The Environmental Bias of Corporate Income Taxation[†]

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Abstract

We study the relationship between corporate taxation and carbon dioxide (CO_2) emissions in the U.S. We show that CO_2-intensive firms benefit more from the tax advantage of debt, and pay lower taxes on their capital income. Building on these new facts, we provide causal evidence that tax cuts lead to a larger expansion of clean firms. We develop a multi-sector general equilibrium model that accounts for our evidence and quantify the impact of tax reforms on aggregate emissions. A policy that eliminates the tax advantage of debt could significantly reduce aggregate emissions without affecting GDP.

Keywords: Corporate Taxes, CO_2 Emissions, Leverage, Tangible Capital.
JEL Codes: H32, Q58.

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1 Introduction

The corporate income tax is a major source of revenue for the U.S. government,[1] yet its effects on the economy are fiercely debated. Those against it emphasize its adverse impact on investment. Tax cuts on corporate income, they argue, boost economic growth. Advocates of corporate income tax, on the other hand, observe that tax rates on large businesses have effectively decreased in the last decades as a byproduct of globalization and international profit shifting, contributing to rising wealth inequality since business ownership is concentrated among the wealthiest individuals. Furthermore, deductions available in the tax code—for instance, firms can deduct interest payments on corporate debt—create heterogeneity in the tax base, leading to a multitude of effective tax rates that generate distortions and resource misallocation.

There is a large literature, both empirical and theoretical, on the effects of corporate taxation on firms' decisions, and on its incidence on shareholders, workers, business reallocation, and prices. We know little, however, about the impact of corporate taxation on the environment. Do dirty firms face a bigger or smaller tax burden relative to clean firms? And what are the consequences of tax reforms for the environment? To the best of our knowledge, we are the first study to address these questions.

[INSERT FIGURE 1]

We uncover a new fact, which is summarized in Figure 1. In the cross-section of firms in our sample, there is a strong and negative relationship between CO_2 intensity, defined as tons of CO_2 emissions per USD 1,000 of output, and effective tax rates, measured as corporate income taxes paid over gross capital income. This correlation suggests that the U.S. corporate tax code contains an implicit *subsidy* on pollution. The main contribution of this paper is to document this new finding, to investigate its determinants, and to quantify the implications of corporate tax reforms for the environment.

Our empirical analysis uses data on CO_2 emissions available for U.S. publicly listed firms from 2003, and link it to accounting data from Standard & Poor's Compustat. We first document that the negative relationship between CO_2 and effective tax rates presented in Figure 1 is driven by tax deductions for interest expenses, commonly referred to as the tax advantage or "tax shield" of debt. Effectively, CO_2-intensive ("dirty") firms have a smaller share of their gross capital income subject to the corporate income tax. We then shed light on the mechanism which lead dirty firms to benefit more from the tax shield of debt. We show that dirty firms sustain higher debt levels as they hold significantly more tangible capital than clean firms. Dirty firms, such as those operating in sectors like manufacturing and energy, tend to rely heavily on tangible capital—such as machinery and equipment—to operate. This high level of tangible capital provides collateral, making it easier for them to borrow. In fact, once we control for differences in tangible capital, both the positive

[1] In 2023, the U.S. federal government collected USD 475 billion in corporate income taxes, which represents about 10% of total federal revenue (source: Congressional Budget Office).

correlation between CO_2 intensity and leverage, and the positive correlation between CO_2 intensity and effective tax rates vanish.

We conduct a battery of tests to verify the robustness of our cross-sectional findings. We find that our results are not driven by any single sector. They are also robust to how we measure firms' CO_2 emissions, to scaling income taxes by either sales or assets (rather than capital income), and to using the logarithm of CO_2 emissions as the main variable of interest. Finally, we show that, while most of the effect stems from differences across industries, the relationships between CO_2 intensity, tangible capital, leverage and taxes hold also within industries, including the energy sector.

In the next step, we exploit the large cut from 35% to 21% in the statutory U.S. federal corporate income tax introduced by the Tax Cuts and Jobs Act (hereafter TCJA) enacted in December 2017 to obtain causal evidence on the heterogeneous impact of corporate income taxation on dirty versus clean firms. Building on the cross-sectional evidence presented above, we hypothesize that clean firms should benefit more from tax cuts, due to the larger proportion of their gross income subject to taxation. Our difference-in-differences estimation confirms this hypothesis: CO_2-intensive firms experienced a smaller reduction in the ratio of federal income taxes to capital income relative to clean firms. Quantitatively, we estimate a relative increase in effective tax rates of 2.4 percentage points for the top quartile of CO_2-intensive firms compared to clean firms post-reform. This relative increase in effective tax rates had significant effects on asset growth, with the top quartile of CO_2-intensive firms experiencing approximately 11% lower asset growth post-reform compared to clean firms. These estimates translate into a semi-elasticity of firm total assets to a one percentage point increase in the effective tax rate of approximately -4.8, in line with prior work. We assess the robustness of our results by replacing the dummy for CO_2-intensive firms with a continuous measure, and obtain consistent results. These findings indicate that tax cuts lead to a larger expansion of clean firms.

One threat to our empirical design is that other policies or time-varying economic shocks may coincide with the federal tax cut. To mitigate this concern, we conduct a series of robustness tests. First, event study graphs show parallel trends in the years prior to the reform. Second, a placebo test reveals no differential effect on non-federal income taxes between clean and dirty firms. Third, we directly test for the potential confounding effects of contemporaneous policy or economic shocks by controlling for exposure to other relevant changes in business taxation, regional carbon taxes, and import tariffs introduced during the sample period. Finally, we address any residual concerns that time-varying industry shocks might drive our results in leave-one-industry-out specifications, and in a triple difference regression including both U.S. and foreign firms. Our estimates remain consistent, both qualitatively and quantitatively, across all robustness checks.

[INSERT FIGURE 2]

Figure 2 plots the aggregate CO_2 intensity of the U.S. economy in the years surrounding the

2017 federal corporate tax cut.[2] Between 2017 and 2021, this intensity fell by approximately 10.6%, compared to a global reduction of around 5.5%, and to a decline of 5.9% among a group of countries with pre-reform CO_2 intensity levels similar to that of the U.S. Although the figure is only illustrative, the timing of the decline in aggregate CO_2 intensity alongside the federal corporate tax cut suggests a possible connection. Since clean firms are more responsive to income tax changes, the 2017 federal tax cut may have played a role in the recent reduction in U.S. CO_2 intensity by reallocating production from dirty to clean sectors. We explore this hypothesis using a rich general-equilibrium model, which is consistent with our empirical estimates on the differential impact of the 2017 federal tax cut on effective tax rates and asset growth of clean and dirty firms.

To quantify the impact of alternative tax policies on emissions, we develop a general-equilibrium model where fossil fuel usage generates CO_2 emissions. Consistent with our empirical findings, the model incorporates two key elements. First, firms belong to industries that are heterogeneous in their capital and CO_2 intensity. Second, firms face a financial friction that links capital—particularly equipment—to debt, an assumption supported by several widely-known theories on asymmetric information in credit markets and the role of collateral in alleviating borrowing constraints.

In addition, we allow for a rich input-output network structure. This is essential for our analysis, as it enables us to study CO_2 emissions by linking them to expenditures on fuel-producing sectors. In fact, since capital is a critical component in our framework, it is key to also account for the emissions generated from capital production. Therefore, alongside the traditional intermediates network, we introduce an "investment network" for each type of capital, where firms use the output from other sectors to produce capital goods. We build on the approach of vom Lehn and Winberry (2021), which constructs a single investment network encompassing all types of capital, and extend it in two ways. First, we construct two separate networks—one specifically for equipment and another for all other types of capital. Second, we extend these investment networks to cover a much larger number of sectors.

The model successfully replicates the aforementioned differential response to the 2017 income tax cut—despite not being specifically calibrated to match this outcome. We can then use it to estimate the absolute effect of the reform on aggregate output and emissions—something that, by design, our difference-in-differences approach is unable to capture. In the Cobb-Douglas benchmark, the reform increases total output by 5.9%, while emissions rise more modestly, by 4.5%. The relatively smaller impact on emissions stems from the heterogeneous response across sectors. In line with our empirical results, a corporate income tax cut disproportionately benefits less CO_2-intensive sectors, therefore, the economy with a lower tax rate exhibits a different sectoral composition, with a larger share of clean sectors.

[2] CO_2 intensity is expressed in metric tons of CO_2 equivalent per 1,000 USD of output, expressed in 2017 constant terms. Data is from The Emissions Database for Global Atmospheric Research, see Crippa et al. (2021) for more details.

Our empirical findings identify the tax shield of debt as the primary driver of the tax advantage for CO_2-intensive firms. We thus study a counterfactual scenario in which the tax shield of debt is removed. Since eliminating the tax shield effectively increases taxes on the corporate sector, we counterbalance this change by simultaneously lowering the tax rate to maintain GDP at its initial level. The tax shield disproportionately benefits CO_2-intensive sectors, whose technology relies more heavily on tangible capital—especially equipment. It follows that the combined policy raises the user cost of capital for CO_2-intensive firms, prompting them to scale down production, which in turn lowers emissions. In the Cobb-Douglas benchmark, the policy achieves a fall in total emissions of 1.3%, while GDP remains constant by design. As with the income tax cut, the fall in emissions arises from the shift in production composition toward less CO_2-intensive industries.

Finally, motivated by our empirical evidence linking emissions to firms' equipment holdings, we move away from the Cobb-Douglas benchmark and consider an alternative setting where equipment and fuel are complements in production. In this alternative setting, we reexamine both our counterfactual reforms—the policy lowering the income tax, and the one removing the tax shield while simultaneously reducing the income tax. The model predicts a significantly larger negative impact on emissions under both policy scenarios. To understand this result, remember that both policies increase the relative cost of equipment capital. As a result, firms reduce their reliance on equipment and, when equipment and fuel are complements in production, they also cut back further on fuel use, which is the source of emissions.

Our work has important policy implications. We show that the existing corporate tax code—and even common, seemingly neutral tax reforms like corporate tax cuts—can have significant implications for the environment. In particular, while previous research has explored the distortions for the cost of capital caused by the differential tax treatment of debt and equity (e.g., Stiglitz, 1973; King, 1974), our analysis demonstrates that the tax advantage of debt indirectly subsidizes emissions. In an ideal world with uniform carbon pricing applied to all CO_2 emissions, corporate income taxation would have no role in climate policy. However, in the presence of political constraints that render optimal climate policies unfeasible, integrating environmental considerations into corporate income tax design could improve welfare. We quantify the environmental impact of harmonizing the tax treatment of different financing sources in a general-equilibrium model.[3] We show that corporate tax cuts shift the sectoral composition of output toward clean firms—a point that, to the best of our knowledge, has been largely overlooked in both academic research and policy discussions.

Our work relates to several strands of literature. We first contribute to a large body of empirical work on the environmental consequences of taxation, such as carbon taxes (e.g., Bruvoll and Larsen, 2004; Andersson, 2019; Metcalf and Stock, 2020; Colmer et al., 2024), energy taxes (Parry and Small, 2005) and import tariffs (Shapiro, 2020).[4] We also relate to the literature on the incidence

[3] Our empirical analysis focuses on publicly listed firms, which account for the majority of aggregate CO2 emissions. Our findings are thus most relevant to large firms and could inform policies targeting this segment. Small firms may respond differently to tax reforms, for instance, due to differences in their reliance on borrowing.

[4] Beyond taxation, there is also a growing literature on the effects of environmental regulations on pollution and

of corporate taxation. While earlier studies focused primarily on the effect of corporate taxes on shareholders (Harberger, 1962; Auerbach, 2006, for a review), more recent work has explored the impacts on firm leverage and investment (Faccio and Xu, 2015; Heider and Ljungqvist, 2015; Ivanov et al., 2024), business reallocation (Giroud and Rauh, 2019), workers (Fuest et al., 2018; Suárez Serrato and Zidar, 2016), and consumer prices (Baker et al., 2023). Carrizosa et al. (2023) and Sanati (2022) examine the effects of the limitation on the interest payments' deductibility introduced in 2017 in the U.S. on firm leverage, investment, and employment.[5] Our study is the first to focus on the consequences of corporate taxation for firms' CO_2 emissions. Our empirical analysis of the causal impact of the 2017 federal tax cut on clean and dirty firms adds to a growing body of research on the TCJA and its effects on U.S. corporations, especially regarding their investment responses (Auerbach, 2018; Barro and Furman, 2018; Chodorow-Reich et al., 2024b,a; Garcia-Bernardo et al., 2024; Kennedy et al., 2024; Albertus et al., 2024). Compared to these studies, we show that tax cuts cause a stronger expansion of clean firms, effectively lowering aggregate CO_2 intensity.

Our paper also adds to the recent literature on the welfare consequences of corporate taxation (Chetty and Saez, 2010; Dávila and Hébert, 2023). In that vein, our contribution is to quantify the environmental consequences of different corporate taxation reforms. For this, we combine insights from the theoretical literature on environmental economics (Bovenberg and Goulder, 1996; Acemoglu et al., 2012; Golosov et al., 2014) with the production network literature (Liu, 2019; Baqaee and Farhi, 2019; Bigio and La'O, 2020). King et al. (2019); Baylis et al. (2013, 2014) study the implications of carbon pricing in multi-sector economies. King et al. (2019) show that raising carbon taxes on central sectors allows to obtain larger reductions in aggregate CO_2 emissions. We show that a policy reform that eliminates the tax deductibility of interest payments and simultaneously lowers the tax rate could significantly reduce emissions without affecting GDP.

We also relate to a fast growing literature in climate finance. Giglio et al. (2021) provide a review of the literature exploring the pricing of climate risks for different asset classes. Piazzesi et al. (2022) document that the recent bond purchases by the European Central Bank (ECB) have implicitly favored firms with higher CO_2 emissions. The reason is that the ECB aims to be market neutral, that is, it purchases bonds in proportion to the outstanding market value. Firms in high-emissions sectors, however, issue more bonds due to their larger holdings of tangible capital. Oehmke and Opp (2022) study theoretically the effects of differential capital requirements for loans to clean and dirty firms. Compared to these papers, we document that corporate income taxes are distorted in favor of dirty firms, and that the distortion stems from the tax advantage of corporate debt.

The remainder of this paper is organized as follows. Section 2 briefly reviews the background

firms' economic activity, see among others Greenstone (2002); Shapiro and Walker (2018); Chen et al. (2024).

[5]See also House and Shapiro (2008); Yagan (2015); Ohrn (2018); Maffini et al. (2019); Liu and Mao (2019); Zwick and Mahon (2017); Moon (2022) for recent empirical work estimating the effects of other types of taxes (such as dividend tax) or tax incentives (such as bonus depreciation).

on corporate taxation and debt tax shield. Section 3 describes the data and presents the empirical results for the relationship between CO_2 intensity and effective tax rates in the cross-section of U.S. firms. Section 4 presents the estimates for the causal impact of the 2017 federal tax cut on the effective tax rates and asset growth of dirty and clean firms. Section 5 presents our general-equilibrium model and studies the consequences of counterfactual reforms. Section 6 contains the conclusion.

2 Background on Corporate Taxation and Debt Tax Shield

Corporate taxation. Firms incorporated under subchapter C of the federal tax code (C corporations) are required to pay corporate income taxes on their taxable income.[6] Taxable income is obtained after deducting a series of tax expenditures allowed by the federal tax code—such as intermediate inputs, labor compensation, capital depreciation and interest payments—from firm revenues. The federal corporate income tax rate has experienced a large cut from 35% to 21%, effective from the fiscal year 2018. Firms are also required to pay corporate income taxes in every state in which they have economic activity.[7] Firms with activities abroad are also subject to income taxes in foreign countries.

Firms also pay a variety of other taxes including social security and payroll taxes, property taxes, environmental taxes, or import tariffs.[8] Corporations may also benefit from tax incentives aimed at certain geographical areas or industries. Our main focus is on the implications of the corporate income tax for the environment, however, we take into account the potential impact of other relevant taxes paid by corporations in our analysis.

Debt tax shield and effective tax rates for clean and dirty firms. The corporate income tax lowers the return on capital and, as a result, depresses investment. Even though two firms in the same location typically face similar statutory tax rates, a series of tax deductions can lead to different *effective* tax rates, depending, for instance, on the type of assets they acquire and the way they finance their activities.

[6] Firms incorporated under subchapter S of the federal tax code, as well as unincorporated firms organized as partnerships and sole proprietorships do not pay taxes at the firm level, but instead pass all profits to their owners. Firms included in our sample are all C corporations.

[7] As for the federal code, most states tax firms on their income at the state-level corporate tax rate, applied to the state's apportioned share of taxable income. A few states—Nevada, Ohio, Texas, and Washington as of 2021—levy instead a gross receipts tax based upon firms' revenues rather than income. States have to determine how much activity of each firm occurred in their jurisdiction, and for this use a weighted average of payroll, property, and sales activity, referred to as apportionment weights. State taxes are deductible expenses for federal income tax purposes. As of 2021, state corporate income tax rates are on average 4.5%.

[8] In 2019, the federal government collected USD 257 billion in corporate income taxes from C corporations, against USD 464 billion in "other taxes and licenses", which are deductible from the computation of the federal income tax. These other taxes include ordinary state and local taxes paid or accrued, social security and payroll taxes, unemployment insurance taxes, excise taxes, import and tariff duties, business, license, and privilege taxes, as well as income taxes paid to foreign countries or U.S. possessions, provided these were not claimed as credits against federal income tax. See Table 2.3 of the IRS 2019 Income Tax Returns Complete Report for more details.

As we investigate in more detail below, one feature of the federal tax code that is especially pertinent to CO_2 emissions is the fact that C corporations are allowed to deduct interest payments from their gross income.[9] Instead, dividends paid to shareholders are not deductible. Since certain types of capital are better suited for debt financing, preferential tax treatment for debt favors these types of capital over others. In particular, tangible capital, such as machinery and equipment, can sustain higher debt, leading to a lower after-tax cost of capital compared to intangible capital. Since CO_2-intensive industries, like manufacturing and energy production, rely heavily on tangible capital like machinery and equipment, they benefit more from the tax deductibility of interest payments, which reduces their tax burden compared to cleaner industries. More broadly, tax policies that affect the user cost of capital differently for clean and dirty firms can influence overall emissions.[10]

Previous work indicates that the tax shield of debt represents a large subsidy to debt financing. Graham (2000); Kemsley and Nissim (2002); Van Binsbergen et al. (2010) calculate the value of the tax benefits associated to debt financing for the U.S. using different approaches, and find it to be about 10% of firm value. Despite its widespread use and economic significance, the rationale behind the introduction of a tax advantage for corporate debt remains unclear. De Mooij (2012) notes that the original rationale is that interest payments are typically perceived as a cost of doing business, whereas equity returns are viewed as business income. These accounting principles are then reflected in the tax code, which allows interest payments to be deductible for the corporate income tax as a cost, unlike dividends. From an economic perspective, both interest and equity payments represent income for capital owners, thus, it is not clear why debt should receive a subsidy. If anything, to the extent that debt financing is associated with negative externalities (Lorenzoni, 2008), most existing theories suggest that the return on debt should be taxed at a higher rate than the return on equity. In addition, the debt tax shield can encourage debt shifting within multinationals (Huizinga et al., 2008). In fact, several policy proposals advocate an elimination of the tax advantage of debt (see, e.g., CBO (1997) and IMF (2016)). From a policy point of view, our paper documents the negative implications of the tax advantage of debt for the environment.

[9] In 2019, C corporations claimed aggregate deductions of USD 1,024 billion for interest paid, against USD 1,732 billion in corporate income subject to income tax. For more details, see the IRS 2019 Income Tax Returns Complete Report. Some countries, including the U.S., introduced measures that put a cap on interest deductibility, often called "thin capitalization rules" or "income stripping rules". See https://www.oecd.org/tax/beps/corporate-tax-statistics-database.htm for data on interest limitation rules across countries.

[10] Policies other than the debt tax shield, such as accelerated depreciation rules for certain types of eligible capital, may also affect clean and dirty firms differentially, and ultimately CO_2 emissions. While not the primary focus of our paper, we consider the impact of bonus depreciation for eligible equipment in our analysis (see also Metcalf (2018) for specific corporate tax deductions in the oil and gas sector).

3 Empirical Evidence

3.1 Data

Our empirical analysis relies on two main data sources: firms' financial information from Compustat Northamerica and firms' CO_2 emissions from Trucost.

Firm-level financial information. We obtain balance sheet and income statement data for all firms headquartered in the U.S. from Compustat Northamerica Fundamentals Annual for the years 2003-2021. We retrieve information on firms' taxes paid on their income (Compustat item TXPD), pretax accounting income (Compustat item PI, net of special items SI), interest payments (Compustat item XINT), debt (the sum of short-term and long-term debt, Compustat items DLC+DLTT), and property, plant, and equipment (Compustat item PPENT). We measure (gross) capital income as sales (Compustat item SALE) minus cost of goods sold (Compustat item COGS) minus selling, general, and administrative expenses (Compustat item XSGA), as in De Loecker et al. (2020). We add back research and development (R&D) expenses (Compustat item XRD) because, consistent with the model presented below, we treat R&D as an investment (in intangible capital) rather than as an expense. We measure firm age as the difference between the current year and the year founded, using information from Jay Ritter's website. If the year founded is missing, the first year in Compustat is taken instead. We compute the share of foreign profits as the ratio of foreign pretax income (Compustat item PIFO) over total pretax income. In our regressions, we also control for the statutory tax rate that each firm faces based on the location of its operations, the construction of which is detailed in Online Appendix B.

In what follows, our measure of effective tax rate is the ratio of income taxes paid to (gross) capital income. The U.S. tax code allows firms to deduct several items from their capital income. We decompose the observed differences in the tax-to-capital income ratio into two parts: the pretax income-to-capital income ratio—the accounting taxable portion of gross capital income—and the tax-to-pretax income ratio, which represents the tax rate on pretax accounting income.[11] In our baseline analysis, we exclude firm-years with negative gross capital income or pretax income because tax rates are difficult to interpret when the denominator is negative. We winsorize all tax rates at zero and one, following, among others, Dyreng et al. (2017).

Firm-level CO_2 emissions. We merge the accounting data to Trucost's firm-level direct (scope 1) greenhouse gas (GHG) emissions—measured in CO_2 equivalent and referred to throughout the paper simply as "CO_2 emissions". Trucost is the data provider with the broadest coverage for firm-level direct CO_2 emissions (Busch et al., 2018).[12] Trucost follows the GHG Protocol, which sets

[11] Differences across firms in the tax-to-pretax income ratio capture various forms of tax reduction achieved through location decisions, income shifting, and other tax planning strategies. For a detailed discussion on the distinctions between pretax accounting income and taxable income reported to the Internal Revenue Service (IRS), see, e.g., Graham et al. (2012).

[12] Coverage in Trucost has expanded over time. By 2017—the reference year for the analysis of the effects of the federal tax cut presented in Section 4—CO_2 emissions data was available for around 60% of publicly listed U.S. firms,

the standards for measuring corporate emissions, and collects data from various sources, including company financial reports, environmental data sources, and publicly available information from company websites or other platforms. As part of this process, Trucost standardizes reported data and addresses reporting errors. If a firm does not disclose emissions, Trucost provides estimated values. Reassuringly, CO_2 emissions for U.S. firms in Trucost are highly correlated with CO_2 emissions from stationary sources reported to the Environmental Protection Agency's (EPA) GHG Reporting Program since 2010, when scaled by firm sales in both datasets (slope 0.94, standard error clustered by firm 0.05).[13] We use Trucost as our baseline data source as the scope of the EPA emissions data is narrower (covering only stationary sources located in the U.S. and emitting more than 25,000 metric tons of CO_2). That said, we show below that our baseline findings are robust to using EPA emissions data instead of Trucost.

Our main variable of interest is CO_2 intensity, expressed in metric tons of CO_2 equivalent per USD 1,000 of output (tCO_2/k\$). Due to differing reporting standards for financial institutions, we exclude financial firms (2-digit SIC codes 60 to 69).

Descriptive statistics. Table 1 shows summary statistics for our sample, which consists of 11,223 Compustat firm-year observations between 2003 and 2021 with positive pretax and gross capital income, for which we observe both CO_2 emissions and financial information. The average firm in our sample emits 0.1 tCO_2/k\$. The distribution of CO_2 intensity across firms is skewed, with a median of 0.02 tCO_2/k\$ and a 99th percentile of 1.5 tCO_2/k\$.

When we compute the tax rate on firms' pre-tax accounting income, we find an average of around 23%, consistent with prior work (see, e.g., Dyreng et al., 2017). In contrast, the effective tax rate on firms' capital income averages around 12%. This difference reflects the fact that the U.S. tax code allows firms to deduct several expenditures, including interest payments.

Finally, the average firm in our sample is large, with sales of around USD 11 billion. The average firm is 43 years old, has a profit margin of around 24%, a share of foreign profits over total profits of around 38%, and faces a statutory tax rate of around 32%. For the average firm, debt represents about 28% of total assets, while property, plant, and equipment account for 23%.

[INSERT TABLE 1]

3.2 Cross-sectional Results on CO_2 Emissions and Corporate Taxes

We now turn to the relationship between CO_2 intensity and corporate income taxes, and estimate the following OLS regression at the firm-year level from 2003 to 2021:

$$Y_{f,t} = \beta \times CO_2\ Intensity_{f,t} + \gamma_t + X_{f,t} + \epsilon_{f,t}, \tag{1}$$

representing 96% of the total market capitalization of U.S. firms in Compustat. In 2017, the aggregate emissions in Trucost for U.S.-based Compustat firms amounted to around 2,200 million metric tons of CO_2 equivalent, accounting for roughly 50% of total emissions produced by the private sector in the United States.

[13]The EPA provides a mapping of facilities to U.S. parent companies which we use to aggregate facility-level emissions up to the parent firm.

where $Y_{f,t}$ is the effective tax rate for firm f in year t, and γ_t are year fixed effects. In some specifications, we also include a vector of baseline controls $X_{f,t}$ for firm size, age, profitability, foreign profit share, and statutory rate. We cluster standard errors at the firm level. Let us emphasize that we do *not* interpret the estimated coefficient $\hat{\beta}$ in equation (1) as the causal impact of CO_2 emissions on effective tax rates. Instead, we interpret equation (1) as a descriptive regression that estimates the relationship between CO_2 intensity and the tax-to-capital income ratio across U.S. firms. In the following section, we investigate why CO_2-intensive firms pay lower income taxes. We show that the negative relationship between CO_2 intensity and income taxes is largely explained by differences in tax deductions for interest payments and, ultimately, by differences in tangible capital across clean and dirty firms. The results of this cross-sectional analysis highlight the mechanisms through which tax cuts disproportionately affect clean and dirty firms, and ultimately influence aggregate CO_2 emissions—a topic we examine in detail in Sections 4 and 5.

[INSERT TABLE 2]

Table 2 presents the results for the relationship between CO_2 intensity and effective tax rates. Columns (1) and (2) report the results of estimating equation (1) with income taxes over capital income as dependent variable, respectively, without and with controls for firm size, age, profitability, foreign profit share, and statutory rates. The point estimate for β is virtually the same in both specifications (respectively, -0.021 and -0.022), and statistically significant at the 1% level. The estimates are economically significant: a one-standard-deviation increase in CO_2 intensity is associated with a decrease in the tax-to-capital income ratio equal to approximately 9% of its standard deviation. We then decompose the tax-to-capital income ratio into two parts: the tax-to-pretax income ratio and the pretax income-to-capital income ratio. Columns (3)-(6) show the results of estimating equation (1) separately for each component. The estimated coefficient on CO_2 intensity for the tax-to-pretax income ratio is small and not statistically significant in columns (3) and (4), whereas the estimated coefficient for the pretax income-to-capital income ratio is both economically and statistically significant in columns (5) and (6). This indicates that the negative relationship between CO_2 intensity and effective tax rates presented in columns (1) and (2) is explained by a lower taxable portion of gross capital income for dirty firms.

3.3 Robustness

In the next subsection, we conduct a series of empirical checks to test the robustness of our baseline findings, the negative correlation between CO_2 intensity and effective tax rates in the cross-section of firms.

Measurement of CO_2 emissions. One concern is that the estimates may be biased due to the way CO_2 emissions are reported by firms. While there is no obvious reason why this should be the case, we address this concern by running our baseline specifications excluding firms that self-report their emissions and focusing on firms for which CO_2 emissions are estimated by Trucost. As shown in column (1) of Online Appendix Table A.1, the coefficient on CO_2 intensity is, if anything, slightly larger. As an additional test, we use CO_2 emissions of stationary sources reported to the EPA's Greenhouse Gas Reporting Program since 2010. As shown in column (2), we find, if anything, a slightly stronger negative relationship between CO_2 intensity and effective tax rates, further mitigating concerns that mismeasurement of CO_2 emissions in Trucost biases our results. Relatedly, we test whether our baseline result holds when broader measures of firms' CO_2 emissions are considered, including indirect emissions from consumption of purchased electricity, heat, or steam (scope 2), and other indirect emissions from the production of purchased materials, product use, waste disposal, and outsourced activities (scope 3). As shown in columns (3) and (4), our baseline coefficients are similar when we consider the sum of scope 1 and scope 2 emissions or the sum of scope 1, scope 2, and scope 3 emissions.[14]

Broader sample. In columns (5) and (6), we scale taxes paid by sales and assets, respectively, instead of capital income, and re-estimate the relationship with CO_2 intensity. This allows us to check whether the negative relationship between CO_2 emissions and corporate taxes still holds when we include firms with negative profits in the sample. The coefficient remains negative and statistically significant at the 1% confidence level.[15]

Log(CO_2 emissions). We then use the log of CO_2 emissions as alternative independent variable to address the concern that the distribution of CO_2 intensity across firms is right-skewed. As shown in column (7), the coefficient remains negative and statistically significant at the 1% confidence level.

Leave-one-industry-out specifications. Finally, we examine whether the link between CO_2 emissions and corporate taxes is driven by any particular sector. Online Appendix Figure A.1 shows estimates of effective tax rates on CO_2 intensity, excluding one industry at a time. The results remain similar in each regression, indicating that the negative relationship between CO_2 intensity and effective tax rates is not tied to a specific sector.

3.4 The Mechanism

In this section, we shed light on the mechanism which leads dirty firms to pay lower taxes. We conjecture and verify that generation of CO_2 emissions involves tangible capital. All else equal, firms with substantial emissions own more tangible capital, enabling them to sustain higher levels of debt and, thus, save on taxes by taking advantage of the tax treatment of debt.

[14] We use scope 1 emission data in our baseline specifications since it is the most consistent across data providers (Busch et al., 2018); moreover, this is the appropriate measure to use for model calibration, as the model explicitly accounts for linkages across industries through its rich network structure.

[15] Given that both taxes paid and CO_2 are scaled by sales in column (5), one can interpret the estimated coefficient as an implicit carbon subsidy implied by corporate taxation, expressed in dollars per tons of CO_2. We obtain a subsidy in corporate taxation of around $5/ton, which is of a similar magnitude to the estimated carbon subsidy in U.S. import tariffs in Shapiro (2020).

Firms' CO_2 emissions and debt tax shield. Since the U.S. tax code allows firms to deduct interest payments from their gross income, differences in taxes paid by clean versus dirty firms might stem from differences in the structure of their liabilities. We thus estimate the relationship between CO_2 intensity and firms' debt and interest payments. In Panel A of Online Appendix Figure A.2, we first show that there is a strong positive relationship between the logarithm of firms' CO_2 intensity and firms' debt-to-asset ratios.

[INSERT TABLE 3]

In columns (1)-(4) of Table 3, we then show that dirty firms benefit from a larger tax shield of debt. The point estimate for β is close to identical in the specifications without and with controls for other firm characteristics: 0.74 for the relationship between CO_2 intensity and debt-to-capital income ratio, and 0.06 for the relationship between CO_2 intensity and interest payments over capital income—all statistically significant at the 1% level. Note that the estimates in columns (3)-(4) on interest payments over capital income have the opposite sign and virtually the same magnitude as the coefficients in columns (5)-(6) of Table 2. This indicates that the negative relationship between taxes and emissions is explained by a higher tax shield of debt for dirty firms. We confirm this result in columns (5)-(6) of Table 3, where we regress firms' hypothetical pretax income assuming they were entirely equity financed—calculated by adding back interest expenses to their pretax income—on their CO_2 intensity. The estimated coefficient is small and not statistically significant, corroborating that there is no robust residual relationship between taxes and CO_2 emissions beyond the link between the debt tax shield and CO_2 emissions uncovered in columns (1)-(4). We conclude, therefore, that the tax advantage of CO_2-intensive firms arises from their higher levels of debt. We are left with the question of what explains this higher debt.

[INSERT TABLE 4]

Firms' CO_2 emissions and tangible capital. We conjecture that differences in debt levels across firms with different CO_2 intensity may be driven by differences in tangible capital. As shown in Panel B of Online Appendix Figure A.2, there is a strong positive relationship between the logarithm of firms' CO_2 intensity and the ratio of property, plant, and equipment (PPE) over total assets.

We confirm this positive relationship in column (1) of Table 4, where we scale PPE by capital income. We then test directly whether this variable alone can explain the relationship between CO_2 intensity, debt, and corporate taxes documented in the previous sections.[16] In particular, we

[16] Other provisions in the corporate tax code allowing firms with more tangible capital to pay lower taxes could, in principle, function as an indirect subsidy for emissions—exactly like the tax shield of debt. While a full account of all the provisions in the corporate tax code is beyond the scope of this paper (and to a large extent practically unfeasible given the complexity of corporate taxation), we discuss in Online Appendix C two other quantitatively important features of U.S. corporate taxation that lead to differential tax burdens based on the nature of firms' capital: accelerated depreciation and property taxes.

run the same specifications presented in column (2) of Table 3, and columns (6) and (2) of Table 2, including the ratio of PPE to capital income as an additional control. Strikingly, the coefficient on CO_2 intensity becomes small and statistically insignificant once PPE over capital income is included as an additional control, in the specifications with either debt, pretax income, or taxes paid as dependent variable. At the same time, the coefficient on PPE over capital income is positive in column (2) and negative in columns (3) and (4)—all statistically significant at the 1% level.

[INSERT TABLE 5]

Next, we ask which type of tangible capital drives the relationship between PPE and CO_2 intensity. For this, we rely on Compustat data, which provides a breakdown of PPE (before substracting accumulated depreciation) into its components, namely machinery and equipment, buildings, leases, land and improvements, construction in progress, natural resources, and other. Although this decomposition is not available for utilities and some firms in other industries, it is observed for around 70% of firms in our sample. We present the relationship between CO_2 intensity and each PPE component in Table 5. In column (1), we verify that the correlation between total PPE and CO_2 intensity remains strongly significant within the subsample of firms reporting information on the different PPE items. In columns (2)-(7), we find that the relationship between PPE and CO_2 intensity is almost fully explained by the relationship between Machinery/Equipment and CO_2 intensity.

To provide a comprehensive view of the link between CO_2 intensity and firms' asset structure, we study the relationship between CO_2 intensity and the different components of intangible capital in Online Appendix Table A.2. We follow Peters and Taylor (2017) and define intangible capital as the sum of a firm's externally purchased intangible capital (Compustat item INTAN) and its internally created intangible capital, which comprises knowledge capital and organizational capital.[17] We find a strong, negative, and statistically significant relationship between CO_2 intensity and each intangible capital item.

3.5 Between Versus Within Industry Effects

A natural question is whether the relationship between CO_2 intensity and tangible capital, debt, and effective tax rates, is driven by variation across or within industries. To shed light on this question, we decompose firms' CO_2 intensity into an industry and a firm-specific component. A challenge in this exercise is that large firms often operate in multiple industries. To overcome this, we use information on firms' sales across industries from Compustat Segments data. We first compute the average CO_2 intensity for each SIC 4-digit industry and year using data from pure-play

[17] Peters and Taylor (2017) measure knowledge and organization capital by accumulating respectively R&D expenses, and a fraction of past selling, general, and administrative spending, using the perpetual inventory method. The measures of intangible capital from Peters and Taylor (2017) can be downloaded directly from Wharton Research Data Services (WRDS).

firms that operate in only one industry. Next, we calculate each firm's sales-weighted CO_2 intensity across the industries reported in the segments data, *Implied Industry CO_2 Intensity*.[18] Finally, we regress the actual firm-level CO_2 intensity on the CO_2 intensity implied by the segment data and predict the residuals, *Firm Residual CO_2 Intensity*.

Online Appendix Table A.4 shows that higher implied industry and firm residual CO_2 intensities are both significantly associated with higher tangible capital and leverage, resulting in a lower taxable fraction of gross capital income and lower taxes paid, all at the 1% significance level. This indicates that the effect operates both across and within industries. However, considering the magnitude of the coefficients, the largest part of the overall effect appears to stem from differences across industries. Therefore, our model features heterogeneity in CO_2 intensity across industries and, for the sake of simplicity, abstracts from within-industry variation.

One potential concern is that clean energy production could also be capital intensive. If dirty energy producers rely less on tangible capital than clean energy producers, our model would overlook an important force in our model pushing in the opposite direction. To address this concern, we rerun our tests within the subsample of energy producers. We combine CO_2 emission data from stationary sources reported to the EPA with energy generator data submitted to the Energy Information Association (EIA) under Form 860, covering all generators at power plants with a combined nameplate capacity of 1 megawatt or more. We then aggregate CO_2 emissions and nameplate capacity of fossil fuel generators (those using coal, petroleum, or natural gas as main energy source) to the firms owning these power plants and restrict the sample to firms operating at least one energy generator in a given year. We present the results in Online Appendix Table A.5. Column (1) shows that firms with greater fossil fuel production capacity (scaled by sales) are more CO_2 intensive. Columns (2)-(5) then confirm that firms with more fossil fuel production capacity have more tangible capital, higher debt, a lower share of gross capital income taxed, and pay lower taxes.

Overall, the evidence shows that the relationships between CO_2 intensity, tangible capital, and taxes paid operate both across and within industries and, importantly, also hold within the energy-producing sector.

In the next section, we exploit the large cut in the U.S. federal corporate income tax to obtain causal evidence on the heterogeneous impact of corporate income taxation on dirty versus clean firms. Building on the findings in this section, we hypothesize that clean firms should experience a greater reduction in their effective tax rate post-reform compared to dirty firms, due to the larger proportion of their gross income subject to taxation. We then study how the observed variation in effective tax rates between dirty and clean firms affects their respective asset growth rates.

[18] If a firm does not appear in the segments data, we set its implied CO_2 intensity to the average CO_2 intensity of its industry in Compustat.

4 Effects of the 2017 Federal Tax Cut on Clean versus Dirty Firms

On December 22, 2017, the United States federal government enacted the Tax Cuts and Jobs Act (TCJA) with the stated goals of boosting capital investment, spurring economic growth, and enhancing international competitiveness. The reform became effective on January 1, 2018. One of the most significant changes introduced by the reform was a reduction in the federal income tax rate for C-corporations from 35% to 21%. In the analysis below, we leverage this tax cut to examine its differential impact on clean versus dirty firms using a standard difference-in-differences research design.

4.1 Empirical Approach

In our baseline approach, we estimate an event-study specification of the following form:

$$Y_{f,t} = \sum_{\tau=2015}^{2021} (\beta_\tau + \beta_{Dirty,\tau} \times CO_2Intensive_{f,2017}) \times Year_\tau + \alpha_f + \epsilon_{f,t}, \tag{2}$$

where the dependent variable, $Y_{f,t}$, represents measures of effective tax rates and firm total assets, respectively. $CO_2\ Intensive_{f,2017}$ is a dummy for dirty firms, defined as those in the top quartile of the CO_2 intensity distribution in the pre-event year 2017, $Year_\tau$ are year dummies, and α_f are firm fixed effects. Since the tax cut affects firms starting in 2018, we omit the year 2017 and thus identify the effects of the policy relative to this baseline year. We cluster standard errors at the firm level.

Our identification strategy assumes that clean and dirty firms would have experienced similar effective tax rates and asset growth in the absence of the federal tax cut. We present below evidence supporting this parallel-trends assumption. First, motivated by the results from the previous section, we hypothesize that the cut in the federal income tax rate affects dirty versus clean firms differentially through differences in the sensitivity of their effective tax rates to the statutory tax rate. We present direct evidence in support of this hypothesis, using the ratio of federal income taxes to capital income as dependent variable in equation (2). We document that dirty and clean firms' ratio of federal income tax to capital income were on parallel trends before the reform, but diverged sharply after the tax cut took effect. Second, we run a placebo test with the same specification but using the ratio of non-federal income taxes to capital income as outcome. Reassuringly, we find that this ratio—which should not have been affected by changes in the statutory federal tax rate—stays on parallel trends even after the tax cut was implemented. Finally, we show that both types of firms experienced similar asset growth in the years prior to the reform.

A natural concern in this setting is that contemporaneous economic or policy shocks may differentially affect the trajectories of dirty and clean firms, thus, leading to a biased inference about the effect of the federal income tax cut.[19] We discuss specific potential threats to identification and how we address them below.

Other aspects of the TCJA refom. The reduction in the statutory corporate tax rate from 35% to 21% is quantitatively the most significant feature of the TCJA. However, other provisions incorporated in the reform may have affected dirty and clean firms differently. We summarize the relevant changes of the TCJA reform for business taxation in Online Appendix D. We focus on four key changes that could act as confounders: (i) the limitation on interest expense deductibility, (ii) changes to international taxation, (iii) restrictions on net operating losses, and (iv) the repeal of the domestic production activities deduction. We address these concerns in two complementary ways: (i) by excluding firms significantly exposed to each of these provisions in subsample analyses, and (ii) by adding controls for firms' pre-reform exposure to each of these provisions in our full sample.

Other economic and policy shocks. We also consider other economic and policy shocks that might have differentially affected dirty and clean firms during the sample period. For example, changes in import tariffs or carbon taxes could influence our results. To account for this, we control for firms' exposure to carbon taxes and tariffs based on their sales distribution across industries and countries. Second, other concurrent environmental policies or industry-specific shocks could potentially confound our results. We gauge the severity of this concern in leave-one-industry-out specifications. We also estimate an augmented specification with foreign firms, in which we include both country $\times$ year and industry $\times$ year fixed effects. This triple-difference approach compares the outcomes of dirty versus clean firms, pre- versus post-2018, in the U.S. versus foreign countries where the corporate income tax rate remained unchanged. This helps address residual concerns that time-varying industry shocks or broader shifts affecting clean and dirty firms differentially might drive our results.

4.2 Baseline Results

Effective tax rates. Figure 3 presents the event-study graphs. Panel A displays the estimated coefficients from equation (2) for the year dummies, β_τ, on the left panel, and for their interaction with the dummy for dirty firms, $\beta_{Dirty,\tau}$, on the right panel, using federal taxes paid over capital income as the outcome variable. As expected, the estimates for the year dummies in the left panel confirm that the tax cut was associated with an immediate and permanent decrease in effective tax rates for all firms in our sample. The right panel plots the main coefficients of interest—those for the year dummies interacted with the dummy for dirty firms. The pre-2018 estimates confirm that, prior to the implementation of the federal tax cut, dirty and clean firms exhibited similar trends. The figure also shows that the tax cut was associated with an immediate and permanent increase

[19] For policies that pre-dated the federal income tax cut, such as the 2015 Paris Agreement, we would expect diverging pre-trends if the policies had any differential effect on the asset growth of dirty and clean firms.

in federal taxes paid by dirty firms (as a fraction of capital income) *relative* to clean firms. Note that statistically significant effects are already visible in the years 2018 and 2019, before the onset of Covid-19, ruling out the concern that differential exposure to the pandemic might explain these results.

[INSERT FIGURE 3]

Panel B displays the β_τ coefficients for a placebo test where the outcome variable is non-federal income taxes paid over capital income, which should not be affected by changes in the federal statutory tax rate. Reassuringly, for this outcome variable, we find that dirty and clean firms are on similar trends both before and after the reform. This reinforces the credibility of our interpretation that the event-study estimates presented in Panel A reflect the causal impact of the cut in the federal tax rate, rather than other contemporaneous changes in corporate taxation.

Asset growth. Figure 4 displays the β_τ coefficients of the estimation of equation (2) when the outcome variable is the logarithm of firm total assets. First, the left panel illustrates the average increase in firm assets over the sample period 2015-2021. The right panel displays the coefficients of interest for the relative impact of the federal tax cut on the asset growth of dirty firms relative to clean firms. The figure shows that before the federal tax cut was implemented, dirty and clean firms were on similar trends. Importantly, it also reveals that the tax cut was associated with a significant decline in asset growth for dirty firms compared to clean firms. This statistically significant effect is observed starting in 2019, before Covid-19, ruling out the possibility that it could be explained by differential exposure to the pandemic.

[INSERT FIGURE 4]

Sensitivity analysis for treatment confidence intervals. While we do not find evidence of diverging pre-trends in the event-study specification for either effective tax rates or asset growth, we go one step further by conducting a sensitivity analysis to assess robustness to possible violations of the parallel trends assumption in the pre-treatment period, using the approach recently proposed by Rambachan and Roth (2023). Rather than assuming that parallel trends hold exactly, this approach bounds treatment effects under plausible deviations from parallel trends, using the following formula (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 $\Delta^{RM}(\overline{M})$ represents the set of plausible post-treatment effects given potential deviations from parallel trends in the pre-treatment period. The parameter $\overline{M}$ scales the maximum allowed post-treatment violation relative to the largest observed pre-treatment deviation. This approach quantifies the sensitivity of our results to small departures from the parallel trends assumption. We apply this framework to bound the treatment effects for federal taxes over capital income in 2018 and log of assets in 2019 (the first year when asset effects are observed). The results presented in Online Appendix Figure A.3 confirm that the null hypothesis of no differential effects of the federal tax cut on both outcomes for dirty versus clean firms can be rejected at the 1% level when $\overline{M} = 0.5$, and at least at the 10% level even when $\overline{M} = 1$.

Magnitudes. We then discuss the magnitudes of the effects of the federal tax cut on effective tax rates and asset growth using a difference-in-differences specifications of the form

$$Y_{f,t} = \beta \times Post_t \times CO_2Intensive_{f,2017} + \gamma_t + \alpha_f + \epsilon_{f,t}, \tag{3}$$

where the dependent variable $Y_{f,t}$ is either effective tax rates or firm log total assets, $Post_t$ is an indicator that equals one after 2017, γ_t and α_f are year and firm fixed effects, respectively, and $CO_2Intensive_{f,2017}$ is a dummy for firms in the top quartile of the 2017-CO_2-intensity distribution. We cluster standard errors at the firm level. We report the results in Table 6 in columns (1) and (3). In columns (2) and (4), we replace the dummy for $CO_2Intensive$ firms with the continuous measure of CO_2 intensity.

[INSERT TABLE 6]

The results confirm that the tax cut was associated with a smaller reduction in effective tax rates and a smaller increase in asset growth for dirty firms relative to clean firms. The coefficients for effective tax rates in columns (1) and (2) are positive while the coefficients for log assets in columns (3) and (4) are negative, all statistically significant at the 1% level. Comparing the estimates for taxes and log assets in columns (1) and (3) indicates a semi-elasticity of firm total assets to a one percentage point increase in the effective tax rate of around -4.8. We obtain a similar magnitude, around -4.1, with the continuous measure of CO_2 intensity in columns (2) and (4). Finally, for robustness, we run the same specifications with the logarithm of the sum of tangible and intangible capital as alternative dependent variable, using data from Peters and Taylor (2017). As shown in Online Appendix Table A.6, we find virtually identical results.[20]

One may wonder how our results translate into elasticities of asset growth with respect to the log of the net-of-tax rate, which is often used in the public finance literature. For this, we run the same specification as the one presented in columns (1) and (2) of Table 6, replacing the dependent variable by the log of 1 minus the ratio of federal income taxes over capital income. We find coefficients of -0.026 and -0.016 respectively (statistically significant at the 1% level). This indicates net-of-tax elasticities of 4.5 and 3.6 respectively, in line with prior work.[21]

[20] The larger decline in effective tax rates for clean firms post-reform is the result of different factors. In particular, clean firms have a higher proportion of capital income initially subject to corporate income taxation. In addition, their leverage responds differently to the tax cut, affecting the share of capital income shielded from corporate income taxation. What matters for asset growth is the overall change in effective tax rates, however, for completeness, in Online Appendix Table A.7 we also report the results of Table 6, using leverage as the dependent variable. We find that dirty firms experience a reduction in their leverage post-reform, compared to clean firms.

[21] Ohrn (2018) exploits quasi-experimental variation created by the Domestic Production Activities Deduction and finds an elasticity of investment with respect to the net-of-tax rate of 6.5. Using variation from differences in exposure to bonus depreciation, Zwick and Mahon (2017) report an elasticity of (net) investment with respect to the net-of-tax rate of 3.9 (see discussion in the Appendix of Ohrn (2018) page 17).

4.3 Robustness checks

We present a series of robustness tests for our baseline result on effective tax rates and asset growth in Online Appendix Table A.8, to ensure that the effects can be ascribed to the federal tax cut itself, and not to other factors.

Robustness to other aspects of the TCJA reform. While the reduction in the statutory federal corporate tax rate from 35% to 21% is quantitatively by far the most important aspect of the tax reform, other provisions in the TCJA might have differentially affected dirty and clean firms, potentially biasing our estimates. To assess the impact of these provisions, we rerun our baseline analyses on effective tax rates and firm assets, excluding, respectively, firms that exceed the interest deductibility limit in 2017, multinational firms (defined as those with more than 20% of their sales abroad in 2017), firms with loss carryforwards exceeding 1% of sales in 2017, and manufacturing firms. The results, presented in columns (1)-(4) of Online Appendix Table A.8, are similar to our baseline findings. Moreover, in column (5), we include controls for firm multinational status, loss carryforwards, high interest coverage ratios, and manufacturing status (all measured in 2017), interacted with year fixed effects, in the full sample. Adding these controls does not materially change the results, alleviating concerns that other aspects of the TCJA are driving the observed effects on effective tax rates and asset growth.

Robustness to other economic shocks. Another set of concerns relates to the potential for concurrent policies and events that differentially affect dirty firms, confounding our interpretation. In column (6), we control for changes to tariff policies using firms' weighted-average exposure to U.S. import tariffs based on their pre-event sales distribution across sectors. In column (7), we control for firms' exposure to carbon taxes, calculated based on their sales distribution across locations (U.S. states and foreign countries) and sectors, using carbon pricing data from the World Carbon Pricing Database.[22] In both cases, the coefficient of interest remains virtually unchanged.

Leave-one-industry-out specifications. A remaining concern is that other economic or regulatory shocks specific to some industries could confound our estimates. If anything, the sample period was marked by a series of steps to ease existing environmental regulation in some industries, which would lead us to underestimate the relative decline in asset growth for dirty firms compared to clean firms associated with the federal tax cut.[23] That said, to address this concern directly, we report in Online Appendix Figure A.4 the same estimate as in column (2) of Table 6 in leave-one-industry-out specifications. For both effective tax rates and log assets, the point estimates remain virtually unchanged.

[22] We use data on carbon tax rates expressed in USD per tons of CO_2 equivalent at the sector level in each country and separately for each U.S. state. See Dolphin and Xiahou (2022) for more details.

[23] This includes for instance looser restrictions on offshore drilling, changes to rules that limit greenhouse gas emissions from power plants and vehicles, and revisions to the 2016 methane rule regulating emissions from oil and gas operations.

Triple differences using foreign-based firms. Finally, we augment our analysis by including foreign-based firms and estimate a triple-difference specification, comparing dirty and clean firms, pre- and post-2018, in the U.S. versus foreign countries where statutory corporate tax rates remained constant:

$$Y_{f,c,t} = (\beta \times Post_t + \beta_{US} \times Post_t \times US) \times CO_2Intensive_{f,2017} + \alpha_f + \gamma_{i,t} + \gamma_{c,t} + \epsilon_{f,t}, \quad (4)$$

where $Y_{f,c,t}$ represents effective tax rates or firm total assets for firm f in country c and year t, $Post_t$ is an indicator equal to one after 2017, US is a dummy for US-based firms, $CO_2Intensive_{f,2017}$ is a dummy for firms in the top quartile of the 2017 CO_2 intensity distribution, and α_f, $\gamma_{i,t}$, and $\gamma_{c,t}$ denote firm, industry $\times$ year, and country $\times$ year fixed effects, respectively. We cluster standard errors at the firm level. As shown in column (8), while the coefficients on the interaction between the $Post$ and the $CO_2Intensive$ dummies are small and insignificant for both effective tax rates and log assets, the triple interaction of the $Post$ dummy with the US and $CO_2Intensive$ dummies is positive for effective tax rates and negative for log assets, both significant at the 1% level. Strikingly, the coefficients on the triple interaction term translate into a semi-elasticity of firm total assets to a one percentage point increase in effective tax rates of around 5.8—a similar magnitude to, and if anything larger than, the semi-elasticity derived from our baseline specification. These results largely mitigate residual concerns that time-varying industry shocks and broader shifts differentially affecting dirty and clean firms might drive our results.

Taken together, these robustness tests confirm that the federal tax cut led to a larger reduction in effective tax rates and a larger increase in asset growth for clean firms compared to dirty firms post-reform. In the next section, we develop a multi-sector general-equilibrium model that we calibrate to the U.S. economy. We validate the model by showing that it replicates the untargeted difference-in-differences estimates of the federal tax cut effects on clean versus dirty sectors. We then use the model to (i) estimate the impact of the federal tax cut on aggregate CO_2 intensity and (ii) assess the effect of a counterfactual tax reform that eliminates the tax shield of debt.

5 The Model

We build a multi-sector general-equilibrium model with CO_2 emissions, where corporate income taxes affect firms' decisions through the user cost of capital. The model endogenously generates a negative correlation between taxes and emissions, as dirty firms hold more pledgeable capital, take on higher debt, and reduce their tax liabilities via the debt tax shield. Finally, the tax shield insulates the user cost of more indebted firms from tax changes.

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 bonds $B_{g,t+1}$, risky corporate bonds $B^f_{i,t+1}$ and equity shares $s^f_{i,t+1}$, for each firm f and sector i. Risk-free bonds pay interest rate r_t. Corporate bonds pay interest rate $r^b_{i,t}$, unless default occurs and the firm is liquidated.[24] 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:

$$C_t \equiv \prod_{i \in \overline{\mathcal{N}}} \left(\frac{c_{i,t}}{\theta_i} \right)^{\theta_i} \quad \text{with} \quad c_{i,t} \equiv \left(\int (c^f_{i,t})^{\frac{\sigma-1}{\sigma}} df \right)^{\frac{\sigma}{\sigma-1}},$$

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

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

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

$$y_{i,t} = \mathcal{Y}_i \left(\ell_{i,t}, \{k^s_{i,t}\}_s, F_{i,t}, \{x_{i,j,t}\}_j \right), \tag{5}$$

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 corporate 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 3.4.

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 $\psi_{i,s}$ of its assets; the remaining capital is seized and transferred lump-sum to households. The assets retained by the firm are 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 assets (which are 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 assets that were transferred to them to restructured and newly-born firms.

Leverage. Since firms in liquidation lose all of their assets, firms in our model cannot issue risk-free debt. More specifically, lenders can recover up to a fraction $\psi_{i,s}$ of type-s assets from firm i in default, unless the firm is liquidated. Debt is thus risky and will command a credit premium in equilibrium, i.e., $r^b_{i,t+1} > r_t$. Finally, note that any borrowing above the threshold $\psi_{i,s}$ 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

$$b_{i,t+1} \leq \frac{1}{1 + r^b_{i,t+1}} \sum_{s \in \mathcal{S}} \psi_{i,s} q^s_{i,t+1} k^s_{i,t+1}. \tag{6}$$

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 (6) will hold with equality. As a result, firms holding more capital with a high $\psi_{i,s}$ will be able to sustain a higher leverage, consistent with the empirical literature (see, e.g., Rajan and Zingales, 1995).[25]

Emissions. We assume that production generates emissions as a byproduct of fossil fuel usage. More specifically, firm i's CO_2 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 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 $\Gamma^s_{i,t}$ 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

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

where

$$\begin{aligned} \Pi_{i,t} =& (1 - \tau_p)\Big(p_{i,t} y_{i,t} - \sum_{j \in \mathcal{N}} p_{j,t} x_{i,j,t} - P^F_{i,t} F_{i,t} - w_t \ell_{i,t} - r^b_{i,t} b_{i,t}\Big) \\ & - \sum_{s \in \mathcal{S}} (1 - \Gamma^s_{i,t}) q^s_{i,t} I^s_{i,t} + b_{i,t+1} - b_{i,t} \end{aligned}$$

[25] The default process implies that leverage increases in the share of certain types of assets, but corporate rates are independent of such assets. It is straightforward to generalize the default process to make both the amount of borrowing and the cost of debt depend on capital: all that is needed is to assume that lenders can recover a fraction of tangible capital even if the firm is liquidated.

and where φ_t is the economy's stochastic discount factor, τ_p 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 bonds and sets lump-sum taxes to satisfy its budget constraint—the formal details are provided in Online Appendix E.

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:

$$y_{i,t} = c_{i,t} + \sum_{j \in \overline{\mathcal{N}}} x_{j,i,t} + \sum_{s \in \mathcal{S}} \sum_{j \in \overline{\mathcal{N}}} i^s_{j,i,t} \quad \text{and} \quad L_t = \sum_{i \in \overline{\mathcal{N}}} \ell_{i,t}. \tag{7}$$

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

5.1 The User Cost of Capital

A crucial variable in our analysis is the user cost of capital, which represents the total cost incurred by a firm to use a unit of capital, including factors such as depreciation, interest expenses, and taxes. We begin by adding the equilibrium corporate-bond rates and equity returns, which we obtain directly from the household's optimal choices of corporate bonds and equity:

$$r^b_{i,t+1} = \frac{\lambda_i + r_t}{1 - \lambda_i} \quad \text{and} \quad r^e_{i,t+1} \equiv \frac{d_{i,t+1} + Q_{i,t+1}}{Q_{i,t}} - 1 = \frac{(1-\tau_d)(\rho_i + \lambda_i) + (1-\tau_h) r_t}{(1-\tau_d)(1 - \rho_i - \lambda_i)}.$$

Remember that $r^b_{i,t+1}$ represents the ex-post compensation for holders of risky debt, conditional on the firm not being liquidated at time t. Similarly, $r^e_{i,t+1}$ represents the ex-post equity return, conditional on no default. Since there is no aggregate risk, the expected (i.e., unconditional) net compensation to investors, both for risky debt and for equity, must be equal to the net interest rate on government debt. In what follows, we assume that $r^e_{i,t} \geq r^b_{i,t}$ for all industries. This assumption essentially requires ρ_i (i.e., the probability of restructuring) to be sufficiently high relative to λ_i (i.e., the probability of liquidation). Also, it is immediately satisfied if $\tau_d = \tau_h$.

We now turn to the firm's problem. The optimal choices of labor and intermediate goods are static, and are reported in Online Appendix E.1; the only dynamic choice is the one about investment $I^s_{i,t}$. As the quantitative analysis will involve comparing steady states, we simplify the exposition by focusing on steady-state values and omitting the time subscript. We also set markups to zero. The general expressions are reported in Online Appendix E.1. The optimal level of type-s capital satisfies the first-order condition $p_i \partial \mathcal{Y}_i / \partial k^s_i = R^s_i q^s_i$, where type-$s$ capital's user cost R^s_i is defined as

$$R^s_i = \frac{1 - \Gamma^s_i}{1 - \tau_p}(\delta^s + r^e_i) - \left(\frac{1}{1-\tau_p} r^e_i - r^b_i \right) \frac{\psi_{i,s}}{1 + r^b_i}. \tag{8}$$

The user cost of capital is the sum of depreciation, tax allowances, and the financing costs that a firm incurs when acquiring capital. More specifically, the first term in (8) captures depreciation and the tax benefits from accelerated depreciation, assuming capital is fully equity-financed. This is the classical concept of user cost, introduced in the seminal work of Jorgenson (1963).

The second term in (8) reflects the advantage of using debt over equity. Debt is advantaged by the tax shield, which allows an indebted firm to lower its tax obligations—this is represented by the factor $1/(1-\tau_p)$. When the tax shield of debt is removed—a reform we consider in our counterfactual analysis—the tax advantage of debt disappears, and the factor $1/(1-\tau_p)$ applies also to r_i^b. Note that the advantage of debt is greater for firms with more pledgeable capital, i.e., capital with a high $\psi_{i,s}$.

5.2 A Closer Look at the Mechanism

To clarify the mechanism connecting corporate taxes to CO_2 emissions, we consider a policy that reduces the corporate tax rate. A lower τ_p has a direct impact on the firm's problem by affecting the user cost of capital. First, a reduced tax rate lowers the fully-equity-financed component of the user cost in (8); the strength of this effect is partially offset by the response of Γ_i^s, as the lower tax rate also reduces the present value of tax allowances. Second, a lower tax rate diminishes the relative advantage of using debt over equity, causing the second term in (8) to decrease. This reduction is stronger for firms that benefit more from the tax shield—those holding highly pledgeable capital. In summary, the user cost of capital decreases with lower tax rates, but the reduction is weaker for firms with more pledgeable capital.

All else being equal, firms respond to the fall in the user cost by cutting their prices and increasing production. In fact, to a first-order approximation, we can derive a simple characterization of the *partial-equilibrium* response of a firm's production, which does not rely on a specific functional form for the production function. We focus on a single firm (hence, we bring back the firm's identifier) and keep all other prices (fuel price, investment price, wage, etc.) constant. We can then express the percentage change in the firm's output as follows:

$$\Delta \log y_i^f = \frac{d \log \mathcal{D}_i^f}{d \log p_i^f} \times \sum_{s \in \mathcal{S}} \frac{d \log \mathcal{MC}_i^f}{dR_i^s} \times \Delta R_i^s, \tag{9}$$

where ΔR_i^s denotes the change in the user cost of type-s capital resulting from the tax adjustment.

The first term is simply the price elasticity of demand. The second term is the semi-elasticity of the firm's marginal cost to a change in the user cost of type-s capital. In Online Appendix E.2, we show that this term is proportional to the firm's holdings of type-s capital scaled by firm's sales: $d \log \mathcal{MC}_i^f / dR_i^s \propto q_i^s k_i^{f,s} / p_i^f y_i^f$. In summary, following a reduction in the corporate income tax, firms with less capital—especially less *collateral*—see a more substantial decrease in their production costs, leading them to lower prices and expand production more significantly. Finally, remember that emissions are a byproduct of fossil fuel usage. Under constant returns to scale, a firm's demand for fuel (and other inputs) scales proportionally with its output. It follows that—in partial equilibrium, where input prices are held constant—a firm's CO_2 intensity is constant, thus, equation (9) captures also the partial-equilibrium change of a firm's emissions.

It is important to emphasize that, while our focus on tax rate changes and the debt tax shield is motivated by our empirical evidence, the discussion in this section applies more broadly to any policy that favors dirty firms by affecting the user cost of different capital types. For instance, policies that accelerate depreciation—such as the bonus depreciation studied in Zwick and Mahon (2017)—will affect R_i^s through Γ_i^s. Since bonus depreciation is often targeted at equipment, changes to this provision are also likely to have an unequal impact on clean and dirty firms.

5.3 Calibration

We present the main elements of the calibration here and leave the details in Online Appendix F. We start from the number of non-financial sectors in the detailed BEA input-output classification, and further exclude government and housing. We have a total of 375 non-fuel sectors. We consider exports as final consumption and assume that all output is produced domestically. We identify the coal sector with sector "Coal mining" (BEA code: 212100), the oil sector with "Petroleum refineries" (BEA code: 324110), and the gas sector with "Natural gas distribution" (BEA code: 221200). Motivated by our empirical analysis, we consider two types of capital: machinery and equipment (superscript $s = e$, for "equipment") and a composite asset combining both all remaining tangible capital and intangible capital (superscript $s = o$, for "other").

We let $U(C) = \log(C)$ 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 implies that, at the optimum, θ_i will coincide with the share in consumption of sector i. 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.[26]

To calibrate the remaining parameters, we combine several datasets for the year 2017. First, from the BEA detailed Input-Output Accounts, we obtain data on (i) the use of commodities by non-financial industries (as intermediate inputs) and by final users (as personal consumption and investment), and (ii) the value added and its composition by industry. Second, from the BEA Fixed Assets we gather data on investment in fixed assets by industry. Investment data by asset type is only available at a higher-level industry classification, so we allocate investment across our more detailed classification using industry value added. Third, from Compustat North America,

[26] 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.

the Center for Research in Security Prices (CRSP), and Trucost, we obtain firm-level data on interest payments, equity returns, debt, assets, and CO_2 emissions, that we aggregate at the BEA sector-level.

In the baseline model, we assume that the production function is Cobb-Douglas:

$$y_{i,t} = z_i \Big(\ell_{i,t}^{\phi_i^\ell} \prod_{s \in \mathcal{S}} \left(k_{i,t}^s\right)^{\phi_i^s} F_{i,t}^{\phi_i^F} \Big)^{\gamma_i} \Big(\prod_{j \in \mathcal{N}} x_{i,j,t}^{\alpha_{ij}} \Big)^{1-\gamma_i}, \quad F_{i,t} = \sum_{j=c,o,g} x_{i,j,t}^{\eta_i^{F,j}},$$

where z_i is (constant) productivity and $\gamma_i, \phi_i^\ell, \phi_i^s, \phi_i^F, \alpha_{ij} \in [0,1]$. Constant returns to scale requires $\phi_i^\ell + \sum_s \phi_i^s + \phi_i^F = 1$, $\sum_j \alpha_{ij} = 1$ and $\sum_j \eta_i^{F,j} = 1$.

The Cobb-Douglas assumption implies that γ_i corresponds to the share of value added plus fuel expenditures in total sales; ϕ_i^F to the fuel share in the sum of value added and fuel expenditures; ϕ_i^ℓ, ϕ_i^s to the labor share and the type-s capital share in the sum of value added and fuel expenditures, respectively; and α_{ij} to the share of input j in the total non-fuel intermediates. To calibrate the investment network ω_{ij}, we follow vom Lehn and Winberry (2021), which we extend in two ways.[27] First, we expand their investment networks to cover 378 sectors. Second, we create two separate investment networks: one for equipment, and the other combining both non-residential structures and intangible capital.

We define leverage as the ratio of debt over assets. We choose liquidation probabilities to match the model-implied interest rates to the sector-specific ratio of total interest payments over debt. For equity returns, we compute industry-specific betas and assume a risk premium of 7% and a nominal risk-free rate of 2.4%. For asset pledgeability, we let $\psi_s = a^\psi + b^\psi$ for equipment and $\psi_s = a^\psi$ for all other capital. We then use condition (6), which must hold as an equality at the optimum, to estimate these parameters. Specifically, we regress firms' total debt on their equipment holdings and obtain $b^\psi = 0.23$ and $a^\psi = 0.35$. For depreciation and amortization rates, we primarily follow Barro and Furman (2018), from which we also obtain the tax depreciation and amortization schedules for various capital types. We then combine these with industry-specific equity returns to calculate the present discounted values of tax benefits Γ_i^s.

To calibrate the emission rates for each fuel, e_j, $j = c, o, g$, we regress our measure of CO_2 intensity on each sector's expenditure share on the coal, oil and gas sectors. Finally, in the baseline model we set $\tau_p = 0.35$, that is, the federal statutory tax rate before 2017.

5.4 Policy Counterfactuals

To study counterfactuals we employ "exact hat algebra" (Dekle et al., 2008; Costinot and Rodríguez-Clare, 2014), that is, we express equilibrium relations in terms of variations from the baseline equilibrium. For example, letting $X_{i,t}$ and $X'_{i,t}$ denote a variable before and after the policy change, respectively, we write equilibrium relations in terms of the change $\hat{X}_{i,t} \equiv X'_{i,t}/X_{i,t}$.

[27] We are grateful to the authors for kindly sharing their data and providing detailed information on their methodology.

A lower corporate income tax. In our first counterfactual exercise, we replicate the fall in the statutory corporate income tax studied in Section 4. More precisely, we compare the steady state to the original economy with $\tau_p = 0.35$ to the one of a counterfactual economy in which $\tau_p = 0.21$. In addition to providing a rich set of insights, this exercise also enables us to validate the model by comparing its results to our empirical estimates.

The reduction in the tax rate results in a 5.6% increase in steady-state aggregate GDP and a 5.9% rise in output. This growth is accompanied by a more modest increase in total emissions, at 4.5%. The less-than-proportional rise in emissions follows from arguments outlined in Section 5.2. In particular, since clean sectors depend relatively less on equipment, and more on other capital—whose user cost is more sensitive to tax changes—the policy makes clean sectors relatively cheaper. This in turn encourages households and firms to redirect demand from CO_2-intensive sectors to cleaner ones, resulting in aggregate emissions rising less than output. The only qualification is that, while equation (9) was derived in partial equilibrium—where emissions scale directly with output—this section incorporates the full general equilibrium response. This allows for changes in input prices, and in particular fossil fuel prices, which prompt firms to adjust their input mix and, consequently, their CO_2 intensity.

To show how the corporate tax change affects the sectoral composition of aggregate output, we replicate the analysis from Section 4.2 using model-generated data. Specifically, we measure the change in firms' effective tax rates and total assets as the corporate tax rate shifts from $\tau_p = 0.35$ to $\tau_p = 0.21$, and relate these changes to their CO_2 intensity.[28] This exercise also serves to validate our calibration, which was not explicitly designed to target these moments. Since firms within each sector are identical in the model, the analysis is effectively conducted at the sector level. Consistent with our empirical analysis, we define a firm's effective tax rate as the ratio of its taxes to gross income—defined in the model as revenues minus expenditures on intermediate inputs and wages. Table 7 presents the results. The model aligns well with our empirical findings: following a reduction in the corporate tax rate, more CO_2-intensive firms face relatively higher taxes—the positive coefficient in column (1)—and expand their assets by less—the negative coefficient in column (2), both significant at the 1% level. The similarity between the regressions on model data and those in Table 6 is remarkable, lending support to our model assumptions and calibration.

[INSERT TABLE 7]

An economy without the tax shield. In our second counterfactual exercise, we eliminate the tax shield on debt. To offset the resulting tax increase and maintain aggregate GDP unchanged, we also reduce the corporate income tax rate, from $\tau_p = 0.35$ to $\tau_p = 0.30$. This policy leads to an emissions reduction of 1.3%, while total output declines only by 0.1% (GDP remains constant by design).

[28] We use a change-in-outcomes specification here for simplicity. With two periods (representing the two steady states) this approach is equivalent to the interaction model used in Table 6.

The drop in emissions, despite almost no change in total production, highlights the heterogeneous impact of the policy across sectors. Firms in cleaner sectors derive less benefit from the tax shield because they rely more heavily on less pledgeable capital. As a result, removing the tax shield makes cleaner sectors relatively cheaper, redirecting demand away from CO_2-intensive sectors.

5.5 A More General Technology

Motivated by our empirical evidence suggesting a tight link between a firm's holdings of equipment and its CO_2 intensity in Table 5, we generalize the production function to allow for complementarity between equipment capital and fossil fuel inputs. We assume[29]

$$\hat{y}_{i,t} = \Big(\hat{\ell}_{i,t}^{\phi_i^\ell} (\hat{K}_{i,t})^{\phi_i^K} (\hat{k}_{i,t}^o)^{\phi_i^o} \Big)^{\gamma_i} \Big(\prod_{j \in \mathcal{N}} \hat{x}_{i,j,t}^{\alpha_{ij}} \Big)^{1-\gamma_i},$$

where $\hat{K}_{i,t}$ is the equipment-fuel bundle:

$$\hat{K}_{i,t} \equiv \Big(\eta_i^F (\hat{F}_{i,t})^{\frac{\rho-1}{\rho}} + (1-\eta_i^F)(\hat{k}_{i,t}^e)^{\frac{\rho-1}{\rho}} \Big)^{\frac{\rho}{\rho-1}} .$$

The parameter ρ controls the elasticity of substitution between equipment capital and the fuel bundle. When $\rho < 1$, equipment and fuel are complements, meaning that, all else being equal, firms reduce fuel consumption when equipment becomes more expensive; the opposite occurs when $\rho > 1$. In the limit with $\rho \to 1$ we recover our Cobb-Douglas specification.

We repeat the two counterfactual exercises from the previous section for different values of ρ, and report the outcome in Table 8. In particular, in the second counterfactual we keep the tax rate fixed at $\tau_p = 0.30$—the value that ensures a constant GDP in the Cobb-Douglas benchmark—across all values of ρ. In both panels, the leftmost values correspond to the results under the Cobb-Douglas specification. As equipment and fuel become stronger complements, emissions increase less when the tax rate is reduced (Panel A), and decline more when the tax shield is removed (Panel B).

To further illustrate the impact of the reforms, we follow Shapiro (2020) and the environmental economics literature (Grossman Gene and Krueger, 1993; Copeland and Taylor, 2005; Levinson, 2009; Shapiro and Walker, 2018), and decompose the total change in emissions as the sum of two components: (i) the change in aggregate output and (ii) the change in aggregate CO_2 intensity, defined as the ratio of aggregate emissions over output. The first component reflects the *scale effect*, that is, how total emissions change due to variations in the overall level of production. If output increased uniformly across all sectors, this would be the sole channel affecting emissions. Changes in aggregate CO_2 intensity reflects a *composition effect*, highlighting how policy reforms shift production across clean and dirty industries and prompt firms to substitute between different

[29] For convenience, we define the production function in deviation from the initial equilibrium, hence, the use of "hats" in the definition.

inputs.[30]

Table 8 presents the decomposition for each counterfactual. Consider Panel A first. A lower tax rate increases total output, generating a positive scale effect, and therefore higher emissions. At the same time, lowering the tax rate makes equipment—whose user cost is less sensitive to tax changes—relatively more expensive than other capital. Since dirty firms rely more on equipment, production shifts away from these firms, leading to a decline in the economy's CO_2 intensity. What is more, this reduction in CO_2 intensity becomes more pronounced as fuel and equipment become stronger complements. The higher cost of equipment in such cases leads firms to lower their fuel demand, resulting in an additional decrease in CO_2 intensity.

[INSERT TABLE 8]

The same mechanism applies in Panel B. In this counterfactual, because the scale effect does not change much and remains close to zero, the tax reform leads to an absolute decline in CO_2 emissions which grows larger as equipment and fuel become stronger complements. Removing the tax shield makes equipment—which is more pledgeable and thus cheaper with the tax shield—relatively more expensive. With a stronger complementarity, the higher cost of equipment dampens fuel demand, further amplifying the overall reduction in emissions.

To further quantify the social welfare impact of these policy counterfactuals, we must take a stance on a specific value for the social cost of CO_2 emissions. Consider, for instance, the second counterfactual. Here, the policy's effect on GDP is constant by design and aggregate consumption *increases* by 0.2%, therefore, any reduction in emissions will likely lead to positive welfare gains. Panel B of Table 8 shows that the emissions impact of this policy depends on the assumed complementarity between equipment and fuel, with effects ranging from -1.3% to over -3.7%. Given that total U.S. CO_2 emissions in 2017 were 6,457 million metric tons,[31] the model predicts an absolute change in emissions between 80 and 240 million metric tons of CO_2.

The reduction in emissions can then be "monetized" by simply multiplying the total fall in emissions by the chosen social cost of carbon. There is, however, significant uncertainty around this measure. Estimates have risen over time: while studies by Pindyck (2019) and Stern (2006) estimate a social cost around USD 100, others suggest a value around USD 185 Rennert et al. (2022). In a recent study, Bilal and Känzig (2024) suggest a much higher value of around USD 1,400. Using the conservative estimate yields a monetized range of USD 8-24 billion, whereas the higher estimate results in values between USD 112 and USD 336 billion. Even this upper range, however, likely underestimates the severe risks of extreme warming due to highly non-linear effects at higher temperatures (Weitzman, 2009). These limitations suggest that focusing on the physical reduction in CO_2 emissions may provide a more reliable measure than its monetized value.

[30] In the decomposition of Shapiro (2020), the "composition" effect reflects only the reallocation of production across industries. Additionally, the paper defines a separate "technique" effect, which captures changes in CO_2 intensity within sectors across countries. In our analysis, we combine these two effects into a broader composition effect.

[31] Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017; available on the EPA website. As noted earlier, we use CO_2 as shorthand for CO_2 equivalent.

6 Conclusion

This paper studies the environmental impact of corporate income taxation. We document that income taxes are systematically distorted in favor of dirty firms, driven by the tax treatment of corporate debt. Dirty firms rely more heavily on tangible capital, which allows them to borrow more and benefit disproportionately from the tax deductibility of interest payments. Building on these insights, we document that dirty firms are less responsive to changes in statutory income tax rates, as a smaller share of their capital income is subject to taxation. Using difference-in-differences specifications around the federal tax cut of 2017, we find that dirty firms experience a relative increase in their effective tax rates, and grow less relative to clean firms post-reform. Finally, we build a general-equilibrium framework with CO_2 emissions and study the aggregate implications of different corporate taxation reforms. The model suggests that a simple policy that removes the tax shield of debt (and simultaneously lowers the tax rate) can substantially reduce CO_2 emissions while leaving GDP unchanged.

References

Acemoglu, D., Aghion, P., Bursztyn, L., and Hemous, D. (2012). The environment and directed technical change. *American Economic Review*, 102(1):131–66.

Albertus, J. F., Glover, B., and Levine, O. (2024). The real and financial effects of internal liquidity: evidence from the tax cuts and jobs act. *Journal of Financial Economics, Forthcoming.*

Andersson, J. J. (2019). Carbon taxes and co_2 emissions: Sweden as a case study. *American Economic Journal: Economic Policy*, 11(4):1–30.

Auerbach, A. J. (2006). Who bears the corporate tax? a review of what we know. *Tax Policy and the Economy*, 20:1–40.

Auerbach, A. J. (2018). Measuring the effects of corporate tax cuts. *Journal of Economic Perspectives*, 32(4):97–120.

Baker, S. R., Sun, S. T., and Yannelis, C. (2023). Corporate taxes and retail prices. *NBER Working Paper 27058.*

Baqaee, D. R. and Farhi, E. (2019). Productivity and Misallocation in General Equilibrium. *The Quarterly Journal of Economics*, 135(1):105–163.

Barro, R. J. and Furman, J. (2018). Macroeconomic effects of the 2017 tax reform. *Brookings papers on economic activity*, 2018(1):257–345.

Baylis, K., Fullerton, D., and Karney, D. H. (2013). Leakage, welfare, and cost-effectiveness of carbon policy. *American Economic Review*, 103(3):332–37.

Baylis, K., Fullerton, D., and Karney, D. H. (2014). Negative leakage. *Journal of the Association of Environmental and Resource Economists*, 1(1/2):51–73.

Bigio, S. and La'O, J. (2020). Distortions in Production Networks. *The Quarterly Journal of Economics*, 135(4):2187–2253.

Bilal, A. and Känzig, D. R. (2024). The macroeconomic impact of climate change: Global vs. local temperature. *NBER Working Paper 32450.*

Bovenberg, A. L. and Goulder, L. H. (1996). Optimal environmental taxation in the presence of other taxes: General-equilibrium analyses. *American Economic Review*, 86(4):985–1000.

Bruvoll, A. and Larsen, B. M. (2004). Greenhouse gas emissions in norway: do carbon taxes work? *Energy Policy*, 32(4):493–505.

Busch, T., Johnson, M., and Pioch, T. (2018). Consistency of corporate carbon emission data. *University of Hamburg Report WWF Deutschland.*

Carrizosa, R. D., Gaertner, F. B., and Lynch, D. P. (2023). Debt and taxes? the effect of tax cuts & jobs act of 2017 interest limitations on capital structure. *The Journal of the American Taxation Association*, 45(2):35–55.

CBO (1997). The economic effects of comprehensive tax reform. *Report, U.S. Congress, Congressional Budget Office, Washington, DC.*

Chen, Q., Chen, Z., Liu, Z., Serrato, J. C. S., and Xu, D. Y. (2024). Regulating conglomerates: Evidence from an energy conservation program in China. *American Economic Review, Forthcoming.*

Chetty, R. (2012). Bounds on elasticities with optimization frictions: A synthesis of micro and macro evidence on labor supply. *Econometrica*, 80(3):969–1018.

Chetty, R. and Saez, E. (2010). Dividend and corporate taxation in an agency model of the firm. *American Economic Journal: Economic Policy*, 2(3):1–31.

Chodorow-Reich, G., Smith, M., Zidar, O. M., and Zwick, E. (2024a). Tax policy and investment in a global economy. *NBER Working Paper 32180.*

Chodorow-Reich, G., Zidar, O., and Zwick, E. (2024b). Lessons from the biggest business tax cut in us history. *Journal of Economic Perspectives*, 38(3):61–88.

Colmer, J., Martin, R., Muûls, M., and Wagner, U. J. (2024). Does pricing carbon mitigate climate change? firm-level evidence from the european union emissions trading system. *Review of Economic Studies*.

Copeland, B. R. and Taylor, M. S. (2005). *Trade and the environment: Theory and evidence*. Princeton university press.

Costinot, A. and Rodríguez-Clare, A. (2014). Trade theory with numbers: Quantifying the consequences of globalization. In *Handbook of International Economics*, volume 4, pages 197–261. Elsevier.

Crippa, M., Guizzardi, D., Solazzo, E., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Banja, M., Olivier, J., Grassi, G., Rossi, S., et al. (2021). Ghg emissions of all world countries. *Publications Office of the European Union*.

Dávila, E. and Hébert, B. (2023). Optimal corporate taxation under financial frictions. *The Review of Economic Studies*, 90(4):1893–1933.

De Loecker, J., Eeckhout, J., and Unger, G. (2020). The rise of market power and the macroeconomic implications. *The Quarterly Journal of Economics*, 135(2):561–644.

De Mooij, R. A. (2012). Tax biases to debt finance: Assessing the problem, finding solutions. *Fiscal Studies*, 33(4):489–512.

Dekle, R., Eaton, J., and Kortum, S. (2008). Global rebalancing with gravity: Measuring the burden of adjustment. *IMF Staff Papers*, 55(3):511–540.

Dolphin, G. and Xiahou, Q. (2022). World carbon pricing database: sources and methods. *Scientific Data*, 9(1):573.

Dyreng, S. D., Hanlon, M., Maydew, E. L., and Thornock, J. R. (2017). Changes in corporate effective tax rates over the past 25 years. *Journal of Financial Economics*, 124(3):441–463.

Faccio, M. and Xu, J. (2015). Taxes and capital structure. *Journal of Financial and Quantitative Analysis*, 50(3):277–300.

Fuest, C., Peichl, A., and Siegloch, S. (2018). Do higher corporate taxes reduce wages? micro evidence from germany. *American Economic Review*, 108(2):393–418.

Garcia-Bernardo, J., Janský, P., and Zucman, G. (2024). Did the tax cuts and jobs act reduce profit shifting by us multinational companies? *NBER Working Paper 30086*.

Giglio, S., Kelly, B., and Stroebel, J. (2021). Climate finance. *Annual Review of Financial Economics*, 13(1):15–36.

Giroud, X. and Rauh, J. (2019). State taxation and the reallocation of business activity: Evidence from establishment-level data. *Journal of Political Economy*, 127(3):1262–1316.

Golosov, M., Hassler, J., Krusell, P., and Tsyvinski, A. (2014). Optimal taxes on fossil fuel in general equilibrium. *Econometrica*, 82(1):41–88.

Graham, J. R. (2000). How big are the tax benefits of debt? *The Journal of Finance*, 55(5):1901–1941.

Graham, J. R., Raedy, J. S., and Shackelford, D. A. (2012). Research in accounting for income taxes. *Journal of Accounting and Economics*, 53(1-2):412–434.

Greenstone, M. (2002). The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 clean air act amendments and the census of manufactures. *Journal of political economy*, 110(6):1175–1219.

Grossman Gene, M. and Krueger, A. B. (1993). Environment Impacts of a North American Free Trade Agreement. *The US Mexico Free Trade Agreement*.

Harberger, A. C. (1962). The incidence of the corporation income tax. *Journal of Political Economy*, 70(3):215–240.

Heider, F. and Ljungqvist, A. (2015). As certain as debt and taxes: Estimating the tax sensitivity of leverage from state tax changes. *Journal of Financial Economics*, 118(3):684–712.

House, C. L. and Shapiro, M. D. (2008). Temporary investment tax incentives: Theory with evidence from bthe pollution premiumonus depreciation. *American Economic Review*, 98(3):737–68.

Huizinga, H., Laeven, L., and Nicodeme, G. (2008). Capital structure and international debt shifting. *Journal of Financial Economics*, 88(1):80–118.

IMF (2016). Tax policy, leverage, and macroeconomic stability. *IMF staff report*.

Ivanov, I., Pettit, L., and Whited, T. M. (2024). Taxes depress corporate borrowing: Evidence from private firms. *NBER Working Paper 32398*.

Jorgenson, D. W. (1963). Capital theory and investment behavior. *American Economic Review*, 53(2):247–259.

Kemsley, D. and Nissim, D. (2002). Valuation of the debt tax shield. *The Journal of Finance*, 57(5):2045–2073.

Kennedy, P. J., Dobridge, C., Landefeld, P., and Mortenson, J. (2024). The efficiency-equity tradeoff of the corporate income tax: Evidence from the tax cuts and jobs act. *Yale University Mimeo*.

King, M., Tarbush, B., and Teytelboym, A. (2019). Targeted carbon tax reforms. *European Economic Review*, 119:526–547.

King, M. A. (1974). Taxation and the cost of capital. *The Review of Economic Studies*, 41(1):21–35.

Laux, R. C. (2013). The association between deferred tax assets and liabilities and future tax payments. *The Accounting Review*, 88(4):1357–1383.

Levinson, A. (2009). Technology, international trade, and pollution from us manufacturing. *American Economic Review*, 99(5):2177–2192.

Liu, E. (2019). Industrial policies in production networks. *Quarterly Journal of Economics*, 134(4):1883–1948.

Liu, Y. and Mao, J. (2019). How do tax incentives affect investment and productivity? firm-level evidence from china. *American Economic Journal: Economic Policy*, 11(3):261–91.

Lorenzoni, G. (2008). Inefficient credit booms. *The Review of Economic Studies*, 75(3):809–833.

Maffini, G., Xing, J., and Devereux, M. P. (2019). The impact of investment incentives: Evidence from uk corporation tax returns. *American Economic Journal: Economic Policy*, 11(3):361–89.

Metcalf, G. E. (2018). The impact of removing tax preferences for us oil and natural gas production: Measuring tax subsidies by an equivalent price impact approach. *Journal of the Association of Environmental and Resource Economists*, 5(1):1–37.

Metcalf, G. E. and Stock, J. H. (2020). Measuring the macroeconomic impact of carbon taxes. *AEA Papers and Proceedings*, 110:101–06.

Moon, T. S. (2022). Capital gains taxes and real corporate investment: Evidence from korea. *American Economic Review*, 112(8):2669–2700.

Oehmke, M. and Opp, M. M. (2022). Green capital requirements. *Swedish House of Finance Research Paper*, (22-16).

Ohrn, E. (2018). The effect of corporate taxation on investment and financial policy: Evidence from the dpad. *American Economic Journal: Economic Policy*, 10(2):272–301.

Parry, I. W. H. and Small, K. A. (2005). Does britain or the united states have the right gasoline tax? *American Economic Review*, 95(4):1276–1289.

Peters, R. H. and Taylor, L. A. (2017). Intangible capital and the investment-q relation. *Journal of Financial Economics*, 123(2):251–272.

Piazzesi, M., Papoutsi, M., and Schneider, M. (2022). How unconventional is green monetary policy? *Stanford University Mimeo.*

Pindyck, R. S. (2019). The social cost of carbon revisited. *Journal of Environmental Economics and Management*, 94:140–160.

Rajan, R. G. and Zingales, L. (1995). What do we know about capital structure? some evidence from international data. *The Journal of Finance*, 50(5):1421–1460.

Rambachan, A. and Roth, J. (2023). A More Credible Approach to Parallel Trends. *The Review of Economic Studies*, 90(5):2555–2591.

Rennert, K., Errickson, F., Prest, B. C., Rennels, L., Newell, R. G., Pizer, W., Kingdon, C., Wingenroth, J., Cooke, R., Parthum, B., et al. (2022). Comprehensive evidence implies a higher social cost of co2. *Nature*, 610(7933):687–692.

Sanati, A. (2022). How does removing the tax benefit of debt affect firms? evidence from the 2017 us tax reform. *American University Mimeo.*

Shapiro, J. S. (2020). The environmental bias of trade policy. *The Quarterly Journal of Economics*, 136(2):831–886.

Shapiro, J. S. and Walker, R. (2018). Why is pollution from us manufacturing declining? the roles of environmental regulation, productivity, and trade. *American Economic Review*, 108(12):3814–3854.

Stern, N. (2006). The economics of climate change: the stern review. *Cambridge University Press.*

Stiglitz, J. E. (1973). Taxation, corporate financial policy, and the cost of capital. *Journal of Public Economics*, 2(1):1–34.

Suárez Serrato, J. C. and Zidar, O. (2016). Who benefits from state corporate tax cuts? a local labor markets approach with heterogeneous firms. *American Economic Review*, 106(9):2582–2624.

Van Binsbergen, J. H., Graham, J. R., and Yang, J. (2010). The cost of debt. *The Journal of Finance*, 65(6):2089–2136.

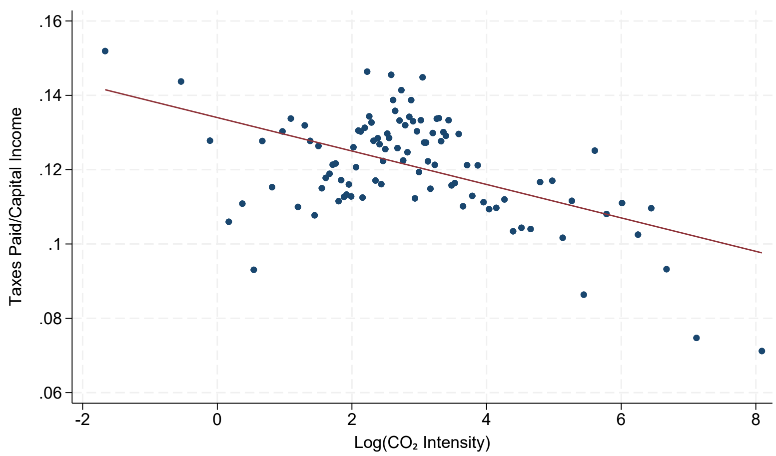
vom Lehn, C. and Winberry, T. (2021). The investment network, sectoral comovement, and the changing u.s. business cycle. *The Quarterly Journal of Economics*, 137(1):387–433.

Weitzman, M. L. (2009). On modeling and interpreting the economics of catastrophic climate change. *The review of economics and statistics*, 91(1):1–19.

Yagan, D. (2015). Capital tax reform and the real economy: The effects of the 2003 dividend tax cut. *American Economic Review*, 105(12):3531–63.

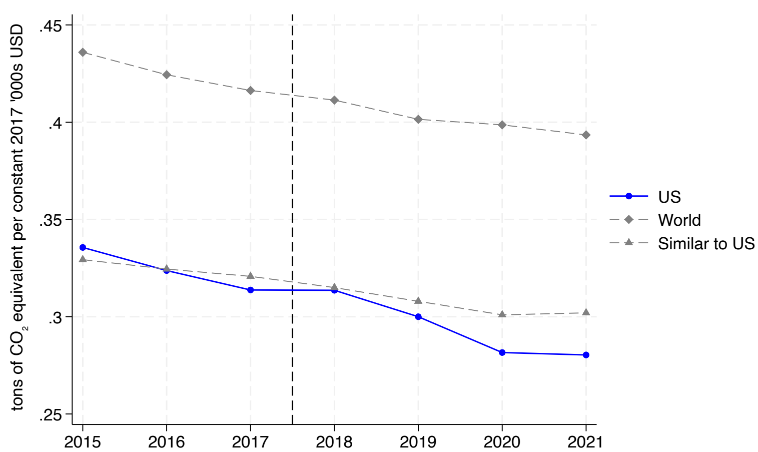
Zwick, E. and Mahon, J. (2017). Tax policy and heterogeneous investment behavior. *American Economic Review*, 107(1):217–48.

Figure 1. The tax advantage of CO_2-intensive firms



Note: This figure reports the relationship between income taxes paid over capital income on the logarithm of CO_2 intensity over the sample period 2003-2021, after absorbing year fixed effects and controlling for capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory 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 2. Aggregate CO_2 intensity of U.S. economy

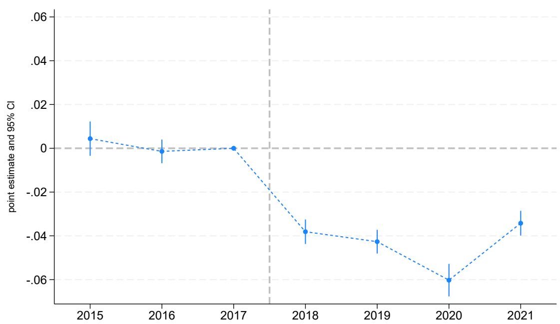


Note: This figure presents aggregate CO_2 intensity (CO_2/GDP) from 2015 to 2021 for the U.S., the World, and a group of countries with emission intensity similar to the U.S. prior to the reform. CO_2/GDP for this group is calculated as the average across countries within a 10% range of U.S. CO_2 intensity 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.

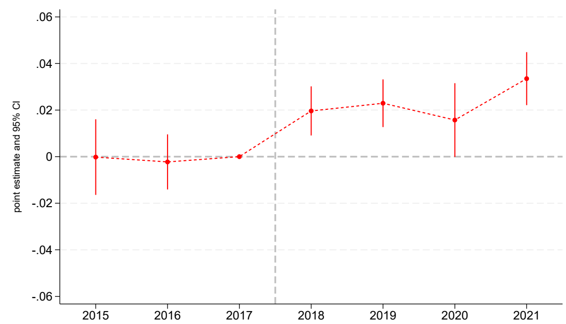
Figure 3. Federal tax cut and effective tax rates of dirty versus clean firms

Panel A. Federal income taxes

(a) Year Dummies

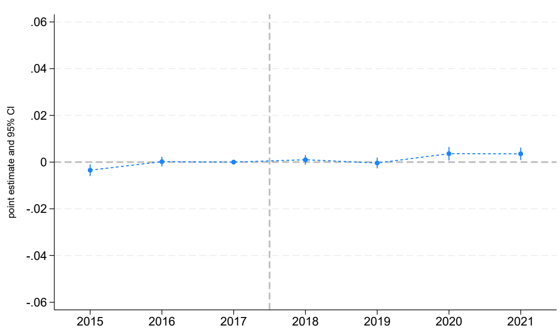


(b) Year Dummies × Dirty Firms

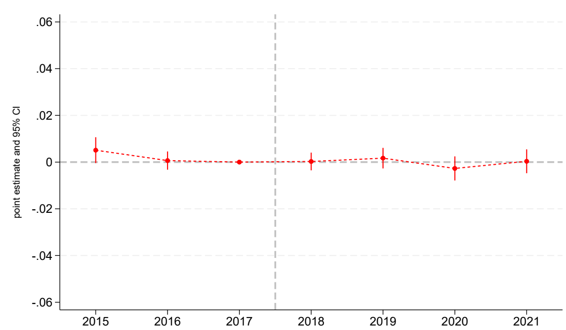


Panel B. Other income taxes

(c) Year Dummies



(d) Year Dummies × Dirty Firms



Note: This figure presents estimates from panel regressions of effective tax rates for dirty versus clean firms around the implementation of the U.S. federal income tax rate cut. The left panels plot estimated coefficients for the year dummies, β_τ, with 95% confidence intervals, while the right panels plot estimated coefficients for the interaction of year dummies with a dummy for dirty firms, $\beta_{Dirty,\tau}$, with 95% confidence intervals, from the following regression:

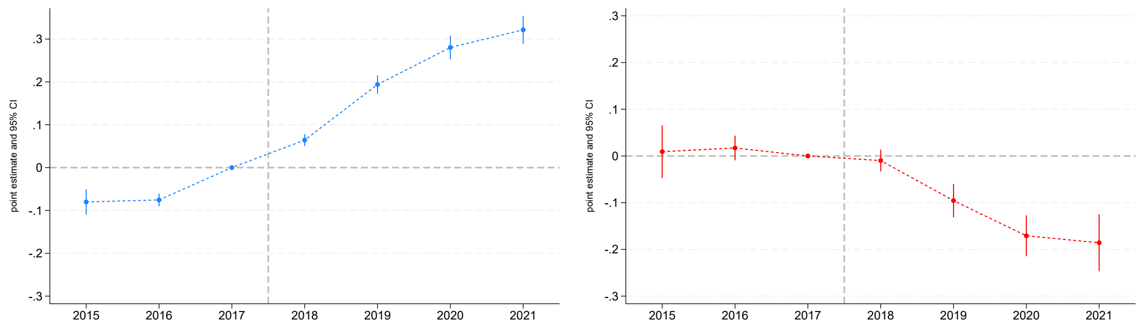
$$Y_{f,t} = \sum_{\tau=2015}^{2021} (\beta_\tau + \beta_{Dirty,\tau} \times CO_2Intensive_{f,2017}) \times Year_\tau + \alpha_f + \epsilon_{f,t},$$

where the dependent variable is either federal income taxes scaled by capital income (Panel A) or other income taxes scaled by capital income (Panel B), $CO_2Intensive_{f,2017}$ is a dummy for dirty firms, defined as those in the top quartile of the CO_2 intensity distribution in 2017, $Year_\tau$ are year dummies around the implementation of the federal income tax rate cut, and α_f are firm fixed effects. Given that the tax cut affects firms starting in 2018, we identify the 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 4. Federal tax cut and asset growth of dirty versus clean firms

Log assets

(a) Year Dummies **(b)** Year Dummies × Dirty Firms



Note: This figure presents estimates from panel regressions of the logarithm of assets for dirty versus clean firms around the implementation of the U.S. federal income tax rate cut. The left panel plots estimated coefficients for the year dummies, β_τ, with 95% confidence intervals, while the right panel plots estimated coefficients for the interaction of year dummies with a dummy for dirty firms, $\beta_{Dirty,\tau}$, with 95% confidence intervals, from the following regression:

$$Y_{f,t} = \sum_{\tau=2015}^{2021} (\beta_\tau + \beta_{Dirty,\tau} \times CO_2Intensive_{f,2017}) \times Year_\tau + \alpha_f + \epsilon_{f,t},$$

where the dependent variable is the logarithm of assets, $CO_2Intensive_{f,2017}$ is a dummy for dirty firms, defined as those in the top quartile of the CO_2 intensity distribution in 2017, $Year_\tau$ are year dummies around the implementation of the federal income tax rate cut, and α_f are firm fixed effects. Given that the tax cut affects firms starting in 2018, we identify the effects of the policy relative to the baseline year 2017. The sample period is 2015-2021. Standard errors are clustered at the firm level.

Table 1. Summary statistics

	Obs.	Mean	SD	p1	p50	p99
CO_2 emissions						
CO_2 Intensity (tCO_2/k$)	11223	0.099	0.362	0.000	0.017	1.452
Taxes paid by U.S. corporations						
Taxes/Capital Income	11223	0.121	0.092	-0.063	0.111	0.412
Taxes/Pretax Income	11223	0.233	0.183	0.000	0.208	1.000
Pretax Income/Capital Income	11223	0.548	0.219	0.032	0.574	1.011
Other variables						
Sales (in USD Million)	11223	11408	30970	117	3285	141576
Firm Age	11223	43.273	25.971	3	40	121
Capital Income/Sales	11223	0.240	0.153	0.024	0.203	0.712
Share Foreign Profits	11223	0.379	0.578	-1.911	0.300	3.072
Tax Rate	11223	0.321	0.052	0.218	0.331	0.406
Debt/Assets	11223	0.276	0.185	0.000	0.259	0.874
Interests/Capital Income	11223	0.098	0.094	0.000	0.073	0.450
PPE/Assets	11223	0.229	0.192	0.016	0.167	0.844

Note: This table presents summary statistics for our sample, which consists of 11,223 firm-year observations between 2003 and 2021. There are 1,483 Compustat firms with positive capital income and pretax income in this sample for which we observe CO_2 emissions in at least one year over the sample period. 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 output. Taxes are Compustat item TXPD. Interest payments are Compustat item XINT. Capital Income is sales (Compustat item SALE) minus cost of goods sold (Compustat item COGS) minus selling, general, and administrative expenses (Compustat item XSGA) plus research and development expenses (Compustat XRD). Pretax Income is measured net of special items. The statutory tax rate is $\tau_{f,t}$ defined in Online Appendix B. Debt is the sum of short term debt (Compustat item DLC) and long term debt (Compustat item DLTT). Share Foreign Profits is the ratio of foreign pretax income over total pretax income. Property, plant, and equipment (PPE) is Compustat item PPENT.

Table 2. CO_2-intensive firms and corporate income taxes

	(1)	(2)	(3)	(4)	(5)	(6)
	Taxes/Capital Income		Taxes/Pretax Income		Pretax Income/Capital Income	
CO_2 Intensity	-0.021	-0.022	-0.012	-0.013	-0.049	-0.053
	(0.006)	(0.006)	(0.011)	(0.010)	(0.009)	(0.010)
Year FE	Y	Y	Y	Y	Y	Y
Firm Controls	N	Y	N	Y	N	Y
R^2	0.049	0.098	0.011	0.052	0.036	0.091
N	11223	11223	11223	11223	11223	11223

Note: This table presents estimates from pooled OLS specifications of income taxes paid over capital income (columns 1 and 2), income taxes paid over pretax income (columns 3 and 4), and pretax income over capital income (columns 5 and 6) on CO_2 intensity. All columns include year fixed effects, whereas columns (2), (4), and (6) include additional controls for capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory tax rate. Standard errors clustered at the firm level are reported in parentheses.

Table 3. CO_2-intensive firms, debt, and interest tax shield

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variables Scaled by Capital Income					
	Debt		Interests		Pretax Inc.+Interests	
CO_2 Intensity	0.748	0.734	0.059	0.059	0.010	0.006
	(0.099)	(0.098)	(0.006)	(0.006)	(0.008)	(0.010)
Year FE	Y	Y	Y	Y	Y	Y
Firm Controls	N	Y	N	Y	N	Y
R^2	0.095	0.148	0.066	0.123	0.019	0.116
N	11223	11223	11223	11223	11223	11223

Note: This table presents estimates from pooled OLS specifications of debt (columns 1 and 2), interest payments (columns 3 and 4), and the sum of pretax income and interest payments (columns 5 and 6), all scaled by capital income, on CO_2 intensity. All columns include year fixed effects, whereas columns (2), (4), and (6) include additional controls for capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory tax rate. Standard errors clustered at the firm level are reported in parentheses.

Table 4. Tangible capital and the tax advantage of CO_2-intensive firms

	(1)	(2)	(3)	(4)
	Dependent Variables Scaled by Capital Income			
	PPE	Debt	Pretax Income	Taxes Paid
CO_2 Intensity	1.883	-0.000	0.002	-0.004
	(0.282)	(0.144)	(0.011)	(0.005)
PPE/Capital Income		0.390	-0.029	-0.010
		(0.026)	(0.003)	(0.001)
Year FE	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y
R^2	0.179	0.279	0.137	0.127
N	11223	11223	11223	11223

Note: This table presents estimates from pooled OLS specifications of PPE, debt, pretax income, and taxes paid, all scaled by capital income, on CO_2 intensity. 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 tax rate. Columns (2) to (4) also include the ratio of PPE over capital income as additional control variable. Standard errors clustered at the firm level are reported in parentheses.

Table 5. Decomposing the relationship between CO_2 intensity and tangible capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent Variables Scaled by Total Assets						
	Gross PPE	Machinery	Buildings	Leases	Land	ConstrProg	Other
CO_2 Intensity	0.395	0.355	0.007	-0.021	0.009	0.016	0.001
	(0.060)	(0.050)	(0.009)	(0.005)	(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	0.111	0.036	0.063	0.019
N	7418	7418	7418	7418	7418	7418	7418
Dep Var Mean	0.456	0.276	0.093	0.028	0.017	0.012	0.017

Note: This table presents estimates from pooled OLS specifications where the dependent variables correspond to the different components of plant, property, 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 is 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 differ from total PPE by more than 10%. 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 tax rate. 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 6. Federal tax cut, taxes paid, and firm total assets

	(1)	(2)	(3)	(4)
	Federal Taxes/Capital Income		Log Assets	
Post Tax Cut × CO_2 Intensive$_{17}$	0.024		-0.116	
	(0.004)		(0.019)	
Post Tax Cut × CO_2 Intensity$_{17}$		0.014		-0.057
		(0.003)		(0.012)
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
R^2	0.536	0.535	0.978	0.978
N	9997	9997	9997	9997
Implied Semi-Elasticity			-4.8	-4.1

Note: This table presents estimates from panel regressions of federal income taxes scaled by capital income and asset growth, respectively, on the interaction of pre-reform CO_2 intensity with a dummy equal to one for years following the federal tax cut. All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The specifications restrict the sample to firms with positive capital income. The last row in columns (3) and (4) reports the implied semi-elasticity of log assets to a 1 percentage point increase in the ratio of federal incomes taxes to capital income.

Table 7. Model-generated data: Tax cut, taxes paid, and firm total assets

	ΔTaxes/Capital Income	ΔLog Assets
CO_2 Intensity	0.025	-0.077
	(0.004)	(0.009)
N	378	378
Implied Semi-Elasticity		-3.08

Note: This table replicates the analysis presented in columns (2) and (4) of Table 6 using model-generated data across 378 BEA sectors. Specifically, we estimate $\Delta Y_i = \beta \times CO_2 Intensity_i + \epsilon_i$, where ΔY_i denotes, for sector i, the change in the ratio of income taxes to capital income in column (1), and the change in log assets in column (2), as the economy moves from a steady state with a corporate tax rate of 35% to one with a corporate tax rate of 21%. The last row reports the implied semi-elasticity of log assets to a 1 percentage point increase in the ratio of federal incomes taxes to capital income.

Table 8. Policy counterfactuals

Panel A:	Lower Corporate Income Tax				
	ρ				
	1	0.8	0.6	0.4	0.2
Change GDP (%)	5.61	5.61	5.60	5.60	5.60
Change Consumption (%)	4.22	4.22	4.22	4.22	4.22
Change Emissions (%)	4.51	4.16	3.80	3.45	3.10
Scale	5.94	5.93	5.92	5.92	5.91
CO_2 Intensity	-1.43	-1.77	-2.12	-2.47	-2.81

Panel B:	No Debt Tax Shield				
	ρ				
	1	0.8	0.6	0.4	0.2
Change GDP (%)	0.00	-0.01	-0.01	-0.02	-0.02
Change Consumption (%)	0.22	0.22	0.22	0.22	0.22
Change Emissions (%)	-1.26	-1.88	-2.49	-3.09	-3.70
Scale	-0.08	-0.09	-0.10	-0.11	-0.12
CO_2 Intensity	-1.18	-1.79	-2.39	-2.98	-3.58

Note: This table presents the results of two policy counterfactuals on the change in GDP, consumption, CO_2 emissions, and CO_2 intensity. The effect on CO_2 emissions is decomposed as the sum of two components: the change in real output ("Scale") and the change in the economy's CO_2 intensity ("CO_2 intensity"). Panel A compares the steady state of the original economy with $\tau_p = 0.35$ to the one of a counterfactual economy in which $\tau_p = 0.21$. Panel B compares the steady state of the original economy to the one of a counterfactual economy in which the tax shield of debt is eliminated and, at the same time, the corporate income tax rate is reduced from $\tau_p = 0.35$ to $\tau_p = 0.30$. The simultaneous reduction in the income tax rate is chosen to ensure that GDP remains unchanged in the baseline Cobb-Douglas case ($\rho = 1$). We report the results for different values of ρ, i.e., the elasticity of substitution between equipment capital and the fuel bundle.

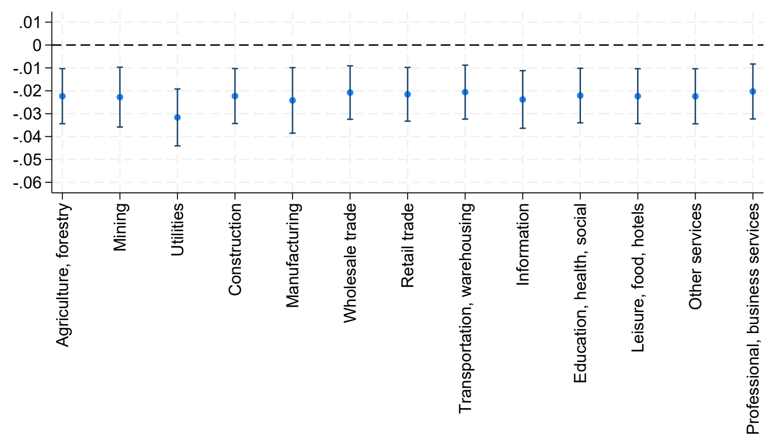
Online Appendix

The Environmental Bias of Corporate Income Taxation

Luigi Iovino and Thorsten Martin and Julien Sauvagnat

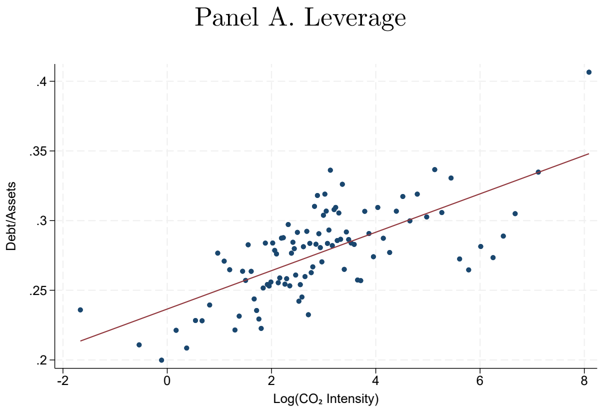
A Additional Figures and Tables

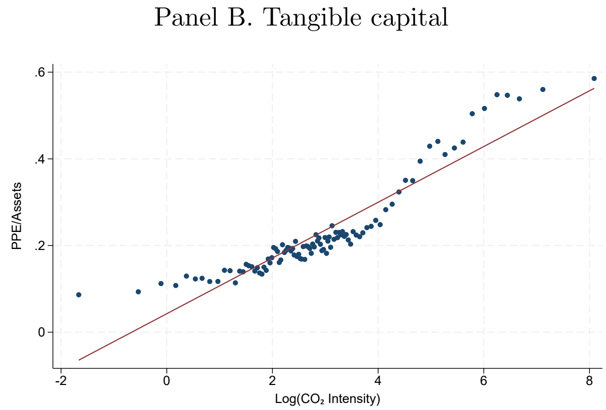
Figure A.1. The tax advantage of CO_2-intensive firms - leave-one-industry-out



Note: This figure displays estimates of pooled OLS regressions of 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 capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory 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.2. CO_2 intensity, leverage, and tangible capital



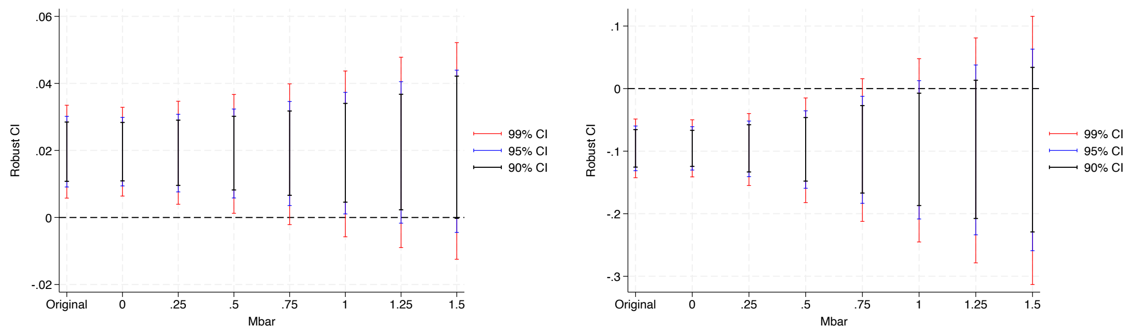


Note: This scatter plot reports the relationship between either debt over assets (in Panel A) or property, plant, and equipment over assets (in Panel B) on the logarithm of CO_2 intensity over the sample period 2003-2021, after absorbing year fixed effects and controlling for capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory tax rate. Each dot represents an equal size bin of firms' CO_2 intensity (100 bins). Debt over assets is defined as Compustat variables DLC and DLTT over assets. Property, plant, and equipment is Compustat item PPENT over assets. Data on CO_2 emissions are from Trucost. Financial data are from Compustat.

Figure A.3. Sensitivity analysis for treatment confidence intervals

Panel A. Federal taxes over capital income

Panel B. Log assets

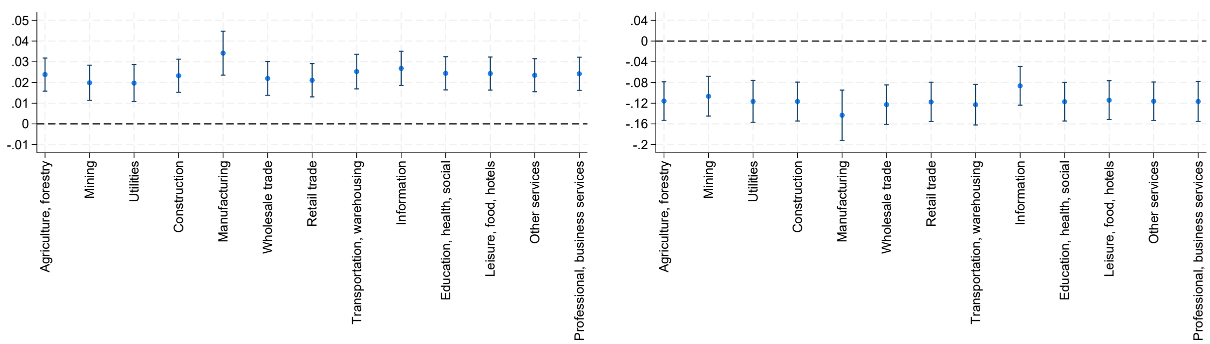


Note: This figure presents sensitivity analyses for treatment confidence intervals following Rambachan and Roth (2023) for the two main outcomes of the event-study specifications presented in the main text, namely federal income taxes over capital income (in 2018) and the logarithm of firm assets (in 2019, the first year asset effects are observed) following the federal tax 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.

Figure A.4. Federal tax cut, taxes, and firm assets - leave-one-industry-out

Panel A. Federal taxes over capital income

Panel B. Log assets



Note: This figure presents estimates from panel regressions of federal income taxes scaled by capital income (Panel A) and log assets (Panel B) on the interaction of the pre-reform dummy for dirty firms, defined as those in the top quartile of the CO_2 intensity distribution in 2017, interacted with the post dummy in leave-one-out specifications in which we exclude observations for firms in a given BEA sector. The specification includes firm and year fixed effects. Standard errors are clustered at the firm level.

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	-0.031	-0.030	-0.020	-0.005	-0.006	
	(0.008)	(0.008)	(0.006)	(0.005)	(0.001)	(0.001)	
Log(CO_2 Emissions)							-0.004
							(0.001)
Year FE	Y	Y	Y	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y	Y	Y	Y
R^2	0.099	0.083	0.100	0.098	0.026	0.102	0.096
N	6884	8502	11223	11223	13393	13393	11223

Note: This table presents variants of the specification presented in Column (2) of Table 2. 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 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 scope 1 emissions as independent variable. Standard errors clustered at the firm level are reported in parentheses.

Table A.2. CO_2 intensity and intangible capital

	(1)	(2)	(3)	(4)
	Dependent Variables Scaled by Total Assets			
	Total Intangibles	Balance-Sheet Intangibles	Knowledge Capital	Organization Capital
CO_2 Intensity	-0.242	-0.106	-0.056	-0.082
	(0.040)	(0.018)	(0.010)	(0.015)
Year FE	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y
R^2	0.123	0.069	0.288	0.143
N	11210	11210	11210	11210

Note: This table presents estimates from pooled OLS specifications of measures of intangible capital, all scaled by firm total assets, on CO_2 intensity. 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 tax rate. The measures of intangible capital are from Peters and Taylor (2017) and obtained through WRDS. Standard errors clustered at the firm level are reported in parentheses.

Table A.3. CO_2-intensive firms and deferred income taxes

	(1)	(2)	(3)
	Deferred Taxes/Capital Income		
CO_2 Intensity	0.009	0.009	0.003
	(0.003)	(0.003)	(0.003)
PPE/Capital Income			0.003
			(0.001)
Year FE	Y	Y	Y
Firm Controls	N	Y	Y
R^2	0.021	0.026	0.028
N	11223	11223	11223

Note: This table presents estimates from pooled OLS specifications of deferred income taxes over capital income on CO_2 intensity. All columns include year fixed effects, whereas columns (2-3) include additional controls for capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory tax rate. Column (3) also includes the ratio of PPE over capital income as additional control variable. Standard errors clustered at the firm level are reported in parentheses.

Table A.4. Tangible capital, debt, pretax income, taxes and CO_2 intensity - Industry effects

	(1)	(2)	(3)	(4)
	Dependent Variables Scaled by Capital Income			
	PPE	Debt	Pretax Income	Taxes Paid
Implied Industry CO_2 Intensity	2.607	0.797	-0.061	-0.028
	(0.253)	(0.120)	(0.012)	(0.007)
Firm Residual CO_2 Intensity	1.121	0.589	-0.040	-0.015
	(0.270)	(0.116)	(0.011)	(0.007)
Year FE	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y
R^2	0.223	0.150	0.092	0.100
N	11200	11200	11200	11200

Note: This table presents estimates from pooled OLS specifications of property, plant, and equipment, total debt, pretax income, and 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 capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory tax rate. Standard errors clustered at the firm level are reported in parentheses.

Table A.5. Tangible capital, debt, pretax income, taxes and CO_2 intensity - Energy sector

	(1)	(2)	(3)	(4)	(5)
		Dependent Variables Scaled by Capital Income			
	CO_2 Intensity	PPE	Debt	Pretax Income	Taxes Paid
Fossil Fuel Capacity	1.320	1.319	1.276	-0.076	-0.016
	(0.292)	(0.184)	(0.212)	(0.010)	(0.004)
Year FE	Y	Y	Y	Y	Y
Firm Controls	Y	Y	Y	Y	Y
R^2	0.473	0.354	0.422	0.235	0.288
N	588	588	588	588	588

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 taxes paid, all scaled by capital income, on fossil fuel production capacity within the energy sector. CO_2 intensity is measured using data on CO_2 emissions from stationary sources reported under the EPA Greenhouse Gas Reporting program scaled by output. Fossil fuel capacity is measured in gigawatts using EIA data on energy generators reported under the form 860 scaled by output. 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 capital income over sales, firm size, firm age, the share of foreign profits, and the firm-level statutory tax rate. Standard errors clustered at the firm level are reported in parentheses.

Table A.6. Federal tax cut and firm total capital

	(1)	(2)
	Log (Tangible+Intangible Capital)	
Post Tax Cut × CO_2 Intensive$_{17}$	-0.112	
	(0.018)	
Post Tax Cut × CO_2 Intensity$_{17}$		-0.057
		(0.015)
Firm FE	Y	Y
Year FE	Y	Y
R^2	0.983	0.983
N	9958	9958

Note: This table presents estimates from panel regressions of the logarithm of the sum of tangible and intangible capital on the interaction of pre-reform CO_2 intensity with a dummy that equals one for years following the federal tax cut. We measure tangible and intangible capital as in Peters and Taylor (2017). All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The specifications restrict the sample to firms with positive capital income.

Table A.7. Federal tax cut and firm leverage

	(1)	(2)
	Leverage (Debt/Assets)	
Post Tax Cut × CO_2 Intensive$_{17}$	-0.031	
	(0.006)	
Post Tax Cut × CO_2 Intensity$_{17}$		-0.016
		(0.003)
Firm FE	Y	Y
Year FE	Y	Y
R^2	0.845	0.845
N	9958	9958

Note: This table presents estimates from panel regressions of leverage, defined as the debt-to-asset ratio, on the interaction of pre-reform CO_2 intensity with a dummy that equals one for years following the federal tax cut. All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The specifications restrict the sample to firms with positive capital income.

Table A.8. Federal tax cut, taxes paid, and firm total assets – Robustness

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Subsamples - Excluding:							US+Foreign
	Above Interest Deduct	Multinat.	Tax Loss Forward	Manuf.	Trends other Reform Changes	Control for Carbon Taxes	Control for Tariffs	Control for Industry Trends
	Federal Taxes/Capital Income							
Post Tax Cut × CO_2 Intensive$_{17}$	0.024	0.032	0.040	0.036	0.028	0.024	0.023	0.001
	(0.004)	(0.005)	(0.006)	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)
Post Tax Cut × CO_2 Intensive$_{17}$ × US								0.014
								(0.005)
R^2	0.538	0.583	0.553	0.562	0.552	0.536	0.536	0.713
N	8887	5438	4692	5434	9997	9997	9997	33732
	Log Assets							
Post Tax Cut × CO_2-intensive$_{17}$	-0.121	-0.119	-0.097	-0.141	-0.125	-0.114	-0.108	-0.004
	(0.020)	(0.025)	(0.024)	(0.025)	(0.019)	(0.019)	(0.019)	(0.012)
Post Tax Cut × CO_2-intensive$_{17}$ × US								-0.081
								(0.020)
R^2	0.981	0.978	0.985	0.978	0.979	0.978	0.978	0.985
N	8887	5438	4692	5434	9997	9997	9997	33732
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Deduct, Multi, Loss fwd, Manuf -Year FE					Y			
Carbon Taxes						Y		
Tariffs							Y	
Industry-Year FE								Y
Country-Year FE								Y

Note: This table presents variants of the specification presented in columns (1) and (3) of Table 6. All regressions include firm and year fixed effects and restrict the sample to firms with positive capital income. Standard errors are clustered at the firm level. In columns (1-4), we exclude from the sample respectively firms that exceed the interest deductibility limit in 2017, multinational firms (defined as those with more than 20% of their sales outside the U.S.), firms with loss carryforwards representing more than 1% of their sales in 2017, and manufacturing firms. In column (5), we add in the full sample pre-reform controls for multinational status, loss carry-forward, high interest coverage ratios, and manufacturing status, interacted with year fixed effects. In columns (6) and (7), we control for firm-level exposure to changes in tariff policies and carbon taxes, respectively. In column (8), we augment our regression with firms located in other countries that have not experienced a change in the statutory tax rate over the sample period 2015-2021, and estimate a triple differences specification comparing the outcomes of dirty versus clean firms, pre- versus post-2018, in the U.S. versus in foreign countries. We include industry-year and country-year fixed effects in this specification.

B Construction of firm-level statutory tax rates

The statutory 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 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 tax rate in U.S. state s in year t, $\omega^{f,Foreign}_{c,t}$ is the tax weight of firm t in foreign country c and year t, and $\tau_{c,t}$ is the tax rate in foreign country c in year t.

For the domestic tax weight $\omega^{f,Domestic}_{s,t}$, we follow Giroud and Rauh (2019) 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 (2019) on apportionment factors, which we extend until 2021. We use information gathered by Infogroup 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 tax rates, we take the data shared by Giroud and Rauh (2019) and Baker et al. (2023), which we extend until 2021. Finally, we use Factset to obtain the distribution of U.S. multinationals' foreign sales across countries. We obtain data on tax rates for each foreign country and year from the Tax Foundation.

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 without changing the overall tax burden.[32] Since investments in machinery and equipment are typically eligible for bonus depreciation, this provision can also act as an implicit subsidy for CO_2-intensive firms.[33] Even though we do not directly observe investments eligible for bonus depreciation in Compustat, we can assess its impact indirectly through deferred income taxes, as bonus depreciation is a major component of deferred taxes (see, e.g, Laux, 2013). In Online Appendix Table A.3, we confirm the positive and statistically significant relationship between CO_2 intensity and the ratio of deferred income taxes to capital income. In columns (1-2), the coefficient is equal to 0.009, both without and with controls for firm size, age, profitability, foreign profit share, and statutory rates. We then add in column (3) the ratio of property, plant, and equipment over capital income as a control to test whether differences in tangible capital (which includes eligible investment for bonus depreciation) can explain this relationship. Strikingly, the coefficient on CO_2 intensity becomes small and statistically insignificant, whereas the coefficient on PPE over capital income is positive and statistically significant at the 1% level.

These results confirm that CO_2-intensive firms benefit from higher tax deferrals. However, the present value of these deferrals is much smaller than the baseline effect on the level of taxes paid reported in Table 2. The coefficient of 0.009 indicates that 1 ton of CO_2 per 1,000 USD in output results in a deferral of 0.009 in taxes, compared to a reduction of 0.022 in taxes in our main result. To compare these values, 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, making the deferral benefit roughly eight times smaller than the direct tax reduction benefit.

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 Table 5), we do not expect property taxes to disproportionately affect CO_2-intensive firms.[34]

[32]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.

[33]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.

[34]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 Other Provisions of TCJA

In this section, we provide a brief overview of the other significant provisions of the TCJA impacting corporations, with their predicted U.S. budgetary impact over the period 2018-2027 in USD billion as estimated by the Joint Committee on Taxation in 2017 (see JCX-67-17 for more details). The predicted budgetary impact for the cut in the federal income tax rate was -1348 billion.

- **Taxation of Foreign Income:** The TCJA introduced several changes to the taxation of corporate income earned abroad, including: (a) deductions for certain dividends received by domestic corporations from certain foreign corporations (-223 billion) (b) a one-time tax on previously accumulated foreign income and the removal of the tax on repatriated income (338 billion), (c) a minimum tax on foreign income above a threshold return on tangible assets, known as Global Intangible Low-Taxed Income (112 billion), (d) a minimum tax on deductible related-party transactions to U.S. subsidiaries, known as the Base Erosion and Anti-Abuse Tax (149 billion), (e) a reduced tax rate on income from foreign sales, referred to as Foreign Derived Intangible Income (-63 billion).

- **Interest Deductions:** The TCJA limited net interest payment deductions to 30% of interest income adjusted taxable income (+253 billion).

- **Bonus Depreciation:** The TCJA temporarily allowed corporations to immediately deduct 100% of the cost of newly acquired eligible capital investments, an increase from 50% before the TCJA, scheduled to phase out starting in 2023 (-86 billion).

- **Net Operating Loss Deductions:** The TCJA restricted net operating loss deductions to 80% of a corporation's taxable income (+201 billion).

- **Domestic Production Activities Deduction (DPAD):** The TCJA repealed the DPAD, which offered a tax deduction to corporations that manufacture goods within the United States (+98 billion).

E Proofs

E.1 Baseline Case

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

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

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

$$c^f_{i,t} = \left(\frac{p^f_{i,t}}{p_{i,t}}\right)^{-\sigma} c_{i,t}, \tag{E.1}$$

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

$$p_{i,t} c_{i,t} = \theta_i C_t, \tag{E.2}$$

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

$$U'(C_t) = (1 + \tau_c)\varphi_t. \tag{E.3}$$

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

$$V'(L_t) = (1 - \tau_h)\varphi_t w_t. \tag{E.4}$$

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

$$r^e_{i,t+1} \equiv \frac{d^f_{i,t+1} + Q^f_{i,t+1}}{Q^f_{i,t}} - 1 = \frac{(\rho_i+\lambda_i)(1-\tau_d) + (1-\tau_h)r_t}{(1-\rho_i-\lambda_i)(1-\tau_d)}. \tag{E.5}$$

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 (E.6). This parameter is set to 1 when the tax shield is present and to $1/(1-\tau_p)$ 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

$$\begin{aligned}\Pi_{i,t} =& (1-\tau_p)\Big(p^f_{i,t}y^f_{i,t} - \sum_{j\in\mathcal{N}} p_{j,t}x^f_{i,j,t} - P^F_{i,t}F^f_{i,t} - w_t\ell^f_{i,t} - \omega_r r^b_{i,t}b^f_{i,t}\Big) \\ &- \sum_{s\in\mathcal{S}}(1-\Gamma^s_{i,t})q^s_{i,t}I^{s,f}_{i,t} + b^f_{i,t+1} - b^f_{i,t},\end{aligned} \tag{E.6}$$

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

$$y^f_{i,t} = z_i\Big((\ell^f_{i,t})^{\phi^\ell_i}\prod_{s\in\mathcal{S}}\Big(k^{s,f}_{i,t}\Big)^{\phi^s_i}(F^f_{i,t})^{\phi^F_i}\Big)^{\gamma_i}\Big(\prod_{j\in\mathcal{N}}(x^f_{i,j,t})^{\alpha_{ij}}\Big)^{1-\gamma_i}, \tag{E.7}$$

where the fuel bundle is

$$F^f_{i,t} \equiv \sum_{j=c,o,g}(x^f_{i,j,t})^{\eta^{F,j}_i}; \tag{E.8}$$

(iii) the law of motion for capital

$$k^{s,f}_{i,t+1} = (1-\delta^s)k^{s,f}_{i,t} + I^{s,f}_{i,t}, \tag{E.9}$$

where the investment bundle is

$$I^{s,f}_{i,t} \equiv \prod_{j\in\mathcal{N}} \left(\frac{i^{s,f}_{i,j,t}}{\omega^s_{ij}}\right)^{\omega^s_{ij}}; \tag{E.10}$$

(iv) the borrowing constraint

$$b^f_{i,t+1} \leq \frac{1}{1+r^b_{i,t+1}} \sum_{s\in\mathcal{S}} \psi_{i,s} q^s_{i,t+1} k^{s,f}_{i,t+1}; \tag{E.11}$$

(v) and the demand schedule

$$y^f_{i,t} = \left(\frac{p^f_{i,t}}{p_{i,t}}\right)^{-\sigma} y_{i,t}. \tag{E.12}$$

Note that monopolistic competitive firms take demand into account when choosing production, this is why (E.12)—which follows from (E.1) 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 (E.12) and $y^f_{i,t}$ from (E.7) into (E.6) and taking the first-order condition with respect to $\ell^f_{i,t}$, we obtain

$$\mu_i \gamma_i \phi^\ell_i = \frac{w_t \ell^f_{i,t}}{p^f_{i,t} y^f_{i,t}}. \tag{E.13}$$

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

$$\mu_i \gamma_i \phi^F_i \eta^{F,j}_i = \frac{p_{j,t} x^f_{i,j,t}}{p^f_{i,t} y^f_{i,t}}. \tag{E.14}$$

Similarly, the choice of any other input $x^f_{i,j,t}$ satisfies

$$\mu_i (1-\gamma_i) \alpha_{ij} = \frac{p_{j,t} x^f_{i,j,t}}{p^f_{i,t} y^f_{i,t}}. \tag{E.15}$$

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 $\lambda_{i,t}^{s,f}$ is the Lagrange multiplier on (E.10). As a result,

$$\sum_{j \in \overline{\mathcal{N}}} p_{j,t} i_{i,j,t}^{s,f} = q_{i,t}^{s} I_{i,t}^{s,f},$$

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

$$i_{i,j,t}^{s,f} = \frac{1}{p_{j,t}} \omega_{ij}^{s} q_{i,t}^{s} I_{i,t}^{s,f}. \tag{E.16}$$

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 $r_{i,t+1}^{e} \geq r_{i,t+1}^{b}$, 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 (E.11) will hold with equality, pinning down the optimal choice of debt. Using (E.9) to replace $I_{i,t}^{s,f}$ into (E.6), the optimal choice of $k_{i,t+1}^{s,f}$ satisfies the first-order condition

$$-(1-\Gamma_i^s) q_{i,t}^{s} + \frac{1}{1+r_{i,t+1}^{b}} \psi_{i,s} q_{i,t+1}^{s} + \frac{1}{1+r_{i,t+1}^{e}} (1-\tau_p) \mu_i \gamma_i \phi_i^s p_{i,t+1}^{f} y_{i,t+1}^{f} \frac{1}{k_{i,t+1}^{s,f}}$$
$$+ \frac{1}{1+r_{i,t+1}^{e}} \Big\{ -(1-\tau_p) \omega_r \frac{r_{i,t+1}^{b}}{1+r_{i,t+1}^{b}} \psi_{i,s} q_{i,t+1}^{s} + (1-\Gamma_i^s)(1-\delta^s) q_{i,t+1}^{s} - \frac{1}{1+r_{i,t+1}^{b}} \psi_{i,s} q_{i,t+1}^{s} \Big\} = 0,$$

where we have used (E.5). In a symmetric equilibrium, this equation can be rewritten as

$$\mu_i \gamma_i \phi_i^s = R_{i,t}^{s} \frac{q_{i,t}^{s} k_{i,t}^{s}}{p_{i,t} y_{i,t}}, \tag{E.17}$$

where

$$R_{i,t}^{s} \equiv \frac{1-(1-\Gamma_i^s)(1-\delta^s)}{1-\tau_p} + \omega_r r_{i,t}^{b} \frac{\psi_{i,s}}{1+r_{i,t}^{b}} + \frac{1}{1-\tau_p} r_{i,t}^{e} \Big(1 - \frac{\psi_{i,s}}{1+r_{i,t}^{b}}\Big)$$
$$+ \frac{1}{1-\tau_p} (1+r_{i,t}^{e}) \Big((1-\Gamma_i^s) \frac{q_{i,t-1}^{s}}{q_{i,t}^{s}} - 1 \Big) \tag{E.18}$$

is the user cost of type-s capital.

Steady state. We now solve for the steady state of the economy. Steady-state variables do not bear a time subscript. Combining equations (E.2) and (E.14) gives

$$\frac{\theta_j / c_j}{\theta_i / c_i} = \frac{p_j}{p_i} = \mu_i \frac{y_i}{x_{i,j}} \gamma_i \phi_i^F \eta_i^{F,j}$$

or

$$x_{j,i} = \mu_j y_j \gamma_j \phi_j^F \eta_j^{F,i} \frac{\theta_j c_i}{c_j \theta_i}. \tag{E.19}$$

Similarly, for (E.15),

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

or

$$x_{j,i} = \mu_j y_j (1 - \gamma_j) \alpha_{ji} \frac{\theta_j c_i}{c_j \theta_i}. \tag{E.20}$$

Summing across fuel and non-fuel inputs yields

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

Also, in steady state (E.17) simplifies to

$$\mu_i \gamma_i \phi_i^s = R_i^s \frac{q_i^s k_i^s}{p_i y_i},$$

where the steady-state user cost is

$$R_i^s \equiv \frac{1 - \Gamma_i^s}{1 - \tau_p} (\delta^s + r_i^e) - \left(\frac{1}{1 - \tau_p} r_i^e - \omega_r r_i^b \right) \frac{\psi_{i,s}}{1 + r_i^b}.$$

The latter coincides with (8) when $\omega_r = 1$, that is, when the tax shield is present. Combining the latter expression with (E.16) yields

$$\frac{p_j i_{i,j}^s}{p_i y_i} = \mu_i \gamma_i \phi_i^s \omega_{ij}^s \frac{\delta^s}{R_i^s}. \tag{E.21}$$

Using equation (E.2) with (E.21) we obtain

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

or

$$i_{j,i}^s = \mu_j \gamma_j \phi_j^s \omega_{ji}^s \frac{\delta^s}{R_j^s} y_j \frac{\theta_j c_i}{c_j \theta_i}. \tag{E.22}$$

Summing across sectors and types of capital, we obtain

$$\sum_{s \in \mathcal{S}} \sum_{j \in \overline{\mathcal{N}}} i_{j,i}^s = \frac{c_i}{\theta_i} \sum_{s \in \mathcal{S}} \sum_{j \in \overline{\mathcal{N}}} \mu_j y_j \gamma_j \phi_j^s \omega_{ji}^s \frac{\delta^s}{R_j^s} \cdot \frac{\theta_j}{c_j}.$$

Using the resource constraint (7) yields

$$y_i = c_i + \frac{c_i}{\theta_i} \sum_{j=c,o,g} \mu_j y_j \gamma_j \phi_j^F \eta_j^{F,i} \frac{\theta_j}{c_j} + \frac{c_i}{\theta_i} \sum_{j \in \mathcal{N}} \mu_j y_j (1-\gamma_j) \alpha_{ji} \frac{\theta_j}{c_j} + \frac{c_i}{\theta_i} \sum_{s \in \mathcal{S}} \sum_{j \in \overline{\mathcal{N}}} \mu_j y_j \gamma_j \phi_j^s \omega_{ji}^s \frac{\delta^s}{R_j^s} \cdot \frac{\theta_j}{c_j}. \quad \text{(E.23)}$$

It is convenient to work with matrix notation. Given a vector $\boldsymbol{x}$, we let $\text{diag}(\boldsymbol{x})$ denote the diagonal matrix whose main diagonal is given by $\boldsymbol{x}$. Equation (E.23) can then be rewritten as

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

where $\Delta \equiv H' \,\text{diag}(\boldsymbol{\mu})\,\text{diag}(\boldsymbol{\gamma})\,\text{diag}(\boldsymbol{\phi^F}) + A' \,\text{diag}(\boldsymbol{\mu})\,\text{diag}(\mathbf{1}-\boldsymbol{\gamma})$
$+ \sum_s (\Omega^s)' \,\text{diag}(\boldsymbol{\mu})\,\text{diag}((\boldsymbol{R}^s)^{-1})\,\text{diag}(\boldsymbol{\delta}^s)\,\text{diag}(\boldsymbol{\phi}^s)\,\text{diag}(\boldsymbol{\gamma})$, and where H and A denote the matrices whose (i,j) entries equal $\eta_i^{F,j}$ and α_{ij}, respectively. Letting $I_{\mathcal{N}}$ denote the identity matrix of dimension $N \times N$, we have

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

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

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

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

$$\text{diag}(\boldsymbol{\theta})\,\text{diag}(\boldsymbol{c})^{-1} \boldsymbol{y} = (I_{\mathcal{N}} - \Delta)^{-1} \boldsymbol{\theta}. \quad \text{(E.24)}$$

Consider now the equilibrium in the labor market. Combining conditions (E.3), (E.4) and (E.13) yields

$$\ell_i = \frac{1-\tau_h}{1+\tau_c} \cdot \frac{U'(C)C}{V'(L)} \theta_i \phi_i^\ell \gamma_i \mu_i \frac{y_i}{c_i} \quad \text{(E.25)}$$

or, in matrix notation,

$$\boldsymbol{\ell} = \frac{1-\tau_h}{1+\tau_c} \cdot \frac{U'(C)C}{V'(L)} \,\text{diag}(\boldsymbol{\phi}^\ell)\,\text{diag}(\boldsymbol{\mu})\,\text{diag}(\boldsymbol{\gamma})\,\text{diag}(\boldsymbol{\theta})\,\text{diag}(\boldsymbol{c})^{-1} \boldsymbol{y}.$$

Using the market-clearing condition for labor (7) and equation (E.24) yields

$$\begin{aligned} L = \mathbf{1}'\boldsymbol{\ell} &= \frac{1-\tau_h}{1+\tau_c} \cdot \frac{U'(C)C}{V'(L)} (\boldsymbol{\phi}^\ell)' \,\text{diag}(\boldsymbol{\mu})\,\text{diag}(\boldsymbol{\gamma})\,\text{diag}(\boldsymbol{\theta})\,\text{diag}(\boldsymbol{c})^{-1} \boldsymbol{y} \\ &= \frac{1-\tau_h}{1+\tau_c} \cdot \frac{U'(C)C}{V'(L)} (\boldsymbol{\phi}^\ell)' \,\text{diag}(\boldsymbol{\mu})\,\text{diag}(\boldsymbol{\gamma}) (I_{\mathcal{N}} - \Delta)^{-1} \boldsymbol{\theta}. \end{aligned} \quad \text{(E.26)}$$

If we divide the production function (E.7) by y_i and use the assumption of constant returns to scale, we obtain

$$1 = z_i \left(\frac{\ell_i}{y_i}\right)^{\gamma_i \phi_i^\ell} \prod_{s \in \mathcal{S}} \left(\frac{k_i^s}{y_i}\right)^{\gamma_i \phi_i^s} \prod_{j=c,o,g} \left(\frac{x_{i,j}}{y_i}\right)^{\gamma_i \phi_i^F \eta_i^{F,j}} \prod_{j \in \mathcal{N}} \left(\frac{x_{i,j}}{y_i}\right)^{(1-\gamma_i)\alpha_{ij}}, \tag{E.27}$$

where we also used the definition of the fuel bundle (E.8). From (E.22),

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

or, since $I_i^s = \prod_j (i_{i,j}^s / \omega_{ij}^s)^{\omega_{ij}^s}$,

$$\frac{I_i^s}{y_i} = \mu_i \gamma_i \phi_i^s \frac{\delta^s}{R_i^s} \cdot \frac{\theta_i}{c_i} \prod_{j \in \overline{\mathcal{N}}} \left(\frac{c_j}{\theta_j}\right)^{\omega_{ij}^s}.$$

Finally, using the fact that in steady state $I_i^s = \delta^s k_i^s$, we obtain

$$\frac{k_i^s}{y_i} = \mu_i \gamma_i \phi_i^s \frac{1}{R_i^s} \cdot \frac{\theta_i}{c_i} \prod_{j \in \overline{\mathcal{N}}} \left(\frac{c_j}{\theta_j}\right)^{\omega_{ij}^s}. \tag{E.28}$$

From (E.19) and (E.20),

$$\frac{x_{i,j}}{y_i} = \mu_i \gamma_i \phi_i^F \eta_i^{F,j} \frac{\theta_i c_j}{c_i \theta_j} \quad \textbf{and} \quad \frac{x_{i,j}}{y_i} = \mu_i (1-\gamma_i) \alpha_{ij} \frac{\theta_i c_j}{c_i \theta_j}.$$

Also, from (E.25),

$$\frac{\ell_i}{y_i} = \frac{1-\tau_h}{1+\tau_c} \cdot \frac{U'(C)C}{V'(L)} \theta_i \mu_i \gamma_i \phi_i^\ell \frac{1}{c_i}.$$

Substituting these expressions into (E.27) gives

$$\begin{aligned} c_i =& z_i \theta_i \mu_i \Big(\gamma_i \phi_i^\ell \frac{1-\tau_h}{1+\tau_c} \cdot \frac{U'(C)C}{V'(L)}\Big)^{\gamma_i \phi_i^\ell} \prod_{s \in \mathcal{S}} \Big(\gamma_i \phi_i^s \frac{1}{R_i^s} \prod_{j \in \overline{\mathcal{N}}} \Big(\frac{c_j}{\theta_j}\Big)^{\omega_{ij}^s}\Big)^{\gamma_i \phi_i^s} \\ & \times \prod_{j=c,o,g} \left(\gamma_i \phi_i^F \eta_i^{F,j} \frac{c_j}{\theta_j}\right)^{\gamma_i \phi_i^F \eta_i^{F,j}} \prod_{j \in \mathcal{N}} \Big((1-\gamma_i)\alpha_{ij} \frac{c_j}{\theta_j}\Big)^{(1-\gamma_i)\alpha_{ij}}, \end{aligned}$$

Taking logs of both sides and omitting unimportant constants,

$$\begin{aligned} & \log(c_i/\theta_i) - \gamma_i \phi_i^F \eta_i^{F,j} \log(c_j/\theta_j) - \gamma_i \sum_{s \in \mathcal{S}} \phi_i^s \sum_{j \in \overline{\mathcal{N}}} \omega_{ij}^s \log(c_j/\theta_j) - (1-\gamma_i) \sum_{j \in \mathcal{N}} \alpha_{ij} \log(c_j/\theta_j) \\ =& \gamma_i \phi_i^\ell \log\left(\frac{1-\tau_h}{1+\tau_c} \cdot \frac{U'(C)C}{V'(L)}\right) - \gamma_i \sum_{s \in \mathcal{S}} \phi_i^s \log R_i^s \end{aligned}$$

or, in matrix notation,

$$\Big(I_{\mathcal{N}} - \operatorname{diag}(\boldsymbol{\gamma})\operatorname{diag}(\boldsymbol{\phi}^{\boldsymbol{F}})H - \sum_{s\in\mathcal{S}} \operatorname{diag}(\boldsymbol{\gamma})\operatorname{diag}(\boldsymbol{\phi}^{s})\Omega^{s} - \operatorname{diag}(\mathbf{1}-\boldsymbol{\gamma})A\Big)(\log \boldsymbol{c} - \log \boldsymbol{\theta})$$
$$= \operatorname{diag}(\boldsymbol{\gamma})\boldsymbol{\phi}^{\ell}\log\left(\frac{1-\tau_h}{1+\tau_c}\cdot\frac{U'(C)C}{V'(L)}\right) - \sum_{s\in\mathcal{S}} \operatorname{diag}(\boldsymbol{\gamma})\operatorname{diag}(\boldsymbol{\phi}^{s})\log(\boldsymbol{R}^{s}).$$

As a result,

$$\log \boldsymbol{c} = \log \boldsymbol{\theta} + (I_{\mathcal{N}} - \Gamma)^{-1}\left[\operatorname{diag}(\boldsymbol{\gamma})\boldsymbol{\phi}^{\ell}\log\left(\frac{1-\tau_h}{1+\tau_c}\cdot\frac{U'(C)C}{V'(L)}\right) - \sum_{s\in\mathcal{S}} \operatorname{diag}(\boldsymbol{\gamma})\operatorname{diag}(\boldsymbol{\phi}^{s})\log(\boldsymbol{R}^{s})\right],$$

where $\Gamma \equiv \operatorname{diag}(\boldsymbol{\gamma})\operatorname{diag}(\boldsymbol{\phi}^{\boldsymbol{F}})H + \sum_s \operatorname{diag}(\boldsymbol{\gamma})\operatorname{diag}(\boldsymbol{\phi}^{s})\Omega^{s} + \operatorname{diag}(\mathbf{1}-\boldsymbol{\gamma})A$. Aggregate consumption satisfies $\log C = \boldsymbol{\theta}'\log \boldsymbol{c}$, therefore,

$$\log C = \boldsymbol{\theta}'\log \boldsymbol{\theta} + \boldsymbol{\theta}'(I_{\mathcal{N}} - \Gamma)^{-1}\left[\operatorname{diag}(\boldsymbol{\gamma})\boldsymbol{\phi}^{\ell}\log\left(\frac{1-\tau_h}{1+\tau_c}\cdot\frac{U'(C)C}{V'(L)}\right) - \sum_{s\in\mathcal{S}} \operatorname{diag}(\boldsymbol{\gamma})\operatorname{diag}(\boldsymbol{\phi}^{s})\log(\boldsymbol{R}^{s})\right]. \tag{E.29}$$

Counterfactuals with "exact-hat algebra". 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 $U(C) = C^{1-\sigma}/(1-\sigma)$ and $V(L) = L^{1+\epsilon}/(1+\epsilon)$. Using the "hat" notation we can rewrite (E.25) as

$$\hat{\ell}_i = \frac{\hat{C}^{1-\sigma}}{\hat{L}^{\epsilon}}\cdot\frac{\hat{y}_i}{\hat{c}_i}. \tag{E.30}$$

From labor-market clearing,

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

or, using (E.30),

$$\hat{L} = \frac{\hat{C}^{1-\sigma}}{\hat{L}^{\epsilon}}\sum_{i\in\mathcal{N}} \vartheta_i^L \frac{\hat{y}_i}{\hat{c}_i}, \tag{E.31}$$

where $\vartheta_i^L \equiv w\ell_i/wL$. Similarly, we can rewrite both (E.19) and (E.20) as

$$\hat{x}_{j,i} = \hat{y}_j \frac{\hat{c}_i}{\hat{c}_j}, \tag{E.32}$$

and (E.22) as

$$\hat{i}_{j,i}^s = \frac{1}{\hat{R}_j^s}\hat{y}_j\frac{\hat{c}_i}{\hat{c}_j}. \tag{E.33}$$

Also, from (E.28), we obtain

$$\frac{\hat{k}_i^s}{\hat{y}_i} = \frac{1}{\hat{R}_i^s} \cdot \frac{1}{\hat{c}_i} \prod_{j \in \overline{\mathcal{N}}} \hat{c}_j^{\omega_{ij}^s}. \tag{E.34}$$

The resource constraint (7) becomes

$$\hat{y}_i = \frac{p_i c_i}{p_i y_i}\hat{c}_i + \sum_{j=c,o,g} \frac{p_i x_{j,i}}{p_i y_i}\hat{x}_{j,i} + \sum_{j \in \mathcal{N}} \frac{p_i x_{j,i}}{p_i y_i}\hat{x}_{j,i} + \sum_{s \in \mathcal{S}} \sum_{j \in \overline{\mathcal{N}}} \frac{p_i i_{j,i}^s}{p_i y_i}\hat{i}_{j,i}^s \tag{E.35}$$

or, using (E.19), (E.20) and (E.22) with (E.32) and (E.33),

$$\frac{\hat{y}_i}{\hat{c}_i} = \vartheta_i^C + \sum_{j=c,o,g} \mu_i \gamma_i \phi_i^F \eta_i^{F,j} \vartheta_{ji}^Y \frac{\hat{y}_j}{\hat{c}_j} + \sum_{j \in \mathcal{N}} \mu_j \alpha_{ji}(1-\gamma_j)\vartheta_{ji}^Y \frac{\hat{y}_j}{\hat{c}_j} + \sum_{s \in \mathcal{S}} \sum_{j \in \overline{\mathcal{N}}} \mu_j \gamma_j \phi_j^s \omega_{ji}^s \frac{\delta^s}{R_j^s} \vartheta_{ji}^Y \frac{1}{\hat{R}_j^s} \cdot \frac{\hat{y}_j}{\hat{c}_j}, \tag{E.36}$$

where $\vartheta_i^C \equiv p_i c_i / p_i y_i$ and $\vartheta_{ji}^Y \equiv p_j y_j / p_i y_i$.

Also, using (E.30), (E.32) and (E.34), we can rewrite (E.27) as

$$\hat{c}_i = \left(\frac{\hat{C}^{1-\sigma}}{\hat{L}^{\epsilon}}\right)^{\gamma_i \phi_i^{\ell}} \prod_{s \in \mathcal{S}} \left(\frac{1}{\hat{R}_i^s} \prod_{j \in \overline{\mathcal{N}}} \hat{c}_j^{\omega_{ij}^s}\right)^{\gamma_i \phi_i^s} \prod_{j=c,o,g} \hat{c}_j^{\gamma_i \phi_i^F \eta_i^{F,j}} \prod_{j \in \mathcal{N}} \hat{c}_j^{(1-\gamma_i)\alpha_{ij}}$$

or, taking logs of both sides,

$$\begin{aligned} \log \hat{c}_i =& \gamma_i \phi_i^{\ell} \log \frac{\hat{C}^{1-\sigma}}{\hat{L}^{\epsilon}} - \sum_{s \in \mathcal{S}} \gamma_i \phi_i^s \log \hat{R}_i^s + \sum_{s \in \mathcal{S}} \sum_{j \in \overline{\mathcal{N}}} \gamma_i \phi_i^s \omega_{ij}^s \log \hat{c}_j \\ &+ \sum_{j=c,o,g} \gamma_i \phi_i^F \eta_i^{F,j} \log \hat{c}_j + \sum_{j \in \overline{\mathcal{N}}} (1-\gamma_i)\alpha_{ij} \log \hat{c}_j. \end{aligned} \tag{E.37}$$

Finally, from the definition of aggregate consumption,

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

therefore,

$$\log \hat{C} = \sum_{i \in \overline{\mathcal{N}}} \theta_i \log \hat{c}_i. \tag{E.38}$$

To sum up, the change in inputs, output and consumption in the counterfactual economy are the solution to equations (E.30), (E.32), (E.33), (E.34), (E.36), (E.37) and (E.38).

E.2 Proofs for Section 5.2

Let us define the firm's cost function:

$$\mathcal{C}_i^f(w_t, \{R_{i,t}^s\}_s, \{q_{i,t}^s\}_s, P_{i,t}^F, \{p_{j,t}\}_j, y_{i,t}^f) = \min_{\tilde{\ell}, \{\tilde{k}^s\}_s, \tilde{F}, \{\tilde{x}_j\}_j} \Big\{ w_t \tilde{\ell} + \sum_{s \in \mathcal{S}} R_{i,t}^s q_{i,t}^s \tilde{k}^s + P_{i,t}^F \tilde{F} + \sum_{j \in \mathcal{N}} p_{j,t} \tilde{x}_j \Big\},$$

subject to

$$y_{i,t}^f = \mathcal{Y}_i(\tilde{\ell}, \{\tilde{k}^s\}_s, \tilde{F}, \{\tilde{x}_j\}_j).$$

The optimal choices from this problem coincide with those in the baseline model when the production function is given by (E.7). However, although we retain the assumption of constant returns to scale, we do not restrict the production function to be Cobb-Douglas.

Constant returns to scale imply

$$1 = \mathcal{Y}_i(\tilde{\ell}/y_{i,t}^f, \{\tilde{k}^s/y_{i,t}^f\}_s, \tilde{F}/y_{i,t}^f, \{\tilde{x}_j/y_{i,t}^f\}_j),$$

for any value of $y_{i,t}^f$. It is thus sufficient to solve the problem for $y_{i,t}^f = 1$ and scale the resulting solution by $y_{i,t}^f$. Therefore, we have

$$\begin{aligned}\mathcal{C}_i^f(w_t, \{R_{i,t}^s\}_s, \{q_{i,t}^s\}_s, P_{i,t}^F, \{p_{j,t}\}_j, y_{i,t}^f) &= \Big(w_t \lambda_{i,t}^f + \sum_s R_{i,t}^s q_{i,t}^s \kappa_{i,t}^{s,f} + P_{i,t}^F \varphi_{i,t}^f + \sum_{j \in \mathcal{N}} p_{j,t} \chi_{i,j,t}^f \Big) y_{i,t}^f \\ &\equiv \mathcal{MC}_i^f(w_t, \{R_{i,t}^s\}_s, \{q_{i,t}^s\}_s, P_{i,t}^F, \{p_{j,t}\}_j) y_{i,t}^f,\end{aligned}$$

where λ, κ, φ and χ denote the solution to the firm's problem for $y_{i,t}^f = 1$, and $\mathcal{MC}_i^f$ is the firm's marginal cost curve. Homogeneity of the problem also implies that firm's optimal choices for any level of output $y_{i,t}^f$ can also be obtained by re-scaling their counterparts for $y_{i,t}^f = 1$, that is, $\ell_{i,t}^f = \lambda_{i,t}^f y_{i,t}^f$, $k_{i,t}^{s,f} = \kappa_{i,t}^{s,f} y_{i,t}^f$, $F_{i,t}^f = \varphi_{i,t}^f y_{i,t}^f$ and $x_{i,j,t}^f = \chi_{i,j,t}^f y_{i,t}^f$.

Given the firm's cost function, the optimal price is the solution to the following problem:

$$\max_{\tilde{p}} \tilde{p} y_{i,t}^f - \mathcal{C}_i^f(w_t, \{R_{i,t}^s\}_s, \{q_{i,t}^s\}_s, P_{i,t}^F, \{p_{j,t}\}_j, y_{i,t}^f),$$

subject to

$$y_{i,t}^f = \left(\frac{\tilde{p}}{p_{i,t}}\right)^{-\sigma} y_{i,t}. \tag{E.39}$$

The first-order condition is

$$\left(\frac{p_{i,t}^f}{p_{i,t}}\right)^{-\sigma} y_{i,t} - \sigma \left(\frac{p_{i,t}^f}{p_{i,t}}\right)^{-\sigma} y_{i,t} + \sigma \mathcal{MC}_i^f(w_t, \{R_{i,t}^s\}_s, \{q_{i,t}^s\}_s, P_{i,t}^F, \{p_{j,t}\}_j) \frac{1}{p_{i,t}^f} \left(\frac{p_{i,t}^f}{p_{i,t}}\right)^{-\sigma} y_{i,t} = 0$$

or, rearranging,

$$p_{i,t}^f = \frac{1}{\mu_i} \mathcal{MC}_i^f(w_t, \{R_{i,t}^s\}_s, \{q_{i,t}^s\}_s, P_{i,t}^F, \{p_{j,t}\}_j). \tag{E.40}$$

Taking the logarithm of the price equation (E.40) and differentiating it with respect to $R^s_{i,t}$ gives

$$\frac{\partial \log p^f_{i,t}}{\partial R^s_t} = \frac{1}{\mu_i p^f_{i,t}} \cdot \frac{\partial \mathcal{MC}^f_i}{\partial R^s_{i,t}}.$$

To compute the derivative of the marginal cost, we apply the envelope theorem to the cost function:

$$\frac{\partial \mathcal{C}^f_i}{\partial R^s_{i,t}} = y^f_{i,t} \frac{\partial \mathcal{MC}^f_i}{\partial R^s_{i,t}} = q^s_{i,t} k^{s,f}_{i,t}.$$

We conclude that

$$\frac{\partial \log p^f_{i,t}}{\partial R^s_{i,t}} = \frac{1}{\mu_i} \cdot \frac{q^s_{i,t} k^{s,f}_{i,t}}{p^f_{i,t} y^f_{i,t}}. \tag{E.41}$$

Finally, using the demand equation (E.39), the log-change in output is

$$\frac{\partial \log y^f_{i,t}}{\partial R^s_{i,t}} = -\sigma \frac{\partial \log p^f_{i,t}}{\partial R^s_{i,t}}. \tag{E.42}$$

Consider now a policy that lowers the tax rate. As discussed in the main text, such policy implies a change in the user cost of type-s capital, which we denote with ΔR^s_i. Combining (E.41) and (E.42) yields, in steady state, equation (9).

Finally, a firm's emissions equal

$$E^f_{i,t} \equiv \sum_{j=c,o,g} e_j x^f_{i,j,t} = \sum_{j=c,o,g} e_j \chi^f_{i,j,t} y^f_{i,t}.$$

Thus, given a steady-state change ΔR^s_i and the corresponding output change Δy^f_i from equation (9), the associated change in emissions can be approximated as

$$\Delta E^f_i = \sum_j e_j \chi^f_{i,j} \frac{\partial \log y^f_{i,t}}{\partial R^s_{i,t}} \Delta R^s_i + \sum_j e_j y^f_i \frac{\partial \log \chi^f_{i,j}}{\partial R^s_{i,t}} \Delta R^s_i$$

or, equivalently,

$$\Delta E^f_i = \frac{E^f_i}{y^f_i} \cdot \frac{\partial \log y^f_{i,t}}{\partial R^s_{i,t}} \Delta R^s_i + y^f_i \sum_j e_j \frac{\partial \log (x^f_{i,j}/y^f_i)}{\partial R^s_{i,t}} \Delta R^s_i.$$

The first term represents the change in emissions due to the change in output, while the second term captures the change in emission intensity resulting from adjustments in the fuel mix for a given output level.

E.3 Proofs for Section 5.5

The household problem is unchanged; the firm's problem coincides with the one in the baseline case except for the different production function. In particular, firm's production is now given by

$$\hat{y}^f_{i,t} = \Big((\hat{\ell}^f_{i,t})^{\phi^\ell_i}(\hat{K}^f_{i,t})^{\phi^K_i}(\hat{k}^{o,f}_{i,t})^{\phi^o_i}\Big)^{\gamma_i}\Big(\prod_{j\in\mathcal{N}}(\hat{x}^f_{i,j,t})^{\alpha_{ij}}\Big)^{1-\gamma_i}, \tag{E.43}$$

where $\hat{K}^f_{i,t}$ is the equipment-fuel bundle:

$$\hat{K}^f_{i,t} \equiv \Big(\eta^F_i(\hat{F}^f_{i,t})^{\frac{\rho-1}{\rho}} + (1-\eta^F_i)(\hat{k}^{e,f}_{i,t})^{\frac{\rho-1}{\rho}}\Big)^{\frac{\rho}{\rho-1}}.$$

As explained in the main text, for convenience we are defining the production function directly in terms of deviations from the baseline equilibrium. The firm optimizes over $(p^f_{i,t})'$, $(y^f_{i,t})'$, $(\ell^f_{i,t})'$, $(i^{s,f}_{i,j,t})'$, $(I^{s,f}_{i,t})'$, $(k^{s,f}_{i,t+1})'$, $(x^f_{i,j,t})'$ and $(b^f_{i,t+1})'$.

The choice of labor satisfies the first-order condition

$$\mu_i\gamma_i\phi^\ell_i(p^f_{i,t})'y^f_{i,t}\hat{y}^f_{i,t} = w'_t(\ell^f_{i,t})'.$$

Dividing the latter by its counterpart in the baseline equilibrium (i.e., $\mu_i p^f_{i,t}\gamma_i\phi^\ell_i y^f_{i,t} = w_t\ell^f_{i,t}$) yields

$$\hat{p}^f_{i,t}\hat{y}^f_{i,t} = \hat{w}_t\hat{\ell}^f_{i,t}. \tag{E.44}$$

Conditional on total investment $I^{s,f}_{i,t}$, the choice of $i^{s,f}_{i,j,t}$ is the same as in the baseline equilibrium, therefore, equation (E.16) continues to hold.

The optimal choice of equipment now satisfies

$$\mu_i\gamma_i\phi^K_i(1-\eta^F_i)(p^f_{i,t})'y^f_{i,t}\hat{y}^f_{i,t}(\hat{K}^f_{i,t})^{\frac{1}{\rho}-1}(\hat{k}^{e,f}_{i,t})^{1-\frac{1}{\rho}} = (R^e_{i,t})'(q^e_{i,t})'(k^{e,f}_{i,t})'$$

where $R^e_{i,t}$ is given by (E.18) with $s = e$. Dividing the latter by its counterpart in the baseline equilibrium yields

$$\hat{p}^f_{i,t}\hat{y}^f_{i,t}\hat{K}^{\frac{1}{\rho}-1}_{i,t} = \hat{R}^e_{i,t}\hat{q}^e_{i,t}(\hat{k}^{e,f}_{i,t})^{\frac{1}{\rho}}. \tag{E.45}$$

The choice for the other type of capital satisfies the same conditon as in the baseline case:

$$\mu_i\gamma_i\phi^o_i(p^f_{i,t})'y^f_{i,t}\hat{y}^f_{i,t} = (R^o_{i,t})'(q^o_{i,t})'(k^{o,f}_{i,t})',$$

which can be divided by its counterpart in the baseline equilibrium to get

$$\hat{p}^f_{i,t}\hat{y}^f_{i,t} = \hat{R}^o_{i,t}\hat{q}^o_{i,t}\hat{k}^{o,f}_{i,t}, \tag{E.46}$$

where $R^o_{i,t}$ is given by (E.18) with $s = o$.

Evaluating (E.44), (E.45) and (E.46) in the symmetric steady state gives

$$\frac{\hat{w}\hat{\ell}_i}{\hat{p}_i\hat{y}_i} = 1, \quad \hat{R}_i^e\frac{\hat{q}_i^e\hat{k}_i^e}{\hat{p}_i\hat{y}_i}\left(\frac{\hat{k}_i^e}{\hat{K}_i}\right)^{\frac{1}{\rho}-1} = 1 \quad \text{and} \quad \hat{R}_i^o\frac{\hat{q}_i^o\hat{k}_i^o}{\hat{p}_i\hat{y}_i} = 1. \tag{E.47}$$

Consider now the choice of fuel $j = c, o, g$. It satisfies the first-order condition

$$\mu_i\gamma_i\phi_i^K\eta_i^F\eta_i^{F,j}(p_{i,t}^f)'y_{i,t}^f\hat{y}_{i,t}^f(\hat{K}_{i,t}^f)^{\frac{1}{\rho}-1}(\hat{F}_{i,t}^f)^{1-\frac{1}{\rho}} = (p_{j,t})'(x_{i,j,t}^f)'.$$

Dividing the latter by its counterpart in the baseline equilibrium gives

$$\hat{p}_{i,t}^f\hat{y}_{i,t}^f(\hat{K}_{i,t}^f)^{\frac{1}{\rho}-1}(\hat{F}_{i,t}^f)^{1-\frac{1}{\rho}} = \hat{p}_{j,t}\hat{x}_{i,j,t}^f.$$

In the symmetric state state,

$$\frac{\hat{p}_j\hat{x}_{i,j}}{\hat{p}_i\hat{y}_i}\left(\frac{\hat{F}_i}{\hat{K}_i}\right)^{\frac{1}{\rho}-1} = 1. \tag{E.48}$$

Finally, the choices of all other inputs are exactly as in the baseline case:

$$\frac{\hat{p}_j\hat{x}_{i,j}}{\hat{p}_i\hat{y}_i} = 1. \tag{E.49}$$

From (E.48), we obtain demand for fuel j:

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

Raising the latter to the power of $\eta_i^{F,j}$, multiplying over $j = c, o, g$, and using the definition of $\hat{F}_i$, we obtain

$$\hat{F}_i = (\hat{p}_i\hat{y}_i)^\rho\hat{K}_i^{1-\rho}\left(\hat{P}_i^F\right)^{-\rho}, \tag{E.50}$$

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

From (E.47), we obtain demand for equipment:

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

Raising both this equation and equation (E.50) 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 applying the definition of $\hat{K}_i$, we obtain

$$\hat{K}_i = \hat{p}_i\hat{y}_i(\hat{P}_i^K)^{-1}, \tag{E.51}$$

where we let $\hat{P}_i^K \equiv \left(\eta_i^F(\hat{P}_i^F)^{1-\rho} + (1-\eta_i^F)(\hat{R}_i^e\hat{q}_i^e)^{1-\rho}\right)^{\frac{1}{1-\rho}}$.

From (E.49), we obtain demand for any non-fuel input, which we can then raise to the power of α_{ij} and multiplying over $j \in \mathcal{N}$ to get

$$\prod_{j\in\mathcal{N}} \hat{x}_{i,j}^{\alpha_{ij}} = \hat{p}_i\hat{y}_i \prod_{j\in\mathcal{N}} (\hat{p}_j)^{-\alpha_{ij}}. \tag{E.52}$$

From (E.47), we obtain demand for labor and capital $s = o$:

$$\hat{\ell}_i = \hat{p}_i\hat{y}_i\hat{w}^{-1}, \quad \hat{k}_i^o = \hat{p}_i\hat{y}_i(\hat{R}_i^o)^{-1}(\hat{q}_i^o)^{-1}. \tag{E.53}$$

Finally, we raise labor demand from (E.53) to the power of $\gamma_i\phi_i^\ell$; equation (E.51) to the power of $\gamma_i\phi_i^K$; demand for capital of type $s = o$ from (E.53) to the power of $\gamma_i\phi_i^o$; and equation (E.52) to the power of $(1-\gamma_i)$. We then multiply the resulting expressions and use (E.43) to obtain

$$\hat{p}_i = \hat{w}^{\gamma_i\phi_i^\ell}(\hat{P}_i^K)^{\gamma_i\phi_i^K}(\hat{R}_i^o\hat{q}_i^o)^{\gamma_i\phi_i^I} \prod_{j\in\mathcal{N}} \hat{p}_j^{(1-\gamma_i)\alpha_{ij}}. \tag{E.54}$$

Given user costs $\{\hat{R}_i^s\}$ from (8), equation (E.54) can be used to solve for prices $\{\hat{p}_i\}$, for given wage $\hat{w}$. We can then use (E.37) and (E.38), together with household's optimality conditions (E.3) and (E.4), to obtain consumption levels $\hat{c}_i$ and $\hat{C}$ and aggregate labor $\hat{L}$, for given $\hat{w}$. Given $\hat{w}$, sectoral output $\hat{y}_i$ comes from the resource constraint (E.35), combined with demand functions (E.33), (E.37), (E.48), (E.49) and (E.53). Finally, the wage $\hat{w}$ must satisfy the labor market clearing condition (E.31).

F Calibration

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

BEA sectors and types of capital. Input-output data is 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 "Customer 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: equipment (Compustat item: *fate*) and a composite asset that combines the remaining part of tangible capital, R&D, other IP, and goodwill. We link Compustat NAICS codes to BEA sector codes and obtain sector-level data on equipment and composite assets by averaging values across Compustat firms in our 2017 sample. For the R&D capital stock, we construct "knowledge capital" by capitalizing firms' R&D expenditures as in Peters and Taylor (2017); the remaining part of tangible capital is constructed by subtracting Compustat item *fate* from Compustat item *ppegt*; 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 31 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 is only available for 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.

Given a tax depreciation schedule for equipment $\{D_t^e\}$, $t = 0, ..., T$, we let

$$\Gamma_i^e = \sum_{t=0}^{T} \frac{D_t^e}{(1 + r_i^e)^t},$$

where r_i^e is the required return on equity for sector i. Similarly, for Γ_i^o, we first compute the above sum 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.

Taxes. We compute firms' 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 $r_i^b b_i$—except in the counterfactual scenario where the tax shield is removed. Next, we subtract tax deductions D_t^s 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 $I_i^s = \delta^s q_i^s k_i^s$, $s = e, o$, each period. It follows that, each period, a firm can deduct $\delta^s \sum_{t=0}^{T} D_t^s = \delta^s$ for type-s capital.