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DISCUSSION PAPER

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The Greener, the Better? Evidence From Government Contractors

The greener, the better? Evidence from government contractors*

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Abstract

Governments can support the green transition through green public procurement. Despite its strategic importance, the impact of this policy on firms remains unclear. Using US data, this paper provides the first empirical analysis of the causal effects of green contracts on corporate environmental and economic performance. We focus on an affirmative program for sustainable products, which represents one-sixth of the total federal procurement budget, and publicly traded firms, which account for one-third of total US emissions. Our results show that securing green contracts reduces emissions relative to firm size and increases productivity, with these effects persisting in the long run. We find no evidence that the program selects greener firms, nor that green public procurement sales crowd out private sales. We propose that increased R&D investment, incentivized by the program's requirements, is a key mechanism behind these improvements.

Keywords: Public Procurement; Environmental Policy; Firm Performance; Greenhouse Gas Emissions; R&D; Recycled materials; Staggered Difference-in-difference.
JEL Codes: D22; D44; H32; H57; Q53; Q54; Q58.

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1 Introduction

Governments and other public authorities can leverage the sheer size of their purchasing activities to pursue policy objectives beyond value for money (OECD, 2017).[1] In particular, governments are large—if not the largest—buyers in sectors that have a significant environmental impact, such as defense, health, construction, and transportation (see, e.g., Hertwich and Peters, 2009 and Wiedmann and Barrett, 2011).[2] Therefore, as sizeable consumers, they do not only have the responsibility to reduce their environmental impact but also the opportunity to drive these markets toward sustainability. By purchasing works, supplies, and services with reduced environmental impact, which is broadly referred to as Green Public Procurement (GPP), public buyers can not only reduce the footprint of their activities but also create demand and markets for green options, thereby incentivizing potential suppliers to invest in greener production processes and business models (Li and Geiser, 2005).[3]

Although the potential of public procurement as an environmental policy is increasingly acknowledged and GPP initiatives and experiences are growing (World Bank, 2021; OECD, 2023), economic research on this topic is sparse.[4] In particular, there is no clear understanding of whether GPP impacts firms; that is, whether and to what extent it actually improves their environmental performance and what its consequences are in terms of their economic performance. The result of this uncertainty is that political commitment has been generally weak, while regulatory frameworks have been relatively soft and uncoordinated, resulting in overall moderate GPP adoption rates across countries.[5] Addressing this lack of clarity is

[1]Public procurement accounts for 12% of global GDP (Bosio et al., 2022).

[2]Government consumption alone is responsible for 10% of carbon footprint globally (Hertwich and Peters, 2009).

[3]This potential market pull role can be critical in the short term when broader environmental policies, such as carbon pricing, are not yet working at full power and, therefore, need to be complemented by other policies to create a sufficient scale of incentives for companies.

[4]See reviews of the literature by Cheng et al., 2018 and Chiappinelli, 2022.

[5]GPP is usually a voluntary policy. Countries, sub-national governments, and individual authorities are left free to decide both the extent and mode of implementation. While GPP policies and practices have been established by environmentally committed countries and motivated high-capacity authorities, the lack of a clear and overarching regulatory framework has so far constituted a barrier to broader GPP implementation (Geng and Doberstein, 2008; Varnäs et al., 2009).

therefore crucial to understanding whether it is worthwhile for governments to invest more commitment and resources in GPP as an environmental and industrial policy tool.

In this paper, we contribute in this direction by providing the first empirical investigation of the effect of GPP on the environmental and economic performance of firms. We focus on a government-level affirmative green procurement program and greenhouse gas emissions at the company level, as well as various economic performance outcomes. We find that the GPP has a positive and persistent impact on *both* the environmental and economic performance of the winning firms.

These results are far from obvious. First, it is not straightforward for GPP to improve the environmental performance of firms. For example, GPP auctions may attract only firms that are, to some extent, already "green", while companies that contribute more to pollution tend to not participate (Lundberg et al., 2015). In addition, firms that secure GPP contracts might redirect their existing supply of green production from private to public customers without increasing the scale of their green production capacity or making their current processes greener (Marron, 1997). If GPP results in such a selection or crowding-out effect, firm environmental performance at the company level will remain unchanged. Additionally, even if GPP were to improve firms' environmental performance, it is not obvious that it would do so without negatively impacting their economic performance. In fact, according to the traditional view, environmental policies and regulations can create a trade-off between environmental and economic performance because they create a compliance cost for companies (e.g., the cost of abating emissions), which could require them to redirect their activities and resources from productive to non-productive uses and objectives (Baumol and Oates, 1988; Palmer et al., 1995; Greenstone et al., 2012). While GPP might differ from other environmental policies insofar as participation in the tenders is optional and being awarded a public contract inherently provides benefits (De Silva et al., 2012; Ferraz et al., 2015; Czarnitzki et al., 2020; Coviello et al., 2021; Goldman, 2019; Gugler et al., 2020; Hebous and Zimmermann, 2020; Cappelletti et al.; di Giovanni et al., 2022; Lee, 2021), the arguments above still apply. First, polluting firms can reduce their environmental impact without switching to green technology, but only by reducing the scale of their economic activity. Furthermore, for firms that switch to green technology, the investment cost and the potential productivity loss might outweigh the benefit of winning the contract. Lastly, even if there is a net benefit of winning a contract, this benefit might not persist beyond the contract period and therefore not result in long-term performance improvements, which means that green firms would not catch up in the longer term with polluting incumbents.[6] Overall, it is therefore not clear whether GPP can impact firms' environmental and economic performance and, if so, in which direction.

In this paper, we aim to address this lack of clarity by providing a first causal analysis of the effect of GPP on firm-level environmental and economic performance. We focus on a federal affirmative procurement program and on publicly traded companies in the United States (US). This setting represents a good laboratory for our purpose for three main reasons. First, it allows us to capture a relevant picture both in terms of procurement expenditures and greenhouse gas emissions. The program accounts for around one-sixth of the annual federal procurement budget (on average 88 billion dollars/year in our data), amounting to one of the largest GPP markets worldwide.[7] Furthermore, publicly traded companies are responsible for a large chunk of greenhouse gas emissions in the US. For example, in 2019, firms in our dataset accounted for approximately 2.39 billion metric tons of greenhouse gas emissions, about 36% of the total 6.56 billion metric tons reported (US Environmental Protection Agency, 2024). The second advantage of this setting is that, while the concept of GPP encompasses a wide range of practices, making it generally challenging to define a GPP purchase and therefore identify its effect on firm-level performance, the affirmative program allows for a precise identification of green purchases.[8] In particular, the program focuses

[6]Evidence for this lack of catching up of targeted firms was found for the case of preferential programs for small businesses (Fadic, 2020; Cappelletti and Giuffrida, 2022).

[7]Source: `usaspending.gov`. With annual expenditures of $694 billion, the US federal government is the largest single consumer globally. This figure pertains to Fiscal Year 2022 and shows an upward trend. For instance, the expenditure was approximately $500 billion in 2008.

[8]GPP implementation options vary across countries. Some countries adopt preferential programs based on a bid discount e.g., the Netherlands (Kadefors et al., 2021) and Germany (BMWK, 2021). Other mechanisms adopted in practice primarily include technical requirements, where bidders are to comply with minimum environmental standards, scoring auctions, where an explicit weight is given to environmental quality relative to

on a set of products that can be manufactured with recycled material content. The set of such products is well-defined, thereby allowing a green purchase to be defined based on whether the purchased product belongs to the set. Third, the program requires authorities to purchase products with the highest recovered material content level practicable, that is, to allocate the contract to the supplier that manufactures the product with the largest amount of recovered material. The program is therefore expected to incentivize companies to upgrade their production processes to incorporate recycled materials as inputs into their production processes, to the maximum extent possible. Reducing reliance on virgin material production can significantly reduce greenhouse gas emissions.[9] The technological changes related to increasingly switching to recycled materials can, in turn, be expected to impact economic outcomes, as well as induce additional environmental spillovers over time.

We combine federal procurement data with firm-level CO2 equivalent (CO2e) emissions and balance sheet data from publicly listed US firms from 2007 to 2019. We use a staggered difference-in-difference methodology to causally identify the effect of green contract awards on the environmental and economic performance of winning firms. This approach enables us to exploit the staggered nature of procurement awards and determine whether firms enhance their performance after securing the first green contract. This strategy allows us to address the multiple layers of endogeneity between green contract awards and firm outcomes.

We find that GPP has a substantial and statistically significant positive impact on *both* corporate environmental and economic performance. Our baseline estimates indicate that receiving green contracts reduces emission intensity—measured as metric tons of CO2e emissions per dollar of total assets, therefore accounting for scale considerations—by approximately 5%. Since firms awarded green contracts do not differ from other firms in terms of emission intensity prior to receiving the contract, there is no evidence of the selection of greener firms in GPP auctions. Both greener and less green firms participate, win, and im-

price, and contract performance clauses, where the contractor must comply with environmental standards. See Appolloni et al. (2019) for a review.

[9]Recycled material manufacturing requires much less energy and processing relative to the production of virgin material, leading to significant reductions in both energy- and process-related greenhouse gas emissions (Gutowski et al., 2013; Bataille et al., 2018; Gerres et al., 2019; IPCC, 2022).

prove their environmental performance, indicating that incentives are active for firms near the environmental technology frontier as well as for those further behind. Notably, these positive effects persist in the long term, extending well beyond the contract duration, suggesting that GPP may create a lasting business case for green investments. These results hold consistently across various robustness checks in our empirical framework. However, we find no detectable impact on absolute emission volumes, even though they show a declining trend post-treatment. This suggests that, due to winning the contract, firms may have expanded the scale of their economic activities. Indeed, we observe that GPP winners experience growth in employment and revenues, among other scale metrics, although there is a selection bias in the size of the firm before the first contract intake, which prevents us from making causal interpretations. On the other hand, we find causal evidence of improvements in firm efficiency post-treatment. These improvements persist over time and align with indistinguishable pre-trends. In particular, labor productivity increases by 10%. In other words, our evidence suggests that green contractors become greener *and* "better," without necessarily becoming bigger.

In exploring the mechanism behind these improvements, we find that R&D expenditures play a crucial role. Winning a green contract leads to a significant increase in R&D spending. Higher R&D expenditures, in turn, correlate with lower emissions intensity and higher productivity in our data. We argue that by awarding contracts to firms with the highest environmental performance, the affirmative program creates robust incentives for firms to invest in technological improvements. These investments enable both environmental and economic benefits.

The dynamic nature of our analysis provides an opportunity to gain more insight into the mechanism by exploring the dynamics and effects of a green award. Our estimates suggest that these effects take some time to materialize. Statistically significant emission intensity improvements appear from the second year following the first award, while economic improvements need three to five years to materialize. This pattern suggests that winning the contract results in an increase in R&D expenditures, which translates first into improvements in environmental performance and subsequently into positive spillovers to economic performance. In addition, the dynamics highlight that the performance gap—on both environmental and economic outcomes—-between GPP winners and other firms not only persists but even appears to widen over time.

Spotlighting the federal procurement activity, we also see evidence of a crowd-out effect of green sales on brown sales. GPP winners replace brown sales with green sales when selling to federal buyers so that brown revenues tend to decrease. In addition, we find that non-procurement revenues increase after treatment, indicating that GPP crowds in sales to private customers.

In exploring the heterogeneity of the impact of winning green contracts, we also find that the effect is stronger for smaller firms, those for which revenues coming from green procurement matter the most to their business, and those less innovative. This evidence is consistent with mechanisms already found in the literature suggesting that winning procurement contracts can boost firm performance by softening resource constraints, allowing for learning by doing, and pushing market penetration (Ferraz et al., 2015; Lee, 2021).

Overall, our results suggest that GPP creates a win-win situation for both environmental and economic performance. The design features of the affirmative program are likely crucial in this regard. By awarding contracts to the best performers based on sustainability requirements, GPP triggers competition for green performance among firms. Laggards are incentivized to catch up with the frontier, while incumbents cannot rest on their laurels and are encouraged to push the frontier further. Therefore, GPP does not seem prone to the criticism often directed at other preferential procurement programs—typically those for small businesses—for distorting competition in favor of less efficient firms without achieving long-term performance improvements (Marion, 2007, 2009; Krasnokutskaya and Seim, 2011; Athey et al., 2013; Cappelletti and Giuffrida, 2022). In contrast, GPP appears to induce productivity improvements that increase both the environmental and economic performance of the winners, with these benefits growing over time. We conclude that governments should consider using GPP more extensively as both an environmental and industrial policy tool.

The remainder of the paper unfolds as follows. Section 2 discusses the contribution to the relevant literature. Section 3 describes the US federal regulatory background of GPP. Section 4 describes the data, presents the empirical strategy, and the main results of the analysis. Section 5 discusses possible mechanisms to explain the empirical evidence. Section 6 concludes.

2 Related literature

Our paper contributes to various strands of the environmental and procurement literature.

First, we contribute to the literature investigating the effectiveness of environmental policies, particularly GPP. The empirical literature on GPP is very scarce. Of the few studies assessing the GPP impact, most are based on case studies focusing on specific sectors.[10] Simcoe and Toffel (2014) show that mandatory green building standards for public buildings stimulate the demand of green buildings from the private sector in California. Lindström et al. (2020) examine organic food purchases by the public sector in Sweden and find a positive impact on organic agriculture. Orsatti et al. (2020) finds a positive correlation between GPP expenditures and green patenting in US Commuting Zones. The only paper we are aware of that provides a cross-sectoral analysis and focuses on firm-level outcomes is Krieger and Zipperer (2022). This paper investigates the effect of winning green contracts (field data) on a firm's introduction of environmental innovations (survey data) in Germany. Similarly to us, the authors exploit difference-in-difference methods and find a demand-pull effect of GPP that is mostly driven by small firms. To our knowledge, no previous research has established a causal relationship between green contracting and firms' environmental performance in terms of emissions —and therefore assessed procurement as an (indirect) climate change policy.[11] In addition, as far as we know we are the first to quantify the effect of green contracts on economic outcomes.

[10]Other studies only assess the potential impact, as proxied by the environmental footprint of government activities, but not the actual impact (Wiedmann and Barrett, 2011; Alvarez and Rubio, 2015; Cerutti et al., 2016; Rietbergen and Blok, 2013).

[11]We provide evidence on the indirect climate effects (i.e., the impact on emissions) of a policy focused on a circularity measure (i.e., the use of recovered materials).

An emerging literature has provided a causal estimation on the impact of cap and trade carbon pricing on firm-level CO2 emissions and/or economic performance, notably the European Emission Trading System (see, e.g., Martin et al., 2016, Marin et al., 2018, Dechezleprêtre et al., 2019, Löschel et al., 2019, Calel, 2020, Dechezleprêtre et al., 2023, Colmer et al., 2024) or analogous programs in the US, such as the California's Carbon Market (Hernandez-Cortes and Meng, 2023), the Regional Greenhouse Gas Initiative (Fell and Maniloff, 2018), and the Regional Clean Air Incentives Market (Fowlie et al., 2012, 2016).[12] The papers closest to ours in the literature are Dechezleprêtre et al. (2023) and Colmer et al. (2024), which both find evidence that carbon pricing led to a reduction in CO2 emissions without detecting a worsening of economic outcomes, therefore providing evidence in favor of the so-called Porter's Hypothesis (Porter and van der Linde, 1995), which, contrary to the traditional view, suggests that environmental regulation, by triggering innovation, optimization and improvement in productivity, does not only improve environmental performance but can also improve economic outcomes.[13] Our paper shows that analogous outcomes can be reached by another policy, green procurement, with results that are in line with the literature.[14] In addition, we provide direct evidence of the R&D channel, something that is generally missing so far. The only other empirical investigation we are aware of the R&D mechanism is by Dechezleprêtre and Kruse (2022), who use patent data and find no evidence that environmental policies either harm or improve the economic performance of regulated firms, in terms of productivity and value added.[15]

Second, we contribute to the literature on the effect of public demand on firm economic performance and, more broadly, to the long-standing debate on whether industrial policy

[12] A related literature focuses on the potential adverse effects on competitiveness of regulated firms in international markets see e.g., Dechezleprêtre and Sato (2017), Zaklan (2023).

[13] See, e.g., Ambec et al. (2013) and Dechezleprêtre et al. (2019) for literature reviews on the work on the Porter's Hypothesis.

[14] The literature tends to find a decrease in both absolute emissions and emission intensity as well as positive impact on investment and productivity, no impact on employment, and mixed evidence on other measures including revenues, and value added (see Marin et al., 2018, Dechezleprêtre et al., 2023, Colmer et al., 2024 and papers mentioned therein).

[15] Colmer et al. (2024) builds a model where carbon pricing induces firms to invest in energy efficiency that reduce marginal costs.

can spur firm responses. Firms exposed to demand shocks from public procurement are found to experience a persistent boost in revenues and employment. This effect is found in Austria (Gugler et al., 2020), Brazil (Ferraz et al., 2015), and South Korea (Lee, 2021). Similar effects are found to be relevant for domestic firms across countries of Sub-Saharan Africa (Hoekman and Sanfilippo, 2020). Firms exposed to positive public demand shocks are also found to have easier access to external borrowing (Goldman, 2019; Hebous and Zimmermann, 2020; Lee, 2021; di Giovanni et al., 2022), have better chances of survival (De Silva et al., 2012; Cappelletti et al.), innovate more (Czarnitzki et al., 2020), and increase capital investments (Hebous and Zimmermann, 2020).[16] Our paper adds to this literature by studying the specific case of green contracts and showing that they can improve not only the long-term economic performance of targeted firms but also their environmental outcomes.

Third, we contribute to the empirical literature on preferential procurement programs. Existing research has studied the effect of preferential programs for small businesses and mostly in the US, either in the form of a bid discount (Marion, 2007, 2009; Krasnokutskaya and Seim, 2011) or of set-asides (Denes, 1997; Nakabayashi, 2013; Athey et al., 2013; Tkachenko et al., 2019; Cappelletti and Giuffrida, 2022). This literature has focused on the effect of these programs on participation and competition in tenders and on the resulting impact on the cost of procurement, finding mixed evidence. In addition, Fadic (2020) and Cappelletti and Giuffrida (2022) investigate the long-term effects of these programs, finding that the positive shock of winning a contract on firm-level outcomes does not persist over time.

To our knowledge, we are the first to provide an empirical assessment of a preferential program for green firms. The only investigations we are aware of are the theoretical works by Marron (1997) and Chiappinelli and Seres (2024). The former investigates the market effects of a set-aside program for green goods. It shows that it is ineffective as an environmental policy because it only results in a substitution effect between public and private relative consumption of green and conventional goods. The latter provides an auction theoretical

[16] If the shock is negative, firms consistently respond by cutting capital (Coviello et al., 2021).

study of a bid discount program and shows that it creates incentives for sufficiently efficient brown suppliers to switch to green technology. Our paper provides empirical evidence consistent with their theoretical results, suggesting that the preferential program effectively induces green investment, enabling long-term benefits both in terms of environmental and economic performance.

3 GPP in the US federal procurement

Sustainable purchases are taken into high consideration by the Federal Acquisition Regulation (FAR), the set of rules governing federal procurement in the US. Indeed, it is an explicit government policy "to acquire supplies and services that promote a clean energy economy that [...] safeguards the [...] environment and reduces greenhouse gas emissions from direct and indirect Federal activities. To implement this policy, federal acquisitions will foster markets for sustainable technologies, products, and services. This policy extends to all acquisitions" (FAR §23.202).

In the FAR, particular attention is devoted to reducing the environmental impact of materials use. Production of materials such as steel, cement, plastics, and aluminum is energy-intensive and responsible for a large share of global emissions.[17] Materials can also have additional environmental impacts in their life cycle, e.g., related to their disposal.

To improve the environmental performance related to materials, the US Environmental Protection Agency (EPA) has therefore put in place the Sustainable Materials Management initiative that promotes a systemic approach to reducing materials use, associated greenhouse gas emissions, and the other environmental impacts over the materials' entire life cycle.[18] As part of the Sustainable Materials Management Initiative, the EPA has established the Comprehensive Procurement Guideline (CPG), an affirmative procurement program in federal procurement for products with recovered materials content, as detailed below.[19]

[17]In 2019, the Materials sector was responsible for 34% of global greenhouse gas emissions. This figure includes indirect emissions from power and heat generation (IPCC, 2022).

[18]For more details see `https://www.epa.gov/smm`.

[19]CPG is not the only GPP program in US government regulation. There are other programs

The US federal affirmative procurement program for products with recovered materials The CPG aims to promote the use of materials recovered from the municipal solid waste stream by requiring all authorities involved in federal procurement to buy products made with recovered materials.[20] The CPG ensures that the materials collected in recycling programs will be used again to manufacture new products. This reduces both the need to produce virgin material and the amount of solid waste that must be disposed of. In particular, the EPA designates a set of products that can be made with recovered materials—the so-called EPA designated products or CPG products.[21]

Three main selection criteria are driving the EPA designation of products. First, items are to be produced with materials representing a significant portion of the solid waste stream or present a solid waste disposal problem.[22] Second, there needs to be a significant impact on government procurement: the item is to be purchased in appreciable quantities by the federal government or state and local governments.[23] Third, to also reduce implementation

covering the purchase of other categories of green products. See https://www.gsa.gov/climate-action-and-sustainability/buy-green-products-services-and-vehicles/buy-green-products. Our data allow us to track down three of these categories, that is, bio-based products, environmentally preferable products, and energy-efficient products. However, the CPG program is by far the largest GPP policy. In our time frame, an average of $88 billion is spent annually on the CPG affirmative program, or about 18% of the total annual federal procurement budget. The other three GPP policies combined account for $9 billion, or about one-tenth of the annual budget for CPG. Source: usaspending.gov.

[20]Congress authorizes the CPG program under Section 6002 of the Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6965) and Executive Order 13834, "Efficient Federal Operations." The procurement requirement applies to all direct purchases of federal agencies, of state and local agencies using federal funds, as well as purchases of contractors to these government agencies.

[21]EPA publishes the list of products and the accompanying information in a Recovered Materials Advisory Notice in the Federal Register (FAR §23.201). EPA issued its first five guidelines from 1983 to 1989 and updated them in the following years, adding new product categories. The current list includes 61 products classified into eight categories: *construction products*, *landscaping products*, *miscellaneous products*, *nonpaper office products*, *paper and paper products*, *park and recreation products*, *transportation products*, and *vehicular products*. Importantly for this study, no new designations have been published since 2007 (the beginning of our dataset). For more details, see http://www.epa.gov/cpg.

[22]For example, the EPA would use the following reasoning to justify the inclusion of plastic picnic tables and benches for recreational areas: "between 6.3 and 9 milk jugs are needed to make a pound of recycled plastic. An average 300-pound picnic table would use between 1,890 and 2,700 milk jugs. Therefore, if federal agencies were to buy 10,000 such picnic tables, 18.9 to 27 million milk jugs would be diverted from the solid waste stream. Similarly, if federal agencies were to buy 10,000 park benches of an average weight of 125 pounds, they would divert between 7.9 million and 11.3 million milk jugs from the waste stream" (Background Document EPA530-R-00-002 September 1999).

[23]For example, in 1996, purchases of picnic tables and park benches by government agencies totaled $3,148,996 (Background Document EPA530-R-00-002 September 1999).

complexity and to limit potential extra costs for contracting authorities, it needs to be economically and technologically feasible to produce the items with recovered materials, and the items need to perform well enough to meet the authority's needs. Primary indicators of this are the extent to which the item is already available in the market and the extent to which the item is already purchased by federal and/or other procuring agencies. In some cases, the EPA may consider designation for an item that is not currently made with recovered materials content, as long as the use of recovered materials has been demonstrated for a similar item.

Authorities are required to purchase EPA-designated products *with the highest recovered material content level practicable* while taking certain limitations into consideration.[24] For each designated product, EPA publishes supporting documentation and background information, including the recommended level of recycled content. The EPA's recommendations typically include the ranges of recovered materials content levels, in terms of minimum and maximum percentages, within which the items are currently commercially available. While authorities should enforce the minimum percentage as a minimum content standard, the EPA recommends that procuring agencies use ranges rather than only the minimum content standard, because manufacturers that are better informed than agencies on the potential in terms of maximum practicable recovered material content may treat the standards as maximum targets, which would hinder innovative approaches for increasing recovered material use.[25] On the other hand, the use of ranges can better encourage manufacturers, especially those producing at the low end of the recovered materials range, to explore ways of increasing their recovered materials usage.[26] In some instances, EPA recommends a specific

[24]In particular, the following conditions must be met: i) a satisfactory level of competition needs to be maintained; ii) the item needs to be available within a reasonable period of time; iii) the item needs to meet the performance standards outlined in the agency's specifications; and iv) the item needs to be available at a reasonable price. If any of these conditions are not satisfied, the procuring agency may choose not to purchase an EPA-designated item with recovered materials (FAR §23.405). However, exceptions are rare in the data. While approximately 10.8% of contracts involve EPA-designated items, only 0.4% of these are granted exceptions.

[25]Authorities should require a pre-award certification that the product at least meets, but may exceed, the relevant minimum recovered materials standard. In addition, contract clauses require the contractor to provide a certification or an estimate of the percentage of recovered material content delivered (FAR §23.406, §52.223).

[26]Another reason to recommend ranges rather than minimum standards is that many items are purchased locally rather than centrally, and the availability of recovered materials (and therefore their cost) is likely to

level (e.g., 50 percent recovered materials content) rather than a range because the item is universally available at the recommended level.

The CPG and firm incentives The design characteristics of the CPG have two crucial implications for how the program is expected to impact firm behavior. First, companies are informed about the relevant competitors in each product market and their recovered material performance. Therefore, they are aware of the technological frontier (in terms of maximum percentage of recovered material) and their position in the range, i.e., their performance relative to the frontier. Second, firms are aware that, to win a contract, they need to be above the minimum standard and as close as possible to the technological frontier, as well as that the frontier moves over time.

The scheme is, therefore, expected to induce firms to adjust their production processes to integrate recycled inputs to the largest possible extent. By incorporating recycled material as inputs into their production processes, companies can significantly reduce the use of fossil fuels in their operations, thereby reducing their direct CO2e emissions (Scope 1). In addition, recycled materials typically require less energy to process than virgin materials, reducing the amount of energy purchased from external sources and thus the indirect CO2e emissions (Scope 2) (Gutowski et al., 2013; Bataille et al., 2018; Gerres et al., 2019; IPCC, 2022).[27] In turn, improvements in production processes and operations may have a spillover impact on economic outcomes, as well as induce further environmental benefits in the longer term.

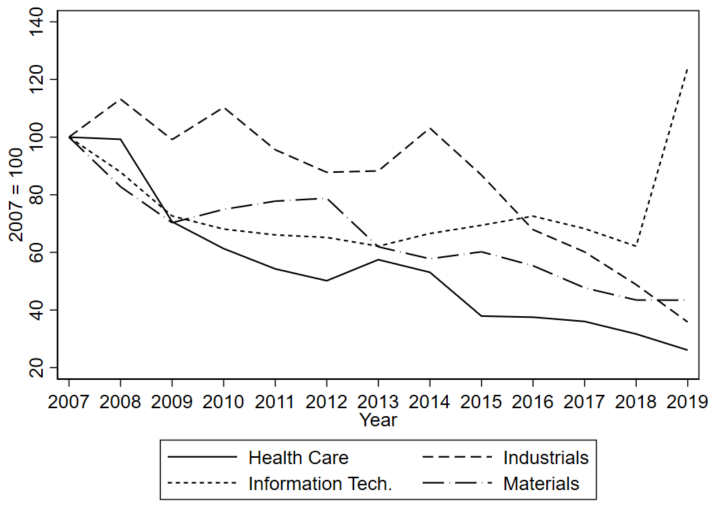
4 Empirical analysis

This section outlines our investigation of the empirical relationship between green contracts and firm-level outcomes. For the purpose of our analysis, a *green contract* is a contract for an EPA-designated product as described in Section 3. For firm outcomes we will look at both

vary across regions. Providing a range of recovered material content, therefore, gives local procuring authorities flexibility when establishing their standards given local market conditions.

[27] For example, melting and alloying recycled aluminum scrap allows a reduction of 95% of the required energy and emits only 5% of the greenhouse gas of virgin material production (Capuzzi and Timelli, 2018).

Figure 1. Total emission volume by sector



Notes: Annual time series of total CO2e emission volumes in our data, aggregated from the total emissions of firms within each sector-year. The year 2007 is used as a benchmark. The time series focuses on the sectors whose firms account for 92% of green contracts in our dataset: Health Care, Industrials, Information Technology, and Materials.

environmental performance, measured via CO2e emissions relative to size, and economic performance, measured via a battery of proxies for scale and efficiency. Building on Section 3, the underlying hypothesis we want to test in our data is that engaging in green contracts incentivizes firms to make operational changes and adopt practices and technologies that reduce emissions, thus improving their environmental footprint. These technological changes are, in turn, expected to impact economic outcomes.

The reason why we focus on firm-level outcomes is that assessing the impact of GPP policies on a broader scale, such as across entire geographies or industries, is challenging due to ongoing trends that make it difficult to isolate the effects of the program. For example, US greenhouse gas emissions have been declining since 2006, driven by structural changes in the economy and advances in energy efficiency.[28] This trend is also evident in our data. As shown in Figure 1, the CO2e emission volumes for the four sectors that account for 92% of green contracts in our dataset are all decreased during the period of analysis.

[28] See https://www.statista.com/statistics/517376/us-greenhouse-gas-emissions/.

However, there remain two main empirical challenges to estimating the causal effects of green contracts on firm-level outcomes. A primary challenge for studying environmental performance is the historical lack of accurate longitudinal emissions data at the firm level. This problem is particularly pronounced the further back in time one looks, as there has historically been less emphasis on firms disclosing this information. Having a long time series of firm-level CO2e emissions data is critical for attributing observed changes in firm performance, specifically to the GPP policy rather than to external factors. We use the Refinitiv database, which collects and provides consistent emissions measures since the early 2000s, irrespective of firm procurement status. We explain the combination of procurement and firm data in Subsection 4.1. We describe the working sample in Subsection 4.2.

Establishing a credible counterfactual is another key challenge for investigating environmental and economic performance, given the inherent differences between firms in the treated and control groups in the context of green contracting. Indeed, firms voluntarily enter the GPP procurement market and choose to participate in specific auctions. Moreover, winning a public tender is the result of a competitive bidding process. These decisions and outcomes may be associated with firms' environmental and economic performance, highlighting the importance of distinguishing the effects of green contracts from the underlying selection processes and competitive dynamics that influence participation and success in these markets. We address these challenges by exploiting the wealth of our firm data and the staggered nature of green contract awards across firms, introducing time and cross-sectional variation. This twofold source of variation is pivotal to applying a staggered difference-in-differences approach, which we argue will be effective in quantifying the direct effects of GPP in our setting. Based on the variation in treatment timing, this method compares changes over time between firms that received a green contract and those that did not, controlling for the timing of each firm's first contract award. The details of this approach are presented in Subsection 4.3. The empirical results on environmental performance are presented in Subsection 4.4, while the ones on economic performance are discussed in Subsection 4.5.

4.1 Data and measurements

Our working dataset covers the period from 2007 to 2019 and is the result of matching two datasets: Refinitiv and the Federal Procurement Data System (FPDS). The former is a financial and corporate emissions information database for publicly traded companies; the latter provides records on US federal contracts. In the following, we describe the information retrieved from the two datasets and the procedure used to match firm-level information with contract-level information.

Refinitiv We retrieve from Refinitiv a panel of annual firm-level environmental and financial data for all publicly traded US companies from 2007 through 2019.[29] The dataset provides multiple firm-level environmental outcome variables, including CO2e emissions.[30] Specifically, we retrieve the Scope 1 CO2e emissions from sources owned or controlled by the company; these include all emissions from the combustion of fossil fuels in plants and vehicles owned or controlled by the company, as well as from physical and chemical processes related to production (*Direct CO2e Emission Volume*). Scope 2 emissions cover the indirect emissions from purchased electricity, heat, or steam consumption, which occur at the facility where electricity, steam, or heat is generated (*Indirect CO2e Emission Volume*). We use these two emission measures to define our *Total CO2e Emission Volume* as the sum of the *Direct CO2e Emission Volume* and *Indirect CO2e Emission Volume*. In addition, we retrieve the *Total Waste Volume*, which includes both the non-hazardous waste plus hazardous waste, and the *Recycled Waste Volume*, which includes both hazardous and non-hazardous waste incinerated to generate energy, as well as waste destined to composting.

In an attempt to control for as many dynamic firm characteristics as possible, we further retrieve a set of variables commonly used in the environmental economics literature (see Dechezleprêtre et al., 2023 and Colmer et al., 2024 among others). Specifically, we

[29]The financial economics literature has widely used the emissions and other environmental outcome data provided by Refinitiv. See among others Bolton and Kacperczyk (2021) and Hsu et al. (2023)

[30]CO2e emissions in Refinitiv represent the sum of CO2 and other greenhouse gases converted to CO2 based on their global warming potential.

additionally retrieve yearly operating revenue excluding discounts, returns, and allowances (*Total Revenues*); the sum of all the long- and short-term assets (*Total Assets*); the total market value of the company at the year end (*Market Capitalization*); the number of employees (*Employment*); the sum of all the direct and indirect costs related to creating and developing new processes, techniques, applications, and products with commercial possibilities (*R&D Expenses*); and the *Environmental Expenditures*, which covers the total of the expenditures for environmental protection or to prevent, reduce, control ecological aspects, impacts, and hazards. We also retrieve information on the sector (e.g., Materials) and industry (e.g., Construction Materials) of each company according to the *Global Industry Classification Standard* (GICS).[31]

In addition, we define several variables from these data. To have a scale-free measure of environmental performance, we define the *Total CO2e Emission Intensity* as the ratio between the *Total CO2e Emission Volume* and the *Total Assets*. This will be our primary metric for firm environmental performance. We also define *Recycled Waste Share* as the ratio between the *Recycled Waste Volume* and *Total Waste Volume*. Furthermore, to measure the firm's contribution to the broader economy, we define the *Value Added* as the difference between *Revenues* and *Operational Expenses*—i.e., the difference between the firm's output and intermediate inputs. Other measures of firm efficiency are as follows. First, *Labor Productivity* is defined as the ratio between *Total Revenues* and *Employment* and measures the efficiency with which a firm utilizes its labor force to generate revenue. Second, *R&D Intensity* is the ratio between *R&D Expenditures* and *Total Revenues* and measures the emphasis a firm places on research and development relative to its overall turnover. Third, *Environmental Expenditure Intensity* is the ratio between *Environmental Expenditures* and *Total Revenues* and stands for the extent to which a firm invests in environmental sustainability relative to its revenue.

[31] The GICS is an industry taxonomy for use by the global financial community. The GICS structure consists of 11 sectors, 74 industries and 163 sub-industries. See https://www.msci.com/our-solutions/indexes/gics.

FPDS: procurement data We retrieve contract-level information from USASpending.gov. When contract value is above the micro-purchase threshold ($3,500 during the period of our analysis), US federal agencies are required to complete procurement action reports, which feed into the FPDS. We retrieve the FPDS records from the fiscal year 2008 (i.e., beginning on October 1, 2007) until the end of the fiscal year 2019 (i.e. September 2019). The downloaded version includes about 12 million unique contracts awarded via competitive procedures and $3.8 trillion in spending. Importantly for this work, the FPDS dataset enables the identification of green contracts by reporting a dummy for when EPA-designated products are procured.[32]

The FPDS dataset provides information on contractors, which we categorize into GPP and Non-GPP. A firm is classified as a GPP firm if it has received at least one green contract, while firms that have never secured such contracts are considered Non-GPP firms.

Also, for each fiscal year, we calculate the number of green contracts awarded to the firm (*Green awards*), the total amount awarded for the green contracts won (*Green revenues*), and the total amount of brown procurement contracts awarded (*Brown Revenues*). In addition, we define *Other Revenues* as the difference between the *Total Revenues* and the sum of the *Green Revenues* and *Brown Revenues* to compute the amount of revenues of the firm that is not coming from government contracting and which therefore approximates the earnings generated by sales to private customers.

Data matching process In Refinitiv, companies are identified via the International Securities Identification Number (ISIN). The ISIN is a unique identifier assigned to firm securities like bonds, shares, derivatives, etc. It is a 12-character alphanumeric code that helps to standardize and identify securities for trading and settlement purposes globally, and it is extensively used in the finance literature. Instead in FPDS, contractors are uniquely identified by a 9-digit code according to the Data Universal Numbering System (DUNS number), which is administered by Dun & Bradstreet, a business information and analytics provider.

[32]CPG requirements apply when contracts are above the micro-purchase threshold. Thus, through FPDS, we get the universe of contracts for EPA-designated products.

The system is primarily used by companies engaging in business-to-business transactions, applying for federal contracts or grants in the US, or seeking to establish business credit. The coverage of firms extends well beyond those that are publicly traded.

The merging exercise aims to associate the DUNS number with the corresponding ISIN. As multiple ISINs per firm are seldom but can happen, especially for large corporations, the merging process exploits the company name and geographical information (i.e., ZIP code of the headquarter) provided by Dun & Bradstreet to retrieve the most likely ISIN and maximize the matching precision.[33] As not all firms participate and are awarded procurement contracts, we cannot match all ISINs from Refinitiv with DUNS codes. Therefore, we consider a Refinitiv company unmatched with FPDS records to be a Non-GPP firm. This expands our definition of Non-GPP firms in our post-matching sample: not only all FPDS companies that are never awarded a green contract (but only brown contracts), but also all companies in Refinitiv that are not matched with FPDS. For our empirical analysis, GPP firms serve as the treatment group, while Non-GPP firms are the baseline control group.[34] Further, companies might or might not be associated with contracts in a specific year. To track the dynamic activity in the procurement market, we create a panel of companies and their procurement performance (i.e., are they awarded green contracts? How many each year? What is their total amount?). Specifically, after merging the Refinitiv with the FPDS data, we end up with a sample of $4,541$ firms, with $59,033$ firm-year observations from 2008 to 2019. The firms in the merged sample account for approximately 2.39 billion metric tons of greenhouse gas emissions, about 36% of the total 6.56 billion metric tons reported (US Environmental Protection Agency, 2024). We further restrict our merged sample to firm-year pairs with a non-missing emission record, since this is the primary outcome of interest in our analyses. Also,

[33] See https://www.dnb.com/de-de/upik-en/. A company will have more than one ISIN if they have multiple share classes, notes, or bonds. A company issues securities in the form of debt or equity, and often, companies issue multiple securities of either/or. Thus, if a company has only one share class and has an ISIN, it would only have 'one' ISIN, while a company with five classes could have up to five ISINs.

[34] As a robustness check, we distinguish between Non-GPP firms that did not win contracts and Non-GPP firms that have secured government contracts but not GPP ones. We specifically use the latter, i.e., matched firms in the FPDS database that did not win green contracts, as a control group, which ensures more accurate comparisons between control and treated groups. In addition, we consider GPP firms that have not yet received treatment as another control group to further validate our approach. Details are provided in the Appendix A.

treated firms that are awarded contracts in 2007, the first year in our data, are mechanically excluded from the difference-and-difference mechanics, as there is no pre-treatment period for these. This results in a working sample of 1,023 firms, with 5,134 firm-year observations from 2007 to 2019.

4.2 Descriptive evidence

Table 1 presents the descriptive statistics for our working sample of firms. It is divided into two panels: Panel (a) focuses on GPP firms, Panel (b) on Non-GPP Firms. The Column *Diff* reports the t-test on the difference between the means of the two groups.

A few interesting facts emerge. For example, the most significant contribution to the total emissions is the direct emissions for both GPP and Non-GPP firms (4 times the indirect on average). Looking at our firm-level procurement characteristics, the average GPP firm wins almost 22 green contracts per year, totaling $12.90 million. The remaining amount is awarded via brown contracts ($127 million). As such, green revenues, on average, appear to be smaller in amount than brown ones. Moreover, looking at the environmental performance of the firms, the average GPP firm in our sample produces 5.44 million tons of total CO2e emissions. In contrast, the Non-GPP firm produces almost 2.34 million tons, and the difference between the two appears to be statistically significant. The higher emission levels for GPP firms may be justified by their size since their total assets amount to almost 87 billion, compared to the 40 billion for Non-GPP firms. The larger scale of the treated emerges when observing other metrics such as *Employment* and *Revenues*. Even if GPP firms appear to pollute more in absolute terms relative to their Non-GPP counterparts, the former have a better environmental performance in generating scale from their operations. Indeed, our environmental measure (*Total CO2e Emission Intensity*) indicates that, on average, GPP firms produce 176 tons of CO2e emissions per million of total assets. In comparison, Non-GPP firms make almost 207 tons per million. The greater environmental performance of GPP firms is also outlined when looking at waste recycling outcomes: GPP firms have a higher *Recycled Waste Share*. GPP firms also appear to perform better than their Non-GPP counterparts in terms of economic efficiency, when considering *Value Added* and *Labor Productivity* as proxies for firm efficiency.

To gain cross-sector insights into how firms derive value from their environmental performance, we aggregate *Total CO2e Emission Volume* and *Total Assets* by sector, creating a measure of aggregated *Total CO2e Emission Intensity*. We also aggregate the total number of *Green awards* by sector to create the share to the total and assess the relevance of GPP across sectors. Figure 2 presents this evidence, where orange diamonds represent sectoral CO2e intensity, and green diamonds represent the share of green awards. The figure shows that utility firms, which contribute the most to overall emissions (see Table B1 in Appendix B), are among the least efficient in emission, with 400 tons of CO2e per million dollars of total assets. These firms receive the lowest share of green contracts. In contrast, firms in the information technology, health care, and industrial sectors are more efficient in emissions and receive a higher share of green contracts. The figure highlights the GPP program's focus on sectors that are both relatively polluting (see Table B1 in Appendix B) and important for public procurement, particularly the Industrials and Materials sectors. These sectors house many products covered by the program, suggesting that GPP is effectively targeting industries where it can have a significant impact.[35] Overall, the descriptive evidence of Figure 2 indicates a wide heterogeneity across sectors regarding firms' average emission intensity and the importance of GPP for their business. We will account for such heterogeneity in our analysis.

Finally, we report the correlation among the firm-year variables in the GPP sub-sample in Table 2 to gauge insights on the relationship between environmental, procurement, and corporate measurement characteristics. The descriptive evidence shows that the *Total CO2e Emission Volume* positively correlates with firm size (*Total Assets*). As expected, larger firms tend to have higher emission volume levels. In addition, the *Total CO2e Emission Volume* are also negatively correlated with *Green awards* and *Green Revenues*, indicating that the more

[35] Products in the program include both raw materials (e.g., cement), and either finished or semi-finished industrial products (e.g., construction products) that are often produced by the material manufacturers.

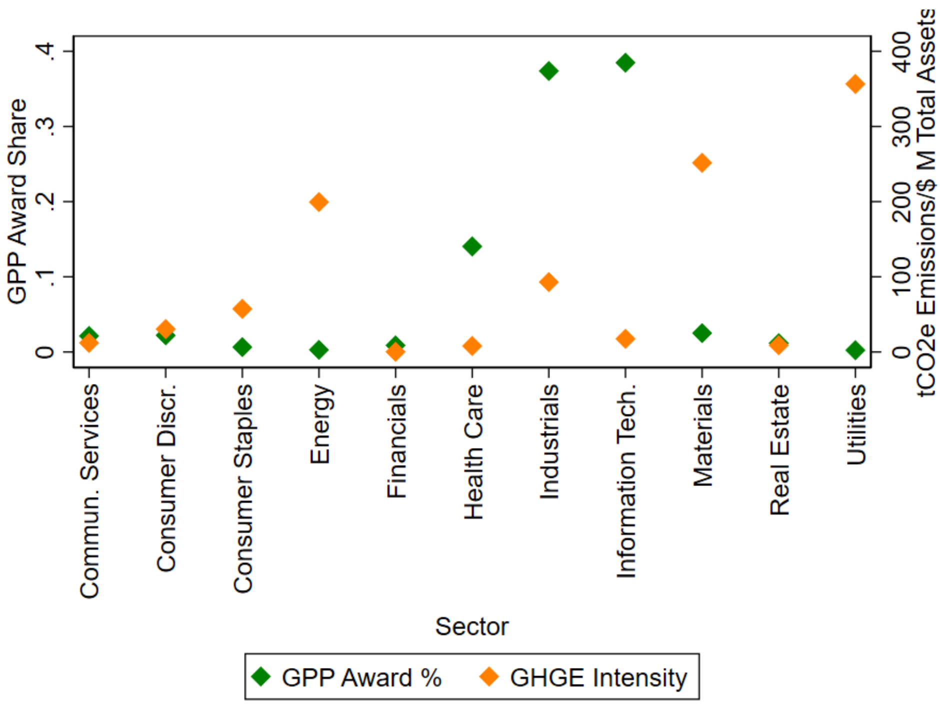
Table 1. Summary statistics

	Panel (a): GPP Firms						Panel (b): Non-GPP Firms						
	Mean	Median	Std. Dev.	Min	Max	N*T	Mean	Median	Std. Dev.	Min	Max	N*T	Diff
Total CO2e Emission Intensity (Tons/Mln$)	176.32	32.02	522.20	0.01	15884.24	2131	206.66	33.65	784.38	0.00	26367.18	3003	-30.34* (-1.56)
Total CO2e Emission Volume (Mln Tons)	5.44	0.51	15.87	0.00	143.00	2133	2.95	0.32	8.29	0.00	105.77	3083	2.49*** (7.39)
Direct CO2e Emission Volume (Mln Tons)	4.41	0.13	14.86	0.00	138.29	2133	2.34	0.07	7.66	0.00	105.52	3083	2.07*** (6.57)
Indirect CO2e Emission Volume (Mln Tons)	1.04	0.27	2.33	0.00	28.50	2133	0.61	0.15	1.71	0.00	54.54	3083	0.42*** (7.53)
Total Waste Volume (Mln Tons)	0.35	0.05	1.59	0.00	28.44	1218	19.03	0.04	109.42	0.00	1067.69	1604	-18.67*** (-5.95)
Recycled Waste Volume (Mln Tons)	0.21	0.02	0.86	0.00	12.34	1153	0.39	0.02	6.25	0.00	188.23	1383	-0.18 (-0.97)
Recycled Waste Share	0.58	0.60	0.25	0.01	1.00	1028	0.54	0.58	0.29	0.00	1.16	1256	0.04*** (3.38)
Green awards	21.85	0.00	100.82	0.00	1511.00	2133	0.00	0.00	0.00	0.00	0.00	3083	21.85*** (12.04)
Green Revenue ($ Mln)	12.90	0.00	132.17	0.00	4977.12	2133	0.00	0.00	0.00	0.00	0.00	3083	12.9*** (5.42)
Brown Revenue ($ Mln)	127.06	0.14	827.75	0.00	20470.38	2133	1.93	0.00	39.22	0.00	1724.88	3083	125.13*** (8.38)
Other Revenue ($ Bln)	30.74	10.87	54.95	0.00	523.96	2131	12.58	6.29	21.12	0.00	242.16	3004	18.16*** (1.8)
Total Revenue ($ Bln)	30.88	10.98	55.01	0.00	523.96	2131	12.58	6.29	21.13	0.00	242.16	3004	18.3*** (16.59)
Total Assets ($ Bln)	86.49	16.30	283.40	0.01	2687.38	2131	39.87	11.23	151.89	0.03	2427.64	3003	46.62*** (7.61)
Market Capitalization ($ Bln)	45.40	16.31	88.11	0.03	1304.76	2131	24.27	9.75	50.28	0.02	921.95	2994	21.12*** (1.94)
# Employees (K)	71.97	28.00	171.38	0.01	2300.00	2118	32.66	12.77	55.78	0.00	537.00	2921	39.32*** (11.58)
Value Added ($ Mln)	3.82	1.32	7.51	-51.29	71.23	2129	1.93	0.79	3.51	-7.79	35.93	2963	1.9*** (12.04)
R&D Expenses ($ Mln)	1332.66	297	2704.06	0	35931	1318	622.82	156.10	1572.51	0	26018	1387	709.84*** (84.54)
R&D Intensity	0.06	0.03	0.07	0.00	0.70	1318	0.07	0.02	0.22	0.00	6.40	1388	-0.01** (-1.7)
Environmental Expenditure Intensity	0.01	0.00	0.03	0.00	0.32	512	0.01	0.00	0.03	0.00	0.34	620	-0.003* (2.53)
Labor Productivity	4.76	0.37	76.66	0.02	2228.29	2118	1.16	0.47	3.31	0.00	42.65	2918	3.6*** (2.53)
US firm (dummy)	0.99	1	.11	0.00	1	2118	0.86	1	0.35	0.00	1.00	3003	0.13*** (2.53)

Notes: We report the pooled summary statistic for the sub-sample of firms that win at least one green contract (**Panel a**), and the sub-sample of firms that win no green contracts (**Panel b**). The *Total CO2e Emission Intensity* (*Tons/Mln$*) is computed as the ratio between the total CO2e emissions over the total assets; *Total CO2e Emission Volume* (*Mln Tons*) is computed as the sum of the Direct and Indirect CO2e in millions of tons (*Mln Tons*); *Direct CO2e Emission Volume* (*Mln Tons*) represents the direct CO2e emissions; *Indirect CO2e Emission Volume* (*Mln Tons*) represents the indirect CO2e emissions; *Total Waste Volume* (*Mln Tons*) is the total waste; *Recycled Waste Volume* (*Mln Tons*) is the recycled waste; *Recycled Waste Share* is computed as the ratio between the recycled and total waste; *Green awards* is the number of green contracts won in a year; *Green Revenues* (*$ Mln*) is the total amount of green contracts won in a year; *Brown Revenues* is the total amount of revenues of the firm minus the revenues coming from public-procurement contracts; *Other Revenues* is the total amount of total revenues minus the sum of the green and the brown procurement revenues; the *Total Revenues* (*$ Bln*) is the total revenue reported in the fiscal year-end balance sheet in billions (*Bln$*); *Total Assets* (*$ Bln*) is the total assets reported in the fiscal year-end balance sheet; *Employment* (*K*) is the total number of employees in thousands (*K*); *Value Added* (*$ Mln*) is the difference between *Revenues* and *Operational Expenses*; *R&D Intensity* is the ratio between the Research & Development expenditures and the total revenues; *Environmental Expenditure Intensity* is the ratio between the environmental expenditure and the total revenues; *Labor Productivity* is the ratio between the total revenues and the number of employees; US firm indicates whether the headquarters are located in the US. The sample comprises 1,023 unique firms (i.e., N)—specifically, 356 GPP and 667 Non-GPP—and 5,134 firm-year pairs (i.e., N×T) from 2007 to 2019. *Diff* is the difference between the means of the two groups, and in round brackets beneath, we report the t-test on the differences between the two means. ***,** and * denote 1%, 5%, and 10% significance, respectively.

active firms are in GPP, the lower their emissions appear to be. The *Total CO2e Emission Intensity* also mirrors such a descriptive piece of evidence. Specifically, firms awarded green contracts display lower emissions per dollars of total assets. The following subsection will discuss our causal investigation of such correlations. Interestingly, R&D expenditures correlate negatively with emissions and positively with economic scale and efficiency variables. Such descriptive evidence suggests a possible relation between winning a green contract and reducing emissions by improving production efficiency thanks to R&D investments. We will explore such a relationship in more detail in Section 5.

Figure 2. Green award share and CO2e Emission intensity across sector



Notes: Sector is defined according to the GICS classification. we report the cross-sector share of green awards and the within-sector CO2e emission intensity. For each sector (x-axis), we report the sum of green awards relative to the total amount of contracts awarded (green diamonds, left y-axis) and the sum of CO2e emission (in *Tons*) relative to the sum of total assets (*Mln*, orange diamonds, right y-axis). Values are aggregated across all years.

Table 2. Pair-wise correlations

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1)	*Total CO2e Emission Intensity*	1.00																	
(2)	*Total CO2e Emission Volume*	0.62	1.00																
(3)	*Direct CO2e Emission Volume*	0.62	0.98	1.00															
(4)	*Indirect CO2e Emission Volume*	0.35	0.64	0.49	1.00														
(5)	*Total Waste Volume*	-0.03	-0.02	-0.01	-0.05	1.00													
(6)	*Recycled Waste Volume*	0.08	0.10	0.09	0.06	-0.05	1.00												
(7)	*Recycled Waste Share*	-0.26	-0.22	-0.20	-0.21	-0.41	0.26	1.00											
(8)	*Green Awards*	-0.11	-0.06	-0.08	0.07	-0.07	-0.04	0.13	1.00										
(9)	*Green Revenues*	-0.06	-0.04	-0.04	-0.01	-0.04	-0.03	0.10	0.30	1.00									
(10)	*Brown Revenues*	-0.13	-0.03	-0.04	0.02	-0.07	-0.06	0.11	0.46	0.20	1.00								
(11)	*Other Revenues*	-0.10	0.36	0.33	0.32	-0.12	-0.06	0.03	0.45	0.11	0.46	1.00							
(12)	*Total Revenues*	-0.10	0.36	0.33	0.31	-0.12	-0.07	0.03	0.45	0.11	0.47	1.00	1.00						
(13)	*Total Assets*	-0.13	0.13	0.11	0.15	-0.04	-0.05	-0.01	0.48	0.08	0.44	0.72	0.72	1.00					
(14)	*Employment*	-0.21	-0.08	-0.10	0.09	-0.13	-0.08	0.23	0.64	0.20	0.54	0.63	0.63	0.54	1.00				
(15)	*Value Added*	-0.18	0.13	0.12	0.15	-0.08	-0.09	0.10	0.51	0.12	0.53	0.85	0.85	0.73	0.66	1.00			
(16)	*R&D Intensity*	-0.27	-0.21	-0.20	-0.16	-0.14	-0.14	0.19	0.03	0.02	0.24	0.11	0.11	0.15	0.15	0.30	1.00		
(17)	*Environmental Expenditure Intensity*	0.02	0.04	0.04	0.01	0.42	-0.05	-0.27	-0.07	-0.04	-0.07	-0.09	-0.09	-0.03	-0.12	-0.09	-0.11	1.00	
(18)	*Labor Productivity*	0.20	0.58	0.59	0.26	0.02	0.02	-0.16	-0.11	-0.06	0.00	0.54	0.54	0.17	-0.18	0.32	-0.14	0.03	1.00

Notes: We report the correlation coefficients for our whole sample of firms. Table 1 defines procurement variables and corporate measurements. The sample comprises 356 GPP firms from 2007–2019.

4.3 Staggered difference-in-differences approach

Using our longitudinal data on firms matched with contracting data, we aim to construct a counterfactual scenario of the environmental and economic outcomes that would have occurred without green contracts. The nature of our data and our setting is particularly conducive to a staggered Difference-in-Differences (DiD) analysis. Using this approach, we compare the outcomes of control firms (Non-GPP firms) with those of treated firms (GPP firms) before and after the staggered award of green contracts.

Our main empirical goal is to capture the effect of receiving green contracts on the outcome of GPP firms, that is, the average treatment effect on the treated (ATT). Anticipating heterogeneous treatment effects in such a dynamic staggered framework with differential treatment dose (i.e., contract size), we follow the recent Callaway and Sant'Anna (2021) approach and estimate cohort-time-specific treatment effects. Specifically, we want to estimate

$$\text{ATT}(g,t) = \mathbb{E}\left[Y_t(g) - Y_t(0) \mid G_g = 1\right], \text{ for } t \geq g, \tag{1}$$

where $\text{ATT}(g,t)$ represents the average treatment effect for firms in the same cohort—i.e., the firms sharing the time of the first green award $g \in T$, in calendar year $t \in T$, where $T \in [2007; 2019]$. The treatment effect of a particular treatment cohort g can be estimated as:

$$Y_{i,t} = \alpha_{1g\tau} + \alpha_{2g\tau} \cdot I\{GPP_i = g\} + \alpha_{3g\tau} \cdot I\{t = \tau\} + \beta_{g\tau} \cdot (I\{GPP_i = g\} \times I\{t = \tau\}). \tag{2}$$

Equation 2 models the relationship between the outcome $Y_{i,t}$ for the firm i at year t and the green award intake—specifically, $I\{GPP_i = g\} \times I\{t = \tau\}$, where $GPP_i = g$ indicates the timing g of the first green award for firm i and $t = \tau$ specifies the time period of interest. The coefficients $\alpha_{1g\tau}$, $\alpha_{2g\tau}$, and $\alpha_{3g\tau}$ represent fixed effects for different group-time combinations. $\beta_{g\tau}$ captures the treatment effect of the GPP intervention. Callaway and Sant'Anna

(2021) shows that $\beta_{g\tau}$ is a valid estimator for ATT(g,t) from Equation (1), whose identification is our focal empirical goal.

Our econometric approach rests on two foundational assumptions. First, firms are unable to predict the timing of the first treatment precisely. This is insured to the inherently competitive nature of federal procurement auctions in our sample. In fact, we only considered those contracts open to competition, for which the award is unpredictable, making it difficult for firms to perfectly anticipate winning specific contracts. Second, the trajectory of GPP firms would have followed the trajectory of Non-GPP firms in the absence of the contract award. In Subsection 4.4 and 4.5, we provide evidence that supports this assumption for environmental and economic efficiency performance, respectively. Under such assumptions, and given the use of the "never treated" as a comparison group—i.e., firms never awarded a green contract, that is Non-GPP firms—we estimate ATT(g, t) for all treatment cohorts (i.e., pooling together the groups of units first treated at time period g) across all calendar year t as

$$\mathrm{ATT_{nev}}(g,t) = \mathbb{E}\left[Y_t - Y_{g-1} \mid G_g = 1\right] - \mathbb{E}\left[Y_t - Y_{g-1} \mid C_{nev} = 1\right], \tag{3}$$

where $C_{nev} = 1$ indicates the never-treated control group of Non-GPP firms.

4.4 Results: Environmental performance

Emission intensity The high cross-sectoral variation in GPP relevance, discussed in Section 4.2, highlights heterogeneity in environmental, economic, and procurement measures. This variation suggests that firms in specific sectors, such as Health Care, Materials, Industrials, and Information Technology, are more likely to be part of the treatment group. Firm size and environmental performance often vary significantly across sectors, as larger firms may be better equipped to comply with GPP requirements, while smaller firms may face greater challenges. On the other hand, bigger firms can create more pollution in absolute terms. These differences in environmental performance, also contribute to the observed heterogeneity in GPP relevance. To address this heterogeneity, we adopt two approaches. First, we use an intensity measure that resizes emission volume relative to total assets. Second, we include sector-level fixed effects in our baseline specification, which controls for sector-specific variations and pre-trends, allowing us to isolate the impact of GPP on CO2e emissions and other outcomes.

Figure 3 (Panel a) shows no evidence of pre-treatment differences in *Total CO2e Emission Intensity* (in green). When jointly testing all yearly pre-treatment differences displayed, we also observe no statistical difference between GPP and Non-GPP firms before the first green award (i.e., $g = 0$). We also stress that firms display indistinguishable pre-treatment trends on other characteristics. We will show this in Subsection 4.5, where the lack of pre-trends expands across efficiency dimensions, corroborating our parallel trend assumptions.

Also, Figure 3 (Panel a) suggests a negative effect of green awards on emission intensity, as indicated by the post-treatment downward trend in β's (in orange). The post-treatment trend is characterized by yearly coefficients that become increasingly negative and significant. The effect of green awards on *Total CO2e Emission Intensity* requires approximately two years from $g = 0$ to materialize and strengthens over time.

Taken together, this evidence indicates two important results. First, the data shows no evidence of a selection effect, meaning that greener firms are not preferentially chosen in GPP auctions. This finding is critical because it suggests that the observed reductions in emission intensity are driven by the impact of green awards themselves, rather than pre-existing differences in environmental performance among firms. Second, the impact of green contracts requires some time to materialize but then grows stronger with each passing year, suggesting that firms progressively enhance their environmental performance as a direct result of GPP engagement for these contracts. Thus, the increasing magnitude of the negative coefficients post-treatment underscores the potential for green contracts to drive substantial long-term improvements in environmental performance among federal contractors. In Section 5, we will investigate this pattern in more detail.

To quantify the treatment effect, Table 3 Panel (a) reports the results of the staggered DiD regressions of *Total CO2e Emission Intensity* as defined in Equation (2). We report the

$\widehat{\beta}_{g\tau}$ from Equation (2) estimating ATT as defined in Equation (3). Column 1 reports the estimates from our most parsimonious DiD model. Column 2 reports the estimates when the outcome is residualized by regressing on sector fixed effects. This is key for our analysis, as discussed above. We use firm-clustered standard errors throughout. This is our preferred specification, which we use as a baseline model in all the subsequent analyses.

The baseline estimates show that receiving green contracts positively affects environmental performance. More specifically, entering the GPP status decreases *Total CO2e Emission Intensity* by ≈ 5% tons of Total CO2e Emission per $ of total assets every year. Therefore, companies improve their net environmental impact over time after securing the first green contract. The results are statistically significant at conventional levels (i.e., 95%).

In Appendix A, we discuss the robustness of these findings in detail. Essentially, these exercises confirm the consistency of our results across various model specifications and alternative control groups. Notably, to address potential concerns related to the selection of control firms, we restrict the control group to Non-GPP firms that have secured government contracts but not GPP ones, which ensures more accurate comparisons between control and treated groups. In addition, to further validate our approach, we consider GPP firms that have not yet received treatment as another control group. These modifications do not significantly alter our results, reinforcing the validity of our conclusions.

Table 3. Environmental performance: The average effect of green contracts

(a) Log total CO2e emission intensity

	(1)	(2)
ATT	-0.045	-0.053**
	(0.033)	(0.024)
N	4,165	4,165

(b) Log total CO2e emission volume

	(1)	(2)
ATT	-0.088	-0.238
	(0.296)	(0.213)
N	4,246	4,246

Notes: We report the $\widehat{\beta}_{g\tau}$ estimate from Equation (2). The model specification uses the staggered DiD estimator following Callaway and Sant'Anna (2021), with the never-treated group as the control group and firm-clustered standard errors. The outcomes are as follows: Column 1 uses Log of *Total CO2e Emission Intensity* or *Total CO2e Emission volume*. Column 2 uses the residuals for the outcome from a regression on sector fixed effects. ** $p < .05$.

Emission volume While our analysis shows a significant post-treatment decrease in *Total CO2e Emission Intensity*, it is important to note again that this measure normalizes *Total CO2e Emissions* relative to *Total Assets*. This focus emission intensity may mask broader *Total CO2e Emission* trends due to a contemporary effect on firm scale (see next subsection). In other words, as companies may become larger through GPP, their total emission volume may show different trends if one of the two effects dominates or show no effect if the two effects tend to balance each other out. Figure 3 (Panel b) shows no evidence of pre-treatment differences in total emission volume, which precedes a negative, but not statistically significant, difference in volume between GPP and Non-GPP firms after the first green award. The ATT for the Log Total CO2e Emission outcome is presented in Table 3, Panel (b), which replicates the model specifications from Panel (a). Despite an estimated 21% reduction in Total CO2e Emission, such an effect is statistically insignificant.

Thus, despite the reduction in *Total CO2e Emission Intensity*, we observe that absolute emission volumes do not significantly decline. This outcome suggests that the environmental efficiency improvements spurred by GPP may be offset by economic expansion, where firms grow without a proportional increase in emissions. If GPP firms are displacing more polluting competitors, the lack of absolute emission reductions may not be problematic—emissions could have been higher without GPP intervention. Furthermore, larger green firms may benefit from economies of scale in emissions reduction, meaning that as they expand, their emissions increase at a slower rate. This dynamic could make the source of demand for green products—whether from the public or private sector—less critical in determining environmental outcomes.

Nevertheless, this raises potential antitrust concerns. As large green firms continue to grow through public funding, their expansion could reduce competition in the green procurement market. While this growth helps reduce emissions, it could also lead to market concentration, with a few dominant firms capturing future green contracts. If the government's primary objective is to minimize emissions, favoring larger firms with emission-related economies of scale might be effective in the short term, but this approach could hinder long-term competition and innovation in the green procurement market.

Emission composition and recycled waste share In Table 4, we build on the baseline staggered DiD model presented in Table 3 to explore the impact on emission components and an additional environmental metric. Specifically, Columns 1 and 2 investigate which component of *Total CO2e Emission Intensity* (direct versus indirect) is more affected by the program. The findings indicate that GPP has a differentiated effect on *Total CO2e Emission Intensity*. Specifically, when examining direct and indirect *Total CO2e Emission Intensity* of total assets separately, we observe that the negative effect on *Total CO2e Emission Intensity* is primarily driven by a more pronounced reduction in *Direct CO2e Emissions Intensity* (Column 1, ATT = -4.4%), suggesting a significant change in processes in response to GPP. In contrast, the impact on *Indirect CO2e Emissions Intensity* is negative but smaller (Column 2, ATT = -1.3%) and insignificant, providing weak evidence of implementing energy-related improvements.

In Column 3, we replicate our DiD model using the share of *Recycled Waste Volume* over *Total Waste Volume* as an additional environmental metric. This ancillary analysis explores whether other environmental performance metrics, particularly waste management, improve following the implementation of the GPP program. We observe a positive effect (significant at 90%) on the share of recycled waste, suggesting that firms may adjust their waste management practices in response to GPP policies. However, it is important to note that the definition of recycled waste in our dataset is broad, encompassing waste used for incineration to generate energy and composting, which may not directly relate to material reuse or closed-loop recycling. Consequently, the observed effects might reflect more general changes in waste management rather than specific improvements in recycling practices. Furthermore, data limitations, including the lower number of observations with information on waste volume (i.e., 1,728 firms- years pairs versus 4,165 of our baseline estimate sample), reduce the robustness of these findings.

Table 4. Further environmental performance

	(1)	(2)	(3)
ATT	-0.045**	-0.013	0.15*
	(0.022)	(0.010)	(0.083)
N	4,165	4,165	1,728

Notes: The estimates of the baseline staggered DiD model from Table 3 (Panel a, Column 2: never-treated as the control group, firm-clustered standard errors, and residualized outcomes) are replicated using other environmental outcomes. Column 1: Log Direct CO2e Emission Intensity; Column 2: Log Indirect CO2e Emission Intensity; Column 3: Share of Recycled Waste Volume. * $p < .1$, ** $p < .05$.

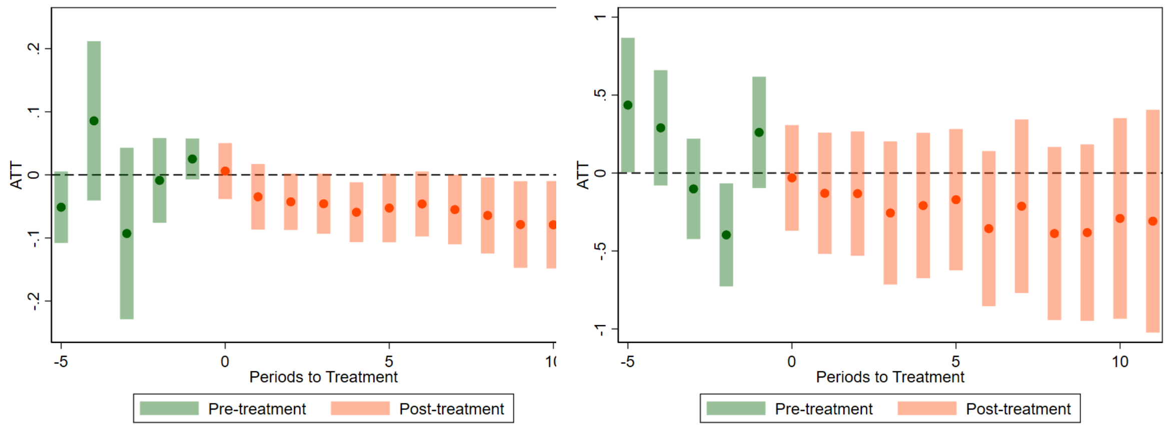
4.5 Results: Economic performance

This subsection provides evidence on the effect of green awards on economic performance. The main aim is to verify whether and to what extent winning a green contract generates better environmental performance but deteriorates economic performance.

Scale effects Improvements in environmental outcomes may be directly driven by a reduction in economic activity. Therefore, it is relevant to discuss the implications of green contracts on firm scale, as understanding these effects is essential in determining whether the observed environmental improvements lead to positive or negative spillovers on economic performance or if there are no significant economic effects. To evaluate this possibility, we replicate our staggered DiD approach in Figure 4 —replicating the leads and lags exercise from Figure 3– using *Total Assets* (Panel a), our intensity rescaling metric, and three firm scale proxies as the outcomes: *Market Capitalization* (Panel b), *Total Revenues* (Panel c), and *Employment* (Panel d), the latter serving as a non-monetary scale variable. All variables are expressed in logarithmic terms.

The visual analysis reveals positive trends overall before and after $g = 0$, suggesting that treated firms are larger than control firms both before and after their first green contract. While treated and control firms appeared similar in *Total CO2e Emission Intensity* (reflecting environmental performance relative to scale) until treatment, treated firms tend to be

Figure 3. Environmental performance – Leads and lags



(a) Log total CO2e emission intensity **(b) Log total CO2e emission volume**

Notes: ATT by periods before and after the first green contract. We use Column 2, Panel (a) of Table 3 as the baseline model. For Log Total Total CO2e Emission Intensity (Panel a) and Log Total CO2e Emission (Panel b), we plot the staggered DiD event-study estimates and 95% confidence intervals for relative time periods from $t = g - 5$ to $t = g + 11$ around the first award time $t = g$. Relative-time period g's point estimates and confidence intervals are in green for the leads (i.e., pre-treatment) and orange for the lags (post-treatment).

significantly larger prior to treatment when it comes to scale. After treatment, these size differences widen, but pre-trends limit our ability to attribute a causal effect on scale. Despite this, our evidence conservatively suggests that GPP firms have reduced *Total CO2e Emission Intensity* without experiencing any economic contraction.

Additionally, we analyze the composition of revenues using our procurement data, isolating log *Brown Revenues* (Panel e) and log *Other Revenues* (Panel f). In Panel (e), we find evidence of a crowd-out effect of GPP sales on brown sales, as GPP firms tend to replace brown sales with green sales when selling to federal buyers, leading to a decrease in *Brown Revenues*. However, *Other Revenues*, shown in Panel (f), increase after treatment, indicating that GPP participation does not crowd out, but rather crowds in, private sales. This suggests that GPP firms can maintain or even expand their private sector activities while fulfilling green contracts, implying that green procurement does not negatively impact a firm's broader business but can instead foster further economic benefits. However, similar to other scale variables, these results rely on significant pre-treatment differences in the outcomes, meaning that the evidence is suggestive rather than definitive, and no causal interpretations can be made.

Efficiency effects Improvements in environmental outcomes might also stem from technological changes that increase firm efficiency, thereby enhancing environmental performance without reducing output levels. To evaluate this possibility, we replicate our staggered DiD approach using standard efficiency metrics in the literature, namely *Value Added* and *Labor Productivity* as defined in Subsection 4.1.

Figure 5 provides a visual representation of these analyses. We find no evidence of pre-treatment differences, indicating that treated and control firms are similar in terms of these efficiency metrics before the first green contract. The evidence supports the notion that treated and control firms are comparable not only in terms of environmental performance but also in efficiency metrics until the treatment intake.

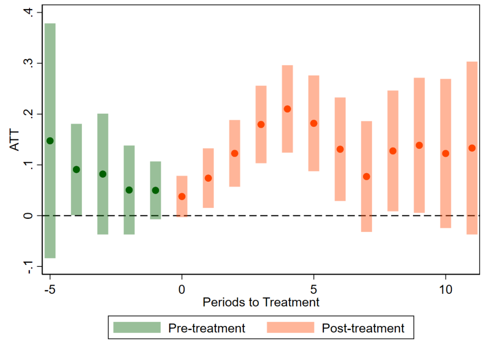
However, after the treatment, we observe significant improvements in *Labor Productivity*. These significant effects take 4 to 5 years to materialize. These dynamics highlight the persistence of the estimated differences between treated and control firms, with these differences sometimes widening over time. Obtaining the intake of green contracts acts as a catalyst for increased labor productivity. Specifically, Table 5, reporting the estimated ATT, shows that labor productivity increases by 10%.

Table 5. Economic performance: Efficiency outcomes

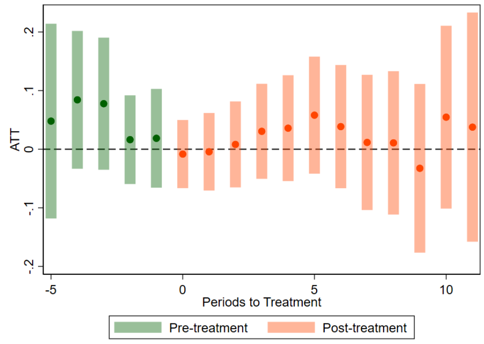
	(1)	(2)
ATT	0.045	0.11^{**}
	(0.058)	(0.049)
N	30,205	34,694

Notes: The baseline staggered DiD model from Table 3 (i.e., Inverse probability weighting DiD estimator, never-treated as the control group, sector fixed effects and pre-treatment employment as covariates, firm-clustered standard errors) is reproduced on firm efficiency outcomes. Column 1 refers to Log Value Added an an outcome. In Columns 2, we regress Log Labor Productivity. ** $p < .05$.

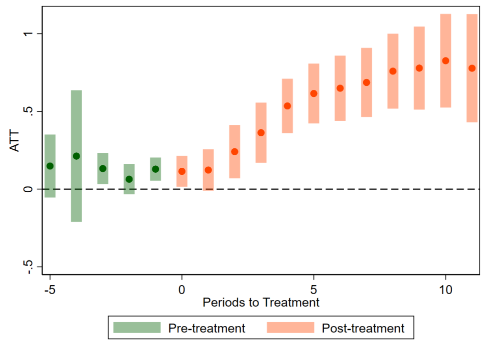
Figure 4. Leads and lags – Economic outcomes



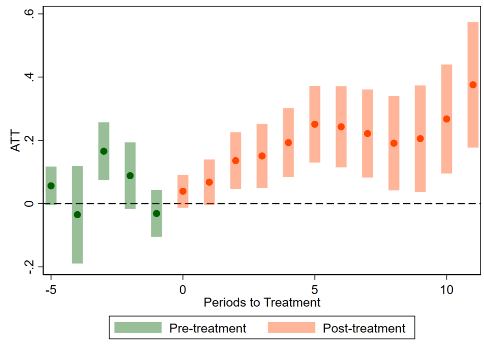
(a) Log Total Assets



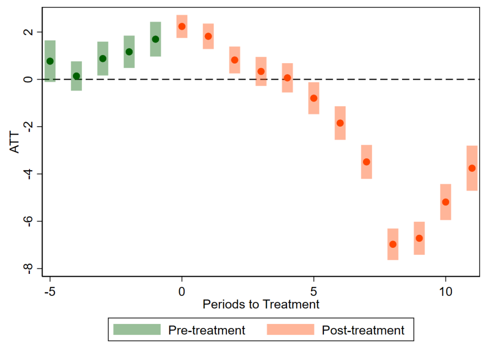
(b) Log Market Cap



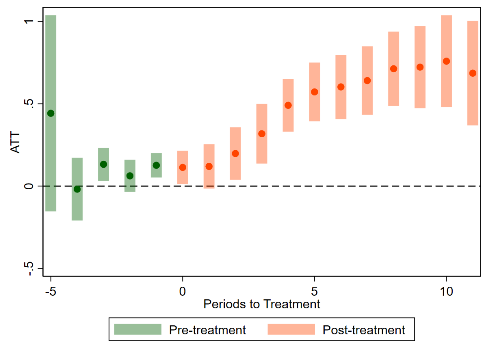
(c) Log Total Revenues



(d) Log Employment



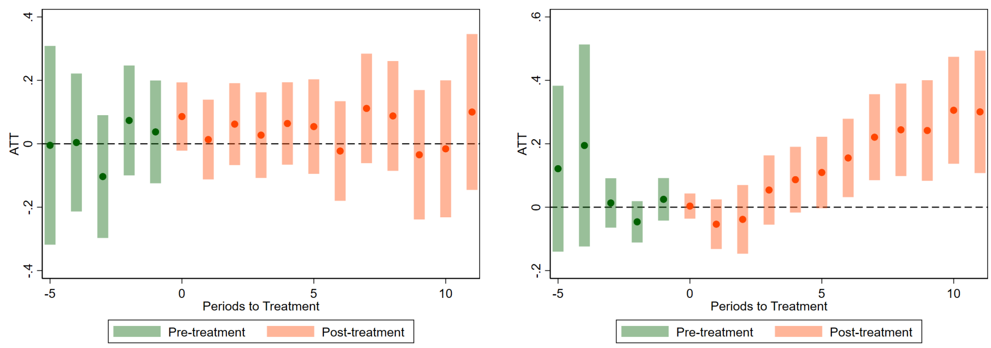
(e) Log Brown Revenues



(f) Log Other Revenues

Notes: ATT by Periods Before and After treatment. The baseline staggered DiD model from Table 3 (i.e., inverse probability weighting DiD estimator, never-treated as control group, sector fixed effects, firm-clustered standard errors) is reproduced on scale outcomes.

Figure 5. Leads and lags – Efficiency outcomes



(a) Log Value Added **(b) Log Labor Productivity**

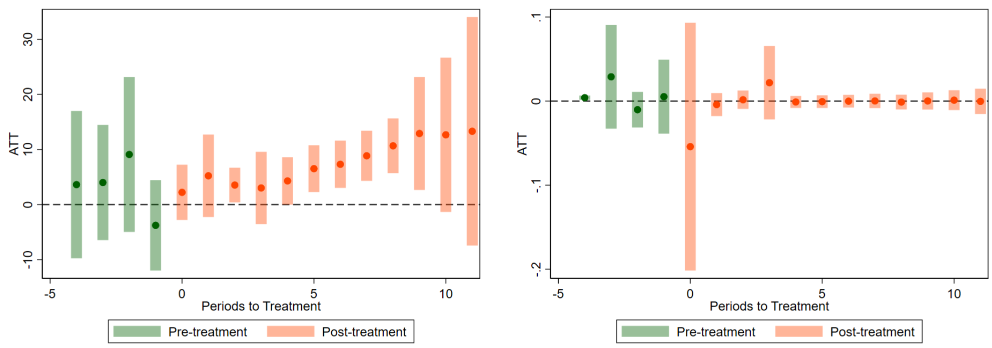
Notes: ATT by Periods Before and After treatment. The baseline staggered DiD model from Table 3 (i.e., inverse probability weighting DiD estimator, never-treated as control group, sector fixed effects, firm-clustered standard errors) is reproduced on scale outcomes.

5 Mechanism

This section explores the potential channels through which green contracts contribute to the observed improvements in environmental and economic performance among GPP firms. First, we provide evidence that green contracts incentivize firms to reduce their *Total CO2e Emission Intensity* and that incentives are heterogeneous across firms. Second, we explore the role of R&D investments as a mechanism. In particular, we show that winning a green contract leads to increases in R&D expenditures and that R&D expenditures negatively correlate with *Total CO2e Emission Intensity* and positively correlate with *Labor Productivity* in our panel of firms. This suggests that investments in R&D enable firms to enhance their environmental efficiency and operational efficiency, reinforcing the long-term benefits of participating in the GPP program.

Firm-Specific incentives and environmental performance As argued above, the estimated demand-pull effect of GPP on firm environmental performance is not guaranteed. Firms may self-select into the GPP market or shift their sales targets from the private to the public sector. These potential selection and crowding-out mechanics could leave the firm's

Figure 6. Leads and lags – R&D expenses



(a) R&D intensity **(b) Environmental expenditure intensity**

Notes: ATT by Periods Before and After treatment. The baseline staggered DiD model from Table 3 (i.e., inverse probability weighting DiD estimator, never-treated as a control group, sector fixed effects, firm-clustered standard errors) is reproduced on R&D intensity (Panel a) and Environmental expenses intensity (Panel b) outcomes.

environmental performance unchanged. Instead, the observed impact on firm *Total CO2e Emission Intensity*—the environmental dimension linked with the GPP program — suggests that the program does provide incentives for environmental improvements. In particular, innovations are incentivized which integrate recycled materials as inputs for the production process to the largest possible extent, while ensuring that they are of sufficiently high quality to meet performance standards required by the tender.[36] These incentives may vary with firm-specific characteristics. We correlate these characteristics to study the heterogeneous effects on *Total CO2e Emission Intensity* reductions. These correlations aim to support the argument that incentives are indeed at play, as firm traits correlate with the magnitude of *Total CO2e Emission Volume* reductions in an anticipated manner.

First, incentives might be stronger for smaller firms. These are typically more resource-constrained and still are in the process of building experience, organizational capital, and a customer base. Thus, for them, the effect of winning the contract might be larger (Ferraz

[36]Indeed, recycling of materials such as steel, aluminum, and plastic is prone to the problem of scrap contamination, which typically produces lower quality material (Gutowski et al., 2013; Capuzzi and Timelli, 2018). As the government requires quality standards, this can be an incentive for innovation in better technologies for sorting, separating, or processing scrap.

et al., 2015; Lee, 2021). In the specific context of environmental performance, the effect of reduction in emission intensity might be larger for smaller firms, while larger firms might be already green to a larger extent and need to implement only marginal improvements to execute the contract and keep at the technology frontier. This type of effect has already been observed in the literature. For example, Krieger and Zipperer (2022) find that the demand-pull effect of winning green contracts on the introduction of green innovation is driven by small and medium enterprises, while no effect is detected for larger firms. Evidence in support of this channel is reported in Table 6, where the sample of treated firms (GPP winners) is divided in the sub-sample of those below median total asset distribution (column 1) or above (column 2) and where the effect is stronger for the former group, although not in conventional statistics terms.

Second, incentives might be stronger for firms with more revenues from green public procurement contracts, as GPP is more critical to their business. Indeed, evidence in Columns 3 and 4 shows that the effect is stronger for firms with higher average green revenues (Column 4), i.e., firms with green revenues above the median. These firms likely view green contracts as central to their strategy, prioritizing compliance and making significant investments to improve environmental performance (-13% of emission intensity), including reducing CO2e emission intensity. In contrast, firms with lower green procurement revenues may prioritize GPP compliance less, as it plays a smaller role in their overall business, leading to a weaker effect (i.e., - 4.6%)

Third, incentives differ between firms with different R&D intensity. Less innovative firms with lower R&D intensity face stronger incentives to comply with GPP requirements upon receiving the first green contract, seeing these contracts as crucial for catching up with industry standards. These firms are more likely to invest in reducing emissions and enhancing R&D efforts. The results in Columns 5 and 6 confirm this, showing that the reduction effect in environmental intensity is driven by firms with lower R&D intensity (i.e., -11%, Column 5), i.e., firms with R&D intensity below the average. While GPP induces an overall boost in R&D intensity (see below), this finding points out that non-innovative firms start from a lower baseline. GPP pushes them to make more substantial improvements, resulting in a stronger observed impact. Therefore, the two results corroborate each other, as GPP both incentivizes environmental performance and increases innovation efforts, particularly for firms lagging in R&D.

R&D investments as a channel As discussed above, GPP companies are incentivized to improve their emission performance. We found that stronger incentives lead to greater reductions in *Total CO2e Emission Intensity*. Additionally, GPP firms also improve their efficiency in terms of larger *Labor Productivity*. However, the mechanism linking these incentives to improvements in *Total CO2e Emission Intensity* and *Labor Productivity* performance is unclear. In this context, the role of R&D spending is worth exploring, as it is likely a critical factor in this process. Investment in R&D allows firms to develop and deploy advanced environmental technologies, thereby reducing their *Total CO2e Emission Intensity* as a by-product. After securing their first green contract, firms are likely to allocate more resources to R&D to meet or exceed the environmental standards required by these contracts and to enhance their market position.

In Figure 6, Panel a, we replicate our leads and lags analysis on *R&D Intensity*. The results reveal no significant pre-trends in the outcome variable, followed by a positive and persistent effect after firms receive their green contracts. This indicates that GPP firms expand their R&D activities as a result of their participation in the program. These findings are crucial, as they demonstrate that green contracts stimulate innovative activity. To further investigate the nature of these R&D expenditures, particularly the distinction between green and brown investments, we extend the analysis to *Environmental Expenditure Intensity*. Although the ideal data would allow us to separate green R&D from other types of R&D, our current dataset only enables us to analyze this broader category. Panel b of Figure 6 shows no significant pre-trends or post-trends in *Environmental Expenditure Intensity*. However, we acknowledge the limited number of firm-year observations available for this variable (see Table 1). As a result, we avoid making strong conclusions regarding this dimension.

To further explore the relationship between increased R&D expenditures, the environmental and efficiency improvements, we examine the direct link between R&D investment and these other dimensions. By focusing on this pathway, we aim to illustrate the critical role that R&D plays in achieving substantial environmental improvements and creating positive spillovers for economic performance.

We hypothesize that increased R&D spending enables firms to develop and deploy less emitting and more efficient technologies. This technological advancement is the mechanism through which R&D investment contributes to both lowering *Total CO2e Emission Intensity* and enhancing *Labor Productivity*. This analysis cannot rely on the DiD design and is not causal, but we can utilize our entire panel of firms to account for sector and time variation. In Figure 7, the left panel illustrates the relationship between the log of *R&D expenses* (Y) and the log of *Total CO2e Emission Intensity* (X) in our dataset. To isolate this relationship, we residualize the variables by accounting for year and sector fixed effects, and then group the data into binned scatterplots. Each dot represents the residualized values within each bin, following the methodology of Cattaneo et al. (2024). The analysis reveals a robust negative correlation, indicating that higher R&D spending is associated with lower *Total CO2e Emission Intensity*. In the right panel, we examine the relationship between residualized *Labor Productivity* (Y) and *R&D Expenses* (X). Here, we observe a positive correlation, showing that increased R&D spending correlates with higher labor productivity. Importantly, these correlations remain consistent when we focus separately on GPP and non-GPP firms (not reported), suggesting that the observed relationships are not unique to firms participating in the GPP program.

These findings reinforce our hypothesis that R&D investment plays a crucial role in driving both environmental and economic outcomes for firms. The negative relationship between R&D expenses and emission intensity suggests that firms investing in innovation are developing cleaner technologies, which in turn improve their environmental performance. At the same time, the positive correlation between R&D spending and labor productivity indicates that these technological advancements also lead to improved operational efficiency.

Together, these results support the idea that increased R&D spending, particularly when induced by green contracts, not only helps firms meet environmental targets but also enhances their overall economic performance. This dynamics creates a virtuous cycle where investments in innovation lead to sustainability improvements and efficiency gains, further reinforcing the positive spillovers of R&D in both environmental and economic dimensions.

Table 6. Heterogeneity analysis of environmental performance

(a) Log Total CO2e Emission Intensity

	(1)	(2)	(3)	(4)	(5)	(6)
ATT	-0.075***	-0.048**	-0.046*	-0.139***	-0.117***	0.003
	(0.010)	(0.024)	(0.025)	(0.047)	(0.034)	(0.024)
N	1,273	4,074	3,969	3,199	3,564	3,598

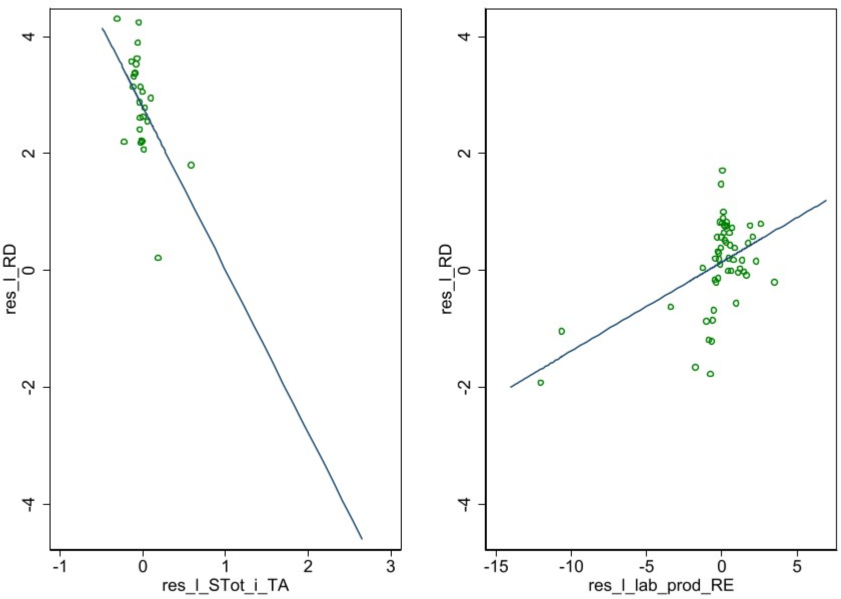
Notes: The baseline staggered DiD model from Table 3 (i.e., never-treated as control group, sector fixed effects and firm-clustered standard errors) is reproduced after sample splitting of the treatment group. Columns 1 and 2: only those firms below (1) or above (2) the cross-sectional total asset distribution of GPP firms are treated. Columns 3 and 4: only those below (3) or above (4) the GPP procurement revenue distribution of GPP firms are treated. Columns 5 and 6: only those below (5) or above (6) the cross-sectional total R&D intensity are treated R&D. * $p < .1$, ** $p < .05$, *** $p < .01$.

6 Conclusion

Despite increasing recognition of GPP as a tool for advancing sustainability, empirical research on its impact has been limited. To help fill this gap, this paper provided a first causal investigation of the effect of a green public procurement program on firm environmental and economic performance. We focused on the case of a US federal affirmative program for products with recycled content, which allows for a precise definition of a green contract and accounts for a big portion of procurement, and on publicly-listed firms, which are responsible for a large share of emissions.

Our findings show that GPP significantly improves both environmental and economic performance of contractors. Winning a green contract reduces a firm's CO2e emission intensity by approximately 5% while boosting labor productivity by 10%. We provide suggestive evidence that these improvements are driven by increased R&D investments, which act as

Figure 7. R&D expenses vs. environmental and efficiency variables



Notes: Graphical representation of the relationships between R&D Expenses (y-axis) and Total CO2e Emission Intensity (x-axis, left panel) or labor productivity (x-axis, right panel). The variables are in logarihmic terms and residualized, including as controls sector fixed effects and year fixed effects. Each graph is a binned scatterplot. representing the mean statistic of the residualized variables inside each bin. The selected number of bins optimizes the (asymptotic) integrated mean-squared error following Cattaneo et al. (2024).

a mechanism for both environmental and productivity gains. Moreover, the benefits of GPP persist over time, suggesting that the program encourages long-term investments in green technology and innovation. The program's success appears to be rooted in its design, which, by prioritizing environmental performance, created continued incentives and fostered competition among firms, resulting in environmental benefits as well as broader efficiency and productivity improvements.

These results suggest that GPP creates a win-win scenario, reinforcing both environmental and economic objectives. Expanding GPP could serve as an effective policy tool for driving sustainability and economic growth, particularly in sectors with significant environmental impacts. However, it is essential to monitor potential market concentration, as larger firms may benefit from economies of scale in emissions reduction. Maintaining a balance between environmental goals and healthy market competition will be crucial for ensuring long-term sustainability. The success of the US affirmative program highlights the importance of credible, long-term political commitment to achieving these outcomes. Policymakers should consider extending GPP policies to other regions and sectors, and future research should explore the broader implications of GPP on smaller firms and market dynamics to guide informed decision-making and accelerate the green transition.

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A Appendix: Robustness checks on environmental performance

In Table A1, we present alternative estimates of our *Total CO2e Emission Intensity* outcome, derived from variations in the empirical specifications. Column 1 replicates the baseline ATT estimates from Table 3, Panel (a), Column 2 for reference. The subsequent columns serve as the primary robustness checks. The results from these robustness exercises are discussed in detail below.

The first concern relates to the selection of control firms. Utilizing Non-GPP firms without additional selection criteria as the baseline control group increases statistical power and enhances the external validity of the results. Columns 2 and 3 demonstrate that our findings are yet robust to different definitions of the control group. In Column 2, we restrict the analysis to a subset of the never-treated control group. Specifically, we differentiate between Non-GPP firms that did not secure any contracts and those that obtained government contracts but not GPP-specific ones. We focus on the latter group, i.e., firms in the FPDS that secure procurement contracts but not green ones, as the control group. The subset of Non-GPP firms awarded only non-green contracts in our data includes firms that, while not engaged in green contracting, do participate in other categories of federal procurement. This selection strategy allows us to compare firms actively engaged in the government procurement market, thereby improving comparability with the treated group. The sample size is reduced by approximately half due to this subsampling of the baseline control group. The negative estimates hold.

In Column 3, we conduct a robustness exercise that builds on the baseline model by incorporating pre-treatment brown procurement revenues as covariates. Instead of restricting the control group to procurement firms only as in Column 2, we control for baseline differences in brown revenue patterns, which helps to address any pre-existing imbalances in observable firm characteristics. This is particularly important given the statistically significant positive pre-trend in brown revenues identified in Subsection 4.5. Such a positive pre-trend likely arises from the inclusion of firms in the control group that are not active in the federal procurement market, in contrast to our treated GPP firms, which engage in various types of federal procurement (see Section 4.1). To account for these differences and prevent selection bias, we augment our staggered DiD model with inverse probability weighting, using firms' pre-treatment brown revenues to calculate propensity scores. This method improves balance by assigning higher weights to control observations that are less likely to have been treated, ensuring that treated and control groups are comparable. By incorporating these covariates and adjusting for revenue-based differences, this approach strengthens the parallel trend assumption, allowing for covariate-specific trends and enhancing the precision of our treatment effect estimates without sacrificing power. Point estimates are negative and significant, statistically indistinguishable from the baseline ones.

In Column 4, we employ an alternative control group consisting of not-yet-treated firms, which are firms that will receive a green contract in the future but have not yet been awarded one. Specifically, we use units that are not treated by time t' (where $t \geq t' \geq t_g$) as comparison groups for the firms initially treated at time t_g. These firms are arguably the most comparable to the treated group, as they are either already active or will soon be active in the green procurement market but have not yet secured a green contract. Formally, using not-yet-treated as an alternative control group instead of never-treated, the formula for the ATT from Equation 3 changes to

$$\text{ATT}_{ny}(g,t) = \mathbb{E}[Y_t - Y_{g-1} | G_g = 1] - \mathbb{E}[Y_t - Y_{g-1} | D_t = 0, G_g = 0]. \tag{4}$$

The results obtained using this alternative control group are virtually identical to the baseline estimates. This suggests that firms that will receive a green contract in the future, but have not yet done so, provide a robust comparison group, further reinforcing the validity of our findings.

In Column 5, we restrict our analysis to US firms. This approach addresses any potential discrepancies due to the inclusion of international firms, ensuring that our results are not influenced by differences in regulatory environments or market conditions between countries. Indeed, as shown by Table 1, while the treatment group is almost just composed of US firms, the control group shows 86% of our firms. The results remain consistent, indicating that the observed effects are robust to this geographical selection of headquarters within the national borders.

In Column 6, we exclude sectors that are not relevant for GPP activity, specifically those in which firms are not observed to receive any green contracts in our data, as identified in Section 4.1. The excluded sectors include Communication Services, Financials, and Utilities, according to the GICS classification. By focusing on sectors with some GPP activity, we ensure that our analysis captures sectors where GPP has the potential to influence environmental performance. The robustness of our findings is preserved even after excluding these sectors.

In Column 7, we use *Value Added* as an alternative proxy of scale to build emissions intensity. This measure accounts for the value generated by the firm, providing a different perspective on emissions relative to economic output. The consistency of the results with this alternative intensity measure further validates our findings and supports the robustness of our empirical approach.

In Column 8, we apply the staggered DiD estimator proposed by Wooldridge (2021) as an alternative to the staggered DiD estimator proposed by Callaway and Sant'Anna (2021). While traditional two-way-fixed effects have received criticism for their inability to correctly identify ATTs, Wooldridge (2021) suggests that when properly implemented, the methodology can still provide an efficient estimation of treatment effects. Wooldridge (2021)'s approach emphasizes the importance of accounting for heterogeneity. Specifically, he proposes interacting cohort effects with time-specific effects, similar to Sun and Abraham (2021), but with a different perspective. By saturating the model with all possible combinations of cohorts and times for effectively treated units, the estimated λ's are equivalent to Callaway and Sant'Anna (2021) ATT(g, t). This method ensures that the dynamic effects are accurately captured, whether using never-treated or not-yet-treated as controls. The results using this alternative estimator align with our baseline findings, reinforcing the validity of our conclusions.

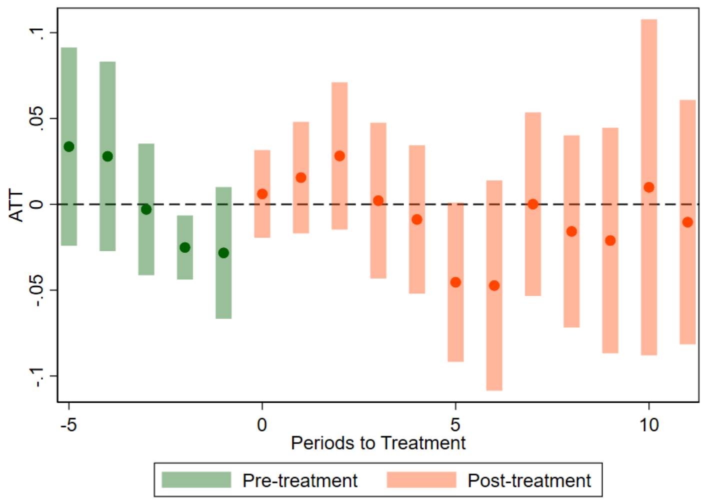
Finally, as a placebo exercise, we replace the definition of GPP firms with firms awarded brown contracts. The control group is switched to firms that never appear in our procurement data as they have never been awarded a federal contract. Regardless of the green awards, we consider the treated firms to be those selling at least one brown contract to the government. Thus, the timing g of the first contract intake represents the year of the first brown contract in the data. This placebo exercise demonstrates that the observed effect is explicitly driven by the green contract intake and not by all procurement contracts, as virtually all firms selling green contracts also sell brown contracts to the government. The DiD leads and lags shown in Figure A1 in the appendix indicate no significant post-treatment trend. This supports the conclusion that the observed effects are due to green contract engagement rather than general government procurement activity.

Table A1. Robustness checks on environmental performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ATT	-0.053**	-0.060**	-0.082***	-0.053**	-0.047*	-0.075**	-0.22**	-0.035*
	(0.024)	(0.030)	(0.025)	(0.024)	(0.025)	(0.030)	(0.099)	(0.018)
N	4,165	2,024	4,165	4,165	3,715	3,336	4,013	3,521

Notes: The estimates of the baseline staggered DiD model from Table 3 (Panel a, Column 2: never-treated as the control group, firm-clustered standard errors, and residualized outcomes) are reproduced in Column 1 for reference. Column 2 restricts the control group to firms awarded brown procurement contracts. Column 3 includes pre-treatment brown procurement revenues as a covariate. Column 4 uses not-yet-treated firms as the control group. Column 5 focuses on treated and control firms based in the US. Column 6 excludes sectors with the least green revenues and awards: communication services, financials, and real estate. Column 7 uses Total CO2e Emission intensity of value added as an alternative outcome. Column 8 replicates the baseline model using the approach in Wooldridge (2021) as an alternative staggered DiD estimator. * $p < .1$, ** $p < .05$, *** $p < .01$.

Figure A1. Placebo exercise: Brown contracts



Notes: ATT by Periods Before and After treatment. The baseline staggered DiD model from Table 3 (i.e., inverse probability weighting DiD estimator, never-treated as control group, sector fixed effects, firm-clustered standard errors) is reproduced using brown contracts instead of green contracts.

B Appendix: Other tables

Table B1. CO2e emissions breakdown by sector and industry

	(1)	(2)	(3)	(4)	(5)	(6)
	Panel (a): GPP Firms			**Panel (b): Non-GPP Firms**		
	Share Total CO2e Emission Volume	*Share Direct CO2e Emission Volume*	*Share Indirect CO2e Emission Volume*	*Share Total CO2e Emission Volume*	*Share Direct CO2e Emission Volume*	*Share Indirect CO2e Emission Volume*
	Sector					
Communication Services	0.09	3.61	0.75	0.37	8.07	1.97
Consumer Discretionary	2.32	10.92	3.92	1.33	6.61	2.43
Consumer Staples	3.15	18.09	5.93	2.10	7.94	3.32
Energy	27.59	8.49	24.03	25.62	23.08	25.09
Financials	0.04	2.43	0.49	0.08	2.03	0.49
Health Care	0.50	3.51	1.06	0.31	2.03	0.67
Industrials	18.41	16.92	18.13	13.19	4.90	11.46
Information Technology	0.54	6.00	1.56	0.59	8.93	2.32
Materials	8.22	16.23	9.71	17.11	25.91	18.94
Real Estate	0.19	1.13	0.37	0.10	1.99	0.50
Utilities	38.95	12.67	34.06	39.21	8.51	32.81
	Industry					
Aerospace & Defense	3.03	9.82	4.29	0.00	0.04	0.01
Air Freight & Logistics	3.26	1.00	2.84	0.02	0.04	0.03
Automobile Components	-	-	-	0.21	1.68	0.52
Automobiles	0.42	4.27	1.14	0.01	0.10	0.03
Banks	0.03	1.93	0.39	0.03	1.24	0.29
Beverages	0.68	2.99	1.11	0.20	0.57	0.27
Biotechnology	0.02	0.15	0.04	0.05	0.19	0.08
Broadline Retail	0.12	0.49	0.18	0.13	0.82	0.27
Building Products	0.01	0.04	0.01	0.78	2.22	1.08
Capital Markets	0.01	0.41	0.08	0.01	0.16	0.04
Chemicals	6.70	11.40	7.58	6.26	10.87	7.22
Commercial Services & Supplies	2.22	0.29	1.86	0.03	0.01	0.02
Communications Equipment	0.02	0.57	0.12	0.02	0.21	0.06
Construction & Engineering	0.01	0.08	0.02	0.02	0.01	0.02
Construction Materials	0.07	0.21	0.10	-	-	-
Consumer Finance	-	-	-	0.01	0.17	0.04
Consumer Staples Dis. & Ret.	1.03	10.57	2.80	0.09	1.11	0.30
Containers & Packaging	1.43	4.57	2.01	0.86	2.93	1.30
Distributors	0.00	0.00	0.00	-	-	-
Diversified Consumer Services	-	-	-	0.00	0.00	0.00
Diversified REITs	-	-	-	0.00	0.00	0.00
Diversified Tel. Ser.	0.08	3.47	0.71	0.18	4.97	1.18
Electric Utilities	29.76	8.88	25.88	14.67	2.11	12.06
Electrical Equipment	0.02	0.31	0.07	0.03	0.67	0.17
Electronic Equ., Ins. & Com.	0.01	0.13	0.03	0.03	1.40	0.32
Energy Equipment & Services	0.01	0.02	0.01	1.36	0.76	1.23
Entertainment	-	-	-	0.15	0.71	0.27

Notes: We report the sample distribution by *Sector* and *Industry* of the share of the Total, Direct, and Indirect CO2e Emission divided under GICS classification. The sample comprises 1,023 unique firms (356 GPP and 667 Non-GPP) over the 2007–2019.

CO2e Emissions Breakdown by Sector and Industry (continued)

	Industry					
	Panel (a): GPP Firms			**Panel (b): Non-GPP Firms**		
	Share Total CO2e Emission Volume	*Share Direct CO2e Emission Volume*	*Share Indirect CO2e Emission Volume*	*Share Total CO2e Emission Volume*	*Share Direct CO2e Emission Volume*	*Share Indirect CO2e Emission Volume*
Financial Services	-	-	-	0.00	0.08	0.02
Food Products	1.08	2.54	1.35	1.19	3.62	1.70
Gas Utilities	0.05	0.00	0.04	0.08	0.01	0.06
Ground Transportation	0.82	0.15	0.70	2.84	0.68	2.39
Health Care Equipment & Supplies	0.06	0.52	0.15	0.13	0.57	0.22
Health Care Providers & Services	0.06	1.11	0.26	0.01	0.25	0.06
Health Care REITs	-	-	-	0.02	0.40	0.10
Hotel & Resort REITs	0.00	0.04	0.01	0.03	0.29	0.08
Hotels, Restaurants & Leisure	1.56	3.34	1.89	0.93	2.65	1.29
Household Durables	0.12	0.77	0.24	0.00	0.06	0.01
Household Products	0.36	2.00	0.66	0.50	2.19	0.85
IT Services	0.06	1.18	0.26	0.03	3.63	0.78
Independent Power and Ren. Ele. Pro.	-	-	-	10.01	0.21	7.97
Industrial Conglomerates	1.20	3.15	1.56	-	-	-
Industrial REITs	-	-	-	0.00	0.00	0.00
Insurance	0.00	0.08	0.02	0.03	0.37	0.10
Interactive Media & Services	-	-	-	0.01	1.88	0.40
Leisure Products	0.00	0.02	0.01	0.02	0.22	0.06
Life Sciences Tools & Services	0.02	0.23	0.06	0.00	0.04	0.01
Machinery	0.21	1.71	0.49	0.07	0.69	0.20
Marine Transportation	0.05	0.00	0.04	0.01	0.00	0.01
Media	0.01	0.14	0.04	0.01	0.16	0.04
Metals & Mining	0.02	0.04	0.02	9.95	12.03	10.38
Mortgage Real Estate Inv. Tru.	-	-	-	0.00	0.00	0.00
Multi-Utilities	9.14	3.79	8.15	14.43	5.71	12.62
Office REITs	0.00	0.11	0.02	0.01	0.26	0.06
Oil, Gas & Consumable Fuels	27.58	8.47	24.02	24.26	22.31	23.85
Paper & Forest Products	-	-	-	0.04	0.08	0.05
Passenger Airlines	7.57	0.30	6.21	9.32	0.28	7.44
Personal Care Products	-	-	-	0.01	0.07	0.02
Pharmaceuticals	0.34	1.50	0.55	0.12	0.98	0.30
Professional Services	0.00	0.05	0.01	0.00	0.10	0.02
Real Estate Man. & Dev.	0.01	0.02	0.01	0.00	0.02	0.00
Residential REITs	0.00	0.01	0.00	0.01	0.05	0.02
Retail REITs	0.00	0.21	0.04	0.00	0.07	0.02
Semiconductors & Sem. Equ.	0.33	1.83	0.61	0.43	2.09	0.77
Software	0.01	1.13	0.22	0.00	0.29	0.06
Specialized REITs	0.17	0.73	0.28	0.04	0.88	0.21
Specialty Retail	0.09	1.90	0.43	0.02	0.98	0.22
Technology Har., Sto. & Per.	0.12	1.16	0.31	0.08	1.29	0.33
Textiles, Apparel & Luxury Goods	-	-	-	0.01	0.09	0.03
Tobacco	-	-	-	0.11	0.38	0.17
Trading Companies & Distributors	0.02	0.03	0.02	0.06	0.16	0.08
Water Utilities	-	-	-	0.01	0.48	0.11
Wireless Tel. Ser.	-	-	-	0.01	0.35	0.08

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