I Z A Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 18212

Carbon Taxation and Firm Behavior in Emerging Economies: Evidence from South Africa

Johannes Gallé
Rodrigo Oliveira
Daniel Overbeck
Nadine Riedel
Edson Severnini

OCTOBER 2025

I Z A Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 18212

Carbon Taxation and Firm Behavior in Emerging Economies: Evidence from South Africa

Johannes Gallé
Potsdam Institute for Climate Impact Research

Rodrigo Oliveira
UNU-WIDER

Daniel Overbeck
National University of Singapore

Nadine Riedel
University of Münster

Edson Severnini
Boston College, Nova SBE, NBER and IZA

OCTOBER 2025

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Carbon Taxation and Firm Behavior in Emerging Economies: Evidence from South Africa*

This paper provides the first comprehensive evidence on how firms in emerging economies respond to carbon taxation. Using detailed administrative data, we study the announcement and implementation of South Africa's 2019 carbon tax—a potential trailblazer for other developing countries with limited state capacity amid the global expansion of carbon pricing. Contrary to concerns that carbon taxes might hinder growth or employment, we find no negative effects on firm performance or jobs. Firms facing higher effective tax rates increased activity following the tax's announcement, four years before implementation, likely reflecting the resolution of regulatory uncertainty and efforts to mitigate stranded asset costs. While we find no measurable reduction in emissions—likely due to this anticipatory behavior—our results suggest that carbon taxation can be implemented without harming economic outcomes, even in the short term and in low- and middle-income settings.

JEL Classification: H23, Q52, Q58, O13, O55

Keywords: carbon pricing, carbon tax, firm performance, employment outcomes

Corresponding author:
Edson Severnini
Boston College
Economics Department & Schiller Institute for Integrated Science and Society
245 Beacon Street
Chestnut Hill, MA 02467
USA
E-mail: edson.severnini@bc.edu

* We thank Megan Shongwe for excellent research assistance. We are grateful for invaluable comments and suggestions from Karen Clay, Maria Antonieta Cunha-e-Sá, Carolyn Fischer, and Akshaya Jha. We also appreciate feedback from seminars participants at Carnegie Mellon University, MCC Berlin, Nova SBE (Lisbon), University College Dublin, and University of Mannheim. Finally, we thank conference and workshop participants at the Empirical Methods in Energy Economics Workshop (World Bank), International Institute of Public Finance (Prague), the German Development Economics Conference (Hannover), UNU-WIDER Workshop on Climate Change, Labour and Inequality (Helsinki), UNU-WIDER Development Conferences (Maputo and Helsinki), UNU-WIDER SA-TIED Work-in-Progress Workshop (Pretoria, South Africa), the World Bank/ODI Global/IFS Public Finance Conference (London), and the AFD-EU International Conference (Paris) – Bridging Divides: Evidence-Based Policies for Inequality Reduction and Sustainable Development. The authors also gratefully acknowledge financial support from Boston College (Schiller Institute for Integrated Science and Society), Carnegie Mellon University (Heinz College), Nova SBE, the European Union's Horizon Europe Programme (101069880, AdJUST), and the Southern Africa – Towards Inclusive Economic Development (SA-TIED) program.

1 Introduction

Carbon pricing has emerged as a cornerstone of climate policy, offering a market-based mechanism to align private incentives with the social costs of greenhouse gas emissions (Timilsina, 2022; Gordon, 2023). Yet implementing carbon pricing—particularly carbon taxes—poses significant challenges for emerging markets and less developed countries. Many low- and middle-income countries (LMICs) have been hesitant to adopt carbon taxation due to concerns that it could impose economic costs and slow development (Strand, 2020). LMICs' reliance on carbon-intensive energy, lower technological capacity, and limited economic resilience may make them especially vulnerable to such effects (Marron and Toder, 2014; Metcalf, 2021).

This paper provides the first comprehensive analysis of how firms in an emerging economy respond to carbon taxation. It focuses on South Africa, the 13^{th}-largest carbon emitter globally and the first African nation to introduce a nationwide carbon tax in 2019. As a potential trailblazer for other developing countries, South Africa's experience is particularly relevant given the growing global emphasis on carbon pricing, with 80 carbon pricing schemes worldwide and 40 more underway (World Bank, 2025). While carbon pricing can in general take the form of carbon taxes or emissions trading systems (ETS), carbon taxes are administratively easier to implement, which may make them relatively more attractive for LMICs.[1] To make it politically feasible, South Africa introduced its carbon tax with substantial allowances during the initial phase to ease the transition.[2]

Using novel and comprehensive administrative tax data, we examine the dynamic effects of the announcement and implementation of the policy on firm behavior. We quantify the carbon tax's economic impact on manufacturing and mining firms, which together generate over 90% of South Africa's carbon tax revenues. Our findings show that the tax did not negatively affect key firm outcomes such as sales, profits, or employment. Notably, the announcement of the tax in 2015—made four years before its implementation—appears to have spurred an increase in firm activity, suggesting anticipatory behavior.

The analysis leverages the universe of corporate income tax returns filed from 2011 to 2021, allowing us to track firms for six years after the release of the draft carbon tax bill and two years following the tax's implementation in June 2019.[3] Beginning in 2019, we integrate detailed data on emissions and tax payments with other firm-level tax records. This enables an in-depth analysis of the carbon tax base, which we find covers

[1] Countries adopting carbon taxes can leverage existing tax authorities and target only large emitters, but often face public resistance to new taxes. Emissions trading systems (ETS), by contrast, can be more politically palatable because governments can allocate permits for free, but they require creating and regulating a new market—often a challenge for LMICs with limited state capacity.

[2] Large emitters mounted intensive lobbying efforts to secure favorable terms from the South African government (Just Share, 2025).

[3] The fiscal year in South Africa begins in March and ends in February of the following year. Therefore, the 2020 fiscal year started in March 2019 and ended in February 2020. This timing means that our estimated effects for 2020 are largely influenced by the implementation of the carbon tax (introduced in June 2019) but remain unaffected by the COVID-19 pandemic, which impacted the subsequent fiscal year.

over 80% of nationwide emissions. Although the statutory tax rate is uniform across industries, we identify significant variation in *effective* tax rates—the actual cost firms pay per tonne of CO_2-equivalent. Our descriptive analysis reveals a non-linear relationship between emissions and tax payments, driven by the tax's design, which includes allowances, exemptions, and special provisions for certain industries.

We use matching techniques to generate a credible comparison between taxed and non-taxed firms, addressing imbalances in observable pre-treatment characteristics. The matched sample exhibits parallel pre-treatment trends and achieves a matching ratio comparable to a recent evaluation of the European Union Emissions Trading System (EU ETS) (Colmer et al., 2025). Based on this matched sample, we estimate event-study regressions to trace the dynamic effects of both the tax announcement (draft bill released in 2015) and the subsequent implementation of the Carbon Tax Act in 2019.

The main results indicate that the announcement of the Carbon Tax Bill in 2015 led to increases in sales, capital, employment, and profits. The positive impacts grew gradually and remained significant after the carbon tax was implemented in 2019; by that year, sales, capital, employment, and profits had risen by roughly 20%. The effects on capital and employment suggest that carbon emissions and these inputs may be substitutes in firms' production functions. The observed increase in profits may seem surprising, but we show in a conceptual framework that the effect is theoretically ambiguous, depending on firms' production choices. Overall, we find no evidence that the carbon tax hindered firm performance or reduced employment, on average.

Although administrative data report firm-level emissions only after the Carbon Tax Act in 2019, we complement this with data from a subset of firms in the Carbon Disclosure Project, applying the same empirical strategy to assess the policy's environmental effects. Our conceptual framework shows that the effect of the policy on emissions is theoretically ambiguous, depending on firms' production choices in response to the tax. Empirically, we find no measurable impact on firm-level emissions; if anything, there is a slight upward trend following the announcement, though it is imprecise. At the national level, a synthetic control analysis likewise shows no consistent reduction in emissions. Emissions appear to rise following the announcement and decline after implementation, but these changes are not statistically significant, indicating that South Africa's emissions remained essentially unchanged relative to its counterfactual.

To examine how differences in exposure to the carbon tax influence firm responses, we conduct a heterogeneity analysis. Firms with fewer allowances—and thus higher *effective* tax rates—experienced significant increases in sales and employment following the tax announcement. In contrast, firms with more generous allowances exhibited more muted responses, with estimated effects on sales and employment that are smaller and, in some cases, statistically indistinguishable from zero after the tax's implementation. This pattern suggests that while low-allowance firms faced stronger financial incentives to adjust their operations, firms with more generous allowances may have leveraged their influence through lobbying or industry associations to shape the regulatory environment, reducing the immediate pressure to modify production or employment decisions.

We explore two mechanisms that could explain the non-negative results. First, the four-year gap between the release of the carbon tax bill and the implementation of the Carbon Tax Act allowed firms to manage uncertainty—both by gaining clarity on future production costs and by confirming that there would be no cap on emissions as long as the tax was paid. This resolution of uncertainty may have enabled firms to plan strategically for the transition. Consistent with this, firms with higher exposure to the carbon tax experienced increased sales and significantly higher depreciation following the bill's announcement. These findings suggest that such firms not only used their capital more intensively but also accelerated the depreciation of emission-intensive machinery in anticipation of the tax. The accelerated depreciation likely reflects an effort to mitigate the risk of stranded assets—machinery that could become uneconomical or obsolete under the new tax regime.

As a second potential mechanism, we examine whether the carbon tax incentivized firms to upgrade their production technology. While we find no evidence of increased R&D investment, treated firms did slightly increase imports between 2018 and 2020. This pattern may indicate that firms sourced more production inputs and machinery from abroad, either to replace domestically taxed inputs or to upgrade their technology. Notably, our analysis shows that on the intensive margin, treated firms primarily imported products within the same categories as in previous years. On the extensive margin, however, they also introduced new products, suggesting some degree of technology or product innovation. Although we cannot entirely rule out technology upgrading, the evidence indicates that this channel is unlikely to explain the substantial effects of the tax announcement and implementation.

This study makes three main contributions to the literature. First, it contributes to the literature on the economic impacts of carbon pricing, which has predominantly focused on cap-and-trade systems and/or developed world settings (Bushnell et al., 2013; Martin et al., 2014a,b; Calel and Dechezlepretre, 2016; Yamazaki, 2017, 2022; Andersson, 2019; Cui et al., 2021, 2023; Dechezlepretre et al., 2023; Colmer et al., 2025). In contrast, we estimate the impacts of a carbon tax in an emerging-economy context, where carbon taxation may be administratively simpler than cap-and-trade given limited state capacity (Metcalf, 2021), and find that the policy may not have hindered firm performance.

Second, it contributes to the literature on environmental policy and labor market outcomes, particularly in the context of politically contentious carbon taxes. Market-based approaches, such as carbon pricing, are widely regarded as more cost-effective than command-and-control regulations (Carlson et al., 2000; Fowlie et al., 2012).[4] While command-and-control policies have been shown to reduce employment and earnings in de-

[4] Yet carbon taxes often face significant public resistance (Douenne and Fabre, 2022; Ewald et al., 2022; Anderson et al., 2023). This resistance is often tied to the tax's distributional implications, which can be politically challenging to defend (Steckel et al., 2021; Fried et al., 2022; Känzig, 2023; Dechezlepretre et al., 2025).

veloped economies (Greenstone, 2002; Walker, 2013), market-based approaches, including carbon taxes, generally do not appear to adversely affect employment (Martin et al., 2014a; Yamazaki, 2017). Our study aligns with this developed world evidence by demonstrating that flexible environmental policies, such as carbon taxes, do not seem to harm economic activity and employment, even in the context of a less developed country with a higher degree of informality.[5]

Third, it contributes to the literature on anticipatory firm behavior, particularly the so-called "green paradox," where environmental policies may temporarily worsen environmental outcomes due to pre-emptive actions by firms (Lueck and Michael, 2003; Di Maria et al., 2014; Lemoine, 2017), unless the output is not storable (Clay et al., 2025). We provide evidence that a carbon tax, even in a setting without emissions caps in the short run, may induce such behavior. This appears to arise from firms resolving uncertainty or seeking to recover costs from stranded assets, offering new insights into how carbon taxes might influence firm behavior in the absence of emissions caps.

The remainder of the paper is organized as follows: Section 2 provides an overview of the institutional background. Section 3 introduces the data sources used in the empirical analysis. Section 4 introduces a conceptual framework that clarifies the key mechanisms driving the impacts of the carbon tax. Section 5 details the empirical methodology, while Section 6 reports and discusses results. Section 7 explores the mechanisms behind the main estimates. Finally, Section 8 offers concluding remarks.

2 Institutional background

South Africa is a middle-income country with a GDP per capita of USD 7,055 and a tax-to-GDP ratio of 21% in 2023. It is one of the few countries in the world to have adopted a carbon tax and, to date, the only African country to have implemented any sort of carbon pricing scheme (World Bank, 2024). Appendix Figure A.1 shows that, in 2023, the carbon tax increased the government revenue by about ZAR 1.5 billion.[6] This section explains the institutional setting and the legal framework of the carbon tax.

Policy process. The implementation of the South African carbon tax in 2019 has been preceded by a long political process in which a variety of private and public stakeholders discussed and pushed their interests. Figure 1 shows the timeline of the main events until the Carbon Tax Act in 2019. In 2010, the Carbon Tax Discussion Paper marked the first official document mentioning a 'carbon tax.' The paper outlined potential ways a

[5]However, studies on the EU ETS suggest that carbon pricing can significantly reduce emissions (e.g., Ellerman et al., 2016; Martin et al., 2016; Colmer et al., 2025), whereas our findings on emissions impacts are more mixed. Thus, our study aligns with prior evidence primarily with respect to economic outcomes rather than environmental effectiveness.

[6]To put this figure into perspective, it is comparable to the amount allocated to the early childhood development grant (ZAR 1.6 billion). For details, see https://shorturl.at/taDvq.

carbon policy could be designed and already signaled the clear intention to regulate carbon emissions in South Africa. Three years later, the Carbon Tax Policy Paper presented a more concrete proposal, but it still lacked details on the final framework. It was not until the end of 2015 that the first draft of the Carbon Tax Bill was published. The draft detailed the various allowances for different sectors and activities. Importantly, it also provided the schedule of GHG emission factors (in CO_2-equivalent), which are used to calculate—rather than directly measure—firms' emissions based on their activities. Hence, previously unaware firms learned at that point how much they emitted and, consequently, how much they would owe. Finally, the Carbon Tax Act was passed in 2019 and took effect in June of that year. The empirical analysis will focus on these latter two events, which we interpret as the *announcement* and the *implementation* of the carbon tax.

The process of the carbon tax enactment was accompanied by much resistance from affected industries (Baker, 2022). In addition, the policy process was open for public comments, allowing affected industries or interest groups to actively engage and participate in the discussions around the design of the carbon tax policy. The opportunity for public comment was heavily used—Appendix B shows the distribution of comments from various stakeholders, ranging from industry associations to individuals. The comments ranged from requests for further clarification to substantial criticism and challenges to the carbon tax. While some comments were taken into consideration, the final Carbon Tax Act still featured all the main elements proposed in the initial Carbon Tax Bill in 2015. Nevertheless, this heavy public engagement illustrates the pressure the legislation was facing in pushing the carbon tax through. It may have led to the initial design of granting various allowances and exemptions meant to attenuate the alleged negative consequences of the tax (Just Share, 2025).

[Figure 1 here]

Exemptions and allowances. In principle, the carbon tax applies to all firms emitting CO_2 if the extent of their polluting activity exceeds a certain threshold as defined in the Carbon Tax Act (2019).[7] These thresholds can be industry- or activity-specific. For example, the threshold for firms with combustion activities was set at 10 MW of installed thermal input capacity. This means that regardless of utilization or fuel type, if a firm has the capacity to combust 10 MW(th), then its emissions will be subject to the carbon tax. If the firm has a smaller capacity, carbon taxes do not apply. This ensures that the smallest firms are exempted altogether.

Initially, the first phase of the carbon tax was set to run from June 1, 2019, to December 31, 2022. However, the government extended this phase by three years to support economic recovery in the wake of the COVID-19 pandemic. At the time of the introduction of the carbon tax in 2019, the statutory tax rate amounted to \$120 ZAR ($\sim$ \$7 USD) per tonne

[7] Appendix Figure A.2 presents a portion of South Africa's Carbon Tax Act of 2019, which specifies the emission thresholds that determine firms' liability for the carbon tax, as well as the allowances that can reduce their effective tax burden.

of CO_2. Despite being relatively low compared to other carbon pricing policies (Timilsina, 2022), the statutory tax rate increases annually by inflation plus 2 percent for the first few years. As of 2024, the statutory tax rate amounts to \$190 ZAR ($\sim$ \$11 USD). This low rate is expected to increase after the end of the transition phase, in December 31, 2025. The government plans to raise the carbon tax rate to at least US\$ 20/tCO_2 by 2026, to US\$ 30/tCO_2 by 2030, and accelerating to higher levels up to US\$ 120/tCO2 beyond 2050 (Qu et al., 2023).

Having said that, in the first few years following the introduction of the carbon tax, the *effective* tax rate could be reduced further through various allowances, as part of the transition from the initial phase of the carbon tax program. First of all, for the majority of sectors, there is a basic tax-free allowance of at least 60% of emissions, which means that only 40% of firms' emissions are actually taxed. Additionally, there are specific allowances for fugitive emissions, for the extent of trade exposure, performance allowances (for firms emitting less than their industry-specific standard) as well as carbon budget and offset allowances. These last two types of allowances refer to credits for voluntarily participating in the carbon budget program or for purchasing carbon offsets, provided the offsets are generated within the country. As a result of the tax-free allowances, which can total up to 95%, the effective rate could be as small as \$6 ZAR (US\$ 0.40) per ton of CO_2 emissions (Steenkamp, 2022). The low rate is aimed at allowing large emitters enough time to transition to clean technologies, but is set to be phased out at the end of the transition phase on December 31, 2025.

In addition to the carbon tax allowances, firms in South Africa can deduct the petroleum and diesel levies, as well as the electricity levy, from their carbon tax liabilities. These levies are pre-existing fiscal tools that interact with the carbon tax policy, all aiming at managing environmental impacts and promoting energy efficiency. The petroleum and diesel levies, introduced in 2003, are charged on petrol and diesel to fund road infrastructure and public transport systems, while also incentivizing fuel efficiency. The electricity levy, implemented in 2009, is applied to electricity consumption to reduce reliance on coal-fired power generation and support the transition to cleaner energy sources. Alongside the carbon tax allowances, these levies are deductible, reducing the overall carbon tax liabilities.[8]

As a result, the Net Emissions Equivalent (NEE), which represents the emissions subject to the carbon tax after accounting for allowances and deductions, is calculated as:

$$NEE = [(E - S) \times (1 - C)] - [D \times (1 - M)] + [P \times (1 - J)] + [F \times (1 - K)], \qquad (1)$$

where E refers to all fuel combustion-related emissions of a taxpayer, from which sequestrated emissions S may be subtracted. C represents the sum of allowances applicable to

[8] As stated by South Africa Revenue Services, the fuel and electricity levies are excluded from the carbon tax calculation to avoid double taxation (South African Revenue Service, 2021).

fuel combustion activities. D corresponds to the CO_2 emissions from petrol and diesel. Since petrol and diesel are already subject to a fuel levy, their emissions are multiplied by their respective allowances M and subtracted, effectively exempting them from carbon taxation to avoid double taxation. P represents industrial process-related CO_2 emissions, and J denotes the corresponding allowances that can be deducted. Lastly, F refers to fugitive emissions, and K represents the applicable allowances for these emissions.

The net emissions, as calculated above, still do not directly correspond to actual carbon tax payments, as certain expenditures on other taxes can be credited against the carbon tax liability. For instance, as mentioned above, electricity providers can deduct the costs incurred from complying with the electricity levy. Thus, electricity providers are effectively "exempt" from the carbon tax during its current introductory phase.

3 Data

Our analysis uses detailed administrative tax data from the South African Revenue Service (SARS), accessed confidentially through the South African National Treasury. The individual data components are described below, but all three data sources can be linked using anonymized tax reference numbers provided by SARS.

Carbon tax data. SARS provides information on all individual carbon tax filings since the implementation of the carbon tax in 2019. Overall, about 300 South African firms are subject to the carbon tax, reporting detailed information on their emissions inventories and tax payments.[9] The reported emissions are further broken down by the components as shown in Eq. (1). This includes information on fuel usage and various types of industrial process and fugitive emissions (see Appendix Figure A.3 for details). In addition, we observe the extent of allowances that are claimed by firms.

Financial and customs data. As a second source of information, we rely on the CIT-IRP5 firm panel, which harmonizes and combines corporate income tax (CIT) information, value-added-tax (VAT) as well as customs tax data on imports and exports (Ebrahim et al., 2021; Pieterse et al., 2018). The CIT-IRP5 firm panel encompasses the entire population of South African firms, totaling over 600,000 annual firm observations. Only 0.05% of these firms are subject to the carbon tax, leaving the vast majority outside its scope. These non-taxed firms provide a large pool for identifying a suitable comparison group. The CIT data is based on corporate tax returns submitted to SARS and comprises information on total sales and profits, capital stock, and the total wage bill. The information is based on

[9] Of the hundreds of thousands of South African firms, only about 300 exceeded the threshold and became liable for the carbon tax, highlighting the relative ease of administering a carbon tax compared with cap-and-trade systems in developing-country settings with limited state capacity.

the South African tax year which runs from March to February of the following year.[10] Customs information is obtained from transaction-level customs declaration forms containing information on the value of the transaction, product code as well as information on the partner country. From the customs-derived data, we mainly use firm-level aggregates of imports and exports. Finally, the data contain information of various transaction-level VAT-forms, which are aggregated to the firm level.

Employment Data. The final source of administrative data we use is the individual panel, which contains individual-level data submitted by employers registered under the pay-as-you-earn (PAYE) scheme (Ebrahim and Axelson, 2019). Since the 2010/2011 tax year it is mandatory for employers to be part of PAYE. As the data is still incomplete for the early years up to 2013, we only use the individual panel starting in 2013. Most importantly, the data allow us to calculate the number of employees and the distribution of wages within each firm by linking it with the CIT-IRP5 firm panel.

Environmental Data. As the carbon tax data provides detailed information on the emission profiles of regulated firms only after the implementation of the Carbon Tax Act in 2019, we obtain two additional datasets for studying the environmental impacts of the carbon tax in the form of greenhouse gas (GHG) emission reductions. First, we obtain firm-level data from the Carbon Disclosure Project (CDP)—covering a subset of our main sample—which constitutes the world's largest primary corporate environmental dataset on annually disclosed GHG emissions (CDP, 2025).[11] The data structure enables the construction of a global firm-level panel that records annual emissions from 2010 to 2023. In addition, the data provides explicit information on whether firms are currently subject to regulation or anticipate regulation under carbon pricing policies in the near future. While the National Treasury has relied on data from the CDP prior to the implementation of the Carbon Tax Act (e.g., National Treasury, 2010), the voluntary nature of disclosures may lead to non-representative reporting of GHG emissions. As a complementary source, we therefore draw on national GHG emissions data from the Emissions Database for Global Atmospheric Research (EDGAR), compiled by the Joint Research Centre of the European Commission (Crippa et al., 2024). Although the dataset does not offer detailed firm-level resolution, it provides comprehensive annual information on national emissions, thereby alleviating concerns regarding selection bias. Taken together, the two datasets provide complementary insights, allowing for a nuanced assessment of the environmental impacts of the South African carbon tax.

Descriptive Statistics. Out of all South African firms, only a small fraction is liable

[10] In contrast to the fiscal year, the reporting period for the carbon tax follows the calendar year and runs from January to December.

[11] Firms voluntarily disclose emissions to the CDP to signal environmental responsibility, respond to investor pressure, benchmark performance, and prepare for future regulation.

for the carbon tax. This implies that the emissions from many firms are not covered. Between 2020 and 2023, only about 300 firms have declared emissions associated with the carbon tax. As panel (a) of Figure 2 shows, however, the country's emissions are highly concentrated within these firms. Overall, the gross emissions reported in carbon tax returns represent approximately 80% of total nationwide emissions (colored in red). This suggests that the carbon tax covers the majority of emissions, even though most firms are exempt.

In contrast to gross emissions, net emissions (colored in green) represent the emissions subject to the carbon tax after applying various allowances, as per Eq. (1). It becomes evident that the large potential of the carbon tax remains yet untapped. Over the years, only about 18% of nationwide emissions have been effectively taxed. This stark difference between gross emissions and net emissions is primarily due to the substantial allowances that firms can claim, reducing the carbon tax base.[12]

[Figure 2 here]

We further illustrate this discrepancy at the firm level in Panel (b) of Figure 2 by examining *effective* tax rates. These reflect how much the average firm pays per ton of emitted CO_2. The statutory tax rate, as defined by law, started at $120 ZAR per ton of CO_2-equivalent and gradually increased to $134 ZAR in 2023, as shown in Panel (b). However, the average effective tax rate is significantly lower, as indicated by the red bar.

[Figure 3 here]

The source and extent of emissions, and thus carbon tax liabilities, vary widely across industries. Panel (a) of Figure 3 plots the distribution of carbon tax revenues across industries. More than 80% of the tax revenues come from manufacturing firms and another 10% from mining firms. Panel (b) suggests, however, that the largest emitters do not necessarily pay the most. In fact, while we see manufacturing firms contributing over 80% of carbon tax payments but only about 25% of emissions, the electricity sector is responsible for about 64% of emissions but contributes only less than 2% of carbon tax payments. This is due to the deduction of the electricity levy. In the mining sector, although on a smaller scale, the share of carbon tax payments is three times larger than its share of emissions. It is noteworthy that a substantial share of firms filing carbon tax returns report no tax liability, effectively categorizing them as non-payers. In our sample, this applies to 17% of the filings (see Figure A.4). There are several reasons why firms may report no carbon tax liability. First, some firms may have no emissions to declare for a given tax period. Second, as mentioned above, electricity providers can offset the carbon tax by crediting the electricity levy. Third, firms might have zero net emissions, either because they only have emissions from petrol and fuel or because their emissions are fully sequestrated elsewhere (see Eq. (1) and Figure A.5 for more details). In fact,

[12]The gap is even more pronounced when turning to net emissions which are actually paid for. In most cases, this is because firms can offset their carbon tax payments by crediting the electricity levy, as detailed in Section 2. In the end, the carbon tax is directly paid for only about 4% of national emissions.

most firms with zero emissions only report emissions from petrol and diesel, meaning they are effectively exempt from explicit carbon taxation.[13]

4 Conceptual Framework

To better understand the factors driving the carbon tax's impact on firm outcomes, we present a simple conceptual framework, building on Bushnell et al. (2013). To fix ideas, we assume competitive markets and express the profits of firm i as:

$$\pi_i = PQ_i - C_i(Q_i, \mathbb{1}(\tau > 0)\tau) - \mathbb{1}(\tau > 0)\tau E_i(Q_i, \tau),$$

where $C_i(Q_i, \mathbb{1}(\tau > 0)\tau)$ represents the total cost of producing Q_i, considering the presence or absence of a carbon tax τ, and $E_i(Q_i, \tau)$ denotes the total CO_2 emissions required to produce Q_i, with or without a carbon tax τ. Thus, the total impact on profits from a marginal change in τ can be expressed as:

$$\frac{d\pi_i}{d\tau} = P\frac{dQ_i}{d\tau} - \frac{\partial C_i}{\partial Q_i}\frac{\partial Q_i}{\partial \tau} - \mathbb{1}(\tau > 0)\left[\frac{\partial C_i}{\partial \tau} + E_i(Q_i, \tau) + \tau\left(\frac{\partial E_i}{\partial Q_i}\frac{\partial Q_i}{\partial \tau} + \frac{\partial E_i}{\partial \tau}\right)\right]. \quad (2)$$

Assuming that firms maximize profits with respect to Q_i, and for shocks that have marginal influence on Q_i, the envelope theorem implies:

$$\frac{\partial \pi_i^*}{\partial Q_i} = P - \frac{\partial C_i}{\partial Q_i} - \mathbb{1}(\tau > 0)\tau\frac{\partial E_i}{\partial Q_i} = 0. \quad (3)$$

Combining (2) and (3), we derive the following expression for how a carbon tax affects firm i's profits:

$$\frac{d\pi_i}{d\tau} = -\left[E_i(Q_i, \tau) + \tau\frac{\partial E_i}{\partial \tau} + \frac{\partial C_i}{\partial \tau}\right] \lesseqgtr 0. \quad (4)$$

The sign of this effect is *ambiguous* because $E_i(Q_i, \tau)$ is positive, $\frac{\partial E_i}{\partial \tau}$ is negative by policy design, as emissions are internalized as an additional input. Furthermore, $\frac{\partial C_i}{\partial \tau}$ can be positive or negative, depending on innovation or the transitional costs of the implementation of the carbon tax.

To further explore the factors influencing total cost, we express it as:

$$C_i = r^I[1 - \delta(\tau)]K_i^I + r^N K_i^N + wL_i,$$

where K represents capital and L labor, the superscripts I and N denote 'incumbent' and 'new,' respectively, and $\delta(\tau)$ represents depreciation. Thus,

$$\frac{\partial C_i}{\partial \tau} = r^I[1 - \delta(\tau)]\frac{\partial K_i^I}{\partial \tau} - r^I K_i^I\frac{\partial \delta}{\partial \tau} + r^N\frac{\partial K_i^N}{\partial \tau} + w\frac{\partial L_i}{\partial \tau} \lesseqgtr 0. \quad (5)$$

[13] The fuel levy, however, was aligned with the carbon tax rate so that their emissions are equivalent taxed via the fuel levy.

The sign of this effect is also ambiguous because $\frac{\partial K_i^I}{\partial \tau}$, $\frac{\partial K_i^N}{\partial \tau}$, and $\frac{\partial L_i}{\partial \tau}$ may be positive if capital and labor substitute for emissions or negative if they complement emissions. Note that these derivatives are taken with respect to the carbon tax, which effectively sets the price of emissions as a new input. As for the impact of the carbon tax on depreciation, $\frac{\partial \delta}{\partial \tau}$, it is expected to be positive, as firms seek to minimize losses from stranded assets.

Lastly, the total impact of the carbon tax on emissions $E_i(Q_i, \tau)$ is given by:

$$\frac{dE_i}{d\tau} = \frac{\partial E_i}{\partial Q_i}\frac{\partial Q_i}{\partial \tau} + \frac{\partial E_i}{\partial \tau} \lesseqgtr 0, \tag{6}$$

The sign of this total derivative is *ambiguous*. Although $\frac{\partial E_i}{\partial \tau}$ is negative by policy design—since emissions are internalized as an additional input—$\frac{\partial E_i}{\partial Q_i}$ can be either positive or negative, depending on the extent of innovation and the length of the transitional period for tax implementation. Firms might expand production using renewable energy, for example, but might be slow to adjust if the transition period is relatively long. Similarly, $\frac{\partial Q_i}{\partial \tau}$ can also take either sign, depending on its effect on productivity. While firms often argue that environmental policies reduce productivity, the Porter Hypothesis suggests that such policies can drive innovation, improving overall production efficiency and leading to a positive productivity impact (Porter, 1991; Ambec et al., 2013). However, if a command-and-control regulation is imposed—directly capping emissions—$\frac{dE_i}{d\tau}$ is more likely to be negative due to potential productivity losses, particularly in emissions-intensive industries.

To sum up, this conceptual framework predicts that the impacts of a carbon tax on firm profits and emissions are ambiguous, making it an empirical question. Additionally, the effects on capital and labor depend on whether they are substitutes or complements to emissions. If capital and labor are substitutes for emissions, the cross-elasticities with respect to the carbon tax would be positive, leading to increases in both capital and labor. However, if they are complements to emissions, the cross-elasticities would be negative, resulting in decreases in both capital and labor, which could lead to underutilized capacity and unemployment.

5 Empirical approach

In this section, we outline our empirical approach to examine the mechanisms proposed by the conceptual framework using real-world data. The analysis relies on a matched difference-and-differences strategy, where matching is based on firms' observable characteristics before the announcement of the carbon tax.

Coarsened Exact Matching. In principle, firms that are liable for carbon tax might be different from those that are not. Due to various exemptions and size thresholds (cf. Section 2), simple comparisons of treated and non-treated firms are prone to selection bias. We address this issue by relying on matching techniques that reduce imbalances in the characteristics of treated and non-treated firms (cf. Colmer et al., 2025; Dechezlepretre et al., 2023).

In particular, we rely on coarsened exact matching (CEM).[14] This involves temporarily coarsening the data based on observed firm characteristics before the treatment period. The coarsening process applies a predefined common binning strategy, creating unique observations within the coarsened data. Each of these unique observations constitutes a stratum. Treated and untreated firms are then exactly matched on these strata. Observations whose strata do not contain at least one treated and one untreated observation are dropped, and weights are used to compensate for the different strata sizes (Iacus et al., 2012). Importantly, and contrary to many other matching strategies, coarsened exact matching does not only account for imbalances in means but also for imbalances in higher moments and interactions (Iacus et al., 2012; Blackwell et al., 2009).

For our main analysis, we match firms exactly at the 3-digit industry level. Additionally, we match firms based on their baseline profits, sales, import and export volume, number of employees, total wage bill, and capital stock. Each of these variables is divided into five equally sized bins. The baseline year is chosen to be the tax year of 2014-15, just before the first Carbon Tax Bill was drafted and made public. In part to address log with zeros issues (Chen and Roth, 2024), we exclude treated firms with sales and capital equal to zero in 2015, i.e., we only keep firms that were operating in 2015.

Estimation strategy. After generating a comparison group through matching, we estimate the causal effect of carbon taxation on firm behavior. In particular, we estimate an event-study type model as follows:

$$\ln(y_{it}) = \sum_{k=2011, k\neq 2015}^{2021} \theta_k \mathbf{1}[t = k] \times \mathbf{1}[i = CarbonTax] + \alpha_i + \gamma_{pt} + \epsilon_{it}, \tag{7}$$

where y_{it} is an outcome of interest for firm i in year t. $\mathbf{1}[i = CarbonTax]$ is an indicator for whether a firm ever files a carbon tax return.[15] α_i and γ_{pt} are firm and province-by-year fixed effects, respectively. Our coefficients of interest are the θ's. We exclude 2015 as the baseline year to account for anticipatory effects upon the release of the draft of the Carbon Tax Bill, but before the actual implementation of the tax. Further, the year 2015 corresponds to the year for which we apply coarsened exact matching. In order to estimate the effect of the carbon tax on firm behavior, it is required to establish a meaningful comparison group. To this end, we estimate Eq. (7) with the weights obtained from the coarsened exact matching. The baseline estimation sample comprises 164 treated firms, i.e., about 80% of all treated mining and manufacturing firms, and to 1,631 comparison

[14] Other applications of CEM in economics include Azoulay et al. (2019) and Aneja and Xu (2022).

[15] Note, however, that due to the deduction of allowances, not all firms that file a carbon tax return have an actual carbon tax liability. However, we classify them as treated since they will begin paying the tax after the end of the transitional period. Therefore, our estimates reflect intent-to-treat effects. See Appendix Figure A.4 for details.

(non-treated) firms from the same sectors.[16]

Identifying assumptions. Our empirical strategy for isolating the causal impact of the carbon tax on firm activity is based on two key identifying assumptions. The first is the assumption of parallel trends of treatment and comparison groups. Put differently, we assume that in the absence of the carbon tax, both treated and untreated firms would have followed the same economic trends over time. Although it is impossible to observe these counterfactual trends, we can scrutinize the plausibility of this assumption by inspecting whether the treatment and comparison groups have followed similar trends prior to the treatment. Given that a lengthy policy process preceded the implementation of the carbon tax, we explicitly allow for anticipatory behavior and define our first treatment as the announcement of the Carbon Tax Bill in 2015. Hence, we would need to assume parallel trends prior to the announcement in 2015.

Figure 4 plots the averages over time for our variables of interest, such as sales, capital, employment, and profits by treatment status. While the dashed lines display the unmatched sample, the solid lines indicate the averages for the matched sample. The visual co-movement prior to 2015 supports the parallel trends assumption needed for a causal interpretation of the treatment effects. Although the parallel trends assumption relies on changes over time, the pre-treatment matching helps to alleviate further validity concerns by reducing cross-sectional differences between the treatment and comparison groups. The reasoning behind this is that carbon tax firms in South Africa are particularly large and could be exposed to systematically different types of contemporaneous shocks. As shown in the figure, matching substantially reduces differences in pre-treatment characteristics, thereby lowering the likelihood of estimation bias due to idiosyncratic contemporaneous shocks.

[Figure 4 here]

The second identifying assumption is the Stable Unit Treatment Value Assumption (SUTVA). This assumption states that the observed trajectories of the treatment and comparison groups depend only on their respective treatment statuses. This assumption would be violated if the matched comparison firms were indirectly treated by the carbon tax policy—for instance, if firms strategically adjust their economic activity to stay below the liability thresholds or are affected by general equilibrium effects. Depending on the direction of the effects, this can either lead to an upward or downward bias in our estimates. In order to alleviate this concern, we run our estimation with different matching stringencies. If we assume that the violation of SUTVA is increasing in the similarity of treatment and comparison firms, the estimation bias arising from SUTVA should become more prevalent the more similar treatment and comparison firms are. On the other hand, allowing for larger cross-sectional differences between treatment and com-

[16] This ratio of matched to unmatched treated firms, as well as the absolute number of matched firms, is comparable to a recent evaluation of the EU ETS (Colmer et al., 2025).

parison firms would attenuate potential biases arising from SUTVA violation. Appendix Figures C.1 to C.7 show our estimation results when using different forms of matching. The reported results are comparable across different matching approaches, indicating that SUTVA violations might not be a major concern in our empirical setting. Moreover, it is important to note that the thresholds defining carbon tax liability are based on thermal input capacity, making them less susceptible to manipulation compared to metrics like sales. This limits the scope for firms to strategically bunch below the treatment threshold.

6 Results

In this section, we report and discuss the results of our empirical analysis. We start with our main findings on how the carbon tax policy affects firm outcomes such as capital, employment, sales, and profits before moving to an analysis of the environmental effects and exploring heterogeneity across firms.

6.1 Baseline results

In our main analysis, we estimate the event-study model Eq. (7) using the matched sample (cf. Figure 4). Figure 5 presents the results for capital, employment, sales, and profits, respectively, as the outcome variables. In each panel, the dashed vertical lines indicate two key events. First, at the end of 2015, the first Carbon Tax Draft Bill was published. To account for anticipation effects that may have begun at that time, we use 2015 as our baseline year. Second, the actual implementation of the Carbon Tax Act occurred in 2019. It is important to note that the fiscal year in South Africa runs from March to February. Therefore, the fiscal year 2020 started in March 2019 and ended in February 2020. As a result, the estimated effects for 2020 largely reflect the impact of the carbon tax (which was implemented in June 2019), without being influenced by the COVID-19 pandemic, which began in the following fiscal year (Burger and Calitz, 2021).

Focusing on the input side first, we observe that the evolution of capital among treated and untreated firms was indistinguishable prior to 2015 (Figure 5, Panel (a)). The pre-trend is virtually flat, with coefficients close to zero and statistically insignificant throughout. Upon the announcement of the Carbon Tax Bill in 2015, this pattern changes substantially. In particular, we observe statistically significant increases in capital in the treated firms relative to the comparison firms. The effects remain significant, increase over time, and appear to level out after the carbon tax is actually implemented in 2019. A similar picture emerges for employment (Panel (b)). While employment data are only available from 2013 onwards, we find no statistically significant differences—and only small differences—between treated and comparison firms prior to the announcement of the carbon tax. However, the announcement appears to have an effect, as we estimate positive and significant impacts in the subsequent years. These findings suggest that capital and labor increase following the carbon tax announcement, consistent with a scenario in which they act as substitutes for emissions. Firms appear to adjust inputs in anticipation of the policy, reflecting forward-looking behavior rather than responses to realized tax liabilities. While the conceptual framework allows for either positive or negative effects, this pattern is consistent with the possibility that the carbon tax raises input use, rather than reducing capital or labor.

Panels (c) and (d) of Figure 5 report the dynamic effects on firm outputs, showing patterns consistent with those for capital and employment. We estimate positive and statistically significant effects after the announcement, along with relatively flat pre-trends prior to the announcement period. If anything, there might have been a downward trend in profits, which was reversed afterward. Appendix C shows that Figure 5 estimates are robust to a variety of different matching strategies. These findings suggest that—contrary to many observers' expectations—neither the announcement of the carbon tax nor the actual implementation hindered firm growth. Instead, firms may have had an anticipatory incentive to expand operations *before* the carbon tax was implemented. This pattern is in line with the conceptual framework's prediction of an ambiguous effect on profits: while the carbon tax could have reduced profits through higher emission costs, it may have been offset by adjustments in inputs or other firm responses. The observed rebound and subsequent growth suggest that, in practice, any negative effects were outweighed by these compensating factors. We pick up this line of thought and discuss potential mechanisms in the following section.

In order to shed more light on the positive employment response, we rely on matched employer-employee data to investigate whether more high-skilled or low-skilled workers are additionally employed. To this end, we compute each firm's median wage in the baseline year, 2015, and deflate wages in all subsequent years relative to this baseline. Figure 6 reports the effects on the number of employees with wages that are higher than this number in the subsequent years. While Panel (a) exhibits no pronounced effect on the lower part of the wage distribution, Panel (b) shows a positive and significant effect on better-paid workers in all periods after the announcement.[17] Suggestively, this shows that the additional employment is concentrated among high-skilled workers, which may reflect firms hiring more skilled employees to comply with regulatory requirements or potentially to support innovation in response to the carbon tax. These patterns are consistent with the idea that employment gains are concentrated in tasks that enhance firm adaptation and productivity, rather than simply replacing lower-skilled labor—contrary to concerns often raised by unions.[18]

[17]It is important to note that average wages do not appear to have changed, as shown in Appendix Figure D.1. While there is some evidence of increases in median wages, we observe no notable changes in the lowest or highest quintiles of the wage distribution.

[18]The effect on average wages as well as on the lowest and highest quintile of wages is muted, while the median wage of treated firms increases slightly (see Appendix D). An example of a union statement in response to the enactment of the carbon tax can be found here: https://mediadon.co.za/cosatu-notes-the-ncops-adoption-of-the-carbon-tax-bill-today/.

[Figure 5 here]

[Figure 6 here]

6.2 Environmental effects

The primary objective of any environmental policy is to reduce harmful emissions. However, a common obstacle to measuring the effects of regulating policies on environmental outcomes is that prior to regulation, there are no reliable data. This is also the case for the administrative tax records we use for our main analysis, in which we only observe reported emissions after the tax was implemented.

To overcome this limitation, we provide two complementary analyses. First, we draw on firms' self-reported emissions from the Carbon Disclosure Project (CDP). Although we cannot link it directly to administrative records, we are confident that the samples overlap for most of the treated firms, as the National Treasury has used the same data prior to the implementation of the Carbon Tax in 2019 to provide information on firm-level emissions in official publications (e.g., National Treasury, 2010). Empirically, we rely on an event-study model to measure the impact of announcement and implementation on firms' emissions. In order to find suitable comparison firms, we match South African firms with non-South African firms based on their industry denomination, annual emissions between 2010 and 2015 as well as their emissions intensity in 2015. Further, we exclude all countries with a carbon pricing policy so that the majority of comparison firms are located in countries such as Brazil, India, Australia or Turkey (for details see Appendix Figure E.1). Second, we use more aggregate measures of emissions from the EDGAR database and estimate the environmental effects at the country level using the synthetic control method.

For the firm-level analysis using CDP data, we examine whether South Africa's carbon tax affected firms' emissions by estimating Eq. (7) with the logarithm of carbon emissions as the outcome variable. Figure 7 presents the estimated event-study coefficients. Panel (a) compares South African firms subject to the carbon tax with firms in other countries, while Panel (b) focuses on firms that report anticipating regulation in the near future. Across both treatment definitions, we find no statistically significant effects of the carbon tax on reported emissions. However, the confidence intervals are wide, suggesting substantial uncertainty. We therefore interpret these results with caution and refrain from drawing firm conclusions about whether the policy reduced, increased, or left emissions unchanged.

[Figure 7 here]

For the country-level analysis, we assess the impact of South Africa's carbon tax using the synthetic control method. This approach constructs a "synthetic" version of South Africa by combining data from countries that did not implement a carbon tax or similar carbon pricing schemes. The synthetic control is a weighted average of these comparison countries, chosen to closely match South Africa's pre-policy characteristics, such as emissions trajectories and economic indicators. By creating this counterfactual benchmark, the method addresses the challenge of not having a well-defined comparison group (Abadie, 2021).

Figure 8 compares the emissions of South Africa to those of "synthetic South Africa". The latter is a convex combination of the emissions of Brazil (50%), Australia (49,6%), and India (0.4%)—the result of matching countries on their emissions prior to 2015 (see Appendix D for details and additional specifications). Panel (a) shows that the synthetic control closely tracks South Africa's emissions trajectory prior to the carbon tax announcement. Beginning in 2016, however, the two series diverge, with South Africa's emissions rising relative to the synthetic control. After the implementation of the carbon tax in 2019, this trend reverses, as South Africa's emissions appear to decline relative to the synthetic benchmark.

[Figure 8 here]

Panel (b) plots the difference in emissions between South Africa and the "synthetic South Africa" over time, where the spike and subsequent drop in emissions are clearly visible. Panel (c) presents the results of a permutation test, which provides a way to assess the statistical significance of the estimated differences shown in Panel (b). Specifically, we compute the same differences for each country that could have served as the treated unit in the synthetic control analysis ("placebo in space"). We then compare South Africa's estimated differences to this distribution to evaluate whether they are unusually large, and calculate the corresponding p-values. For example, for the peak difference observed in 2018, only 9 out of 54 countries display an absolute difference larger than South Africa's, yielding a p-value of $9/54 = 0.17$ (Abadie et al., 2010; Andersson, 2019; Abadie, 2021). Thus, although a visible difference in emissions is apparent, it is not statistically significant. The same conclusion holds for all other years.[19]

Turning to placebo treatments "in time," we simulate hypothetical carbon tax implementations in earlier decades to further assess the robustness of our findings. In particular, we re-estimate the synthetic control method assuming carbon tax introductions in 2009, 1999, 1989, and 1979, respectively, instead of 2019. Across all scenarios, the emissions gap between South Africa and its synthetic counterpart diverges from zero within three years of the policy announcement. However, only the actual 2019 implementation is associated with a temporary increase in emissions prior to the tax, consistent with potential anticipatory behavior by firms.

6.3 Heterogeneity analysis by allowance take-up

We next examine whether firms' responses to the carbon tax and its announcement vary by the extent to which they benefited from tax allowances. Allowances are a key feature of South Africa's carbon tax policy, as they determine firms' effective tax rates and thus the

[19] The calculated p-values are: 2016: 0.15; 2017: 0.24; 2019: 0.15; 2020: 0.27; 2021: 0.10; 2022: 0.15.

intensity of their treatment (cf. Section 2). Figure 9 presents results separately for firms in the lowest (1st quintile) and highest (5th quintile) allowance groups. Firms in the 1st quintile, which were limited in claiming allowances and therefore faced higher effective tax rates, exhibit a more immediate and pronounced response to the policy announcement. In contrast, the effects for firms in the 5th quintile, which benefited most from allowances, are much smaller and often statistically indistinguishable from zero.

[Figure 9 here]

The stronger response among low-allowance firms is consistent with anticipatory behavior in response to higher effective tax rates, whereas firms with more generous allowances may have faced less immediate pressure to adjust, as the financial cushioning reduced the urgency to modify operations or emissions intensity. While this pattern suggests that the allowance system effectively mitigated the short-run adjustment costs of the carbon tax, it is also possible that firms with greater allowance take-up exercised lobbying power or other means to influence, delay, or partially obstruct regulation. The Just Share (2025) report notes that "most corporate influence on government legislative processes appears to take place via industry associations. This allows individual companies to maintain public positions of purported support for climate action, while indirectly undermining the policies needed for the country to meet its climate goals. Industry associations, therefore, play a central role in advocating against effective climate policy." This observation aligns with our descriptive analysis of public comments on the carbon tax, the vast majority of which were submitted by industry associations (see Appendix B), providing additional support for the lobbying interpretation.

As an additional heterogeneity analysis, we examine whether the results vary by sector or firm size. Running the analysis separately for manufacturing and mining firms (Appendix Figure D.2) and across firm-size groups (Appendix Figure D.3) yields qualitatively similar results. Although the estimates for mining are noisier due to the smaller sample size, the effects of the carbon tax and its announcement are consistent across both dimensions, suggesting that our core findings hold across industries and firm sizes. It is important to highlight, however, that the sectoral breakdown is motivated by a National Treasury (2019) statement, which emphasized transitional incentives designed to cushion energy-intensive industries—such as mining—during the carbon tax rollout, which is also consistent with the lobbying interpretation.

Overall, the results suggest that firms' responses to the carbon tax are primarily shaped by their effective tax exposure through the allowance mechanism, rather than by industry or firm size. We now explore these mechanisms further.

7 Mechanisms

We have shown that the announcement and implementation of the carbon tax led to positive effects on sales, capital, employment, and profits, particularly among firms claiming fewer allowances. In this section, we explore two potential channels that could explain this pattern. Specifically, we focus on how uncertainty resolution, firms' anticipation of future costs, and technology upgrading may have driven firms to increase their activity following the tax announcement.

7.1 Uncertainty and anticipation

Firms must make decisions under uncertainty across many dimensions, including the regulatory framework in which they operate, particularly regarding taxation. Environmental accountability through taxation had been part of the South African policy agenda well before its formal implementation in 2019, with discussions about its structure and purpose taking place as early as 2010 (cf. Figure 1).

The release of the Carbon Tax Bill in 2015 represents a key milestone, as it outlined the core elements of what would later become the Carbon Tax Act and clarified several previously uncertain aspects of the policy. It provided critical details, such as the emission factors—how much CO_2 a specific production activity would generate—as well as the applicable tax rates and the allowance structure, allowing firms to calculate their likely tax liability with greater certainty. Moreover, the tax design itself, which does not impose an emissions cap as a cap-and-trade system would, likely eased concerns about production limits. Under this framework, firms retained the flexibility to produce as much as they desired, as long as it was economical to pay the associated tax, reducing a significant layer of uncertainty.

This resolution of uncertainty can be seen as a positive information update to firms' expectations, particularly in less developed economies where uncertainty about carbon pricing is likely to be high (Fuchs et al., 2024). Consistent with this anticipation mechanism, Appendix E documents a sharp increase in the number of firms explicitly reporting that they were expecting a carbon tax in 2017-2019, providing further evidence that firms updated their expectations in response to the policy announcement.

Firms may have responded strategically to this update by anticipating future costs: in the sense of Sinn (2012), they might shift production from the expensive future (under the carbon tax) to the cheaper present (before the tax applies). As firms allocate capital and adjust production over time, they may increase output upon the policy announcement and reduce or stabilize it after implementation. Sectors with "dirty" capital might similarly have incentives to use up existing capacity before higher taxes take effect. Our analysis shows that firms were affected heterogeneously, reflecting differences in allowances both across and within industries. Since these allowances—and approximately the effective tax rates—became known upon the 2015 announcement, firms with higher expected tax rates reacted more strongly, as corroborated in Figure 9.

We present two additional observations in Figure 10 that support this channel. First, Panel (a) shows the dynamic effects of the announcement on the inventory levels of treated firms, distinguishing by their allowance take-up. The results indicate a modest increase in inventory following the 2015 announcement for firms with low allowance take-up (and therefore facing relatively higher effective tax rates). This upward trend continues until 2019, with an observed inventory increase of approximately 30% in 2018, significant at the 5% level, but statistically indistinguishable from firms with high allowance take-up. This pattern suggests that some firms accumulated inventory in anticipation of the tax implementation. After the tax came into effect in 2019, the estimated coefficients decline, consistent with a reduction in production.

Second, Panel (b) illustrates a sharp rise in capital depreciation following the announcement, with effects concentrated among firms with low allowance take-up. Together with the positive effects on sales reported in Panel (a) of Figure 9, these findings collectively imply that firms expecting higher tax rates may have intensified the use of emission-intensive machinery before the tax implementation. The accelerated depreciation likely reflects an effort to mitigate the risk of stranded assets—machinery that could become uneconomical or obsolete under the new tax regime.[20] We cannot rule out, however, that firms may have also employed bookkeeping strategies or asset management practices to speed up depreciation, potentially to reduce taxable income or to adjust the valuation of assets on their balance sheets in response to the anticipated tax burden. This could have been a way to optimize their financial position under the carbon tax.

[Figure 10 here]

7.2 Technology upgrading

Another complementary explanation for the increase in firm activity following the carbon tax announcement is technology upgrading. Firms may anticipate higher future tax liabilities and respond by investing in cleaner production technologies, which can lower emissions, reduce tax payments, and enhance competitiveness and profitability (Porter and Linde, 1995; Acemoglu et al., 2012). However, such upgrades typically require time and resources. In the short term, firms may rely more heavily on existing capital, both to avoid stranded assets and to strategically manage production before implementing new technologies. Evidence from other contexts shows that environmental regulation can stimulate innovation: the introduction of an Emissions Trading System (ETS) has triggered

[20] Around the same time, South Africa adjusted its depreciation schedule, slightly increasing the rate of accelerated depreciation in 2015. We argue that this is an unlikely confounder to our results. Previous studies have shown that accelerated depreciation programs are more likely to be utilized by small and liquidity-constrained firms (Zwick and Mahon, 2017). As firms under the carbon tax are large by definition, this is only a minor concern here. In addition, Appendix Figure D.3 shows that the positive effects prevail for both large and small firms.

investments in cleaner technologies (Calel and Dechezlepretre, 2016; Calel, 2020), and in China, Cui et al. (2023) find that the ETS induced innovation that gave participating firms a comparative advantage and higher productivity.

In South Africa, we find only limited evidence that innovation or investments in cleaner technology were the primary drivers of the positive effects of the carbon tax, suggesting that short-term anticipation of future costs—rather than immediate technology upgrading—played a larger role. In Figure 11, we re-estimate our baseline specification using three indicators of innovation or technology upgrading as dependent variables. It is important to note that we did not have access to patenting data for these firms, which is why we use these alternative proxies instead.

Panels (a) and (b) show that there is generally no significant effect on R&D expenditures—if anything, the point estimates are often negative. This suggests that firms subject to the carbon tax did not increase innovation. Panels (c) and (d) display the dynamic effects on total imports, which can serve as an indicator of whether firms are purchasing clean technology or new machinery from abroad. We observe positive effects on import volume following the carbon tax announcement, but these are only statistically significant on the extensive margin. When focusing on *new imports* in Panels (e) and (f), we find a positive effect on the extensive margin after the tax announcement, but no effect on the intensive margin. While we cannot rule out some impact on innovation and technology upgrading, these analyses collectively suggest that these factors are unlikely to play a major role in explaining the positive baseline results.

[Figure 11 here]

8 Concluding Remarks

This paper provides the first comprehensive analysis of how carbon taxation affects firm performance in a large emerging economy. Using detailed administrative data from South Africa, we quantify the impact of the introduction of a nationwide carbon tax on various firm outcomes. Contrary to many expectations, our findings suggest that the carbon tax does not have negative effects on sales, capital, employment, or profits. In fact, treated firms appear to experience greater growth in these outcomes compared to their matched counterparts. Upon the announcement of the tax—four years prior to its implementation—treated firms begin to increase activity, and this positive trend continues even after the tax takes effect.

Additional analyses suggest that these positive effects may result from firms anticipating the tax and adjusting their economic activities in the short term. In particular, firms may have intensified the use of emission-intensive machinery or accelerated capital depreciation to avoid the risk of stranded assets—machinery that could become uneconomical or obsolete under the new tax regime. While we cannot fully rule out alternative explanations, we do not find robust evidence that firms invested in cleaner production methods through R&D or the adoption of new, low-emission equipment.

From a policy perspective, firms' ability to adapt—particularly those with lower allowances facing higher effective tax rates—helps mitigate anticipated costs. Firms with more generous allowances, in contrast, may face less immediate pressure to adjust and could potentially leverage their influence through lobbying or industry associations to shape the regulatory environment. This pattern highlights that the allowance system both cushions firms from short-term adjustment costs and interacts with the political economy of policy implementation. Overall, while the carbon tax can prompt short-term behavioral adjustments, its effectiveness in driving long-term environmental improvements may be limited, given the lack of robust evidence for investments in cleaner technologies or practices.

These findings provide important context for evaluating future policy developments. South Africa will reach the end of the transition period on December 31, 2025, when allowances are scheduled to be phased out and the carbon tax rate will increase to its statutory value. In parallel, exporters to the European Union may face additional costs under the Carbon Border Adjustment Mechanism (CBAM), which effectively raises the price of CO_2 for exported goods such as aluminum, steel, and iron. Our results suggest that well-designed policies that reduce uncertainty and provide clear information—combined with careful attention to potential lobbying pressures—can improve firms' ability to anticipate costs and adjust production decisions efficiently, supporting a more effective transition toward cleaner production.

References

Abadie, Alberto, "Using synthetic controls: Feasibility, data requirements, and methodological aspects," *Journal of Economic Literature*, 2021, *59* (2), 391–425.

__, **Alexis Diamond, and Jens Hainmueller**, "Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program," *Journal of the American statistical Association*, 2010, *105* (490), 493–505.

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous, "The environment and directed technical change," *American Economic Review*, 2012, *102* (1), 131–166.

Ambec, Stefan, Mark A. Cohen, Stewart Elgie, and Paul Lanoie, "The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?," *Review of Environmental Economics and Policy*, 2013, *7* (1), 2–22.

Anderson, Soren, Ioana Marinescu, and Boris Shor, "Can Pigou at the Polls Stop Us Melting the Poles?," *Journal of the Association of Environmental and Resource Economists*, 2023, *10* (4), 903–945.

Andersson, Julius J., "Carbon Taxes and CO2 Emissions: Sweden as a Case Study," *American Economic Journal: Economic Policy*, 2019, *11* (4), 1–30.

Aneja, Abhay and Guo Xu, "The Costs of Employment Segregation: Evidence from the Federal Government Under Woodrow Wilson," *Quarterly Journal of Economics*, 2022, *137* (2), 911–958.

Azoulay, Pierre, Christian Fons-Rosen, and Joshua S. Graff Zivin, "Does Science Advance One Funeral at a Time?," *American Economic Review*, 2019, *109* (8), 2889–2920.

Baker, Lucy, *The Political Economy of South Africa's Carbon Tax*, Institute of Development Studies, 2022.

Blackwell, Matthew, Stefano M Iacus, Gary King, and Giuseppe Porro, "Coarsened exact matching in Stata," *The Stata Journal*, 2009, *9* (4), 524–546.

Burger, Philippe and Estian Calitz, "Covid-19, economic growth and South African fiscal policy," *South African Journal of Economics*, 2021, *89* (1), 3–24.

Bushnell, James B., Howard Chong, and Erin T. Mansur, "Profiting from Regulation: Evidence from the European Carbon Market," *American Economic Journal: Economic Policy*, 2013, *5* (4), 78–106.

Calel, Raphael, "Adopt or Innovate: Understanding Technological Responses to Cap-and-Trade," *American Economic Journal: Economic Policy*, 2020, *12* (3), 170–201.

__ **and Antoine Dechezlepretre**, "Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market," *Review of Economics and Statistics*, 2016, *98* (1), 173–191.

Carbon Tax Act, *Carbon Tax Act*, Pretoria: Government of the Republic of South Africa, 2019.

Carlson, Curtis, Dallas Burtraw, Maureen Cropper, and Karen L. Palmer, "Sulfur Dioxide Control by Electric Utilities: What Are the Gains from Trade?," *Journal of Political Economy*, 2000, *108* (6), 1292–1326.

CDP, "CDP Climate Change Data 2010 - 2023," `https://www.cdp.net/en` 2025. Accessed: 2025-08-29.

Chen, Jiafeng and Jonathan Roth, "Logs with Zeros? Some Problems and Solutions," *Quarterly Journal of Economics*, 2024, *139* (2), 891–936.

Clay, Karen, Akshaya Jha, Joshua A. Lewis, and Edson R. Severnini, "Impacts of the Clean Air Act on the Power Sector from 1938-1994: Anticipation and Adaptation," *NBER Working Paper No. 28962*, 2025.

Colmer, Jonathan, Ralf Martin, Mirabelle Muûls, and Ulrich J Wagner, "Does pricing carbon mitigate climate change? firm-level evidence from the european union emissions trading system," *Review of Economic Studies*, 2025, *92* (3), 1625–1660.

Crippa, Monica, Diego Guizzardi, Federico Pagani, Marcello Schiavina, Michele Melchiorri, Enrico Pisoni, Francesco Graziosi, Marilena Muntean, Joachim Maes, Lewis Dijkstra et al., "Insights into the spatial distribution of global, national, and subnational greenhouse gas emissions in the Emissions Database for Global Atmospheric Research (EDGAR v8. 0)," *Earth System Science Data*, 2024, *16* (6), 2811–2830.

Cui, Jingbo, Chunhua Wang, Junjie Zhang, and Yang Zheng, "The effectiveness of China's regional carbon market pilots in reducing firm emissions," *Proceedings of the National Academy of Sciences*, 2021, *118* (52), e2109912118.

_ , Junjie Zhang, and Yang Zheng, "Carbon Price, Innovation, and Firm Competitiveness," *Mimeo*, 2023.

Dechezlepretre, Antoine, Adrien Fabre, Tobias Kruse, Bluebery Planterose, Ana Sanchez Chico, and Stefanie Stantcheva, "Fighting Climate Change: International Attitudes toward Climate Policies," *American Economic Review*, 2025, *115* (4), 1258–1300.

_ , Daniel Nachtigall, and Frank Venmans, "The joint impact of the European Union emissions trading system on carbon emissions and economic performance," *Journal of Environmental Economics and Management*, 2023, *118*, 102758.

Di Maria, Corrado, Ian Lange, and Edwin van der Werf, "Should we be worried about the green paradox? Announcement effects of the Acid Rain Program," *European Economic Review*, 2014, *69*, 143–162.

Douenne, Thomas and Adrien Fabre, "Yellow vests, pessimistic beliefs, and carbon tax aversion," *American Economic Journal: Economic Policy*, 2022, *14* (1), 81–110.

Ebrahim, Amina and Chris Axelson, *The creation of an individual panel using administrative tax microdata in South Africa* number 2019/27, WIDER Working Paper, 2019.

_ , Friedrich Kreuser, and Michael Kilumelume, "The guide to the CIT-IRP5 panel version 4.0," Technical Report, WIDER Working Paper 2021.

Ellerman, A. Denny, Claudio Marcantonini, and Aleksandar Zaklan, "The European Union Emissions Trading System: Ten Years and Counting," *Review of Environmental Economics and Policy*, 2016, *10* (1), 89–107.

Ewald, Jens, Thomas Sterner, and Erik Sterner, "Understanding the resistance to carbon taxes: Drivers and barriers among the general public and fuel-tax protesters," *Resource and Energy Economics*, 2022, *70*, 101331.

Fowlie, Meredith, Stephen P. Holland, and Erin T. Mansur, "What Do Emissions Markets Deliver and to Whom? Evidence from Southern California's NOx Trading Program," *American Economic Review*, 2012, *102* (2), 965–93.

Fried, Stephie, Kevin Novan, and William B Peterman, "Understanding the Inequality and Welfare Impacts of Carbon Tax Policies," Technical Report, Working Paper 2022.

Fuchs, Maximilian, Johannes Stroebel, and Julian Terstegge, "Carbon vix: Carbon price uncertainty and decarbonization investments," Technical Report, National Bureau of Economic Research 2024.

Gordon, Roger H, "Carbon Taxes: Many Strengths but Key Weaknesses," Technical Report, National Bureau of Economic Research 2023.

Greenstone, Michael, "The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufacturers," *Journal of Political Economy*, 2002, *110* (6), 1175–1219.

Iacus, Stefano M, Gary King, and Giuseppe Porro, "Causal inference without balance checking: Coarsened exact matching," *Political Analysis*, 2012, *20* (1), 1–24.

Just Share, *The Obstruction Playbook: How Corporate Lobbying Threatens South Africa's Just Transition*, Cape Town, South Africa: Just Share, May 2025. Accessed September 21, 2025.

Känzig, DR, "The unequal economic consequences of carbon pricing (Working Paper No. 31221)," *National Bureau of Economic Research. https://doi. org/10*, 2023, *3386*, w31221.

Lemoine, Derek, "Green Expectations: Current Effects of Anticipated Carbon Pricing," *Review of Economics and Statistics*, 2017, *99* (3), 499–513.

Lueck, Dean and Jeffrey A. Michael, "Preemptive Habitat Destruction under the Endangered Species Act," *Journal of Law & Economics*, 2003, *46* (1), 27–60.

Marron, Donald B and Eric J Toder, "Tax policy issues in designing a carbon tax," *American Economic Review*, 2014, *104* (5), 563–568.

Martin, Ralf, Laure B. de Preux, and Ulrich J. Wagner, "The impact of a carbon tax on manufacturing: Evidence from microdata," *Journal of Public Economics*, 2014, *117*, 1–14.

_ , Mirabelle Muûls, and Ulrich J. Wagner, "The Impact of the European Union Emissions Trading Scheme on Regulated Firms: What Is the Evidence after Ten Years?," *Review of Environmental Economics and Policy*, 2016, *10* (1), 129–148.

_ , Mirabelle Muuls, Laure B. de Preux, and Ulrich J. Wagner, "Industry Compensation under Relocation Risk: A Firm-Level Analysis of the EU Emissions Trading Scheme," *American Economic Review*, 2014, *104* (8), 2482–2508.

Metcalf, Gilbert E, "Carbon taxes in theory and practice," *Annual Review of Resource Economics*, 2021, *13*, 245–265.

National Treasury, "Carbon Tax Discussion Paper," 2010.

_ , "Media Statement: Carbon Tax Act," May 2019.

Pieterse, Duncan, Elizabeth Gavin, and C Friedrich Kreuser, "Introduction to the South African Revenue Service and National Treasury Firm-Level Panel," *South African Journal of Economics*, 2018, *86*, 6–39.

Porter, Michael E., "America's Green Strategy," *Scientific American*, 1991, *264* (4), 168.

Porter, Michael E and Claas van der Linde, "Toward a new conception of the environment-competitiveness relationship," *Journal of Economic Perspectives*, 1995, *9* (4), 97–118.

Qu, H, S Suphachalasai, S Thube, and S Walker, "South Africa Carbon Pricing and Climate Mitigation Policy," *Selected Issues Papers*, 2023.

Sinn, Hans-Werner, *The green paradox: a supply-side approach to global warming*, MIT press, 2012.

South African Revenue Service, "Frequently Asked Questions - Carbon Tax," https://www.sars.gov.za/wp-content/uploads/Docs/CarbonTax/Frequently-Asked-Questions-Carbon-Tax_3.0.pdf 2021. Accessed: 2025-01-22.

Steckel, Jan C, Ira I Dorband, Lorenzo Montrone, Hauke Ward, Leonard Missbach, Fabian Hafner, Michael Jakob, and Sebastian Renner, "Distributional impacts of carbon pricing in developing Asia," *Nature Sustainability*, 2021, *4* (11), 1005–1014.

Steenkamp, Lee-Ann, "South Africa's carbon tax rate goes up but emitters get more time to clean up," *The Conversation*, 2022.

Strand, Jon, *Supporting Carbon Tax Implementation in Developing Countries through Results-Based Payments for Emissions Reductions*, The World Bank, 2020.

Timilsina, Govinda R, "Carbon taxes," *Journal of Economic Literature*, 2022, *60* (4), 1456–1502.

Walker, W. Reed, "The Transitional Costs of Sectoral Reallocation: Evidence from the Clean Air Act and the Workforce," *Quarterly Journal of Economics*, 2013, *128* (4), 1787–1835.

World Bank, "State and Trends of Carbon Pricing," Technical Report, The World Bank, Washington D.C. 2024.

— , "State and Trends of Carbon Pricing," Technical Report, The World Bank, Washington D.C. 2025.

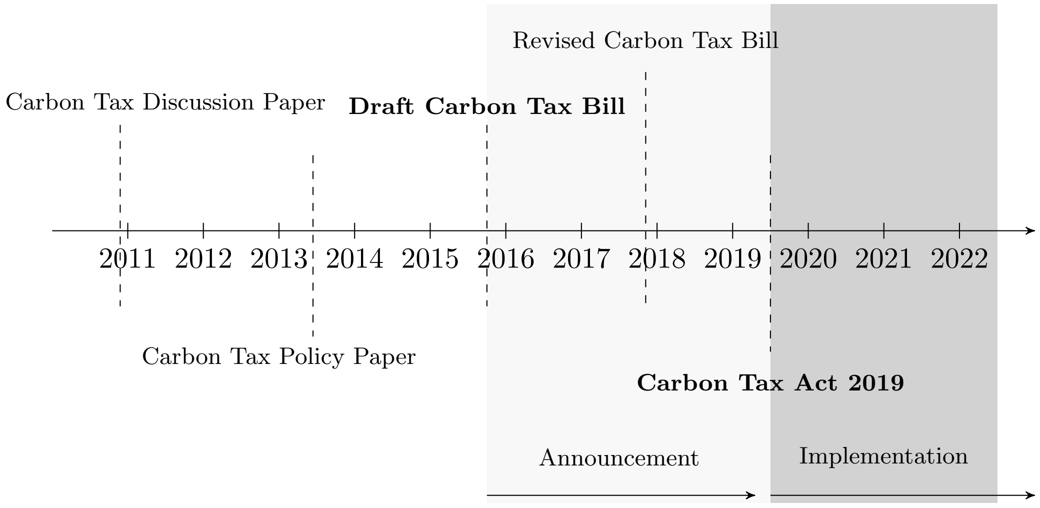
Yamazaki, Akio, "Jobs and climate policy: Evidence from British Columbia's revenue-neutral carbon tax," *Journal of Environmental Economics and Management*, 2017, *83*, 197–216.

— , "Environmental taxes and productivity: Lessons from Canadian manufacturing," *Journal of Public Economics*, 2022, *205*, 104560.

Zwick, Eric and James Mahon, "Tax policy and heterogeneous investment behavior," *American Economic Review*, 2017, *107* (1), 217–248.

Figures

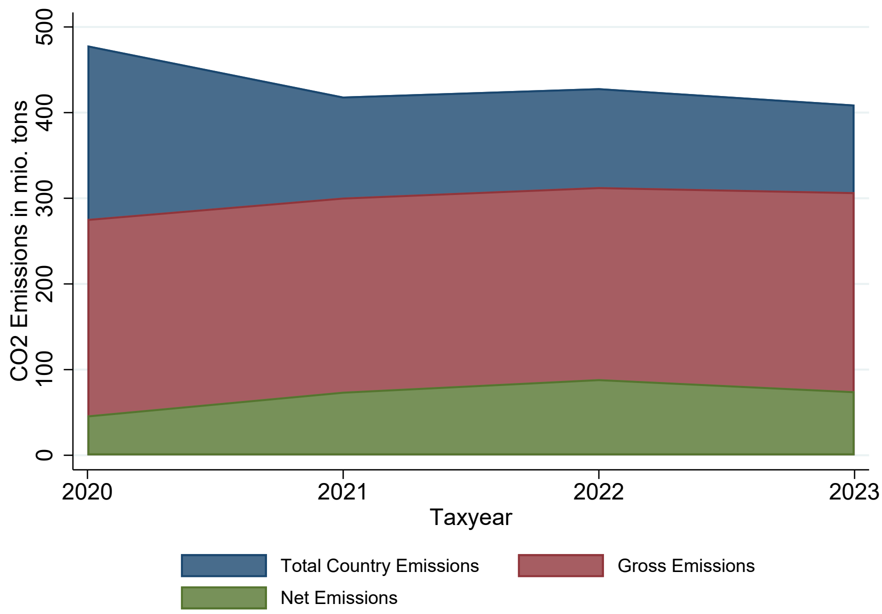
Figure 1: Carbon tax policy timeline



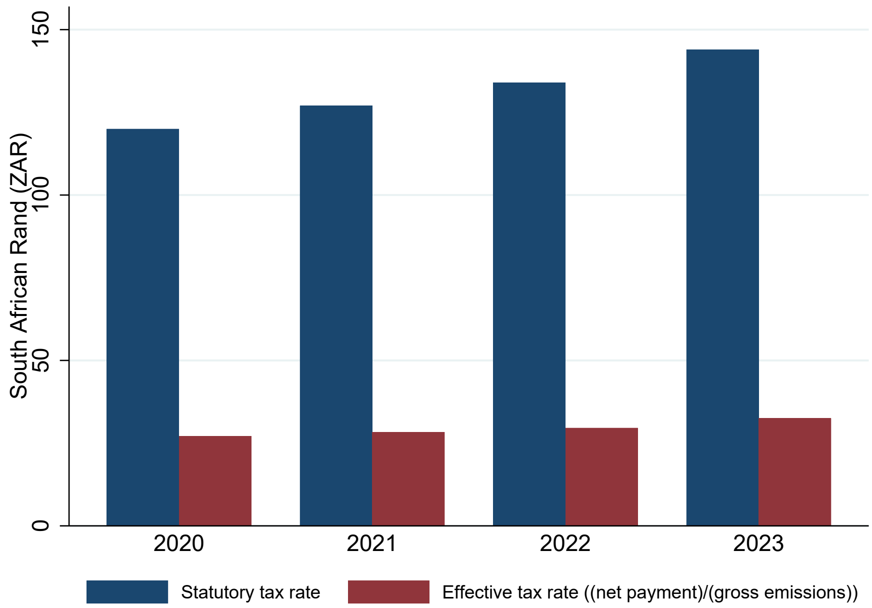
Notes: This figure plots the main events between the Carbon Tax Discussion Paper and the Carbon Tax Act in 2019.

Figure 2: Carbon tax coverage and effective tax rates

(a) Gross and net emissions



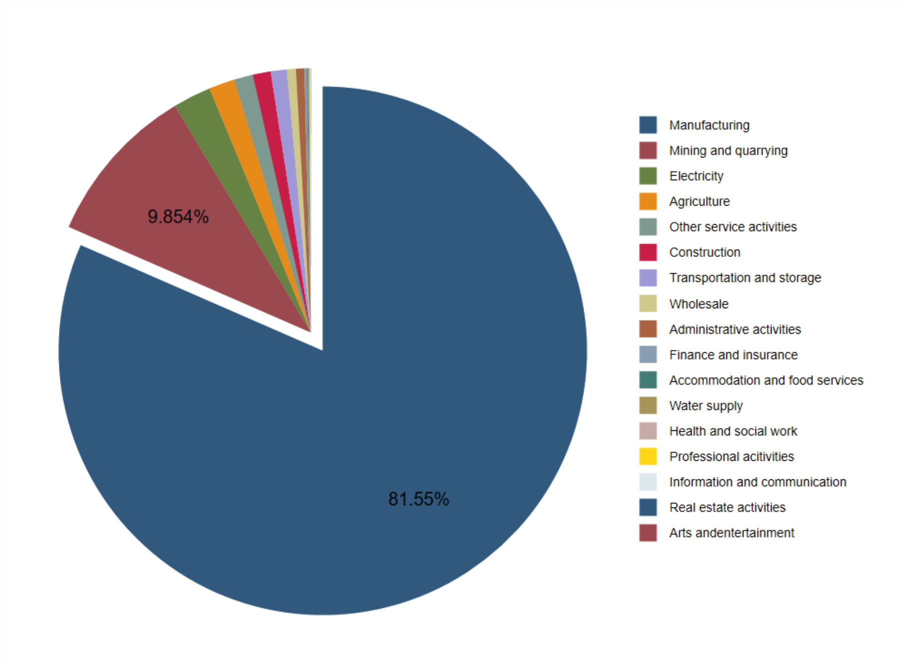
(b) Effective tax rate



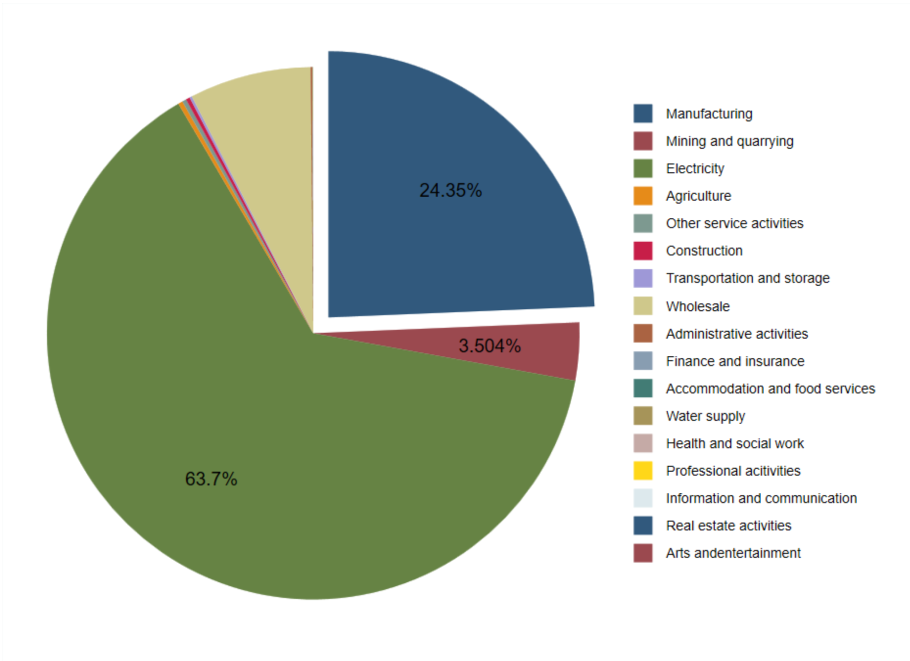
Notes: This figure plots in Panel (a) the nationwide emissions of South Africa (blue) from the Emissions Database for Global Atmospheric Research (EDGAR), the total emissions from the carbon tax firms (red), the net-of-allowances emissions (green). Panel (b) shows the statutory tax rates (blue) and the effective tax rates i.e. tax paid per tonne of CO_2 unweighted (red) and weighted by emissions (green). Blue bars represent the statutory tax rate, and red and green bars are the effective tax rate paid after allowances. The tax year always refers to the reporting period in the previous calendar year. Hence, the tax year 2021 refers to the reporting period of January 2020 until December 2020. Data Source: SARS and EDGAR.

Figure 3: Heterogeneity by industry

(a) Carbon tax revenue by industry

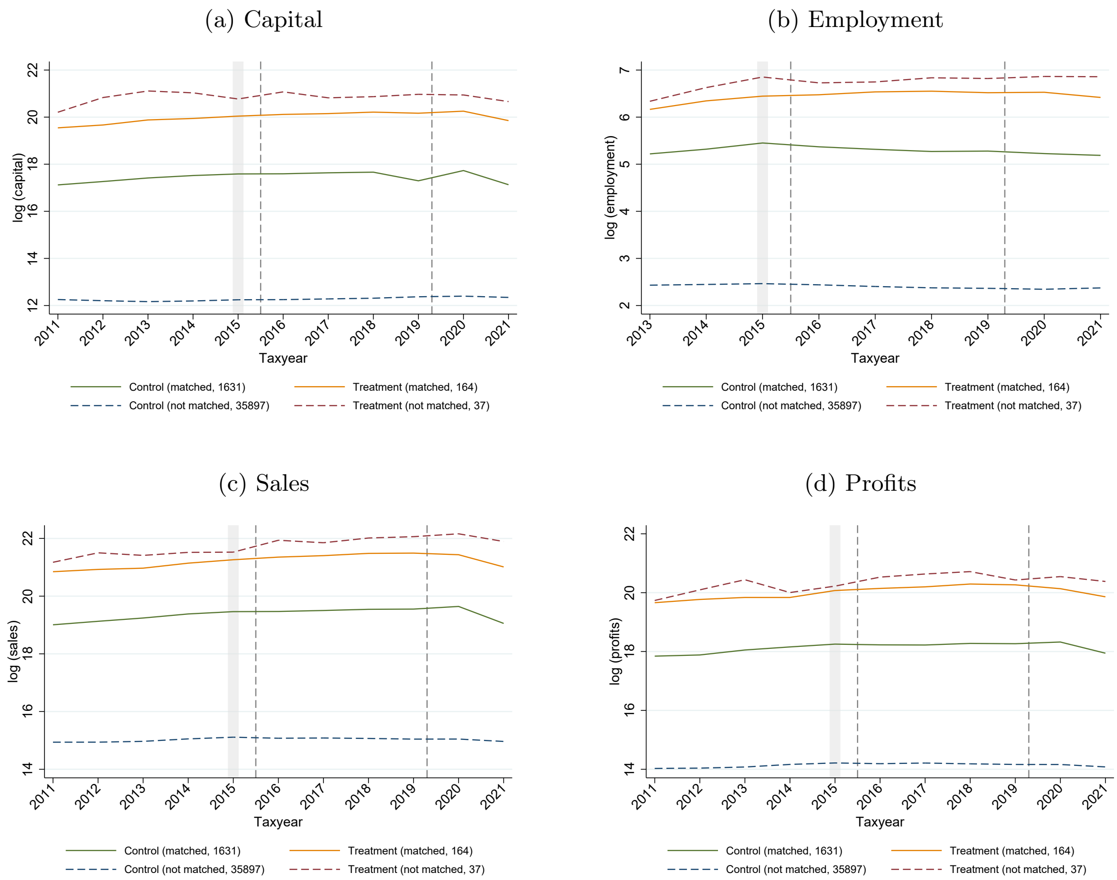


(b) Gross emissions by industry



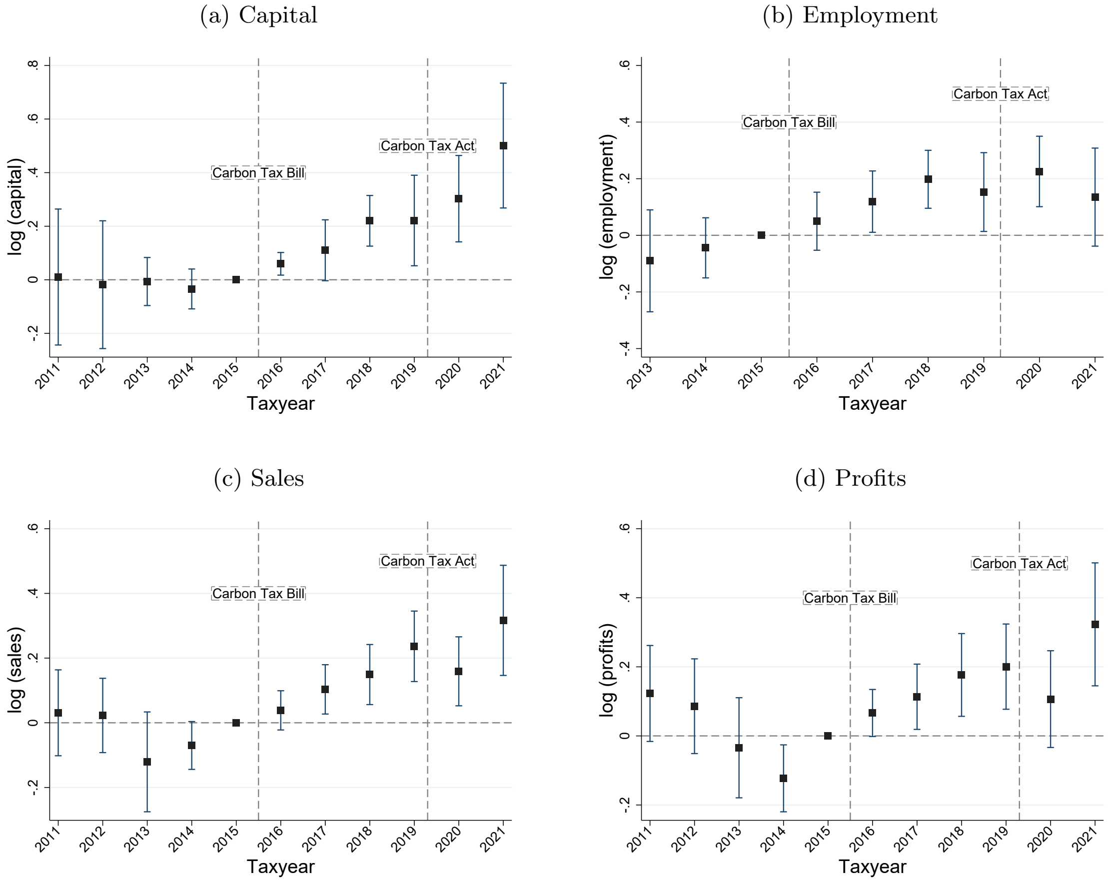
Notes: This figure plots various descriptive statistics based on the carbon tax returns filed by South African firms. Panel Panel (a) displays the aggregate carbon tax revenue for the tax years 2020-2023 by industry. Panel (b) displays the aggregate emissions of treated carbon tax firms for the tax years 2020-2023 by industry. Data Source: SARS.

Figure 4: Trends in firm outcomes over time by group of firms



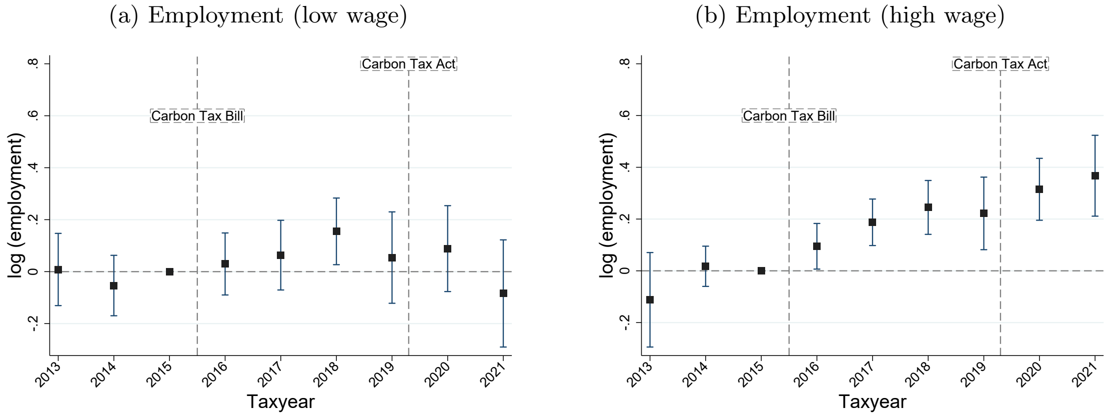
Notes: This figure plots the raw means of observable firm characteristics differentiated by treatment and matching status. The dashed red line depicts unmatched treated firms that are subject to the carbon tax. The yellow line depicts matched treated firms, and the green line matched comparison firms that are not subject to the carbon tax. The dashed blue line depicts all remaining untreated firms that were not matched. Firms were matched exactly on the 3-digit industry and coarsened with 3 cutpoints for sales, capital, number of employees, and profits based on the year 2015. Data Source: SARS.

Figure 5: Carbon tax and firm outcomes



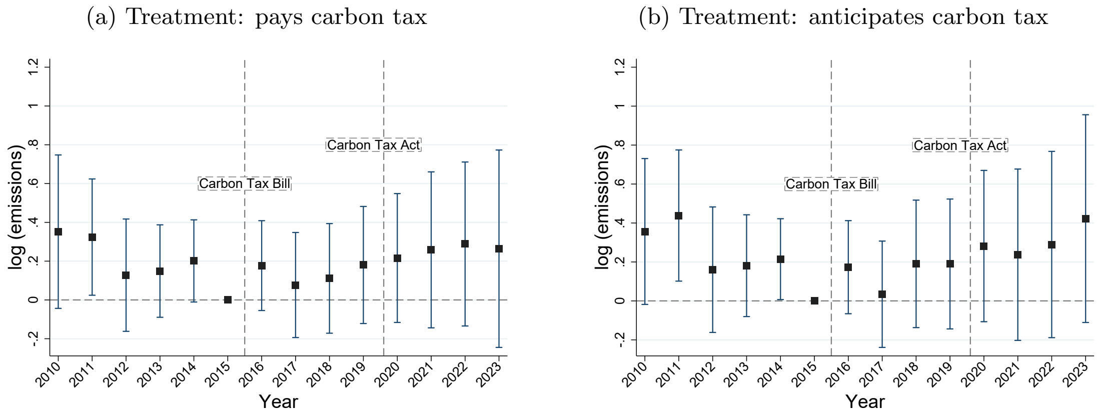
Notes: This figure plots the θ_k coefficients estimated from Eq. (7) with capital, employment, sales and profits as the outcome variables. The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure 6: Carbon tax and employment across the wage distribution within firms



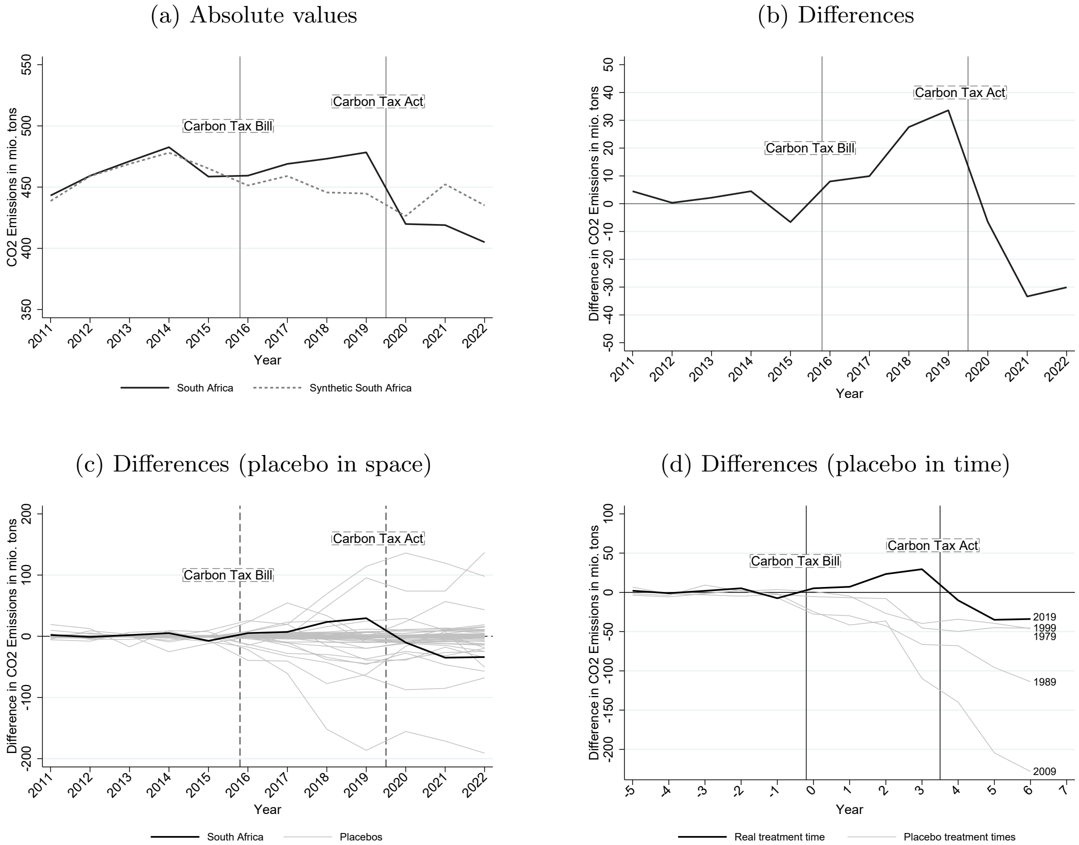
Notes: This figure plots the θ_k coefficients estimated from Eq. (7) with employment below and above the baseline median (2015) wage, respectively, as the outcome variable. The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure 7: Carbon tax and firm-level emissions



Notes: This figure plots the θ_k coefficients estimated from Eq. (7) with emissions as the outcome variable. The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. For details on the composition of the control group see Figure E.1 in the appendix. Data Source: Carbon Disclosure Project.

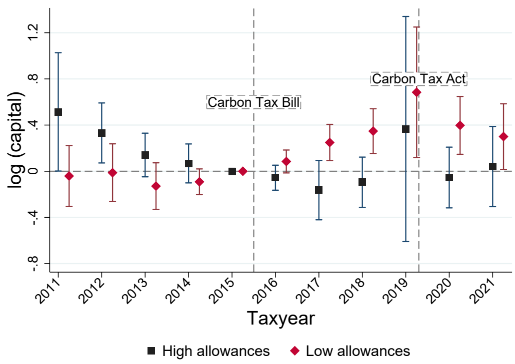
Figure 8: Carbon tax and country-level emissions (synthetic control)



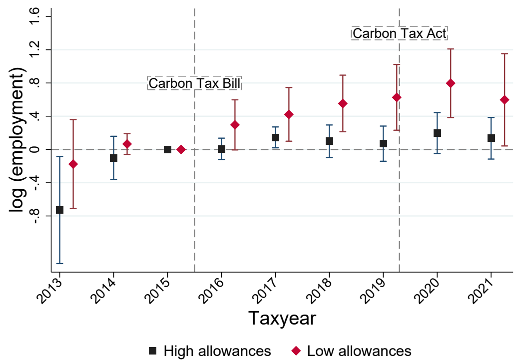
Notes: This figure plots the effect of the carbon tax policy on CO_2 emissions using the synthetic control method. Panel a) shows the absolute values of CO_2 emissions. Panel b) depicts the difference in CO_2 emissions between South Africa and its synthetic counterpart. Panels (c) and (d) show placebo tests in-space as well as in-time. The plotted emission values cover total annual emissions obtained from the EDGAR database. "Synthetic South Africa" is constructed based on South Africa's annual emissions between 2011 and 2015. Countries that have implemented a carbon pricing policy are removed from the pool of potential donor countries. Further, the donor pool is restricted to countries featured in the firm-level analysis of the Carbon Disclosure Project. For details, see Table D.1 and Figure E.1 in the appendix. Data Source: EDGAR and Penn World Tables.

Figure 9: Heterogeneous effects of the carbon tax by allowance take-up

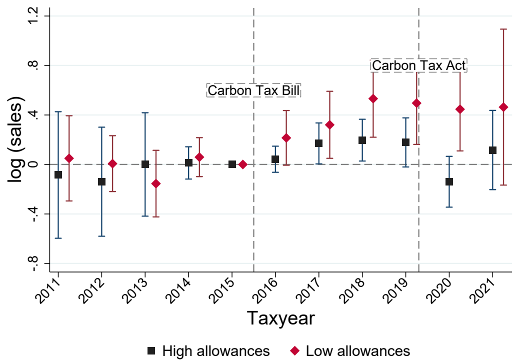
(a) Capital



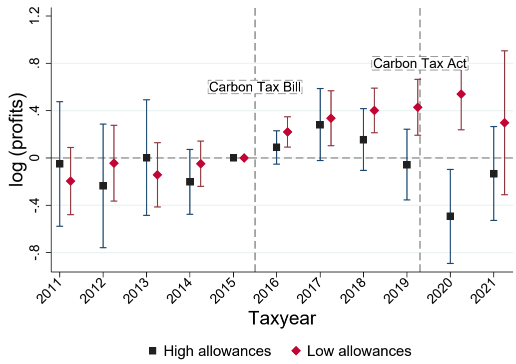
(b) Employment



(c) Sales



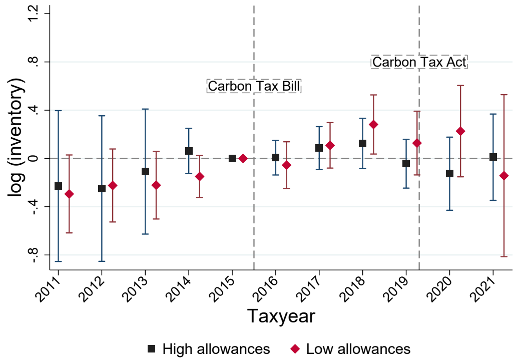
(d) Profits



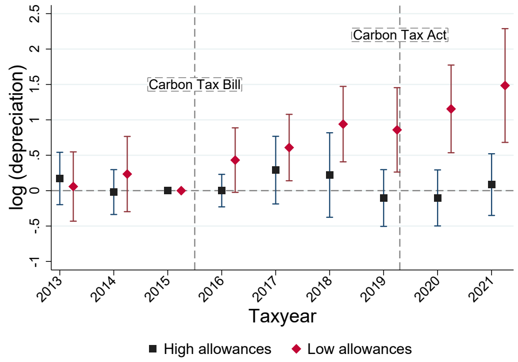
Notes: This figure plots the θ_k coefficients estimated from Eq. (7). The black squares represent the point estimates for firms with high allowance take-up (5th quintile), while the red diamonds represent the point estimates for firms with low allowance take-up (1st quintile). The vertical bars around the point estimates represent the 95% confidence intervals. "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure 10: Heterogeneous effects of the carbon tax policy by allowance take-up: inventory and depreciation

(a) Inventory

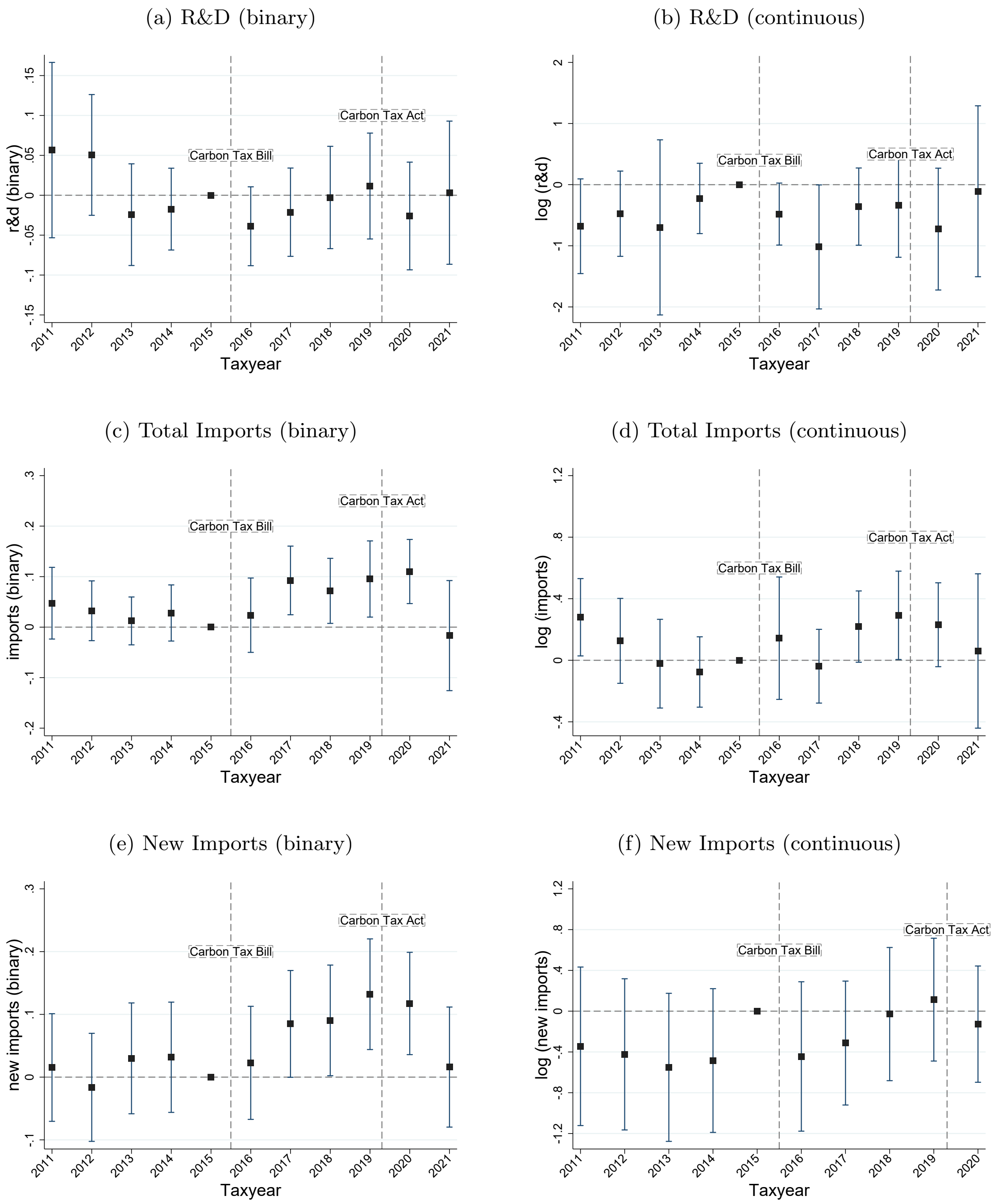


(b) Depreciation



Notes: This figure plots the θ_k coefficients estimated from Eq. (7). The black squares represent the point estimates for firms with high allowance take-up (5th quintile), while the red diamonds represent the point estimates for firms with low allowance take-up (1st quintile). The vertical bars around the point estimates represent the 95% confidence intervals. The "tax year" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure 11: Effects of the carbon tax policy on R&D and imports (total vs. new products)



Notes: This figure plots the θ_k coefficients estimated from Eq. (7). The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. "Binary" refers to an outcome that is a dummy variable (extensive margin), while "continuous" refers to an outcome that is measured on a continuous scale (intensive margin). "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Online Appendix to **"Carbon Taxation and Firm Behavior in Emerging Economies: Evidence from South Africa"**

Johannes Gallé Rodrigo Oliveira Daniel Overbeck Nadine Riedel
Edson Severnini

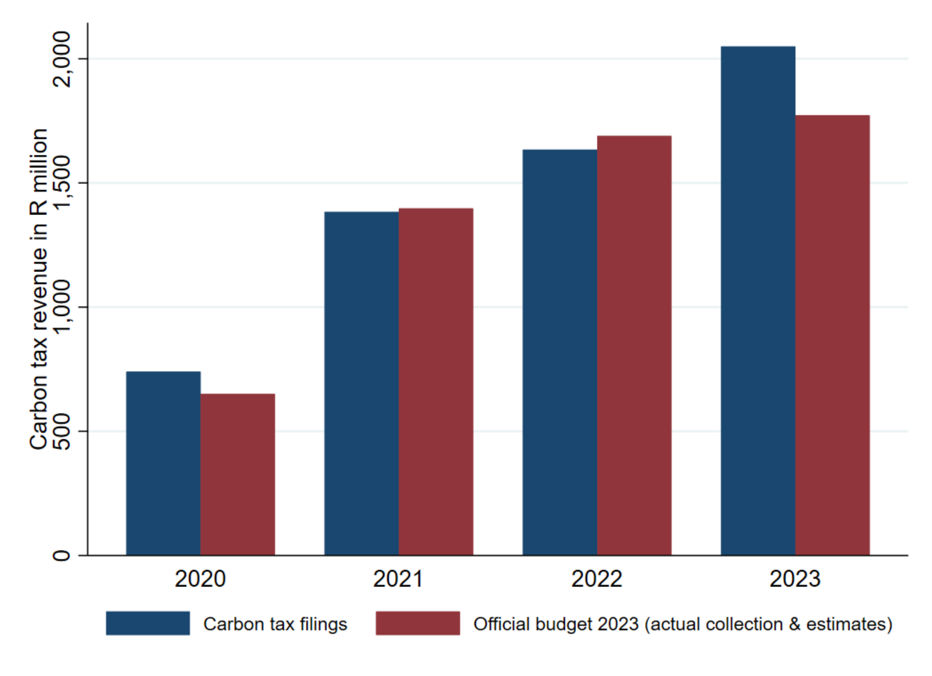
October 2025

Potsdam Institute for Climate Impact Research
UNU-WIDER
National University of Singapore
University of Münster
Boston College, Nova SBE, NBER & IZA

A Additional descriptive results

This appendix provides additional descriptive results on the anatomy of the carbon tax, complementing Sections 2 and 3. Figure A.1 shows the annual carbon tax revenue as depicted by the official budget as well as by aggregating the raw carbon tax micro data. Figure A.2 presents a portion of South Africa's Carbon Tax Act of 2019, which specifies the emission thresholds that determine firms' liability for the carbon tax, as well as the allowances that can reduce their effective tax burden. Figure A.3 depicts the different emissions sources for fuel combustion, industrial process emissions as well as for fugitive emissions. Figure A.4 breaks down carbon tax firms that eventually do not pay any carbon tax. Figure A.5 displays the emission types by industry.

Figure A.1: Aggregate carbon tax revenue



Notes: This figure depicts the annually aggregated carbon tax payments. Blue bars show the aggregate numbers for the carbon tax filings provided by SARS. Red bars indicate the aggregate figures by the Treasury in their budget review for 2023. The red bars for 2022 and 2023 are estimations by the Treasury, while 2020 and 2021 refer to actual revenue. Data Source: SARS.

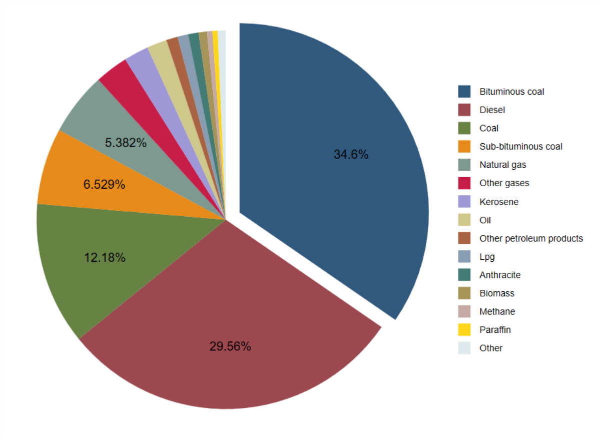
Figure A.2: Carbon Tax Act of 2019 – Thresholds and Allowances (Schedule 2)

IPCC Code	Activity/Sector	Threshold	Basic tax-free allowance for fossil fuel combustion emissions %	Basic tax-free allowance for process emissions %	Fugitive emissions allowance %	Trade exposure allowance %	Performance allowance %	Carbon budget allowance %	Offsets allowance %	Maximum total allowances %
1	**Energy**									
1A	**Fuel Combustion Activities**									
1A1	**Energy Industries (including heat and electricity recovery from Waste)**									
1A1a	Main Activity Electricity and Heat Production (including Combined Heat and Power Plants)	10 MW(th)	60	0	0	10	5	5	10	90
1A1b	Petroleum Refining	10 MW(th)	60	0	0	10	5	5	10	90
1A1c	Manufacture of Solid Fuels and Other Energy Industries	10 MW(th)	60	0	0	10	5	5	10	90
1A2	**Manufacturing Industries and Construction (including heat and electricity recovery from Waste)**		60	0	0	10	5	5	10	90
1A2a	Iron and Steel	10 MW(th)	60	0	0	10	5	5	10	90

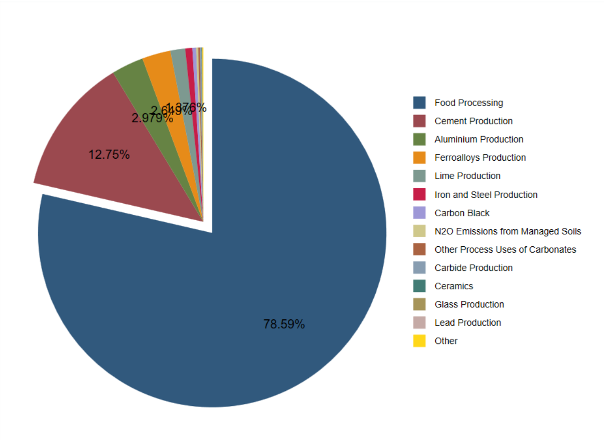
Notes: This figure presents a portion of Schedule 2 of South Africa's Carbon Tax Act of 2019. Under the Act, a firm becomes liable for carbon tax if it conducts an activity that results in greenhouse gas emissions exceeding the threshold specified for that activity or sector in Schedule 2. The tax is levied on the carbon dioxide equivalent of emissions, but firms can lower their effective liability through several allowances. Key allowances include those for fossil fuel combustion, industrial process emissions, fugitive emissions, trade exposure, performance, carbon budgets, and approved offsets. These mechanisms are intended to reflect differences in emissions intensity across activities, protect trade-exposed industries, and provide flexibility for firms to transition gradually toward cleaner technologies, while maintaining incentives to reduce overall greenhouse gas emissions. *Source:* Carbon Tax Act (2019).

Figure A.3: Emissions sources

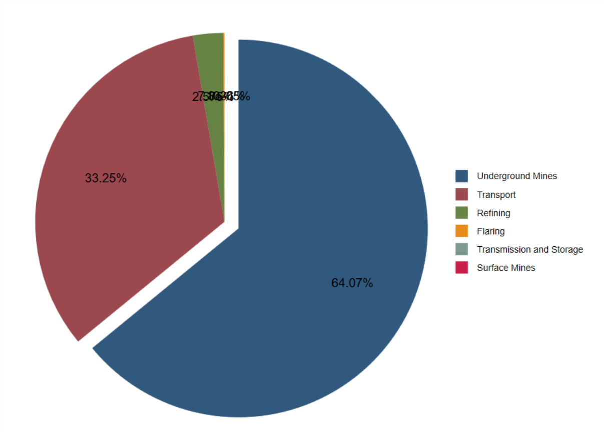
(a) Fuel combustion emissions



(b) Industrial process emissions

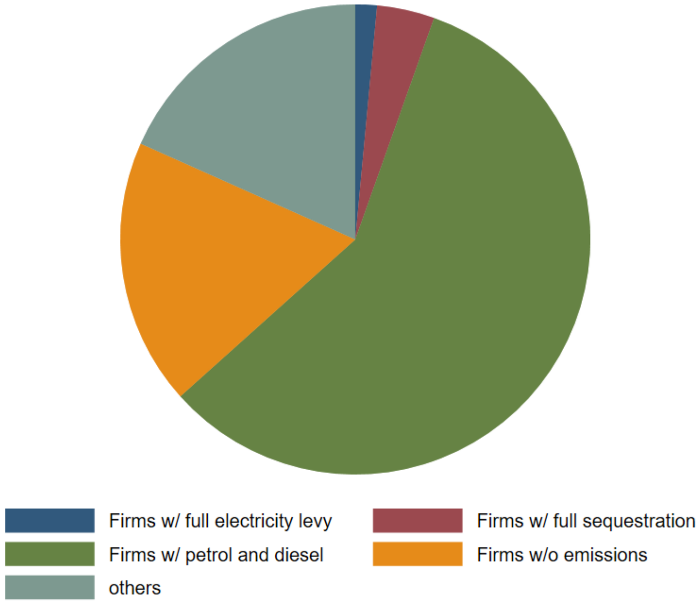


(c) Fugitive emissions



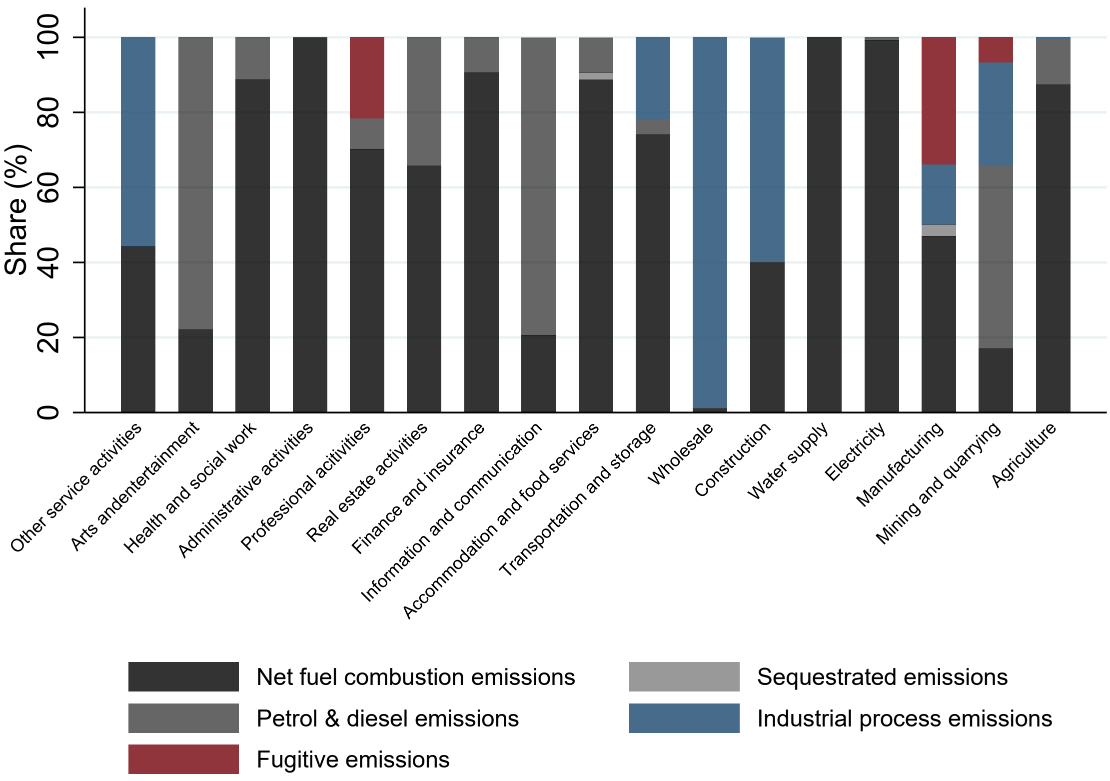
Notes: This figure plots various descriptive statistics based on the carbon tax returns filed by South African firms. Panel (a) depicts the share of fuel combustion emissions disaggregated by fuel type. Panel (b) plots industrial process emissions disaggregated by activity. Panel (c) plots fugitive emissions disaggregated by activity. All data is based on reported emissions of carbon tax firms for the taxyears 2020-2023. Data Source: SARS.

Figure A.4: Anatomy of non-payers



Notes: This figure plots the anatomy of carbon tax firms that eventually do not pay any carbon tax during the period 2020-2023. The green area depicts firms that only use petrol and diesel. The red area refers to firms that can fully sequestrate their emissions. The blue area depicts electricity firms that can fully deduct the electricity levy. The orange area depicts firms that report zero gross emissions. The remaining firms are all other firms that can not be exclusively classified in one of those categories. Data Source: SARS.

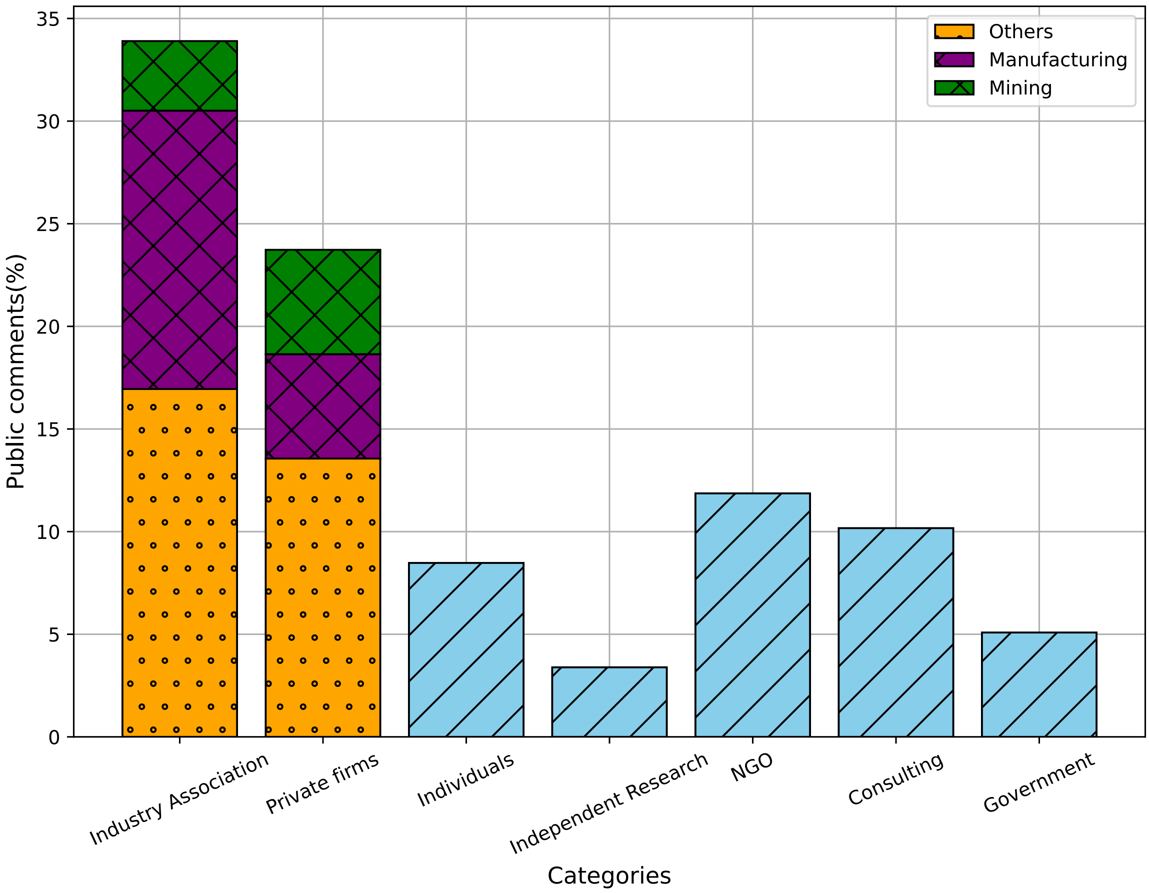
Figure A.5: Emission type by industry



Notes: This figure plots the share of emissions types by industry disaggregated according to Eq.(1). Data Source: SARS.

B Public comments

Figure B.1: Type of commentators



Notes: This figure plots categorization of public comments from the Carbon Tax Bill 2018. Industry associations and private firms are further categorized by their main industry denomination.

Some examples of public comments include:

- It is suggested that the formula to calculate the tax liability as in equation (1) is amended to allow sequestration to be deducted not only from fuel combustion emissions but also for process and fugitive emissions (*Not accepted.* Carbon Tax Bill 2018).
- Inconsistency of the tax treatment of waste management activities in the bill, where the provision of the 100 percent allowance for GHG emissions needs to be applied consistently across all sectors and provision should be made accordingly in the Bill (*Accepted. The bill has been amended to allow for a 90 percent tax-free threshold for waste incineration activities.* Carbon Tax Bill 2018).

- For performance allowances, developing an industry benchmark for the lime industry in South Africa may be challenging as there are currently only two large lime manufacturers in the country and three smaller producers. (*Noted.* Carbon Tax Bill 2018).

- The recognition of a renewable energy premium included in the electricity tariff is welcomed. It is proposed that this rebate should be extended to include renewable energy allowed as a recovery of cost by Eskom as well and not limited to the Independent Power Producers only (*Accepted. The bill has been amended to provide the credit for all renewable energy producers.* Carbon Tax Bill 2015).

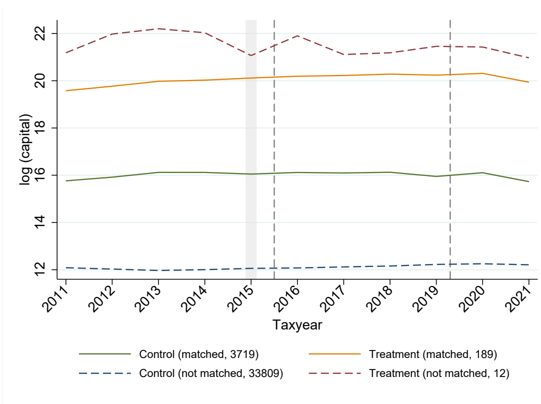
- Nampak estimates that the emission factor should be closer to 0.1500 to 0.1700 tonnes CO2 per tonne of glass excluding cullet production. This factor is overstated by 25 per cent. The 2006 IPCC Guidelines emissions factor of 0.200 tonnes CO2 per tonnes of glass does not necessarily hold true for all glass production. (*Noted. The emissions factors provided in the Schedule 1 of the carbon tax bill are default emissions factors based on the 2006 IPCC Guidelines and are aligned with the Mandatory reporting regulations and Technical Guidelines. A process to submit alternative emission factors is clearly stated in the NGERs and associated technical guidelines of the DEA.* Carbon Tax Bill 2015).

C Robustness

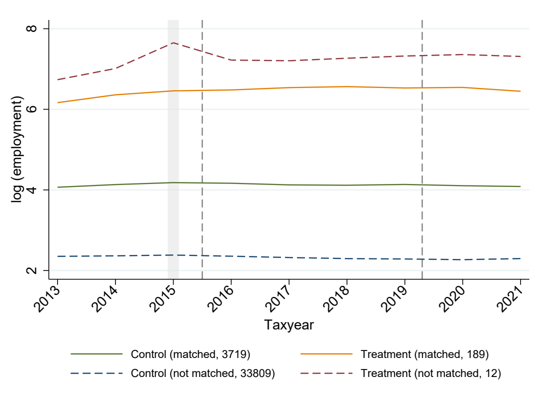
This appendix further complements Section 6 by providing robustness checks to the main results. Figures C.1 and C.2 plot the raw means, when matching less or more restrictively on observable than in the main specification (see figure notes for details). Figures C.3 and C.4 show the corresponding event study results. In figure C.5, we demonstrate that the results are insensitive to the choice of the baseline year.

Figure C.1: Coarsened Exact Matching means (less stringent / wide matching)

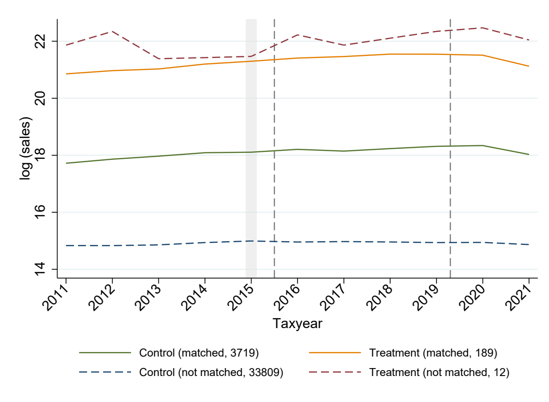
(a) Capital



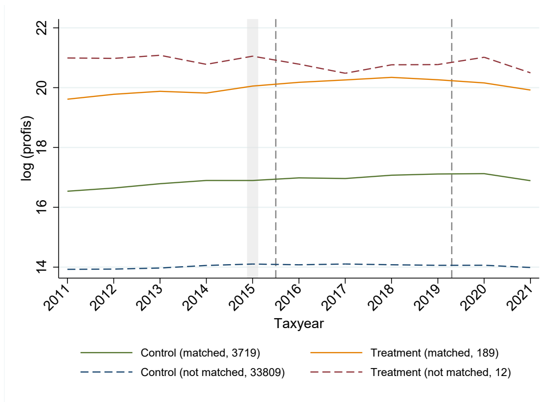
(b) Employment



(c) Sales



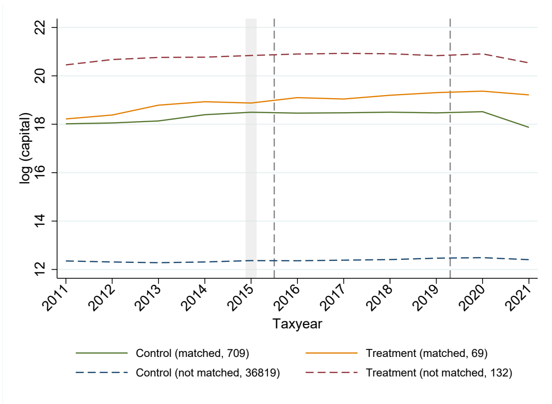
(d) Profits



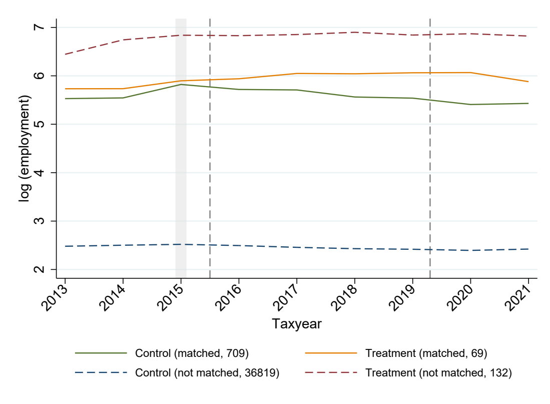
Notes: This figure plots the raw means of observable firm characteristics differentiated by treatment and matching status. The dashed red line depicts unmatched treated firms that are subject to the carbon tax. The yellow line depicts matched treated firms, and the green line matched comparison firms that are not subject to the carbon tax. The dashed blue line depicts all remaining untreated firms that were not matched. *Firms were matched exactly on the 3-digit industry and coarsened with only 1 cutpoint* for sales, capital, number of employees, and profits based on the year 2015. Data Source: SARS.

Figure C.2: Coarsened Exact Matching Means (more stringent / narrow matching)

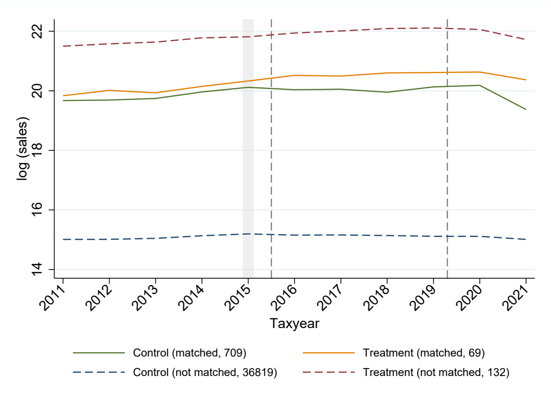
(a) Capital



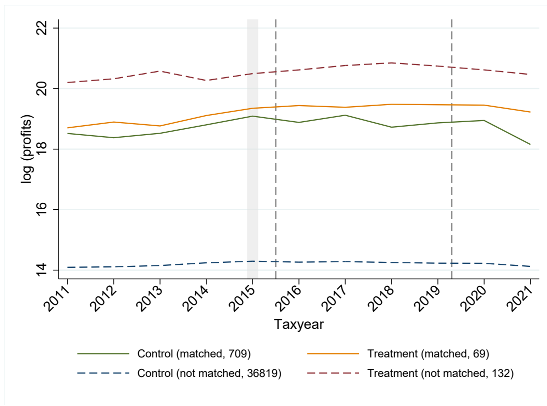
(b) Employment



(c) Sales



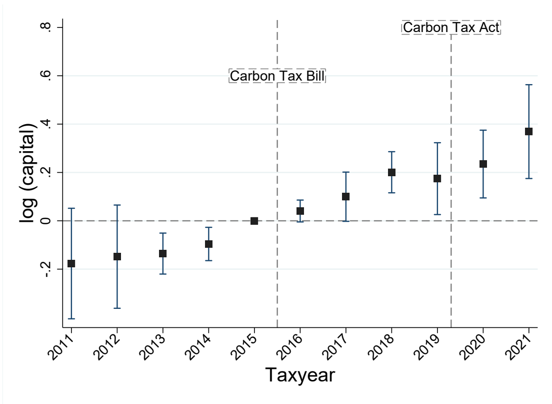
(d) Profits



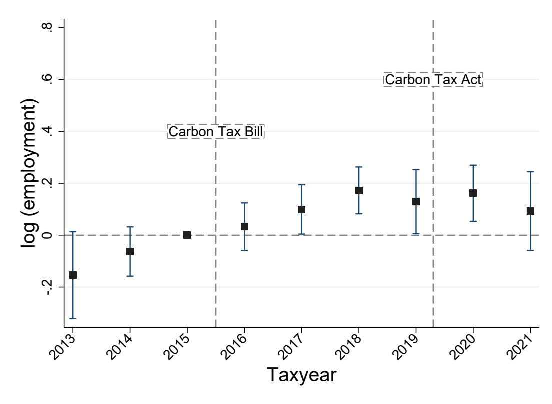
Notes: This figure plots the raw means of observable firm characteristics differentiated by treatment and matching status. The dashed red line depicts unmatched treated firms that are subject to the carbon tax. The yellow line depicts matched treated firms, and the green line matched comparison firms that are not subject to the carbon tax. The dashed blue line depicts all remaining control firms that were not matched. *Firms were matched exactly on the 1-digit industry and coarsened with 10 cutpoints* for sales, capital, number of employees, and profits based on the year 2015. Data Source: SARS.

Figure C.3: Carbon tax and firm outcomes (less stringent / wide matching)

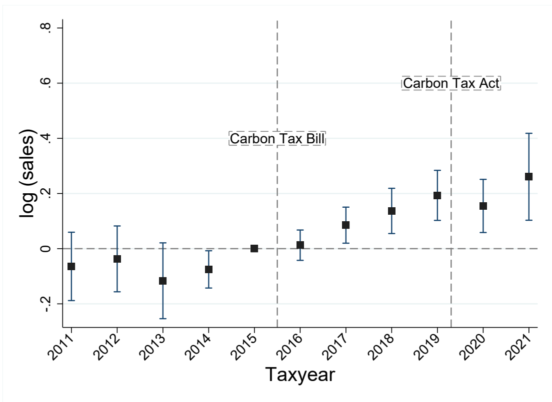
(a) Capital



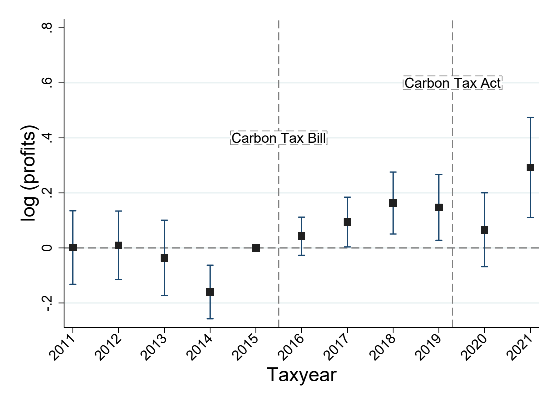
(b) Employment



(c) Sales

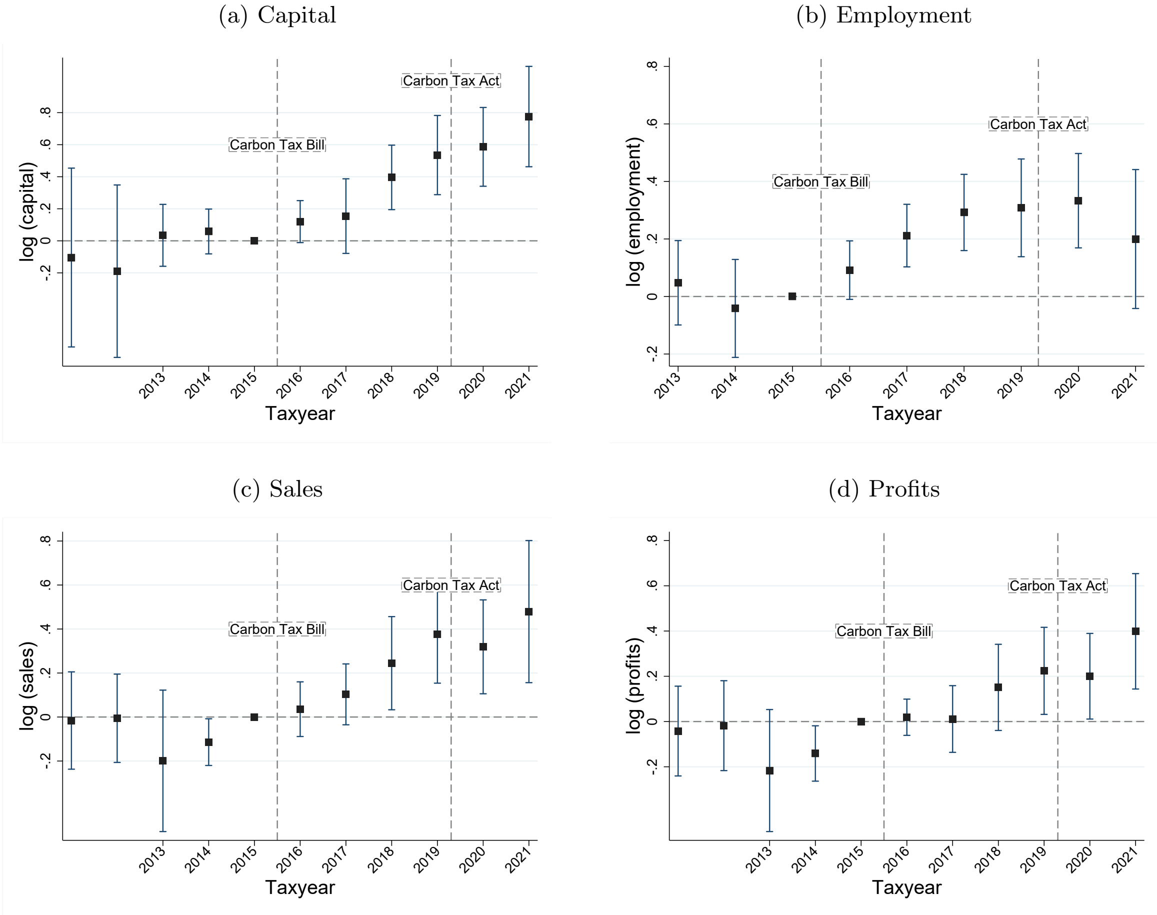


(d) Profits



Notes: This figure plots the θ_k coefficients estimated from equation (7). The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. The "tax year" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

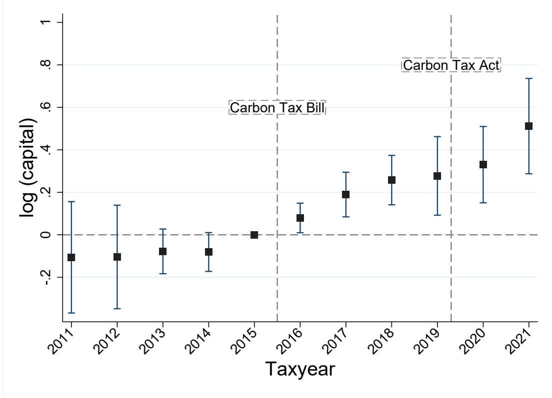
Figure C.4: Carbon tax and firm outcomes (more stringent / narrow matching)



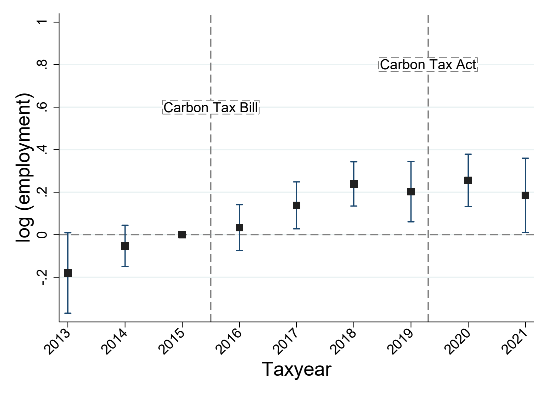
Notes: This figure plots the θ_k coefficients estimated from equation (7). The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. The "tax year" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure C.5: Carbon tax and firm outcomes (2013 as the baseline matching year)

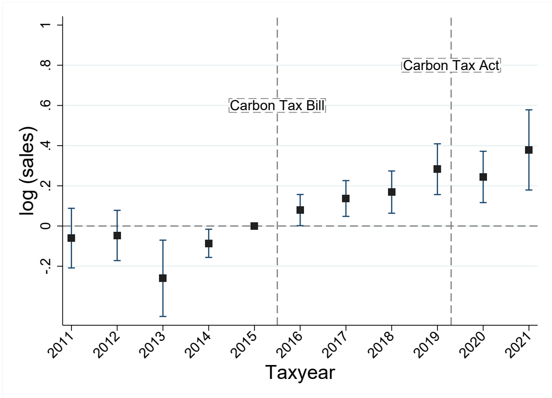
(a) Capital



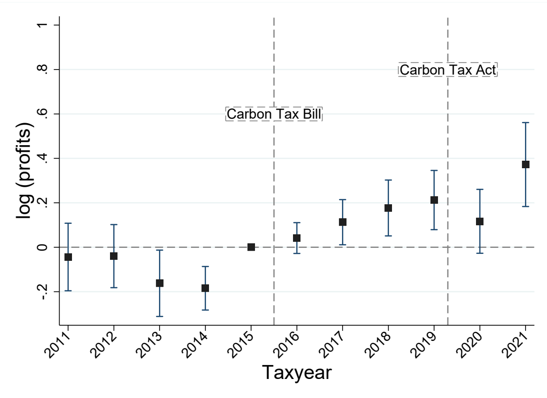
(b) Employment



(c) Sales

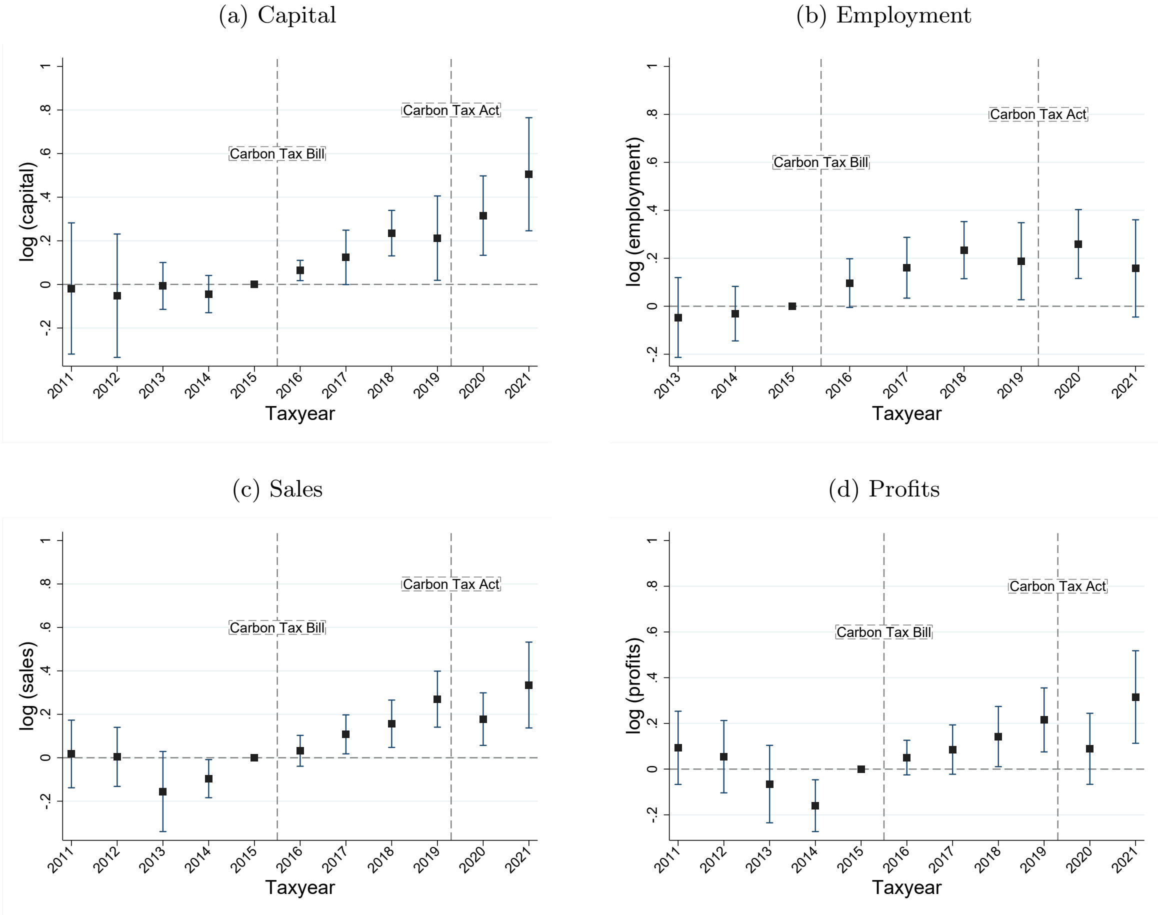


(d) Profits



Notes: This figure plots the θ_k coefficients estimated from Eq.(7), where 2023 is used as the year for matching instead of 2015. The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. “Taxyear” always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

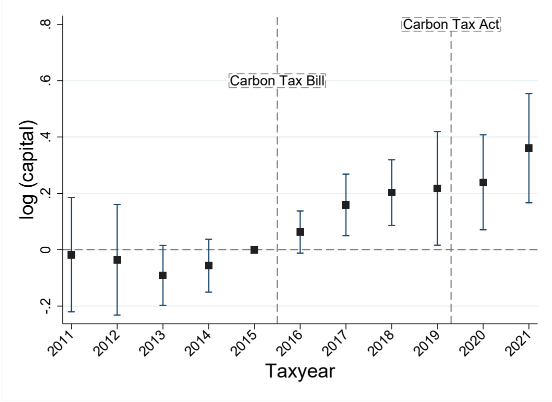
Figure C.6: Carbon tax and firm outcomes (5 digit industry matching)



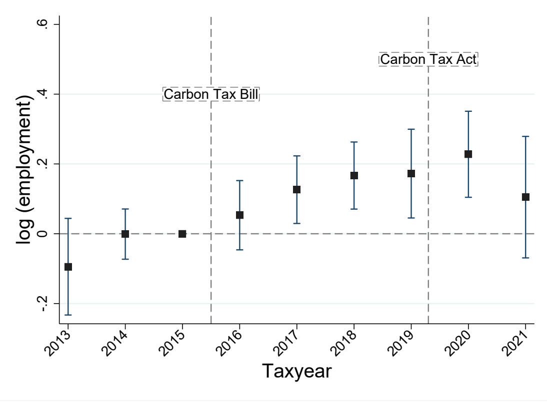
Notes: This figure plots the θ_k coefficients estimated from Eq. (7), where firms are matched at the 5 digit industry level. The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure C.7: Carbon tax and firm outcomes (matching on trends)

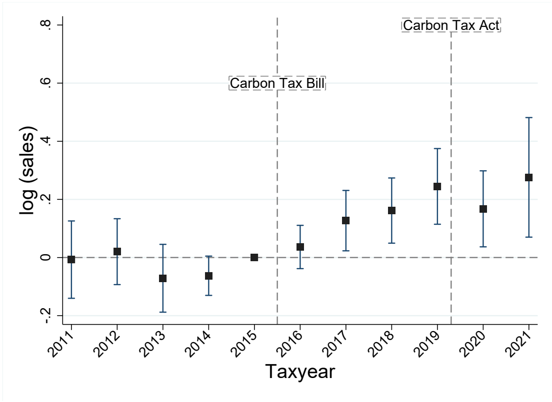
(a) Capital



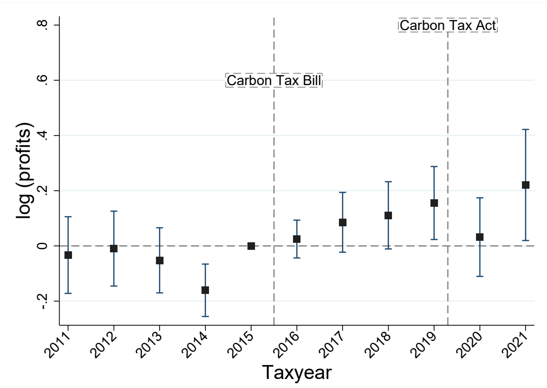
(b) Employment



(c) Sales



(d) Profits

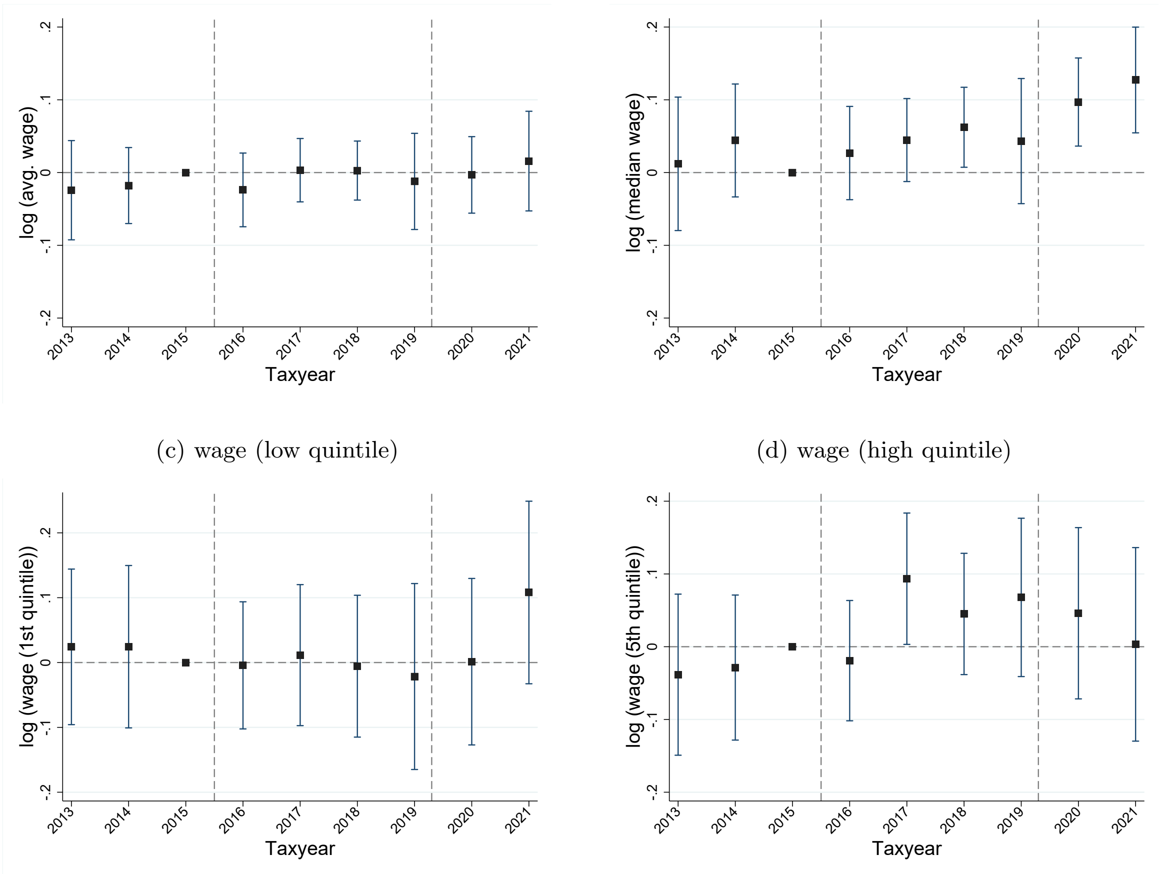


Notes: This figure plots the θ_k coefficients estimated from Eq. (7). The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

D Additional regressions results

This appendix complements Section 6 by providing additional results from our empirical analyses. Figure D.1 shows how the wage distribution of treated firms changed with the policy announcement and implementation. Figure D.2 shows the estimated effects by industry (manufacturing vs. mining). Figure D.3 shows the estimated effects for firms of different sizes. Tables D.1 and D.2 show more details on the synthetic control approach. Table D.3 and Figure D.4 show the same with a different matching approach.

Figure D.1: Carbon tax and wages within firms



(a) average wage

(b) median wage

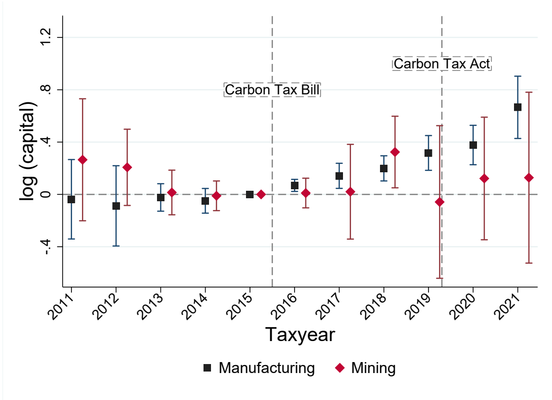
(c) wage (low quintile)

(d) wage (high quintile)

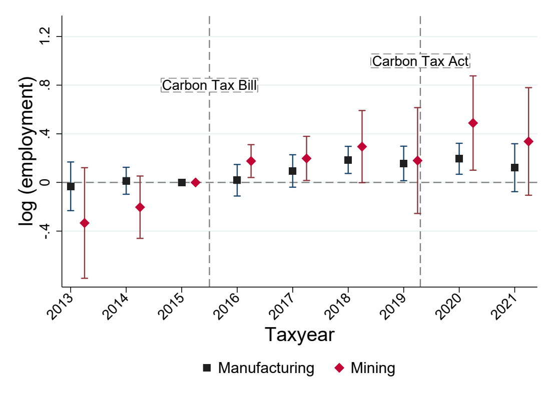
Notes: This figure plots the θ_k coefficients estimated from Eq. (7). The vertical bars around the estimates, represented by the squares, show the 95% confidence intervals. "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure D.2: Heterogeneous effects of the carbon tax by industry

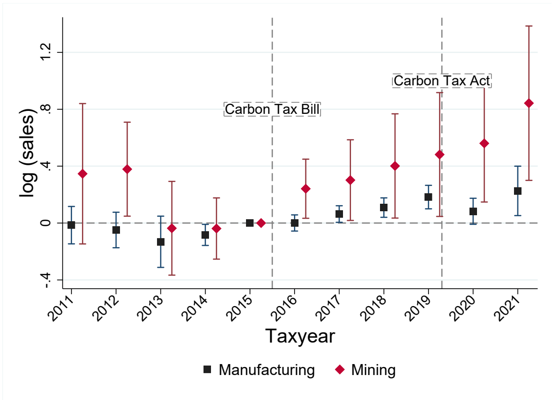
(a) Capital



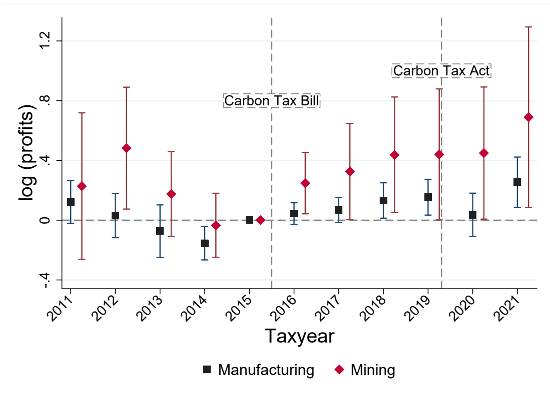
(b) Employment



(c) Sales



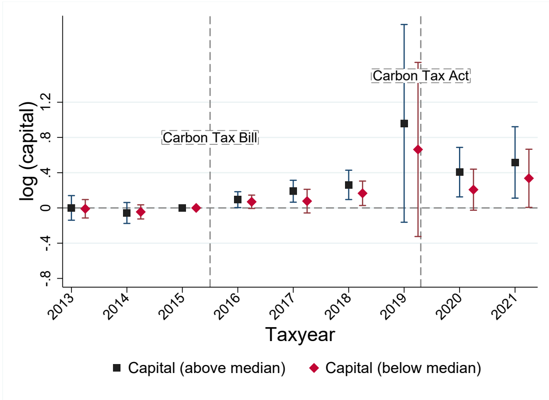
(d) Profits



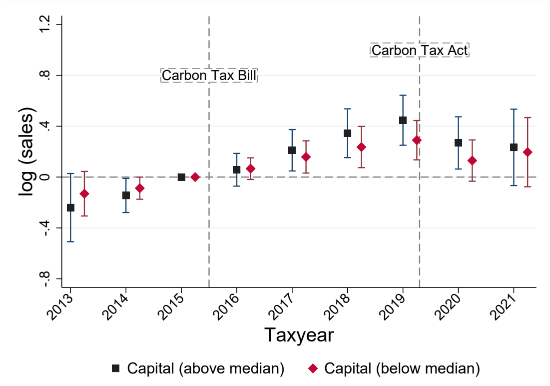
Notes: This figure plots θ_k coefficients estimated from Eq. (7) with different outcome variables. The black squares depict the point estimates for the manufacturing sector. The red diamonds depict the point estimates for the mining sector. The vertical bars around the point estimates represent the 95% confidence intervals. "Taxyear" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Figure D.3: Heterogeneous effects of the carbon tax policy by firm size (above/below median 2015)

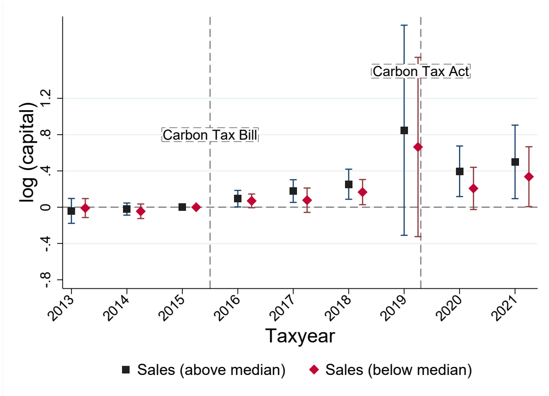
(a) Capital (above/below capital 2015)



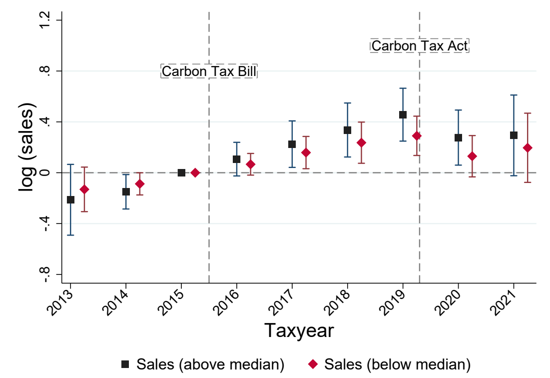
(b) Sales (above/below capital 2015)



(c) Capital (above/below sales 2015)



(d) Sales (above/below sales 2015)



Notes: This figure plots the θ_k coefficients estimated from Eq. (7). The black squares represent the point estimates for firms with high pre-treatment sales (5th quintile), while the red diamonds represent the point estimates for firms with low pre-treatment sales (1st quintile). The vertical bars around the point estimates represent the 95% confidence intervals. The "tax year" always refers to the previous fiscal year; for example, 2020 corresponds to the period from March 2019 to February 2020. The first dashed line marks the publication of the first draft of the Carbon Tax Bill, and the second dashed line marks the implementation of the Carbon Tax Act in June 2019. Data Source: SARS.

Table D.1: Composition of "synthetic South Africa" (matched on emissions)

Share (%)	Countries
50.0	Australia
49.6	Brazil
0.4	India

Notes: This table features the contributed weights of each country in order to construct a "synthetic South Africa". "Synthetic South Africa" is constructed based on South Africa's annual emissions between 2011 and 2015 obtained from the EDGAR database.

Table D.2: Balance table (matched on emissions)

	South Africa	Synthetic South Africa
Emissions 2011 (mio. t)	443.13	441.25
Emissions 2012 (mio. t)	459.23	460.28
Emissions 2013 (mio. t)	471.12	469.17
Emissions 2014 (mio. t)	482.59	477.38
Emissions 2015 (mio. t)	458.58	466.03
Population 2011 (mio.)	52.00	114.24
Population 2012 (mio.)	52.83	115.36
Population 2013 (mio.)	53.69	116.46
Population 2014 (mio.)	54.54	117.55
Population 2015 (mio.)	55.39	118.62
GDP 2011 (mio. 2017 USD)	660,463	2,053,430
GDP 2012 (mio. 2017 USD)	675,082	2,097,341
GDP 2013 (mio. 2017 USD)	691,859	2,158,460
GDP 2014 (mio. 2017 USD)	704,637	2,180,899
GDP 2015 (mio. 2017 USD)	713,049	2,144,313

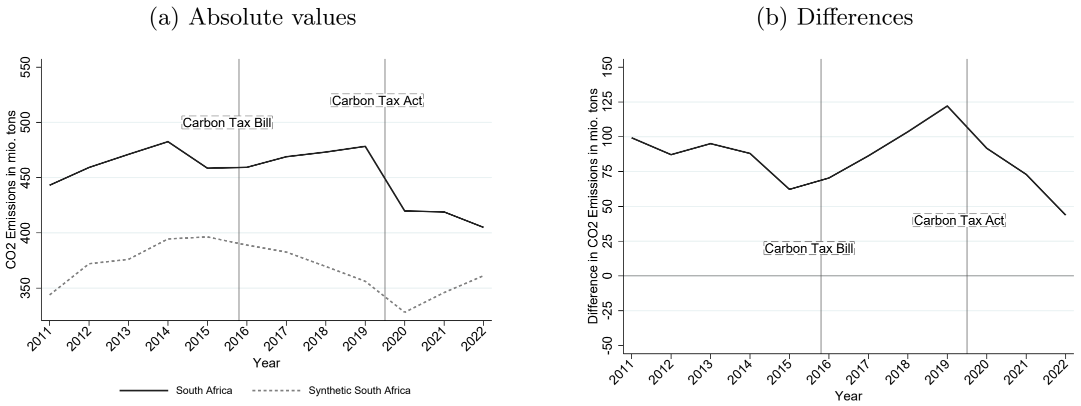
Notes: This table features annual emissions, population and GDP of South Africa and "synthetic South Africa" for the years 2011 - 2015. "Synthetic South Africa" is constructed based on South Africa's annual emissions between 2011 and 2015 obtained from the EDGAR database. GDP and populationa re obtained from the Penn World tables

Table D.3: Balance table (matching emissions, population, GDP)

	South Africa	Synthetic South Africa
Emissions 2011 (mio. t)	443.13	343.84
Emissions 2012 (mio. t)	459.23	372.08
Emissions 2013 (mio. t)	471.12	376.04
Emissions 2014 (mio. t)	482.59	394.55
Emissions 2015 (mio. t)	458.58	396.36
Population 2011 (mio.)	52.00	51.80
Population 2012 (mio.)	52.83	52.74
Population 2013 (mio.)	53.69	53.64
Population 2014 (mio.)	54.54	54.43
Population 2015 (mio.)	55.39	55.06
GDP 2011 (mio. 2017 USD)	660,463	688,113
GDP 2012 (mio. 2017 USD)	675,082	725,419
GDP 2013 (mio. 2017 USD)	691,859	748,906
GDP 2014 (mio. 2017 USD)	704,637	779,806
GDP 2015 (mio. 2017 USD)	713,049	815,597

Notes: This table features annual emissions, population and GDP of South Africa and "synthetic South Africa" for the years 2011 - 2015. "Synthetic South Africa" is constructed based on South Africa's annual emissions, population and GDP between 2011 and 2015 obtained from the EDGAR database and the Penn World Tables. "Synthetic South Africa"consists of Venezuela (55.9%), Saudi Arabia (42.1%) and India (1.9%).

Figure D.4: Carbon tax and country level emissions (matching emissions, population and GDP)

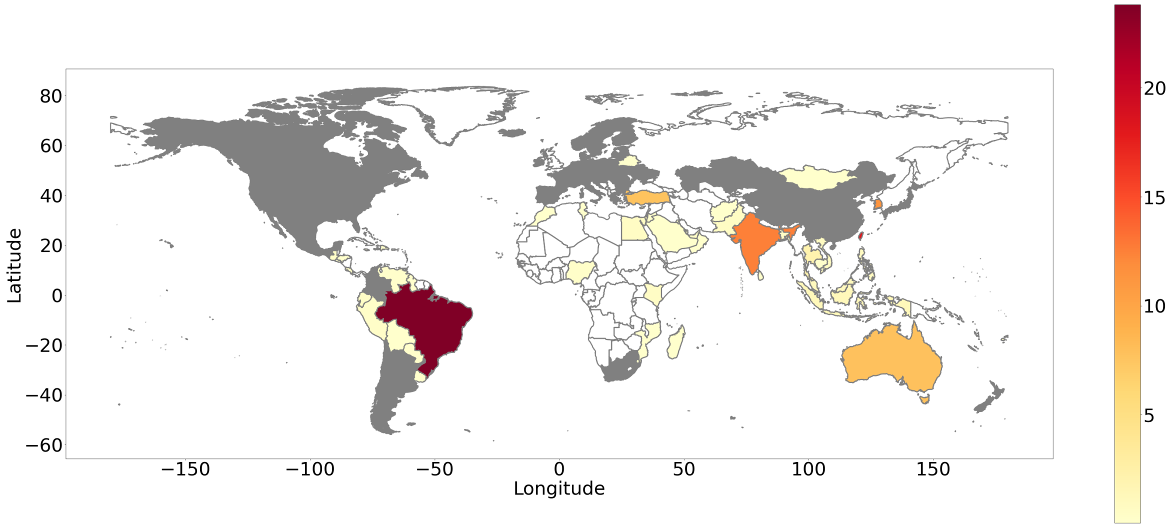


Notes: This figure plots the effect carbon tax policy CO_2 emissions using the synthetic control method. Panel a) shows the absolute values of CO_2 emissions. Panel b) depicts the difference in CO_2 emissions between South Africa and its synthetic counterpart. The plotted emission values cover total annual emissions obtained from the EDGAR database. "Synthetic South Africa" is constructed based on South Africa's annual emissions, population and GDP between 2011 and 2015. Countries that have implemented a carbon pricing policy are removed from the pool of potential donor countries. Further, the donor pool is restricted to countries featured in the firm-level analysis of the Carbon Disclosure Project. For details see Figure D.3 in teh appendix. Data Source: EDGAR and Penn World Tables.

E Carbon Disclosure Project

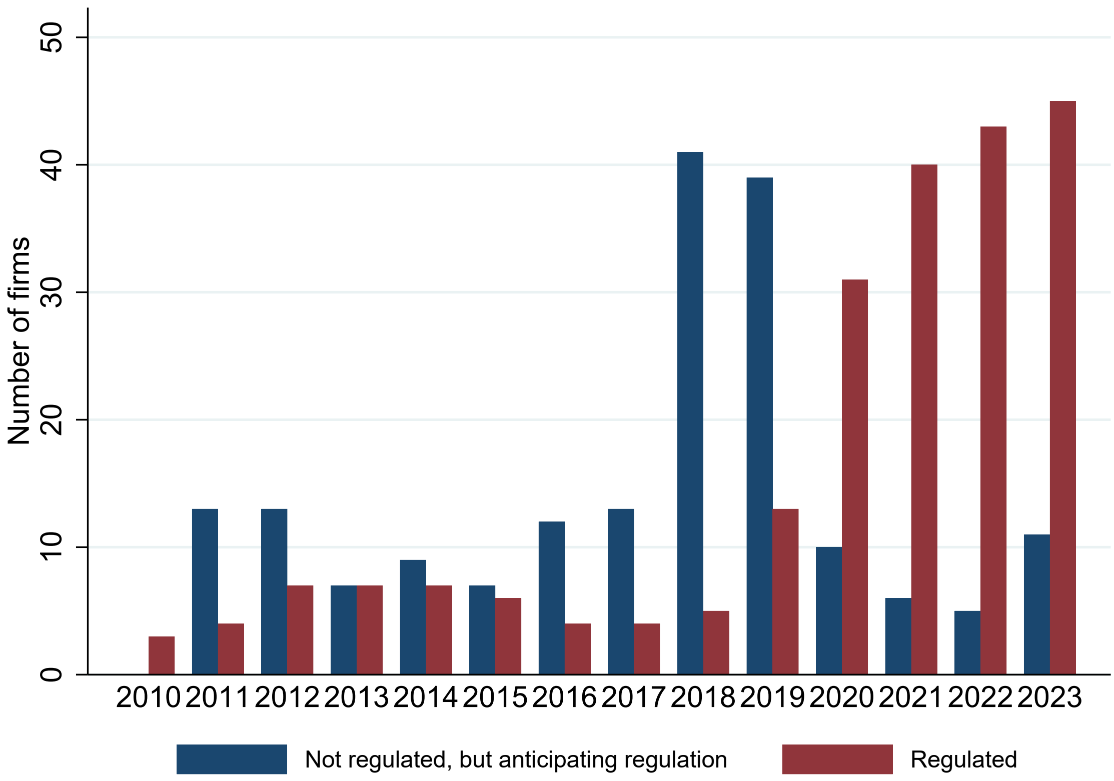
This appendix provides more information on the Carbon Disclosure Project. Figure E.1 maps the distribution of control firms across countries. Figure E.2 plots the number of firms regulated or anticipating regulation across years and Figure E.3 shows the support for Carbon Pricing, highlighting that South African firms have exhibited stronger opposition than those in the average CDP country.

Figure E.1: Countries with control firms in the CDP analysis



Notes: This figure shows the percentage share of the matched control firms in the Carbon Disclosure Project by origin country. Firms based in countries shaded in gray are excluded from pool of suitable control firms due to the existence of (sub-)national carbon pricing regulations.

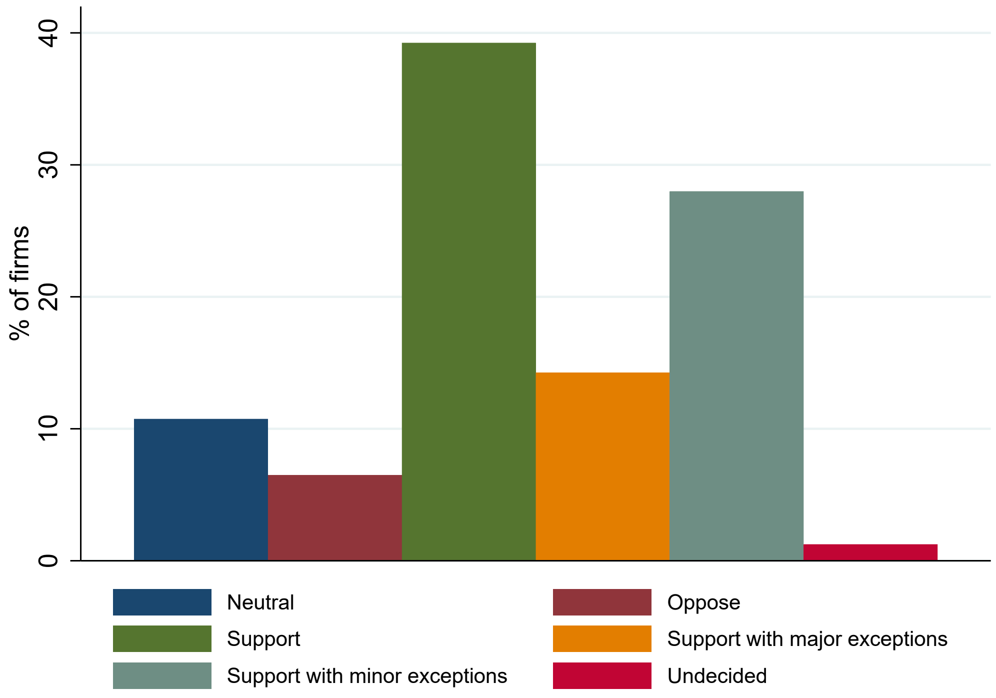
Figure E.2: Carbon pricing regulation and anticipation



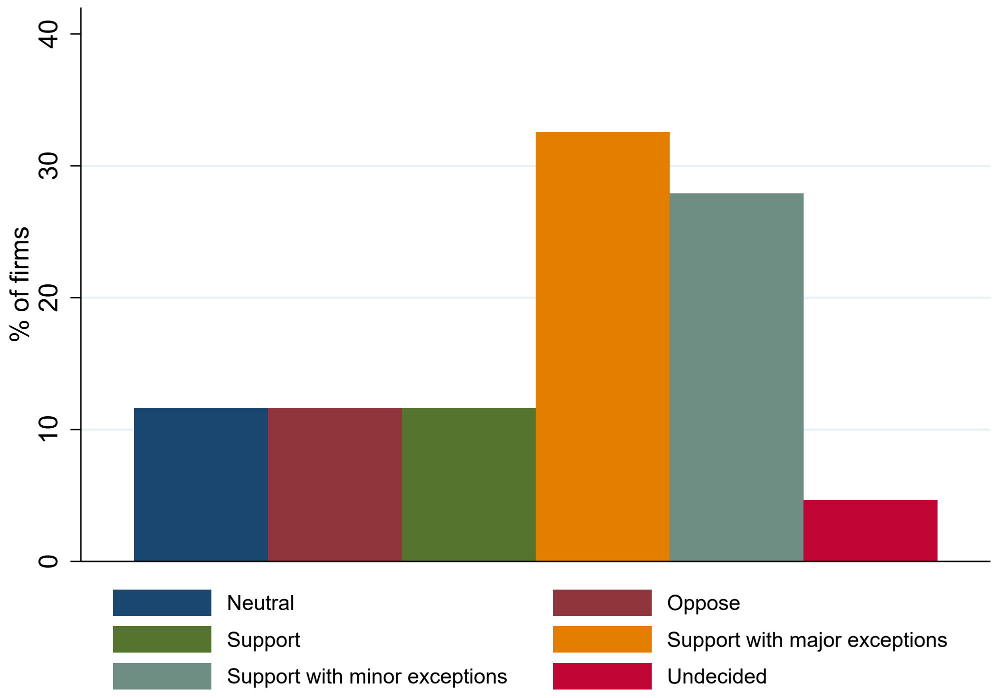
Notes: This figure plots the number of firms represented in the Carbon Disclosure Project Data which state to be either regulated (blue) or anticipate to be regulated in the near future (red). Data Source: CDP.

Figure E.3: Support of Carbon Pricing in 2015

(a) Global



(b) South Africa



Notes: This figure plots firms' support for opposition against Carbon Pricing as stated in the Carbon Disclosure Data. Data Source: CDP.

F Guide for data usage

This data appendix has been prepared in accordance with UNU-WIDER guidelines for users of the National Treasury Secure Data Facility (NT-SDF) and details the data generation process and data sets that have been used in the NT-SDF.

Data Access

The tax administrative micro-data was accessed at the NT-SDF in Pretoria. Access to the data was granted under a non-disclosure agreement and all produced results were reviewed to ensure that the anonymity of any firm or individual remained protected. The results do not represent any official statistics of the National Treasure or South Africa revenue Services.

Data used: SARS Treasury Matched Firm Panel (`stmfp_2008_2022_e5_v1`), year-by-year IRP5 job-level data (v4) and the firm-level carbon tax data (beta-version). Date of first access for this project: 5 January 2024. Last accessed: 22 January 2025.

Software

The data generation and econometric analysis was conducted using STATA 17. User-written programs include `reghdfe` (Correia 2014), `cem` (Blackwell et al. 2010) and `ftools` (Correia 2017)

Variables

Variables used from the Treasury Matched Firm Panel include `imp_mic_sic7_1d, c_type, g_sales, x_labcost, g_grossprofit, k_ppe, k_faother, k_inventory, cust_export, cust_import, x_rd, x_officel, x_cprof`.

For calculating employment and the wage distribution within firms the following variables have been used from the year-by-year IRP5 job-level data (v4): `totalperiodsinyearofassessment, totalperiodsworked, periodemployedto, periodemployedfrom, kerr_income, ptrs_income, kerr_emp, kerr_emp_inc, ptrs_emp, ptrs_emp_inc, revisionnumber, transactionyear, amtpaye`.

In order to construct the descriptive characteristics of carbon tax firms the following variables from the carbon tax data haven been used `net_emissionequiv, grosslevypayamt, netlevypayamt, totpaymentamt, gross_emissionequiv, totfuelcombustionemissions, sequestratedemissions, petrolanddieselemissions, totindustrialprocessemissions, totfugitiveemission`.

Cleaning and sample notes

We have excluded all dormant firms in the SARS Treasury Matched Firm Panel (`c_type = 0` and `c_type = 1`. Further, all firms without an anonymized tax reference number (`taxrefno`) have been dropped. The variable on capital used in the analysis is constructed as the sum of the variables `k_ppe` and `k_faother`. For the firm-level employment information and wage distribution, individuals employed in public sector firms are excluded. If individuals have worked in multiple jobs, we keep their income record of the main job so the each individual is assigned to a single firm. Further details on the construction of employment and income varibles are outlined in Pieterse et al. (2016) and Kerr (2021). These notes highlight key data cleaning and sample construction steps; full details are available in our do-files at the NT-SDF.