For capital of type $s = e$, we first use the "hat" notation with (D.20) and the fact that $\hat{I}_i^e = \hat{k}_i^e$ to obtain

$$\hat{i}_{i,j}^e = \hat{q}_i^e\hat{k}_i^e\hat{p}_j^{-1}.$$

We then combine the latter with (D.45) and (D.46):

$$\hat{i}^e_{i,j} = (\hat{P}^K_i)^{\rho-1}(\hat{q}^e_i)^{1-\rho}(\hat{R}^e_i)^{-\rho}\hat{p}_i\hat{y}_i\hat{p}_j^{-1}. \tag{D.56}$$

We can then substitute (D.25), (D.27), (D.30) (and the analogous expression for capital of type $s = e$), (D.54), (D.47), (D.48), (D.55), and (D.56) into (D.53) to obtain

$$\begin{aligned}\hat{p}_i\hat{y}_i =& \vartheta^C_i + \sum_{j=c,o,g} \mu_j\gamma_j\phi^K_j\eta^F_j\eta^{F,i}_j\vartheta^Y_{ji}\hat{p}_j\hat{y}_j(\hat{P}^K_j)^{\rho-1}(\hat{P}^F_j)^{1-\rho} + \sum_{j\in\mathcal{N}}\mu_j(1-\gamma_j)\alpha_{ji}\vartheta^Y_{ji}\hat{p}_j\hat{y}_j \\ &+ \sum_{j\in\overline{\mathcal{N}}}\mu_j\gamma_j\phi^K_j(1-\eta^F_j)\omega^e_{ji}\frac{\delta^e}{R^e_j}\vartheta^Y_{ji}\frac{1}{(\hat{R}^e_j)^\rho}(\hat{P}^K_j)^{\rho-1}(\hat{q}^e_j)^{1-\rho}\hat{p}_j\hat{y}_j \\ &+ \sum_{j\in\overline{\mathcal{N}}}\mu_j\gamma_j\phi^o_j\omega^o_{ji}\frac{\delta^o}{R^o_j}\vartheta^Y_{ji}\frac{1}{\hat{R}^o_j}\hat{p}_j\hat{y}_j,\end{aligned} \tag{D.57}$$

where $\vartheta^C_i \equiv p_ic_i/p_iy_i$ and $\vartheta^Y_{ji} \equiv p_jy_j/p_iy_i$, which are given by (D.33) and (D.34), respectively.

Equation (D.52) and (D.57) can then be solved to obtain sectoral output $\hat{y}_i$ and prices $\hat{p}_i$ for given wage $\hat{w}$. Finally, to solve for the wage, we use (D.54) to rewrite (D.39) as

$$\hat{L}^{1+1/\epsilon} = \hat{C}^{-\nu}\sum_{i\in\overline{\mathcal{N}}}\vartheta^L_i\hat{p}_i\hat{y}_i, \tag{D.58}$$

and solve it jointly with (D.37), (D.54), and aggregate consumption

$$\hat{C} = \prod_{i\in\overline{\mathcal{N}}}\hat{c}_i^{\theta_i}.$$

Proof for equation (8). We work directly in steady state and focus on the clean firm—which by assumption uses only type-o capital; the dirty firm case is analogous. In the model, capital income is defined as sales minus the cost of labor and intermediate inputs (including fuel):

$$\text{Capital Income} \equiv p_iy_i - w\ell_i - \sum_{j\in\mathcal{N}}p_jx_{i,j} - P^F_iF_i.$$

Pretax income is instead defined as capital income minus depreciation deductions and interest expense:

$$\text{Pretax Income} \equiv \text{Capital Income} - \left(\delta^o + r^b_i\frac{\psi_o}{1+r^b_i}\right)q^o_ik^o_i.$$

Using (D.17), (D.18), (D.23), (D.25), and letting $\sigma\to\infty$, we can rewrite capital income as

$$\text{Capital Income} = R^o_iq^o_ik^o_i.$$

Similarly, pretax income becomes

$$\text{Pretax Income} = \frac{1}{1-\tau} r_i^e \left(1 - \frac{\psi_o}{1+r_i^b}\right) q_i^o k_i^o.$$

Finally,

$$\frac{\text{Pretax Income}}{\text{Capital Income}} = \frac{\frac{1}{1-\tau} r_i^e \left(1 - \frac{\psi_o}{1+r_i^b}\right)}{\delta^o + r_i^b \frac{\psi_o}{1+r_i^b} + \frac{1}{1-\tau} r_i^e \left(1 - \frac{\psi_o}{1+r_i^b}\right)}.$$

Let $R^c \equiv R_i^o$ and, analogously, $R^d \equiv R_i^e$ (we drop the index i for simplicity), and consider the derivative

$$\begin{aligned}
\frac{\partial \log R^c}{\partial \tau} &= \frac{\partial}{\partial \tau} \log \left[\delta^o + r_i^b \frac{\psi_o}{1+r_i^b} + \frac{1}{1-\tau} r_i^e \left(1 - \frac{\psi_o}{1+r_i^b}\right)\right] \\
&= \frac{\frac{1}{(1-\tau)^2} r_i^e \left(1 - \frac{\psi_o}{1+r_i^b}\right)}{\delta^o + r_i^b \frac{\psi_o}{1+r_i^b} + \frac{1}{1-\tau} r_i^e \left(1 - \frac{\psi_o}{1+r_i^b}\right)} \\
&= \frac{1}{1-\tau} \cdot \frac{\text{Pretax Income}}{\text{Capital Income}}.
\end{aligned}$$

To obtain equation (8) we compute $\partial(\log R^c/R^d)/\partial\tau$ around $\tau \approx 0$:

$$\begin{aligned}
\frac{\partial}{\partial \tau} \log \frac{R^c}{R^d} &\approx \frac{\partial \log R^c}{\partial \tau} - \frac{\partial \log R^d}{\partial \tau} \\
&= \left.\frac{\text{Pretax Income}}{\text{Capital Income}}\right|^c - \left.\frac{\text{Pretax Income}}{\text{Capital Income}}\right|^d.
\end{aligned}$$

E Calibration

In this section, we provide additional details on the model calibration.

Household. We let $U(C) = \log(C)$, which corresponds to the limit $\nu \to 1$ of the specification in Appendix D, and $V(L) = L^{1+1/\epsilon}/(1 + 1/\epsilon)$, where ϵ is the Frisch elasticity of labor supply, which we set to 0.5 (Chetty, 2012). We also set $\beta = 0.99$ to target a risk-free real interest rate in steady state of about 1%. The Cobb-Douglas specification for the consumption basket (D.1) implies that, at the optimum, θ_i will coincide with the share in consumption of sector i.[6] We use data from the U.S. Environmental Protection Agency (EPA) to estimate households' direct CO_2 emissions, finding that they account for 23% of total U.S. domestic CO_2 emissions, with the remaining share attributed to the corporate sector.[7]

BEA sectors and types of capital. We consider the limit case as $\sigma \to \infty$. Our specification implies that γ_i corresponds to the share of value added plus fuel expenditures in total sales; η_i^F to the fuel share in total spending on equipment and fuel; ϕ_i^ℓ and ϕ_i^o to the labor share and type-o capital share in the sum of value added and fuel expenditures, respectively; ϕ_i^K to the share of equipment and fuel spending in the sum of value added and fuel expenditures; α_{ij} to the share of input j in total non-fuel intermediates; and $\eta_i^{F,j}$ to the share of fuel type j in firm i's total fuel use.

Input-output data are from the most disaggregated BEA's Use Table (Supply-Use Framework) for the year 2017. We start with the 402-industry classification and remove the financial sector (BEA codes: 52A000-525000), the "Customs Duties" sector (BEA code: 4200ID), the "Owner-occupied housing" and "Tenant-occupied housing" sectors (BEA codes: 531HSO and 531HST). We end up with $N = 375$ non-fuel sectors and 3 fuel sectors: "Coal mining" (BEA code: 212100), "Petroleum refineries" (BEA code: 324110) and "Natural gas distribution" (BEA code: 221200). For each sector, we obtain data on value added and its composition. The intermediates network is constructed directly from the BEA's Use Table, excluding the sectors specified above.

We consider two types of capital: (i) equipment and (ii) a composite capital good that combines the remaining part of tangible capital, R&D, other IP, and goodwill. We link Compustat NAICS codes to BEA sector codes[8] and obtain sector-level data on equipment and composite capital by averaging values across Compustat firms in our 2017 sample. Compustat does not report net equipment, only gross equipment (Compustat item: *fate*). To construct net equipment holdings, we scale net tangible capital (Compustat item: *ppent*) by the share of gross equipment to gross tangible capital (Compustat item: *ppegt*). For the R&D capital stock, we use "knowledge capital"—firms' capitalized R&D expenditures—from Peters and Taylor (2017b); the remaining part of tangible

[6]We measure consumption-price inflation using the BEA Personal Consumption Expenditures chain-type price index (U.S. Bureau of Economic Analysis, 2026).

[7]This estimate is based on data from the U.S. Greenhouse Gas Emissions and Sinks report of 2017, calculating households' emissions as the sum of residential CO_2 emissions and the portion of transportation CO_2 emissions from passenger cars and light-duty trucks.

[8]Industry codes are harmonized across data sources using standard concordances (U.S. Census Bureau, 2024; Iovino et al., 2026).

capital is constructed by multiplying net tangible capital by the non-equipment share of gross tangible capital; other IP corresponds to Compustat item *intano*; goodwill equals Compustat item *gdwl*.

For the capital networks, we closely follow vom Lehn and Winberry (2021)'s approach, extending it to accommodate the much larger number of sectors in our calibration. We use sector-level data on 38 different types of assets: 25 different types of equipment, 9 types of non-residential structures, and 4 types of intellectual property assets. Since investment data by asset type are available only for a less granular industry classification (66 non-financial sectors), we distribute investment across our finer classification based on each industry's value added. Finally, vom Lehn and Winberry (2021) creates three separate networks for equipment, structures, and intangibles, which are then combined into a single investment network. In contrast, we keep the equipment network distinct, and aggregate the networks for structures and intangibles into a single network.

Depreciation and amortization. To calibrate depreciation and amortization rates, we follow Barro and Furman (2018), and use 0.088 for equipment, 0.020 for the other tangible capital, 0.122 for R&D, and 0.196 for other IP. Estimating goodwill amortization is challenging. Since 2001, U.S. GAAP has classified goodwill as an indefinite-lived asset, meaning it is generally not amortized over time. Instead, publicly listed companies are required to conduct an annual impairment test to check if the asset's fair value has dropped below its recorded amount. Prior to 2001, however, goodwill could be amortized over a period of up to 40 years. We use this period as an estimate of goodwill's economic life, and approximate the 40-year linear amortization schedule with an exponential decay model, yielding an amortization rate of 0.047, which corresponds to a half-life of approximately 15 years.

Tax deductions. The U.S. tax code outlines specific depreciation and amortization schedules for tax deductions. It generally uses the Modified Accelerated Cost Recovery System (MACRS) for depreciable assets. Under MACRS, equipment typically falls into 5-year or 7-year property classes and uses a double-declining balance method. The tax code prescribes a 39-year straight-line depreciation for non-residential real property (commercial buildings) and a 27.5-year straight-line schedule for residential rental property; other types of structures follow shorter straight-line schedules. Starting in 2022, R&D costs are no longer immediately deductible but must be amortized through a 5-year straight-line schedule. Finally, for other IP, the tax code provides different amortization schedules based on the specific asset type.

We thus follow Barro and Furman (2018) and assume: *(i)* for equipment, an average of two double-declining schedules (5-year and 7-year); *(ii)* for structures, an average of three straight-line schedules (20-year, 27.5-year, and 39-year); *(iii)* for R&D, a 5-year straight-line schedule; and *(iv)* for other IP, a 5-year double-declining schedule. Finally, not all goodwill generates tax deductions, as this depends on the specifics of the originating transaction. In the absence of a better alternative, we assume a 40-year straight-line schedule for goodwill, aligning its tax life with its economic life.

For equipment, we incorporate bonus depreciation as follows. Given a tax depreciation schedule for equipment $\{D^e_t\}$, $t = 0, ..., T$, we first compute the PDV of depreciation allowances without bonus depreciation, which we denote with $z^e_{0,i}$:

$$z^e_{0,i} = \sum_{t=0}^{T} \frac{D^e_t}{(1 + r^e_i)^t},$$

where r^e_i is the required return on equity for sector i. The cross-sectional average of $z^e_{0,i}$ is 0.83, consistent with its analogue in Zwick and Mahon (2017b). Then we let $z^e_i = b + (1 - b)z^e_{0,i}$, where $b \in [0, 1]$ is bonus depreciation. In the baseline analysis (Tables 7 and 8), we assume a constant bonus depreciation of 50% ($b = 0.5$). In the Supplemental Appendix (Tables A.12 and A.13), we let bonus depreciation increase from 50% to 100%.

For the composite capital good, we first compute the PDV of depreciation allowances for each component, then take a weighted average using the shares of other tangible capital, R&D, other IP, and goodwill, calculated across all firms in our sample in 2017 (23% for other tangible capital, 19% for R&D, 20% for other IP, and 38% for goodwill). For this capital type, there is no bonus depreciation, therefore, $z^o_i = z^o_{0,i}$. The cross-sectional average of z^o_i is 0.56.

Corporate income taxes. We compute firms' corporate income taxes starting from gross income, defined as revenues minus expenditures on intermediate inputs and labor, and then subtract applicable deductions. First, we subtract the tax shield, which equals $r^b_i b_i$—except in the counterfactual scenario where the tax shield is removed. Next, we subtract tax deductions D^s_t (including bonus depreciation when applicable) as defined above. Since economic and tax lives may differ, we must account for different vintages of capital. In steady state, firms in sector i invest $I^s_i = \delta^s k^s_i$, $s = e, o$, each period. It follows that, each period, a firm can deduct $\delta^s \sum_{t=0}^{T} D^s_t = \delta^s$ for type-s capital.

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