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Does cap-and-trade scheme impact energy efficiency and firm value? Empirical evidence from India

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A B S T R A C T

Governments worldwide have adopted environmental regulations to fight global warming. In 2012, the Government of India introduced the Perform, Achieve and Trade (PAT), a cap-and-trade scheme, to achieve energy efficiency for large-sized industries. The extant literature is divided on the impacts of environmental regulations on firm performance. While the win-win argument of Porter and Van der Linde (1991) proposes a positive effect, the cost-regulation theory suggests a negative impact. Against this backdrop, we examine the impact of the PAT scheme on energy efficiency and firm value. As an identification strategy, we employ difference-in-differences (DID) combined with propensity score matching methods on firm level data from 2006 to 2015. We do not find evidence of a statistically significant impact of the PAT scheme on firms' energy efficiency. In contrast, our results suggest that the scheme adversely affects firm value. Furthermore, we find that increased expenditure on repair and maintenance, research and development, rising plant and machinery purchases, and a fall in productivity are the potential channels through which the PAT scheme impacts firm value. Our results are robust to alternative definitions of energy intensity, firm value, and empirical specifications.

1. Introduction

> *"There should be no rollback of environmental laws and regulations. In fact, it might turn out to be counter-productive as I believe environmental regulations and implementations might actually be good for business in many ways,"*
> *- Anirban Ghosh, Chief Sustainability Officer, Mahindra Group.*[1]

In recent years, governments worldwide have adopted environmental regulations to reduce their industries' carbon footprints. Alongside regulators, corporations across the globe are also increasingly becoming environmentally conscious, and India is no exception. In 2012, the government of India introduced the Perform, Achieve, and Trade (PAT) scheme, a market-based environmental regulation intended to improve Indian firms' energy efficiency.

The Perform, Achieve and Trade (PAT) scheme is the bellwether programme of the NMEEE (National Mission for Enhanced Energy Efficiency) under the Bureau of Energy Efficiency. It is aimed at increasing the energy efficiency of energy intensive industry groups. Plants belonging to different firms whose energy consumption exceeds a pre-specified cutoff are subjected to the PAT scheme (DCs or Designated Consumers) and given a target energy consumption level to achieve to make them relatively energy efficient. Firms that fail to achieve such targets must buy certificates (Escerts) from firms that overachieve the specified target. The scheme contributed to more than 50% of energy savings in 2018–19 (Bureau of Energy Efficiency, 2020).

However, existing literature offers mixed evidence about the impact of the PAT scheme on energy efficiency (Sharma et al., 2019; Misra, 2019; Oak and Bansal, 2022). Moreover, according to Blackman (2010), developing countries poorly enforce environmental regulations; hence, studying the scheme's effectiveness is imperative. In this paper, we examine the impact of the PAT scheme on the energy efficiency of Indian firms using a unique dataset.

Furthermore, environmental regulations compel firms to internalise the cost of polluting the environment, impacting firm performance. Hence, this paper also examines the impact of the environmental regulation, i.e., the PAT scheme, on firm value. We derive the theoretical underpinnings of the empirical analysis carried out in this paper from

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[1] https://carboncopy.info/the-questionable-business-of-weakening-indias-environmental-regulation-2/

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two competing theories: Porter's win-win hypothesis and the cost-regulation theory. A well-designed environmental standard is expected to benefit firms (Porter and Van der Linde, 1991). In contrast, cost regulation theory suggests that environmental regulations may not always be value-enhancing for firms and may adversely impact their profitability (He et al., 2020; Xepapadeas and De Zeeuw, 1999). Only a handful of notable studies investigate the impact of environmental regulation on firm value (Caragliu, 2021; King and Lenox, 2001). However, little is known about the impact of the PAT scheme on firm value in India. Therefore, this paper has twin objectives. First, it examines the effectiveness of the PAT scheme in enhancing the energy efficiency of Indian firms. Second, the paper also evaluates the impact of the PAT scheme on the value of the firms affected by the scheme.

To empirically investigate the research questions described above, we use firm level data on Indian firms between 2006 and 2015. We construct a unique database by collating firms' financial and energy consumption data. The energy consumption data allows us to map different energy sources and their corresponding price and quantity consumed by each firm. This unique database enables us to measure energy efficiency with greater precision and, hence, improves the validity and accuracy of the analysis.

Since the PAT scheme has pre-determined criteria for selecting plants that fall under its purview, any empirical analysis that uses data from firms corresponding to these plants raises endogeneity concerns.[2] This is because firms subjected to the PAT scheme could be systematically different from firms not being subjected to the said scheme due to both observed and unobserved heterogeneity at the firm-level. We address endogeneity concerns in two ways. First, we employ firm fixed effects in all our regressions to control for time-invariant unobserved heterogeneity. Second, we employ the difference-in-differences (DID) technique combined with the propensity score matching (PSM) technique, as the PAT scheme is an exogenous policy shock.

We do not find any statistically significant impact of the PAT scheme on energy efficiency for Indian firms, and we propose two plausible reasons for the same. First, the availability of low-cost energy and second, the possibility of a spillover or anticipation effect on firms not being subjected to the PAT scheme.[3] We reject the presence of any spillover effect on further assessment. Moreover, our results are not biased to the specification of the energy efficiency variable.[4]

Regarding our second objective, we observe that the PAT scheme negatively affects the firm value. This result allows us to refute Porter's win-win hypothesis in the Indian context. We also examine the potential mechanisms and find that increased purchases of plants and equipment, enhanced expenditure on repairs and maintenance, research and development and declined productivity are possible reasons for the decline in firm value. We also observe that firms' costs towards the scheme are substantially more than the savings from reduced energy consumption. These channels are in line with the cost regulation theory.

We also perform a set of robustness checks to confirm the validity of our results. Furthermore, we examine the persistence of our baseline results across cycles of the PAT scheme. To the best of our knowledge, this paper is the first study to consider cycle II of the PAT scheme to infer the long-term impact of the scheme. We apply staggered DID following the approach developed by Callaway and Sant'Anna (2021) and find that the negative impact of the PAT scheme on firm value persists in cycle II as well. Overall, our findings are robust to alternative definitions of energy efficiency, firm value, and other econometric specifications.

Our paper contributes to the emerging literature on the PAT scheme in multiple ways. First, our paper provides a holistic analysis of the impact of the PAT scheme. Prior studies evaluate the impact of the PAT scheme on firm level outcomes for two specific industries: cement and iron and steel. Both industries are highly energy-intensive, justifying the attention they receive. However, evaluating these two industries does not provide a clear understanding of the effectiveness of the PAT scheme concerning firm value across other industries. This paper fills the gap in the existing literature by focusing on six of the eight industries subjected to the PAT scheme in cycle I: textile, paper and pulp, cement, chlor-alkali, iron and steel and aluminium.[5] Unlike prior studies, we assess the PAT scheme's overall impact along with the scheme's differential impact across various industries.

Second, to the best of our knowledge, this study is the first to use energy consumption data to estimate the impact of the PAT scheme on energy efficiency. Prior studies have used power and fuel expenses to measure energy efficiency. We collate a unique dataset using energy consumption data and construct a more direct variable for computing energy efficiency. The presence of measurement bias in the definition of energy efficiency used by prior studies further provides a superior edge to our specification for energy efficiency. Following the literature, we use energy intensity as the proxy for energy efficiency and measure it using the ratio of total energy consumption and total output.[6]

Third, our paper is the first to evaluate the impact of the PAT scheme on firm value. We test Porter's hypothesis in the Indian context, contributing to the debate between the win-win and cost regulation hypotheses. Fourth, our findings have implications that may be useful for policymakers in designing new and effective environmental regulatory schemes. Our analysis highlights the need for more stringent targets to attain a more balanced cost and benefit balance sheet. The results also call for the need to consider the inherent structure of the industry while designing policies.

Finally, this study also contributes to the broader literature on market-based instruments for environmental protection in the context of developing countries like India. The results help assess the likely effects of future cycles of the PAT scheme and also provide learnings for other countries formulating environmental policies of a similar kind.

The remainder of the paper is organised as follows. Section 2 provides a brief account of the PAT scheme. Section 3 briefly reviews the related literature on energy efficiency. Section 4 describes the data used in the analysis. Section 5 discusses the empirical model employed in this paper. Section 6 presents the empirical results. Section 7 establishes the robustness of our baseline results. Section 8 investigates the channels. Section 9 concludes.

2. Institutional settings

There is a global acceptance that energy efficiency is an avenue to achieving desired energy and climate goals (Sarangi and Taghizadeh-Hesary, 2020). Several studies show that energy consumption is a significant source of carbon emissions (Adewuyi and Awodumi, 2017; Ahmad et al., 2016; Alkhathlan and Javid, 2015; Ang, 2008; Tiba and Omri, 2017; Zhang and Cheng, 2009). According to IEA (2021), India's energy consumption increased by 50% between 2007 and 2017, primarily due to energy-intensive transportation and increased usage of electrical appliances and other machines.

Against this backdrop, India has pledged to reduce its emission intensity by 45% by 2030 and become net zero by 2070 ("U.N. Climate Change Conference COP26," 2021). India launched a National Action Plan for Climate Change (NAPCC) in 2008 to address various aspects of

[2] Government first determines industries to be targeted for the scheme. Furthermore, a series of cumbersome calculations and pre-defined criteria identify the plants within these industries to which the scheme would be implied. The scheme is applicable at the plant level.

[3] Low energy cost tends to act as a disincentive for firms to adhere to environmental regulations (Zhao et al., 2009).

[4] As a robustness check, we rerun our base regressions using the energy efficiency variable constructed aka (Oak and Bansal, 2022) and find qualitatively similar results.

[5] Due to data availability, we restrict our sample to six industries.

[6] We follow the approach of Chen et al. (2020) to define energy intensity.

sustainable development. Among the eight missions of NAPCC, the National Mission for Enhanced Energy Efficiency (NMEEE) aims to decrease the energy inefficiency of the Indian industries. Ministry of Power and the Energy Conservation Act 2001 provides the legal backing to this mission. It is managed by the Bureau of Energy Efficiency (BEE) and has four platforms to serve different needs to achieve the mission of enhanced energy efficiency.

i. Market Transformation for Energy Efficiency (MTEE): The scheme is designed to expedite the adoption of energy-efficient appliances. The two programmes under it are the Bachat Lamp Yojana (BLY) and the Super Efficient Energy Program (SEEP). They provide affordable CFL bulbs and ceiling fans to Indian households and firms.
ii. Perform Achieve and Trade (PAT): A cap-&-trade model to increase the energy efficiency of large companies through a market-led system.
iii. Framework for Energy Efficient Economic Development (FEEED): This scheme focuses on fiscal instruments for promoting energy efficiency. There are four initiatives under FEEED, namely: Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE), Partial Risk Sharing Facility (PRSF), Venture Capital Fund for Energy Efficiency (VCFEE), and Energy Efficiency Financing Facility (EEFF).[7] The four initiatives help companies, MSMEs, municipalities, and the real estate industry to raise finances to meet their energy efficiency goals. It also shares risks borne by financial institutions in financing energy efficiency projects.
iv. Energy Efficiency Financing Platform (EEFP): It facilitates green financing and helps various stakeholders build capacity and adopt energy-efficient financing. It generates awareness through workshops and publications on the success of various BEE programmes. The platform conducts training for financial institutions and conferences named Investment Bazaar to guide the identification of viable energy efficiency projects.[8]

The introduction of the PAT scheme underscores a recently developed “environmental asset” class.[9] The environmental assets originate from the environment and can earn future income through SO_2 and NO_2 allowances, renewable energy and energy-efficient assets, water assets, CO_2 allowances, and sustainable indices (Dow Jones Sustainability Indices, Global Carbon Index, Indian carbon markets).

In this paper, we focus on the PAT scheme, which uses market mechanisms to enhance energy efficiency in a cost-effective manner. It is analogous to the emission trading system (ETS) or cap-and-trade model extensively used to limit environmental pollution (Dasgupta et al., 2015). However, ETS can also limit inefficient resource consumption like energy consumption (Hu et al., 2020; Marin et al., 2018). The EU-ETS is the first and the most popular emission trading scheme and has inspired other countries to adopt ETS to curtail their carbon emissions (Grubb et al., 2012; Jiang et al., 2016; Marin et al., 2018; Martin et al., 2013). Several studies compare the Indian PAT scheme and EU-ETS (Dasgupta et al., 2015; Grubb et al., 2012; Upadhyaya, 2010; Virmani and Rao, 2015) and highlight their similarities in terms of the design of the respective scheme and target groups. However, the broad goals of the two schemes are different. While EU-ETS or general ETS aims to reduce carbon emissions, the PAT scheme seeks to enhance energy efficiency. (Grubb et al., 2012) find that emerging economies like India and China use cap-and-trade model-based schemes more for enhancing energy efficiency than controlling carbon emissions, highlighting the versatile use of trading schemes to address climate change issues.

Focusing on the PAT scheme, it is based on a perfectly competitive market and the polluter's par principle. It is a mandatory scheme wherein plants crossing an energy consumption threshold[10] are subjected to the Designated Consumers (DCs) scheme.[11] The model, as envisaged by the PAT scheme, works as follows. DCs are given a ‘cap’, i.e., a unit-specific energy consumption (SEC) target at the plant level. In return, DCs that can achieve the target are awarded energy-saving certificates (Escerts). The certificates are measured by the metric ton of oil equivalent energy consumed (Mtoe.) and are ‘tradable’.

In particular, the targets or cap is derived from the baseline calculation of the average SEC over the last three years, i.e., 2007–10. The calculated SECs are normalised considering capacity utilisation and other factors (Ministry of Power, 2012).[12] Firms that incur less cost to enhance energy efficiency reduce their energy intensity more than required. They are awarded Escerts for overachievement. Escerts can either be utilised in future by the firm or sold to underachieving firms. On the other hand, DCs that find it expensive to reduce energy consumption must buy Escerts from firms having Escerts through the market to meet the target or pay a penalty.[13]

The cap-and-trade model has the benefit of making firms automatically internalise inefficient energy costs. The allowance of trade makes Escerts dearer and incentivises firms to enhance their energy efficiency beyond the specified level. Moreover, the cost of improving energy efficiency will be less in the cap-and-trade model compared to the command-and-control approach. Through the PAT scheme, the government aims to provide a market-led, cost-effective, and efficient way of enhancing energy efficiency.

The scheme has been rolled out in cycles, adding new target industries every cycle. During cycle I, the scheme covered the eight most energy-intensive industries in India through 478 DCs.[14] These eight sectors are aluminium, cement, chlor-alkali, fertilisers, thermal power plants, iron and steel, pulp and paper, and textile. The scheme targets 10 plants from the aluminium industry, 85 from cement, 22 from chloral alkali, 29 from fertiliser, 67 from iron and steel, 31 from paper and pulp, 90 from textile, and 144 from the thermal power industry.

Cycle I commenced in 2012–13 and ended in March 2015. In consultation with the Ministry of Power, the BEE is targeted to save

[7] The scheme was introduced post 2015.
[8] The schemes were introduced post-2015.
[9] According to Sandor et al. (2014) “Environmental asset classes include the securities or instruments created through the commoditisation of environment and natural resource assists, such as emissions rights and water; instruments arising from the monetisation of specific environmental attributes, such as renewable energy or energy efficiency; and equity indices, called sustainable indices, to reflect the overall environmental performance of their constituent companies.”

[10] Each industry has a different threshold. For more information, please see https://beeindia.gov.in/sites/default/files/Notification%20for%20Minimum%20annual%20energy%20consumption%20to%20become%20a%20Designated%20Consumer%202007_0.pdf
[11] DESIGNATED CONSUMER: “As per the provision of the clause (e) and (f) of section (14) of the Energy Conservation (EC) Act 2001, the Central Government notified the criteria for Designated Consumers vide SO no. 394(E) dated 12th March 2007 under which industrial units from 9 energy intensive sectors (Aluminium, Cement, Chlor-Alkali, Fertiliser, Iron & Steel, Paper & Pulp, Railways, Thermal Power and Textile) have been notified as Designated Consumers. The government has notified the mandatory Energy Audit vide SO 1378 (E) dated 27th May 2014 for the Designated Consumers to help in identifying various energy saving opportunities in energy intensive industries & other establishments.”
[12] https://beeindia.gov.in/sites/default/files/PAT%20Rules%2C%202012%281%29.pdf
[13] A DC member would be penalised with a fine of ₹10 lakhs on failure to comply with the provisions. Moreover, a continuing failure would attract an additional penalty of the price of every metric ton of oil equivalent of energy. The amount payable will be treated as arrears of land revenue on non-payment of a penalty.
[14] 478 DCs or plants belonging to the eight industries were responsible for approximately 60% of the total energy consumption of the country (Sarangi and Taghizadeh-Hesary, 2020)

energy worth 6.886 Mtoe. The first cycle achieved 8.67 Mtoes of savings, leading to the issuance of 3.82 million (approx.) Escerts to 306 over-achieving DCs. Furthermore, 110 DCs fell short of their target and had to buy 1.42 million Escerts. The trading began in September 2017 and concluded in January 2018. 1.29 million Escerts were traded in 17 sessions, amounting to approximately $12 million (BEE report, 2018).[15]

Two trading platforms, Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL), were established for easy, low-cost trading of Escerts. Central Electricity Regulatory Commission (CERC) is the regulatory body, while the Bureau of Energy Efficiency oversees the trading process. A double-sided uniform price auction mechanism is used to determine the trading price of the Escerts. The price fluctuated between ₹200 and ₹1200 for each Ecsert during cycle 1 (BEE report, 2018).[16] Moreover, the scheme does not impose any ceiling or floor price on Escerts trading.

3. Literature review

3.1. Energy efficiency regulation

Across the globe, governments design and implement energy-saving schemes to reduce their carbon footprint (Tanaka, 2011). For example, in China, annual targets are stipulated in five-year plans (FYPs) to reduce energy intensity. Chen et al. (2020) find that the stricter regulation of binding FYPs leads to a significant decline in firms' energy intensity and triggers a shift from dirty to cleaner energy sources. In a similar vein, Zhu et al. (2018) analyse the Chinese' Top 100-enterprises' program and conclude that both embodied and disembodied technological improvement lead to a decline in the energy intensity of the firms. Geller et al. (2006) explore the energy-saving policies in the OECD countries. They observe that the nine different policies of the U.S. led to a decline of 11% in primary energy use in 2002. They also conclude that the regulations in Japan and European countries effectively improve energy efficiency. Using Data Envelopment Analysis (DEA), Sueyoshi et al. (2013) document that the U.S. Clean Air Act effectively protects the U.S. environment by enhancing managerial disposability. The authors also suggest increasing the act's scope to limit CO_2 emissions. García-Quevedo and Jové-Llopis (2021) investigate different environmental policies in Spain regarding tax, subsidies, and carbon emission regulations and find that subsidies provided by the government significantly influence energy-efficiency investment. Using the multi-stakeholder economic efficiency model, Franzò et al. (2019) find that the white paper scheme of the Italian government is beneficial for all the stakeholders. Malinauskaite et al. (2019) analyse the Italian white paper scheme and find it cost-effective for enhancing energy efficiency. It is evident from the extant literature that many schemes aiming to improve energy efficiency have successfully achieved their desired objectives.

3.2. Energy regulation and firm value

The literature on the effect of environmental regulation on firm value comprises two contrasting theories: Porter's win-win hypothesis based on sustainability theory and cost regulation theory. The following subsections briefly explain these two theories.

3.2.1. Porter's win-win hypothesis

The first strand of literature advocates that environmental regulations help firms stimulate cost-saving innovations, increasing firm value (Porter and van der Linde, 1995; Porter and Van der Linde, 1991). According to Porter's win-win hypothesis, a well-designed environmental regulation induces firms to innovate (Chen et al., 2020; Zhu et al., 2018) and optimise resource use (Porter and van der Linde, 1995), resulting in productivity gains (Kumar and Managi, 2009) and hence higher profitability (André et al., 2009). Alpay et al. (2002) find that environmental regulations in the U.S. and Mexico increased the productivity and profitability of firms. Eli and Bui (2001) study the local air pollution regulation of Los Angeles and find that the abatement investments increased firms' productivity for oil refineries.[17] Caragliu (2021) deduce that the Italian White paper has a significant and positive relation with firm performance. Along similar lines, the PAT scheme can also impact firm value positively.

3.2.2. Cost regulation theory

The second strand of the literature suggests that environmental regulations may not be value-enhancing for firms (Gray and Shadbegian, 2003; He et al., 2020; Xepapadeas and De Zeeuw, 1999). The cost regulation theory suggests that shifting a firm's resources, such as labour and capital, to fulfil environmental regulation adversely affects its ability to pursue profit-seeking activities (Petroni et al., 2019). Ambec and Barla (2006) argue that emission control technology may hamper production efficiency and firm productivity. Consequently, any investment in abatement capital can crowd out productive investments. Furthermore, compliance with environmental regulations may require heavy investment with a long gestation period, leading to low profitability and affecting the survival ability of compliant firms. Such investments can be made in various forms: Research and Development (R&D), repairs and regular maintenance of plant and machinery, and purchase of new equipment. In contrast, since environmental regulations target highly polluting firms, these firms are unlikely to gain any competitive advantage compared to the low-polluting firms (Petroni et al., 2019). Brännlund and Lundgren (2009) document that a few Swedish firms experienced reduced profitability due to environmental regulation. Gray (1987) and Gray and Shadbegian (2003) observe a decline in the firm's productivity due to increased pollution abatement operating costs for pulp and paper mills, steel mills, and oil refineries. Moon and Min (2020) evaluate the impact of environmental regulation on firm performance and find that Korean firms that use high pure energy in their production generally find it challenging to improve financial performance. Similarly, Jiang et al. (2021) find that Chinese textile firms face a trade-off between energy efficiency and output efficiency.

In this study, we pit Porter's win-win hypothesis against cost regulation theory by evaluating the impact of the PAT scheme on firm value. Porter's win-win hypothesis's applicability depends upon the regulation's design and enforcement. However, according to Blackman (2010), energy regulations such as the PAT scheme will have a limited impact on firm value due to poor enforcement of policies by developing nations. A few prior studies have also highlighted the leniency towards enforcing the PAT scheme targets and the mismanagement in its implementation (Bhandari and Shrimali, 2018; Kumar and Agarwala, 2013). As a result, the impact of the PAT scheme on firm value remains an interesting empirical question. Furthermore, Porter's win-win hypothesis has minimal applicability in a developing country context. The difference in political connections and property rights in developing and developed countries affects the hypothesis's aptness. He et al. (2020) find that environmental regulation in China is a mere 'paper law', so politically connected firms can easily bypass it. The authors also find that the ecological interventions by the government lower the firm's financial performance. Several studies also evaluate the impact of environmental regulation in the context of developing countries such as China and Brazil and find evidence of the negative impact of such regulation on firm performance (Guo et al., 2018; Lai and Wong, 2012; Seroa da Motta, 2006).

[15] In PAT cycle I, Escerts worth ₹1000 million were traded. The figure has been converted at the exchange rate of ₹1 = $83.33

[16] Please see Fig. 1A in Appendix for trading details of Escerts.

[17] Paper focused on specific regional environmental regulations in California ratified by South Coast Air Quality Management District (SCAQMD).

3.3. The PAT scheme

Given the recent implementation of the PAT scheme in India, evidence about its impact on firm level variables is limited in the existing literature. Potdar et al. (2016) review India's whole energy regulation system. The authors compare various steps taken under the market, command-and-control, and voluntary systems and infer that the PAT scheme will pave the way for achieving the status of a low-carbon nation. Bhattacharya and Kapoor (2012) compare the new Indian system with the existing one in the U.K. The authors suggest enhancing the scheme's scope and better management of the price stability of the Escerts. They further propose incentivising the producers of energy-efficient technology to increase investments. Kumar and Agarwala (2013) examine PAT's Escerts and Renewable Energy Certificate (REC) from the perspective of target setting and recommend better coordination between regulators, traders (of both REC and Escerts), and DCs to achieve higher efficiency. In a similar study, Paul (2011) evaluates the PAT scheme and concludes that the scheme brings net socio-economic benefits to society.

Furthermore, Bhandari and Shrimali (2018) discuss the leniency of the targets and the transaction costs associated with the trading of Escerts. They suggest a standardised auditing process for energy consumption. Using a sample of Indian firms in the cement industry, Oak and Bansal (2017) investigate the effects of the PAT scheme on energy efficiency. The authors find that the PAT scheme has been ineffective in improving energy efficiency. Using panel data from the iron and steel industry, Sharma et al. (2019) investigate the impact of the Energy Conservation Act (ECA) 2001, including the PAT scheme. They conclude that ECA 2001 has significantly improved energy efficiency and that the PAT scheme is effective only when coupled with ECA. Misra (2019) examines the impact of the PAT scheme on the efficiency of the cement, iron and steel industries. The author shows that the PAT scheme is inefficient for the cement, iron, and steel industries. Oak and Bansal (2022) analyse the impact of the PAT scheme on the energy efficiency of cement, fertiliser, paper and pulp industries. The authors show that the scheme has been effective for the cement and fertiliser industries but not for the paper and pulp industries.

The PAT scheme plays a pivotal role in achieving India's target as per the Kyoto Protocol, and yet there is limited availability of literature regarding the impact of the PAT scheme on firm performance.[18] Hence, evaluating the PAT scheme's impact on the firms' energy efficiency is imperative. A scheme, to be effective, must provide a framework wherein a firm improves its energy efficiency and can enhance or maintain its value.

4. Data and summary statistics

We obtain data for this study from Prowess I.Q., a database maintained by the Center for Monitoring the Indian Economy (CMIE) for 2006–2015. We focus on cycle I of the PAT scheme.[19] The data used in this study has two parts: financial data (including market data) and energy data. Prowess provides data for each firm's energy consumption quantity, per unit cost and the total cost corresponding to every type of fuel used. Units for each energy source are converted into a kilo calorie (kcal) for uniformity and comparability. The conversion rate is taken from the PAT notification issued in the Indian government gazette.

A novelty of our analysis is that we measure firms' energy efficiency using energy consumption. The energy data provides us with a direct measure of energy efficiency, unlike the prior studies that use the ratio of power and fuel expense to total output as a proxy for the same. Moreover, the power and fuel expenditure as a proxy for energy consumption has a drawback because, for some industries, Prowess sometimes includes other raw materials under power and fuel charges. For example, coal is used as a raw material and an energy source for the cement industry. Prowess includes the total cost of coal under power and fuel expenses. Using a direct measure allows us to avoid such issues resulting in measurement error.

[18] India agreed to reduce its emissions by 40% by 2020 compared to the levels of the 1990s("UN Climate Change Conference COP26,", 2021).

[19] We expand our study to cycle II for the purpose of robustness analysis.

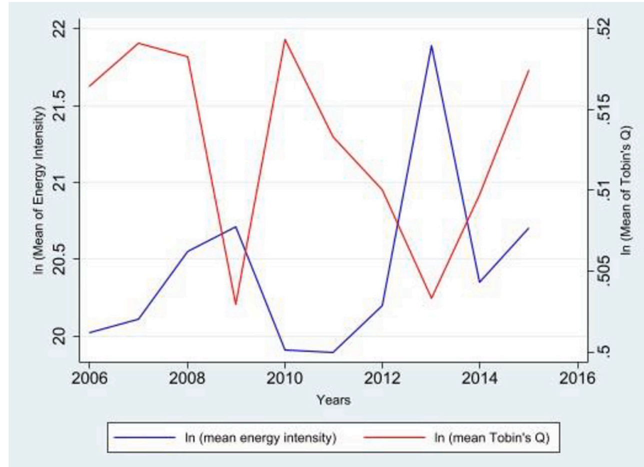


Fig. 1. Mean Distribution of Dependent Variables.
Source: Authors' calculations

Further, to identify the firms subject to the PAT scheme, the PAT notification in the Indian government gazette is used. The government has defined targets at the plant level. Hence, a firm is considered treated if at least one of its plants is subjected to the PAT scheme. The rest of the firms are considered as a control group. Names of every firm are manually matched from the dataset with the gazette notification. Firms that have undergone a name change are matched using their last name. Individual firms' websites and Ministry of Company Affairs (MCA) websites are cross-checked to confirm the names of firms and participation status.

The sample is restricted to only BSE-listed firms.[20] Further, firm-year observations with a negative net worth are dropped.[21] Following the literature, we replace all missing research and development expense values with zero (Black and Kim, 2012; Servaes and Tamayo, 2013). We winsorise all the accounting ratios except the dependent variables at 1% and 99%.[22] The study has two dependent variables: energy efficiency proxied by energy intensity and firm value proxied by Tobin's Q ratio. Energy efficiency and energy intensity have an inverse relationship. An energy-intensive firm is low in energy efficiency (Sudhakara Reddy and Kumar Ray, 2011). The PAT scheme applies to energy-intensive industries to reduce their energy consumption intensity and improve energy efficiency. Further, in the related literature, Tobin's Q ratio is widely used as a proxy for firm value (Black and Kim, 2012; Servaes and Tamayo, 2013). We use the natural logarithmic form of the dependent variables.[23]

Fig. 1 depicts the mean distribution of the log of energy intensity (a proxy for energy efficiency) in panel A and the log of Tobin's Q (a proxy for firm value) in panel B. The figure shows the fluctuations in the dependent variables over the sample period. It is evident from Panel A that the overall intensity of the firms has increased over time.

[20] We use BSE-listed firms in our analysis as it is the largest and the oldest stock exchange in India (Black and Khanna, 2007).

[21] We follow the approach adopted by Durnev et al., 2004.

[22] We use the natural logarithmic form for our dependent variables

[23] In our empirical model we use the log of energy intensity as done in other studies (Sharma et al., 2019) and the log of Tobin's Q as per prior studies (Black and Kim, 2012).

Table 1 presents the summary statistics for the firms subject to the PAT scheme (columns 1 and 2) and firms not being subjected to the scheme (columns 3 and 4).[24] Firms in both groups are similar in terms of profitability. Firms in the treatment group have higher energy consumption and energy cost figures, which bring these firms under the purview of the PAT scheme.

5. Methodology

In the PAT scheme, each industry is assigned a target, which is further allocated to each plant crossing a specific threshold on a pro-rata basis.[25] The threshold is calculated based on the average energy intensity of the plant over the three years 2007–10. Using retrospective data and complex calculations makes it difficult for a firm to anticipate its treatment status. Therefore, we can consider the PAT scheme as an exogenous policy intervention. The inherent design and implementation of the scheme result in two groups that we exploit for identification: treatment and control. The treatment group comprises firms subjected to the PAT scheme and required to reduce their unit-specific energy consumption to the targeted level. The control group comprises firms not being subjected to the PAT scheme.

The assignment of the firms to either group is done in a non-random manner, which results in potential selection bias. In other words, treatment firms might systematically differ from control firms based on pre-intervention firm level characteristics. We address this form of endogeneity by adopting DID combined with propensity score matching (PSM).

PSM allows us to match firms subjected to the PAT scheme with firms not subject to the scheme using observable firm level characteristics. Next, we compare the difference in outcome variables such as energy efficiency or firm value between firms subjected to the PAT scheme and firms not subject to the scheme both during the pre- and post-PAT period. We can causally estimate the scheme's impact on the outcome variables by employing DID combined with PSM. Thus, our empirical approach cleanly estimates the causal impact of the PAT scheme on both energy efficiency and firm value. We explicate the methodology further in the following sections.

5.1. Matching based on observable characteristics

At first, we match firms belonging to treatment and control groups based on observable firm level characteristics. Based on existing literature, we identify pre-treatment firm level characteristics to estimate each firm's probability (propensity score) in the treatment group. We briefly discuss the firm level characteristics used for matching below.

The impact of the firm's age on energy efficiency is ambiguous. According to Zhou et al. (2021), older firms have more resources to spend on energy efficiency-enhancing technologies than younger firms. Older firms also reap the benefits of the learning-by-doing effect. In contrast, a firm's age can also affect a firm negatively, as replacing energy-intensive machinery is difficult and costly, leaving older firms with less efficient plants and machinery. Golder (2011) observe that newer Indian manufacturing firms are more energy efficient. We use age and age squared in logarithmic terms (Firm age) (Firm age square) for matching to capture the non-linear relation between a firm's age and energy intensity.

Several studies show that scale economy exists in energy-intensive industries (Cole et al., 2006; Fisher-Vanden et al., 2006; Golder, 2011; Hassen et al., 2018). Since the Indian government implemented the PAT scheme targeting predominantly large industries, we use firm size (Firm Size) as an observable firm characteristic in our matching technique. In this context, it is also pertinent to note that capital-intensive (Capital Intensity) firms are generally energy-intensive (Cole et al., 2006; Lan et al., 2011). Extant literature suggests that a firm with high research intensity (Research Intensity) tends to have low energy intensity (Misra, 2019; Oak and Bansal, 2017; Sharma et al., 2019). If energy prices are low, the incentive to improve energy efficiency or to become less energy-intensive will reduce and vice versa. We use total energy cost in logarithmic terms (Total Energy Cost). All the variables mentioned above are employed for the matching procedure for the dependent variables, i.e., energy intensity and Tobin's Q. While conducting PSM for Tobin's Q, we also consider (Total Energy Consumption) logarithmic form of the total energy consumed. The amount of energy consumed affects the energy intensity of a firm, in turn affecting its probability of getting the treatment. We control for industry-fixed effects in our probit equations for estimating probabilities.

We estimate probabilities of getting treated based on cross-sectional data using the abovementioned variables. We use pre-treatment data, i.e., 2008, to estimate the probability of treatment for two reasons. First, variables measured in 2008 are unaffected by the introduction of the PAT scheme. Second, the data for 2008 provides us with the largest sample size. After obtaining the propensity scores, we match treatment firms with control firms using kernel-based matching.

The validity of PSM critically depends on three assumptions. First, the assumption of conditional independence suggests that the selection of firms into the treatment group is entirely random once firm level observables are controlled. It cannot be tested empirically. However, given the scheme's design, the probability of a firm being in the treatment group depends upon its energy intensity alone. Second, common support implies sufficient overlap between the distributions of propensity scores of the two groups: treatment and control. We test this assumption graphically using Fig. 2a and Fig. 2b for energy intensity and Tobin's q, respectively. Third, post-matching, the two groups are similar regarding observable firm level characteristics on average. It is called the test of balance between treatment and control, and we test it empirically in Table 2.

5.2. Difference-in-differences with matching

PSM as an identification method is insufficient if the selection is based on unobservable firm level characteristics. Therefore, we combine the DID technique with matching to account for time-invariant unobserved heterogeneity. We use only the sample of firms matched using PSM for DID estimation. In DID estimation, we compare the average outcome variable of interest between treatment and control groups across pre- and post-treatment periods to get a reliable estimate of the impact of the PAT scheme on energy efficiency and firm value. Employing the DID strategy for identification also allows us to control the introduction of any other energy-related schemes in the post-PAT period, as discussed in Section 2, as long as there is no reason why those schemes will impact treatment and control firms differently.[26] For our analysis, we consider 2006–2011 as the pre-treatment period and 2012–2015 as the post-treatment period. We estimate the following DID specification:

$$Y_{i,t} = \beta_0 + \beta_1 (Treatment_i \times Post_t) + \beta_2 Treatment_i + \beta_3 Post_t + X'\gamma + \eta_i + \delta_t + \epsilon_{i,t} \tag{1}$$

Where indices i and t denote firm and year, respectively. Y represents the dependent variables: energy intensity and Tobin's Q. Treatment is the binary variable; it equals 1 for firms subject to the PAT scheme

[24] Industry-wise firm-year observations are available in Table A1 in the appendix

[25] Every industry will have plants that are subjected to the scheme (they crossed a specified threshold) and plants that are not subjected to the scheme (energy consumption is below the threshold).

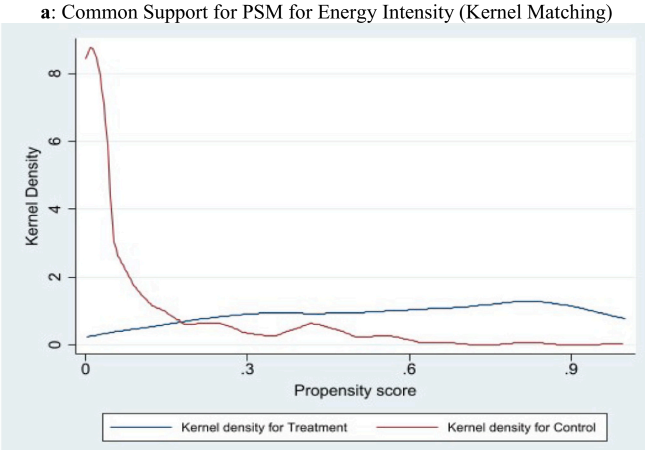
[26] To our knowledge, we are not aware of new energy scheme introduced during 2012–2015.

Table 1
Summary statistics of key variables of sample firms between 2006 and 2015.

Variables	Median			Mean		
	Treatment	Control	Diff	Treatment	Control	Diff
Total energy consumed	27.55	23.60	3.95***	27.41	23.47	3.94***
Total energy cost	7.25	4.34	2.91***	7.32	4.21	3.11***
Tobin's Q	0.54	0.52	0.02***	0.53	0.50	0.03***
Energy intensity	18.44	16.00	2.44***	18.11	16.12	1.99***
Firm age	3.58	3.22	0.36***	3.57	3.17	0.40***
Firm size	9.46	7.06	2.40***	9.59	7.04	2.55***
Sales	9.28	7.24	2.04***	9.37	7.15	2.22***
Leverage	1.29	0.92	0.37***	2.01	1.56	0.45***
Export intensity	0.10	0.16	−0.06***	0.20	0.24	−0.04***
Profitability	0.08	0.09	−0.01	0.09	0.09	0
Research intensity	0.00	0.00	0***	0.00	0.00	0***
Capital intensity	0.46	0.34	0.12***	0.45	0.35	0.10***
N		1045			6605	

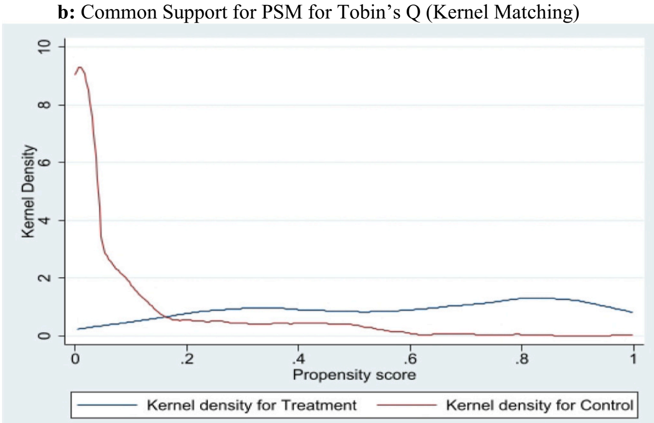
[1] Table 1 provides the summary statistics for the critical variables for the treatment and control groups for the entire study period. It shows the difference in median and mean between the two groups. [*significant at 10%. **significant at 5%. ***significant at 1%.]
[2] The units of measurements for total energy consumed is kilo calorie, for total energy cost and sales is rupees, for energy intensity it is kilo calorie per rupee, for age is years and rest of the variables are unit-free.

a: Common Support for PSM for Energy Intensity (Kernel Matching)



Source: Authors' calculations

b: Common Support for PSM for Tobin's Q (Kernel Matching)



Source: Authors' calculations

Fig. 2. a: Common Support for PSM (Kernel Matching).
Source: Authors' calculations.
2b: Common Support for PSM (Kernel Matching).
Source: Authors' calculations.

(treatment group) and 0 for firms not subjected to the PAT scheme (control group). The *Post* is a dummy variable that takes the value of one for the post-treatment year (2012–2015) and 0 for the pre-treatment period (2006–2011). η_i and δ_t indicate the firm fixed-effects and year fixed-effects, respectively. X' is the vector of firm level control variables. Control variables for the DID specification when the dependent variable is energy intensity are the log of firm age, the log of firm age square, firm size, capital intensity, repair intensity, R&D intensity, the log of total energy cost, export intensity, promoters' share percentage and foreign promotors dummy. Control variables for the dependent variable Tobin's Q are the log of firm age, the log of firm age square, firm size, R&D intensity, export intensity, liquidity and leverage, promoters' share percentage and foreign promotors dummy. The definition for all the control variables is presented in Appendix A. All standard errors are clustered at the firm-level (Petersen, 2009).

Table 2
Test of balance.

Panel A: Balancing Test for Dependent Variable: Energy Intensity			
Independent variables	Treatment group	Control group	t- stat
Firm age	3.50	3.54	−0.57
Firm age square	6.86	6.99	−0.58
Firm size	9.19	9.40	−0.85
Capital intensity	0.46	0.44	0.67
R&D intensity	0.00	0.00	0.02
Total energy cost	6.97	7.11	−0.46
N	98	408	
Panel B: Balancing Test for Dependent Variable: Tobin's Q			
Independent variables	**Treatment group**	**Control group**	**t- stat**
Firm age	3.52	3.49	0.38
Firm age square	6.96	6.89	0.33
Firm size	9.40	9.70	−1.20
Capital intensity	0.44	0.43	0.59
R&D intensity	0.00	0.00	−0.36
Total energy cost	7.05	7.52	−1.46
Total energy consumed	27.04	27.42	−0.93
N	95	357	

[1] This table shows the balancing test with energy efficiency as the dependent variable in panel A and the balancing test with firm value as the dependent variable in panel B.
[2] The treatment group refers to the firms subject to the PAT scheme, and the control group refers to the firms not part of the PAT scheme.

The validity of DID estimation depends crucially on the parallel trend assumption. The parallel trend assumption suggests that there is no differential trend between treatment and control in the pre-treatment period (2006–2011), implying that in the absence of any policy intervention, the trends of the dependent variable would remain the same for both groups. We test this assumption in two ways. First, we conduct a placebo experiment. We restrict our sample to the pre-treatment period, i.e., 2006–2011, and then we treat 2009 as the pseudo-treatment year and estimate Eq. (1) for the shorter time.[27] Second, we consider a trend variable and interact it with the treatment variable to show that the coefficient of the interaction variable is statistically indistinguishable from zero.

6. Empirical results

6.1. Matching results

In this section, we discuss the results of testing the underlying assumptions of PSM, as discussed in Section 5.1.

Fig. 2a and 2b show an overlapping region between the propensity score distributions of the treatment and control groups. Therefore, the common support assumption holds good; hence, PSM is feasible for our analysis.

Table 2 reports the balancing test results for the firms matched using the kernel-based matching technique. Panel A presents the balancing test for energy efficiency as the dependent variable. In total, 98 treatment firms are matched with 408 control firms. Panel B shows the balancing test for firm value as the dependent variable. Here, 95 treatment firms are matched with 357 control firms when firm value is the dependent variable.

The results show that the t-stats corresponding to the observed firm level characteristics in panels A and B of Table 2 are all statistically insignificant. These results suggest that the matched groups are similar on average regarding observable firm level characteristics during the baseline year 2008.[28]

6.2. Impact on energy efficiency

Our first objective in this paper is to examine whether the PAT scheme impacts a firm's energy efficiency proxied by energy intensity. Table 3 presents the DID combined with matching estimation results for energy intensity.

Table 3
Difference-in-differences (DID) combined with matching results.

	Log of Energy Intensity		
	(1)	(2)	(3)
Treatment × Post	−0.052	−0.034	−0.002
	(0.102)	(0.103)	(0.101)
Treatment	–	–	–
Post	−0.324***	–	–
	(0.065)		
Firm age	−5.011**	−0.388	−0.282
	(2.420)	(3.407)	(1.841)
Firm age square	2.052**	0.241	0.161
	(0.980)	(1.339)	(0.670)
Firm size	−0.427***	−0.392***	−0.404***
	(0.105)	(0.112)	(0.105)
Capital intensity	0.690***	0.679***	0.618***
	(0.237)	(0.238)	(0.234)
Repair intensity	6.735	6.063	6.742
	(6.776)	(6.844)	(6.458)
R&D intensity	4.330	4.750	4.269
	(11.532)	(11.429)	(11.124)
Total energy cost	0.670***	0.676***	0.671***
	(0.066)	(0.067)	(0.065)
Export intensity	−0.278	−0.310	−0.265
	(0.257)	(0.263)	(0.240)
Promoters	0.001	0.001	
	(0.003)	(0.003)	
Foreign promoters_dummy			0.013
			(0.086)
Constant	19.592***	15.830***	16.188***
	(1.454)	(2.641)	(1.799)
N	2977	2977	3146
R-squared	0.233	0.238	0.221
Firm FE	Yes	Yes	Yes
Year FE	No	Yes	Yes

[1] The dependent variable is the natural log of energy intensity. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011 (pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[2] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

Column 1 in Table 3 shows the result for the base model with firm fixed effects but without year-fixed effects. In Column 2, we control for both firm- and year-fixed effects in our base model. Column 3 shows the results when the empirical model uses a foreign promoter dummy variable instead of a promoter variable. In all three models, the coefficient of interest (i.e., Treatment × Post) is statistically insignificant, suggesting a lack of empirical evidence that the PAT scheme impacted the energy efficiency of the firms. These results align well with prior studies (Misra, 2019; Oak and Bansal, 2017; Sharma et al., 2019). Furthermore, unlike our bottom-up approach, a study by Jain (2022) adopts a top-down approach to evaluate India's various energy efficiency schemes and arrives at results similar to ours.

In Table 4, we report the results for the parallel trend assumption. The dependent variable is the natural logarithm of energy intensity. In Column 1, the differential trend is tested for the pre-treatment period, and in Column 2, 2009 is considered a pseudo-treatment year. The coefficient of interest (β_1) in both columns is statistically insignificant. The results lend further credence to our baseline results. The results suggest the absence of any differential trend between treatment and control in the pre-treatment period.[29]

Unlike our measure, a few prior studies have used power and fuel expense scaled by sales to measure energy intensity (Misra, 2019; Oak, 2022; Oak and Bansal, 2022; Sharma et al., 2019).[30] We follow Oak and Bansal (2022) to construct alternative energy intensity measures and run the analysis to examine the consistency of the results across different energy intensity measures. We find qualitatively similar results, providing further credence to our main empirical results. In sum, we do not find any statistically significant impact of the PAT scheme on the energy efficiency of Indian firms.[31]

Potential reasons

There could be several reasons why we did not find any statistically significant impact of the PAT scheme on energy efficiency. First, there might be a decline in energy prices that resulted in higher energy consumption. Zhao et al. (2009) find that low energy prices reduce firms' incentives to adopt energy-efficient technologies. Fig. 3 depicts the trend in energy consumption in panel A and energy prices in panel B. It seems that energy consumption increased post-2012 due to falling energy prices in India.

In other words, Fig. 3 indicates a positive relation between energy price and energy intensity, in contrast to the proposed argument. Among all the energy sources in the study sample, electricity contributes the most towards energy consumption. Hang and Tu (2007) find that electricity price elasticity is positive for China because of the income and

[27] Pseudo-treatment year implies that we consider hypothetically 2009 as the year of enactment of the PAT scheme.
[28] The probit results for PSM are presented in Table A2 in the appendix
[29] We run a series of robustness checks and derive qualitatively similar results. The results are available on request to the authors.
[30] We measure energy intensity as the ratio of total energy consumed to total output. It has less chance of measurement bias. Please see the data section for further details.
[31] Please refer to Table A3 in Appendix for the results.

Table 4
Test of the parallel trend for energy intensity.

	Log of Energy Intensity	
	(1)	(2)
Treatment × post		0.030
		(0.130)
Treatment × trend	−0.001	
	(0.042)	
Treatment	–	–
Post	–	–
Trend	−0.047	
	(0.042)	
Firm age	−1.189	−1.012
	(4.283)	(4.282)
Firm age square	0.535	0.472
	(1.601)	(1.603)
Firm size	−0.397***	−0.417***
	−1.189	(0.134)
R&D intensity	0.912	1.718
	(11.838)	(11.931)
Export intensity	−0.080	−0.115
	(0.242)	(0.251)
Promoters	−0.001	−0.001
	(0.002)	(0.002)
Capital intensity	0.554**	0.544**
	(0.255)	(0.258)
Repair intensity	9.792	9.597
	(6.091)	(6.154)
Total energy cost	0.738***	0.738***
	(0.082)	(0.082)
Constant	16.443***	16.348***
	(4.038)	(4.069)
N	1867	1867
R-squared	0.307	0.310
Firm FE	Yes	Yes
Year FE	No	Yes

[1] The dependent variable is the natural log of energy intensity.
[2] In column 1, every year is treated as the hypothetical treatment year to test differential trends. Treatment x Trend is the primary interaction term. The trend is a categorical variable assuming values 1 for 2006, 2 for 2007, 3 for 2008, and so on.
[3] In Column 2, 2009 is treated as a pseudo-treatment year to validate the parallel trend assumption. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2008 (pre-treatment period) and 1 for 2009–2011 (post-treatment period).
[4] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

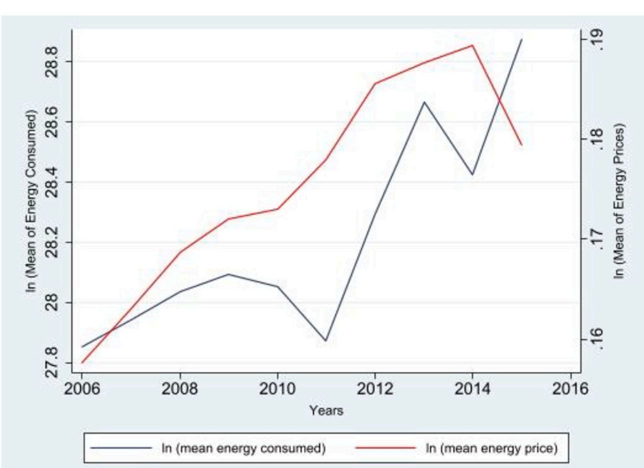


Fig. 3. Trend in Energy Consumption and Energy Price.
Source: Authors' calculations.

population effect. Despite this, the authors document that a price rise reduces energy intensity. In India, the income and population effects are substantial for the study period, leading to the positive own-price elasticity of electricity (Wang and Li, 2016). Our proposed rationale remains valid in line with (Hang and Tu, 2007).

The second reason for not witnessing a decline in energy intensity is the PAT scheme's anticipation or potential spillover effect on firms not being subjected to the PAT scheme. The PAT scheme is claimed to be successful as it overachieved its targets (Sarangi and Taghizadeh-Hesary, 2020). However, comparing the PAT-subjected firms with non-PAT-subjected firms, we find that the PAT scheme could not reduce energy intensity. A tenable argument for this could be that the control firms also enhanced their energy efficiency. The control firms might do so for two possible reasons. First, their fear of missing out on the gains their peers tend to enjoy for being subjected to the PAT scheme. Second, because of the anticipation of being included in the PAT scheme.

The Stable Unit Treatment Value Assumption (SUTVA) would fail in the presence of a spillover effect or anticipation effect. Fulfilment of the SUTVA assumption is critical for the validity of the DID methodology. We test for the spillover effect by conducting a placebo experiment.

Firms of similar size often experience spillover effects (Bansal et al., 2021). On average, firms in the treatment group are larger than those in the control group. We restrict our sample to the control group for the spillover analysis. We examine whether there is heterogeneity of treatment across different size classes in the control group.

We use pre-treatment year 2011 to divide the control group into a hypothetical treatment group and a pure control group, with firms in the

Table 5
Spillover test/placebo test.

	Log Of Energy Intensity	
Variables	(1)	(2)
Placebo_treatment × Post	0.080	0.073
	(0.114)	(0.105)
Placebo_treatment	–	–
Post	–	
Firm age	0.521	0.370
	(3.541)	(1.756)
Firm age square	−0.135	−0.088
	(1.396)	(0.637)
Firm size	−0.379***	−0.384***
	(0.109)	(0.100)
Capital intensity	0.704***	0.638***
	(0.231)	(0.224)
Repair intensity	6.728	7.616
	(6.500)	(6.044)
R&D intensity	6.641	5.089
	(10.947)	(10.354)
Total energy cost	0.672***	0.663***
	(0.064)	(0.061)
Export intensity	−0.368	−0.293
	(0.247)	(0.224)
Promoters	−0.000	
	(0.003)	
Foreign promoters_dummy		−0.000
		(0.084)
Constant	15.221***	15.509***
	(2.675)	(1.701)
N	3247	3477
R-squared	0.239	0.222
Firm FE	Yes	Yes
Year FE	Yes	Yes

[1] The dependent variable is the natural log of energy intensity.
[2] Placebo_treatment x Post is the primary interaction term. Placebo_treatment = 1 if a firm belongs to the first three deciles of the control group or 0 otherwise. Post is 0 for 2006–2011 (pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[2] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%]

first three deciles of firm size considered treated and the firms in the remaining deciles as the control group. Table 5 presents the results of the placebo test. The insignificance of the coefficient of the interaction term (β_1) suggests the absence of any spillover effect.

Third, our sample firms belonging to the six industries might lack natural advantages that help reduce energy intensity, or they could be further away from technological frontiers, which stifles achievement of energy efficiency targets (Mukherjee, 2010). Fourth, according to the BEE report (2018), some firms have experienced capacity reduction due to market demand fluctuation, making it difficult to achieve energy efficiency. The report further highlights other technical and financial barriers DCs face that hinder the process of reducing energy intensity. Fifth, the PAT scheme might have limited impact on energy efficiency due to the "productivity dilemma hypothesis" in the Indian manufacturing industries (Bagchi and Sahu, 2020). A "productivity dilemma hypothesis" postulates the inability of a firm to exploit the existing technologies and explore new ideas or innovate simultaneously while maintaining a stable output and adapt to changing conditions (Adler et al., 2009). Sixth, existing literature documents an inverted U-shaped relationship between innovation or new energy development and energy intensity or CO_2 emissions (Xiong and Mo, 2023). Therefore, it is possible that our sample firms are at the peak of the U-shaped curve during the initial PAT cycles wherein the peak is somewhat flat and hence, no impact on energy intensity is observed. Moreover, energy intensity will start declining only in the long-run due to "time lag effect" (Xiong and Mo, 2023). Lastly, our results are in line with Javid and Khan (2020) who compare India and China with USA, Germany and Japan and find that any technological progress induced energy-efficiency improvements in India and China are offset by exogenous factors such as changes in economic structure, consumers' preferences and regulations.

In sum, we can conclude that to achieve energy efficiency in India, the country requires stricter targets and higher governmental support that can stimulate disruptive innovations leading to positive results in the long-run.

6.3. Impact on firm value

The PAT scheme did not impact the firm's energy efficiency. Hence, examining the scheme's impact on firm value becomes imperative. On surveying the related literature, we find ambiguous results. Some studies show that regulation-induced environmental standards increase a firm's profitability (Ambec and Barla, 2002; Jaffe and Palmer, 1997; Schmutzler, 2001). In contrast, prior studies show that environmental regulations negatively impact firm value (Brännlund and Lundgren, 2009; Xepapadeas and De Zeeuw, 1999). Therefore, investigating the PAT scheme's impact on firm performance remains an important empirical question.

We present the DID with matching results for firm value in Table 6. Column 1 shows the estimation results of our baseline model without year effects. Column 2 shows the results of the baseline model with year effects. In Column 3, we use a foreign promoter dummy instead of the promoter's variable. We have used firm-fixed effects in all the models. The coefficient of interest (β_1) is negative and statistically significant at the 5% level in Columns 1 and 2, while it is statistically significant at the 10% level in Columns 3. The results imply that the PAT scheme negatively impacted firm value. We treat Column 2 as our base model. The results suggest that the treatment firms, on average, have 1.7% lower Tobin's Q than control firms.

In Table 7, we report the results from the parallel trend tests. Column 1, 2009, is considered a pseudo-treatment year, and in Column 2, the differential trend between treatment and control is tested for the pre-treatment period. The coefficient of interest (β_1) in both columns is statistically insignificant. These results lend further credence to our baseline result. The results suggest an absence of any differential trend between treatment and control in the pre-treatment period.

To sum up, we find evidence supporting the argument that regulation-induced environmental standards negatively affect the firm value.

Table 6
Difference-in-differences (DID) combined with matching results.

	Log of Tobin's Q		
	(1)	(2)	(3)
Treatment × Post	−0.020**	−0.017**	−0.014*
	(0.008)	(0.008)	(0.008)
Treatment	–	–	–
Post	−0.004	–	–
	(0.004)		
Firm age	−0.302	0.249	−0.010
	(0.243)	(0.306)	(0.246)
Firm age square	0.116	−0.099	0.007
	(0.102)	(0.124)	(0.099)
Firm size	0.023**	0.030***	0.030***
	(0.010)	(0.011)	(0.010)
Liquidity	−0.094**	−0.094***	−0.099***
	(0.037)	(0.036)	(0.036)
R&D intensity	−1.690**	−1.509**	−1.568**
	(0.681)	(0.676)	(0.691)
Leverage	0.014***	0.015***	0.014***
	(0.001)	(0.001)	(0.001)
Export intensity	−0.004	−0.002	−0.001
	(0.019)	(0.018)	(0.018)
Promoters	0.000	0.000	
	(0.000)	(0.000)	
Foreign promoters_dummy			−0.022**
			(0.010)
Constant	0.550***	0.080	0.284*
	(0.098)	(0.190)	(0.168)
N	3340	3340	3373
R-squared	0.197	0.224	0.225
Firm FE	Yes	Yes	Yes
Year FE	No	Yes	Yes

[1] The dependent variable is the natural log of Tobin's Q. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011(pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[2] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

6.4. Heterogeneity analysis

Our analysis above estimates the average impact of the PAT scheme on firm value. In this section, we investigate the heterogeneous effects of the PAT scheme on firm value across industries.[32] We study six industries: textile, paper and pulp, cement, chlor-alkali, iron and steel, and aluminium. Firms are divided into different industrial categories based on four-digit level NIC codes. We chose these industries because they are energy intensive and are subjected to the PAT scheme.

Table 8 reports that firms that belong to the chlor alkali industries suffered the highest decline in Tobin's Q than other industries. However, firms in the aluminium industry experienced increased firm value, implying the PAT scheme had a differential impact on firms across different industries. Each industry has a different number of plants subjected to the scheme. Moreover, the energy requirements and business cycles are different for different industries. According to the BEE report (2018), there has been a technological shift in the chlor-alkali industry while there has been an increase in capacity utilisation in the aluminium industry. These industries have not been researched before in the context of the PAT scheme. The results indicate that each industry will react differently to the PAT scheme. However, we are cognisant that the findings of some of these sub-sample analyses should be interpreted

[32] The heterogeneous impact of the PAT scheme on energy intensity is presented in Table A4 in the appendix

Table 7
Test of the parallel trend for Tobin's Q.

	Log of Tobin's Q	
	(1)	(2)
Treatment × Post		−0.005
		(0.007)
Treatment × Trend	−0.001	
	(0.002)	
Treatment	–	–
Post	–	–
Trend	−0.009***	–
	(0.002)	
Firm age	0.277	0.252
	(0.302)	(0.301)
Firm age square	−0.096	−0.085
	(0.115)	(0.115)
Firm size	0.027**	0.027**
	(0.012)	(0.012)
R&D intensity	−1.547***	−1.600***
	(0.574)	(0.555)
Export intensity	−0.024	−0.016
	(0.022)	(0.021)
Promoters	0.001***	0.001***
	(0.000)	(0.000)
Liquidity	−0.104***	−0.102**
	(0.040)	(0.040)
Leverage	0.016***	0.017***
	(0.001)	(0.002)
Constant	−0.028	−0.026
	(0.225)	(0.225)
N	2012	2012
R-squared	0.240	0.262
Firm FE	Yes	Yes
Year FE	No	Yes

[1] The dependent variable is the natural log of Tobin's Q.
[2] In column 1, every year is treated as the hypothetical treatment year to test differential trends. Treatment x Trend is the primary interaction term. The trend is a categorical variable assuming values 1 for 2006, 2 for 2007, 3 for 2008, and so on.
[3] Column 2, 2009, is treated as a pseudo-treatment year to validate the parallel trend assumption. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2008 (pre-treatment period) and 1 for 2009–2011 (post-treatment period).
[4] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

with caution as the number of observations under each industry is small.

7. Robustness checks

We carry out a battery of robustness tests as follows:

7.1. Alternative matching technique

We use alternative matching techniques: nearest neighbour matching and caliper matching.[33] Panel A of Table 9, columns 1 and 2, presents the results of the alternative matching technique. The results are qualitatively similar; hence, our baseline results are not sensitive to the underlying matching technique.

7.2. Alternative pre-treatment periods for matching

As a robustness check, we also employ an alternative matching using 2006 (cross-section) and then panel data from 2007 to 2010 separately for PSM analysis to check whether our findings are similar to those we report in our base model.[34] In Panel A, column 3 of Table 9 presents the results of DID estimation combined with matching using cross-sectional data for 2006. Column 4 presents the results of DID estimation combined with matching using panel data for 2007–10. The coefficient of interest (β_1) remains negative and statistically significant for both columns.

7.3. Alternative dependent variable

Firm value is one of the dependent variables in our study. Hence, it is imperative to employ alternative definitions of firm value to show that our results are qualitatively similar to baseline results. Therefore, we employ the price-to-book ratio as a proxy for firm value. The result for the P/B ratio is presented in Panel B of Table 9. In column 1, the coefficient of interest (β_1) is negative and statistically significant at 1 %, reinforcing our baseline results that the PAT scheme has a negative impact on firm value.

We also investigate the PAT scheme's impact on the firm's profitability. We use Return on Assets (ROA) and Return on Equity (ROE) as the proxy for the firm's profitability. Columns 2 and 3 present the estimation results for ROA and ROE, respectively, in Table 9 (Panel B). The coefficient of interest (β_1) is negative but not statistically significant, suggesting that the PAT scheme had a minimal impact on the firm's profitability.

7.4. Alternative control variables

We chose an alternative definition of our control variables to check the consistency of our results. First, we define research intensity as the ratio of research and development expenditure (R&D expenses) to total capital employed. The same approach is adopted by Pant and Pattanayak (2007). Following Nini et al. (2012), alternatively, liquidity is proxied by the current ratio. The log of the number of employees is used as an alternative proxy of firm size (Servaes and Tamayo, 2013).[35] Leverage is alternatively measured as a ratio between total long-term liability and assets (Pérez-González and Yun, 2013). Column 4 in Panel B of Table 9 presents the results using these alternative definitions of control variables. The coefficient of interest (β_1) is still negative and statistically significant at 1%.

7.5. Industry dummies

In our baseline specification, we controlled for both firm and year-fixed effects. In this section, we use industry-fixed effects and industry along with year-fixed effects to account for industry-specific and time trends. Columns 1–2 in Panel C of Table 9 present the estimation results with these alternative fixed effects. The coefficient of interest (β_1) is negative and statistically significant at the 5% level for both industry-fixed and industry-and-year fixed effects, which aligns with baseline regression results.

7.6. Staggered DID

To check the robustness of our main results, we extend the study timeline to cycle II of the PAT scheme, i.e., 2016–2019. We follow other studies that examine the effect of staggered adoption of schemes or policies (Chen and Xie, 2022; Leung et al., 2019; Mbanyele et al., 2022) and adopt the staggered DID approach without matching proposed by (Callaway and Sant'Anna, 2021). To make this method operational, we divide the entire sample period into three sub-periods: 2006–2011 is the

[33] We adopt a 1:1 neighbour matching technique (J. Chen et al., 2018) and 2% distance for caliper matching(Bhandari and Shrimali, 2018).

[34] The government used cumulative energy consumption data for the year 2007–10 for identifying DCs. The average specific energy consumption for 2007–10 acts as a baseline for the cycle I of the PAT scheme.

[35] We also use the log of market capitalisation as a proxy for firm size and obtain qualitatively similar results.

Table 8
Heterogeneity analysis.

	Log of Tobin's Q					
	Textiles	Paper & pulp	Cement	Chlor-alkali	Iron & steel	Aluminium
Treatment × Post	−0.013	0.044	0.043	−0.053**	−0.006	0.118**
	(0.009)	(0.027)	(0.031)	(0.023)	(0.017)	(0.043)
Treatment	–	–	–	–	–	–
Post	–	–	–	–	–	–
Firm age	0.229	1.020	3.365	−0.628	0.839**	23.365
	(0.357)	(9.285)	(3.316)	(0.673)	(0.417)	(41.408)
Firm age square	−0.089	−0.324	−1.398	0.244	−0.350**	−10.658
	(0.142)	(4.280)	(1.435)	(0.296)	(0.164)	(19.312)
Firm size	0.038***	−0.002	−0.003	0.049***	0.034***	−0.039
	(0.013)	(0.033)	(0.066)	(0.014)	(0.010)	(0.053)
Liquidity	−0.083*	−0.350	−0.217	−0.118*	−0.018	0.044
	(0.049)	(0.289)	(0.142)	(0.062)	(0.097)	(0.144)
R&D intensity	1.591	5.050*	−6.267	−2.061***	−1.870	1.281
	(2.112)	(2.881)	(4.512)	(0.630)	(5.174)	(2.968)
Leverage	0.013***	0.013***	0.024***	0.014***	0.013***	0.083**
	(0.001)	(0.003)	(0.007)	(0.003)	(0.002)	(0.035)
Export intensity	−0.012	−0.073	−0.006	−0.001	0.005	−0.281
	(0.030)	(0.302)	(0.075)	(0.027)	(0.035)	(0.206)
Promoters	−0.000	0.002*	−0.002	0.001	0.001**	0.002
	(0.000)	(0.001)	(0.002)	(0.001)	(0.000)	(0.002)
Constant	0.055	−0.903	−1.448	0.584	−0.296	−6.857
	(0.258)	(3.023)	(1.577)	(0.378)	(0.314)	(11.053)
Observations	1034	172	320	1208	536	70
R-squared	0.336	0.444	0.319	0.267	0.405	0.641
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

[1] The dependent variable is the natural log of Tobin's Q. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011(pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[2] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

pre-treatment period, 2012–2015 and 2016–2019 are the post-treatment periods 1 and 2, corresponding to cycles I and II, respectively. The staggered DID model is valid under a few identifying assumptions. First, the setting does not allow a treatment firm to switch to the control group in any post-treatment period (the assumption of the irreversibility of treatment).[36]

Second, each firm is randomly drawn from a large population of interest so that firm level potential outcomes are random and independent of each other (i.i.d). Third, firms' ability to anticipate being treated in future is reasonably limited.[37] Fourth, the treated and never treated groups show no pre-treatment differential trend once observed firm level characteristics are controlled, termed a conditional parallel trend assumption.[38]

We estimate the "group-time average treatment effect" for treated firms of the cycle I (G2012) and the overall average treatment effect aggregated across groups (GAverage) by allowing for treatment effect heterogeneity and dynamic effects.[39] To explicate further, the staggered DID estimator in Table 10 presents the incremental change in the firm value for firms that are subject to the PAT scheme (treatment group) relative to the change in firm value for firms that were never subject to the scheme (never treated group as the comparison group) during the same period.

Fig. 4 presents our estimated coefficients. The estimated coefficients for the overall treatment effect (GAvarege) and the firms treated in 2012 (G2012) are both negative and statistically significant (the 95% confidence interval does not contain zero). Thus, staggered DID results also suggest that the PAT scheme has led to a fall in the firm value. It shows the persistence of the negative effect in the long run and lends further credence to our main result.

8. Channels

This section examines the potential pathways through which the PAT scheme impacts firm value. Firms subject to the PAT scheme must reduce their energy intensity. In other words, a reduction in energy intensity improves energy efficiency. Achieving energy efficiency requires firms to periodically repair the existing machinery to improve its efficiency or buy upgraded energy-efficient machinery. Jasiulewicz-Kaczmarek and Drozyner (2011) advocate the role of green maintenance in achieving sustainable development. The authors emphasise the importance of constant maintenance and plant repairs to achieve efficiency and reduce wastage. Due to the PAT scheme, the repair cost or the purchase of new machinery would become necessary. Firms subject to the PAT scheme might also invest in in-house research and development (R&D) to improve their energy efficiency. Ambec et al. (2013) find that environmental regulation positively impacts R&D even though it negatively impacts a firm's performance. Prior studies also show a positive relationship between energy efficiency and research intensity (Golder, 2011; Sahu and Narayanan, 2011). The firms in the control group (not subjected to the PAT scheme) will not experience any compulsion to spend on plant and machinery or R&D. If the costs associated with these investments outweigh the benefits of reduced energy cost, it will lead to a fall in the firm value.

According to the BEE report (2018) 'Enhancing energy efficiency through industry partnership', the total investment made by all eight industries together is ₹261 billion against the ₹8.67 million gain from the energy savings. The considerable difference between the cost and

[36] For compliance, we dropped nine firms whose status shifted from treatment to control from our study sample.
[37] The extensive calculations are done by the government for deciding the PAT scheme participants make the intervention exogenous.
[38] The three additional assumptions are conditional parallel trends based on "Not-yet-treated" groups; a positive fraction of firms gets treated at a particular period.
[39] We use the "*csdid*" package in Stata for the estimation. It is superior to the two-way fixed effect (TWFE) technique as it does not suffer from the "negative weight problem" (A. Goodman-Bacon et al., 2019)

Table 9
Robustness test result.

Panel A: Alternative Matching Techniques and Period

Variables	Nearest neighbour matching	Caliper matching	PSM 2006	PSM 2007–10
	Log of Tobin's Q			
Treatment × Post	−0.018**	−0.018**	−0.017**	−0.018**
	(0.007)	(0.007)	(0.008)	(0.007)
Treatment	–	–	–	–
Post	–	–	–	–
Firm age	0.237	0.237	0.297	0.230
	(0.303)	(0.303)	(0.383)	(0.303)
Firm age square	−0.095	−0.095	−0.128	−0.090
	(0.123)	(0.123)	(0.160)	(0.123)
Firm size	0.029***	0.029***	0.029**	0.031***
	(0.011)	(0.011)	(0.012)	(0.011)
Liquidity	−0.094***	−0.094***	−0.093**	−0.091**
	(0.036)	(0.036)	(0.041)	(0.036)
R&D intensity	−1.479**	−1.479**	−1.337*	−1.200*
	(0.673)	(0.673)	(0.684)	(0.621)
Leverage	0.015***	0.015***	0.014***	0.015***
	(0.001)	(0.001)	(0.001)	(0.001)
Export intensity	0.002	0.002	−0.009	0.000
	(0.018)	(0.018)	(0.020)	(0.017)
Promoters	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.104	0.104	0.118	0.085
	(0.188)	(0.188)	(0.213)	(0.187)
N	3437	3437	2946	3544
R-squared	0.226	0.226	0.219	0.226
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Panel B: Alternative Dependent and Control Variables

Variables	Alternative dependent variables			Alternative control variables
	P/B Ratio	**ROA**	**ROE**	**Log of Tobin's Q**
Treatment × Post	−0.069***	−0.921*	−0.032	−0.036***
	(0.020)	(0.546)	(0.024)	(0.010)
Treatment	–	–	–	–
Post	–	–	–	–
Firm age	−0.435	22.534	0.650	0.743*
	(0.984)	(19.986)	(0.839)	(0.386)
Firm age square	0.157	−9.272	−0.286	−0.286*
	(0.388)	(8.097)	(0.334)	(0.156)
Firm size	−0.000	−0.281	0.038*	0.025***
	(0.024)	(0.585)	(0.020)	(0.009)
Liquidity	0.206*	6.926**	0.206**	−0.028***
	(0.110)	(3.438)	(0.080)	(0.007)
R&D intensity	−2.395	−60.982	−1.382	0.037
	(2.267)	(50.190)	(2.129)	(0.024)
Leverage	0.036***	−0.937***	−0.076***	0.251***
	(0.007)	(0.094)	(0.008)	(0.022)
Export intensity	0.022	3.949**	0.129**	−0.025
	(0.044)	(1.881)	(0.062)	(0.028)
Promoters	0.000	0.014	0.001	−0.000
	(0.001)	(0.021)	(0.001)	(0.000)
Constant	0.520	−6.682	−0.377	−0.277
	(0.743)	(14.777)	(0.602)	(0.291)
N	3340	3346	3348	1499
R-squared	0.134	0.152	0.323	0.390
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Panel C: Alternative Fixed Effects

Table 9 (*continued*)

Panel A: Alternative Matching Techniques and Period
Variables | Nearest neighbour matching | Caliper matching | PSM 2006 | PSM 2007–10 | Log of Tobin's Q

Variables	Industry Fixed Effects	Industry & Year Fixed Effects
	Log of Tobin's Q	
Treatment × Post	−0.019**	−0.019**
	(0.008)	(0.008)
Treatment	−0.010	−0.011
	(0.010)	(0.010)
Post	−0.016***	–
	(0.005)	
Firm age	−0.022	−0.034
	(0.163)	(0.162)
Firm age square	0.006	0.012
	(0.076)	(0.075)
Firm size	0.018***	0.019***
	(0.004)	(0.004)
Liquidity	−0.228***	−0.231***
	(0.074)	(0.074)
R&D intensity	−1.564	−1.524
	(1.444)	(1.442)
Leverage	0.022***	0.022***
	(0.002)	(0.002)
Export intensity	−0.058***	−0.058***
	(0.019)	(0.019)
Promoters	0.001***	0.001***
	(0.000)	(0.000)
Constant	0.370***	0.379***
	(0.059)	(0.058)
N	3340	3340
R-squared	0.356	0.364
Year FE	No	Yes
Industry FE	Yes	Yes

[1] In panel A, the dependent variable is the natural log of Tobin's Q. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011 (pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[2] In panel B, the P/B ratio, ROA, ROE, and the natural log of Tobin's Q are the dependent variables for columns 1, 2, 3, and 4, respectively. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011 (pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[3] In panel C, the dependent variable is the natural log of Tobin's Q. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011 (pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[4] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

Table 10
Staggered DID analysis.

	Log of Tobin's Q
ATT	−0.018**
	(0.008)

[1] The dependent variable is the natural log of Tobin's Q. We include cycle 1 (2012–2015) and cycle 2 (2016–2019). ATT is the effect on the treated population of the intervention.
[2] [*significant at 10%. **significant at 5%. ***significant at 1%.]

benefit is one of the probable causes for the decline in Tobin's Q. Fig. 5 highlights the investment made by each sector and drives our argument home.

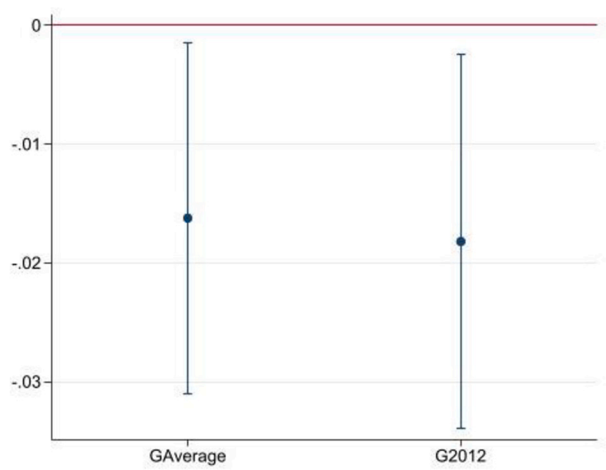


Fig. 4. Staggered DID.
Source: Authors' calculations.

To prove our conjecture, we run regressions with growth in gross property, plant and equipment (PPE), growth in net PPE, plant repairs and maintenance, and log of R&D expenditure as the dependent variables. We investigate the impact of the PAT scheme on the variables mentioned above by considering each of them as the dependent variable and estimate Eq. (1). Columns 1, 2, 3, and 4 of Table 11 present gross in PPE, growth in net PPE, repairs and maintenance of plants, and research and development, respectively. The coefficient of interest (β_1) is positive and statistically significant, indicating that the firms subject to the PAT scheme, on average, buy more PPE and spend more on repairs and maintenance of plants and research and development as compared to firms in the control group (not subjected to PAT scheme).

Rexhäuser and Rammer (2014) study regulation-induced environmental standards and voluntarily adopted commitments. The authors argue that implementing environmental standards increases firm value if an environmental standard induces energy or material efficiency. If the standard cannot enhance efficiency, it leads to a decline in the firm value. Our results suggest that the PAT scheme was unsuccessful in improving the energy efficiency of Indian firms subjected to the scheme, and therefore, it caused a fall in firm value. Thus, our results follow the findings of Rexhäuser and Rammer (2014). In addition, we study the PAT scheme's effect on the firm's productivity. Following Rexhäuser and Rammer (2014), we define productivity as total output over total input. We use sales as a proxy for total output and the cost of goods sold as a proxy for total input.

Column 5 of Table 11 presents the results. The coefficient of interest (β_1) is negative and statistically significant at a 1% level. It suggests that the PAT scheme reduced treatment firms' productivity compared to control firms and led to a decline in firm value. Our results align with the findings of Bagchi and Sahu (2020). The authors find a negative relation between productivity and energy intensity. Consequently, firms that cannot improve their energy efficiency might suffer from a decline in productivity. As a result, firm value might decline.

9. Conclusion and policy implications

Achieving energy efficiency is crucial in the fight against global warming and energy scarcity (L. Jiang et al., 2021). The Indian government launched a cap-and-trade scheme named the Perform, Achieve and Trade (PAT) scheme as its flagship program for enhancing the energy efficiency of large-sized industries in India. This paper investigates Porter's hypothesis that a well-designed environmental regulation can improve a firm's performance. More specifically, we test the impact of the PAT scheme on energy efficiency (proxied by energy intensity) and firm value (proxied by Tobin's Q). We use a quasi-experimental setting to investigate the impact of the PAT scheme on energy efficiency and firm value. To address the potential concern about "selection bias", we combine PSM with DID to account for both selections on observables and time-invariant unobserved heterogeneity.

Using firm level data for the period between 2006 and 2015, we do not find evidence that the PAT scheme has any influence on the energy efficiency of the firms. The results align with the prior literature (Misra, 2019; Sharma et al., 2019). A plausible reason for the ineffectiveness of the scheme is the availability of low-cost energy. Moreover, we also find evidence of the negative impact of the PAT scheme on firm value. The result supports the argument that regulation-induced environmental standards negatively affect the firm value. Subjecting to the PAT scheme, the average firm value (proxied by Tobin's Q) of treatment firms is lower by 1.7% compared to the average firm value of firms not subjected to PAT (control). We also study the scheme's impact on individual industries and find that the PAT scheme significantly harms the value of firms in the Chlor alkali industries.

Further, to deepen our analysis, we investigate the channels through which the PAT scheme affects the firm value. Our results suggest that the increased cost of repairs and maintenance, research and development

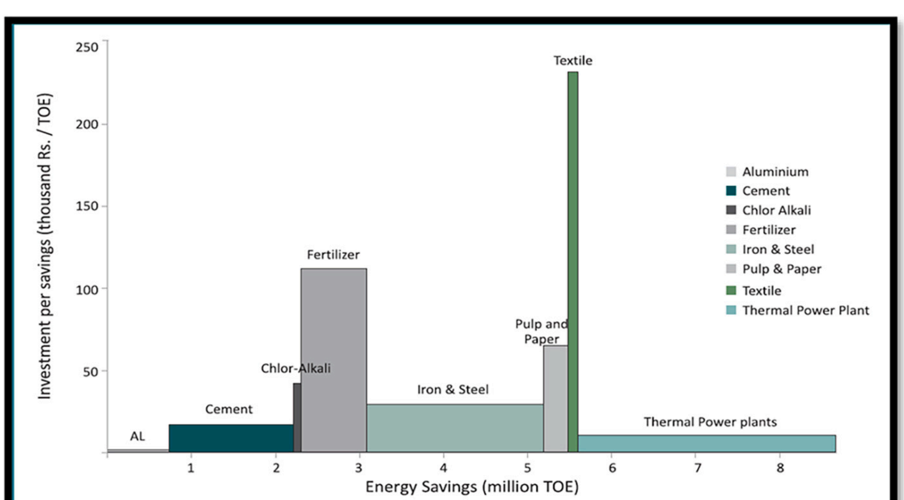


Fig. 5. Investment made by each industry for the savings made.
Source: BEE report "Enhancing energy efficiency through industry partnership (outcome and way forward)."

Table 11
Channels.

	Growth in Gross PPE	Growth in Net PPE	Repair And Maintenance of Plant	R&D Expenditure	Productivity
	(1)	(2)	(3)	(4)	(5)
Treatment ×Post	15.665*	21.043**	334.986**	0.203*	−0.046***
	(8.937)	(10.570)	(147.218)	(0.107)	(0.016)
Treatment	–	–	–	–	–
Post	–	–	–	–	–
Firm size	−5.513	3.144	115.837**	0.156***	0.002
	(12.342)	(13.200)	(48.828)	(0.046)	(0.013)
Firm age	120.345**	161.458**	−92.967	−0.515***	
	(60.805)	(69.591)	(245.883)	(0.177)	
Liquidity	−25.243	11.221	1247.041	−0.252	
	(37.527)	(54.446)	(1267.780)	(0.287)	
R&D intensity	68.370	4519.471			
	(438.295)	(3756.327)			
Profitability	48.817	−28.998		−0.167	
	(39.782)	(50.818)		(0.252)	
Leverage	−2.313	−1.360		−0.010	
	(2.268)	(2.164)		(0.009)	
Log of R&D					−0.019***
					(0.007)
Asset/sales					−0.002***
					(0.000)
Total energy cost					0.023***
					(0.008)
Export intensity				0.002	
				(0.001)	
Constant	−216.285	−390.036	−506.834	1.207**	1.329***
	(236.824)	(258.026)	(795.486)	(0.590)	(0.093)
N	4108	4099	3825	4186	3954
R-squared	0.039	0.044	0.028	0.116	0.193
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

[1] The dependent variables are growth in gross PPE, growth in net PPE, repair and maintenance of plant, the natural log of R&D, and productivity for Columns 1, 2, 3, 4, and 5, respectively. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011 (pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[2] All standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

and more purchases of property, plant and equipment led to the fall in firm value. Following Rexhäuser and Rammer (2014), we also test the impact of participation in the PAT scheme on firm productivity. The results indicate a decline in the firm's productivity, which could be a possible cause for the fall in the firm value. The study contributes in the following ways: first, it examines the broader impact of the PAT scheme. Unlike prior studies considering only one industry, we study six industries subjected to the PAT scheme. Second, we construct a unique dataset for the analysis by compiling firm level data with energy consumption data. Compared to prior studies, our dataset provides a better measure of energy efficiency. Third, our study is the first to evaluate the impact of the PAT scheme on the value of a firm.

Fourth, our results have important implications for policymakers. An environmental regulation should not hyper-focus on reducing environmental externalities but should provide a platform to enhance a firm's performance while reducing its carbon footprint. We suggest the government redesign the scheme to bridge the gap between the cost and the benefit of being a DC. Bhandari and Shrimali (2018) accentuate the unchallenging targets of the PAT scheme as its constraints. Furthermore, Dasgupta et al. (2016) compare the PAT scheme and EU-E, pointing out the adverse effects of lenient targets. The authors warn that the absence of stringency will lead to the overallocation of allowance (Escerts), leading to lower realised energy efficiency gains. Given the literature, we advocate for stringent targets to enhance the value of the scheme.

The study has a few limitations. First, the number of observations is less for a few industries. Second, the period under study is relatively small as we focus only on cycle I of the scheme. Therefore, we still need to learn more about the long-term impact of the PAT scheme on firm value. Third, though the scheme is applicable at a plant level, the non-availability of plant level data is a limitation to examining the scheme's true impact at the plant level. Future studies can shed light on some of these issues by considering plant level data. Our analysis calls for a stricter version of the PAT scheme to meet the net zero pledge.

CRediT authorship contribution statement

Kalyani Pal: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Jyoti Prasad Mukhopadhyay:** Writing – review & editing, Validation, Supervision, Methodology. **Praveen Bhagawan:** Writing – review & editing, Validation, Supervision, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Finance, Accounting, Accountability and Governance [ASFAAG], and Asian Meeting of The Econometric Society in East and Southeast Asia (AMES). All remaining errors are our own.

Appendix A. Appendix

Variable definition

Variable	Definition of variable	Units
Tobin's Q	(Book Value of Assets + Market Value of Equity – Shareholders' Funds) /Book Value of Assets (Black and Kim, 2012).	Unit-free
Energy intensity	The ratio of total energy consumed to total output. (Total Output = Sales + Change in the Stock of Finished Goods) (D. Chen et al., 2020)	Kilo calorie/rupee (₹)
Firm Age	Log of (Year- Incorporation Year) (Fang et al., 2009)	Years
Firm age square	Square of Log of Firm Age (Zhou et al., 2021)	*Years*^{2}
Firm size	Log of Total Assets (Allayannis et al., 2012; El Ghoul et al., 2017)	Unit-free (logarithmic)
Capital intensity	The ratio of net fixed assets to total assets. (Cole et al., 2006; Lan et al., 2011)	Unit-free (ratio)
Repair intensity	The ratio of plant repairs and maintenance to total output. (Sharma et al., 2019)	Unit-free (ratio)
R&D intensity	R&D/Sales (Misra, 2019; Oak and Bansal, 2017; Sharma et al., 2019)	Unit-free (ratio)
Export intensity	A ratio of export earnings to sales (Black and Kim, 2012)	Unit-free (ratio)
Promoters	Percentage of shares held by promoters (Pant and Pattanayak, 2007)	Unit-free (percentage)
Foreign promoters_dummy	A binary variable equals one if a firm has a foreign promoter or 0. (Pant and Pattanayak, 2007)	1 or 0
Liquidity	Cash and Cash Equivalents/Total Assets (Nini et al., 2012)	Unit-free (ratio)
Leverage	Borrowed fund/ own funds (Black and Kim (2012); Carter et al., 2001)	Unit-free (ratio)
Growth in gross PPE	(Gross PPE -Gross PPE_{t-1}/ Gross PPE_{t-1} (Muñoz, 2013)	Unit-free (ratio)
Growth in net PPE	(Net PPE -Net PPE_{t-1} /Net PPE_{t-1} (Muñoz, 2013)	Unit-free (ratio)
Productivity	Sales/COGS (Diewert and Nakamura (2005); Mitra and Chaya, 1996)	Unit-free (ratio)

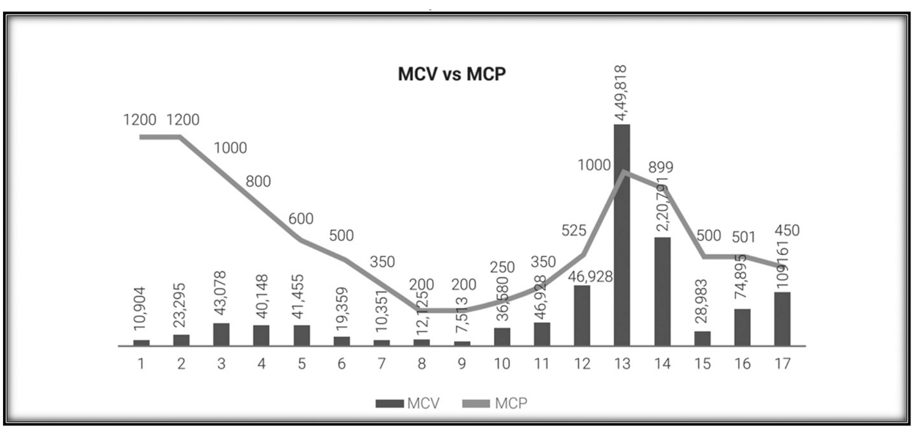


Fig. 1A. Market clearing Price and Volume for Escerts under PAT Cycle I.
Source: BEE report "Lessons learnt in Escerts Trading under PAT scheme: Experience at IEX during PAT cycle I, and Way forward."

Table A1
Pre-treatment distribution of firms per industry for the sample period (2006–2015).

Industry	Treatment	Control
Textile	318	1815
Paper n Pulp	151	409
Cement	207	593
Chlor-Alkali	155	2299
Iron n Steel	184	1188
Aluminium	30	301
N	1045	6605

The table provides an industry-wise distribution of firm-year observations.

Table A2
Probit regression of PSM.

	Log of Energy Intensity	Log of Tobin's Q
Firm age	4.275	6.187**
	(2.565)	(3.082)
Firm age square	−1.852	−2.751**
	(1.190)	(1.439)
Firm size	0.216**	0.320***
	(0.102)	(0.109)
Capital intensity	1.966***	2.028***
	(0.705)	(0.739)
R&D intensity	−2.36	−4.588
	(45.11)	(45.390)
Total energy cost	0.50***	0.311***
	(0.09)	(0.104)
Total energy consumed		0.139**
		(0.064)
Constant	−8.00***	−11.786***
	(1.20)	(1.917)
N	506	452
Log likelihood	−127.653	−116.800
Industry FE	YES	YES
LR chi2(11)	242.10	231.23
Prob > chi2	0***	0***
Pseudo R2	0.486	0.497

[1] This table shows the Probit regression of PSM with energy efficiency as the dependent variable in column A and the Probit regression of PSM with firm value as the dependent variable in column B.

Table A3
Robustness check for energy intensity.

	Power And Fuel Expenses/ Total Sales
Treatment × Post	−0.002
	(0.002)
Treatment	–
Post	–
Firm age	0.120
	(0.074)
Firm age square	−0.047
	(0.031)
Firm size	−0.002
	(0.003)
Capital intensity	0.029***
	(0.005)
Repair intensity	0.552***
	(0.168)
R&D intensity	0.134
	(0.128)
Export intensity	−0.003
	(0.007)
Promoters	−0.000***
	(0.000)
Constant	−0.028
	(0.045)
N	3858
R-squared	0.094
Firm FE	Yes
Year FE	Yes

[1] The dependent variable is energy intensity, per Oak and Bansal (2022).
[2] Treatment x Post is the primary interaction term. Treatment = 1 if a firm belongs to the first three deciles of the control group or else 0. Post is 0 for 2006–2011 (pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[3] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

Table A4
Heterogeneity analysis.

	Log of energy intensity					
VARIABLES	Textile	Paper & Pulp	Cement	Chlor-alkali	Iron & Steel	Aluminium
Treatment ×post	−0.137	0.040	0.113	−0.260	0.041	0.098
	(0.171)	(0.108)	(0.313)	(0.203)	(0.273)	(0.180)
Treatment	–	–	–	–	–	–
Post	–	–	–	–	–	–
Firm age	−3.068	−0.491	22.266	−4.808	−17.042*	88.256
	(6.420)	(46.239)	(41.576)	(4.855)	(9.779)	(245.942)
Firm age square	1.164	0.963	−8.194	2.271	6.566*	−40.691
	(2.528)	(21.412)	(18.282)	(1.940)	(3.801)	(114.087)
Firm size	−0.500**	−0.324**	−0.152	−0.344**	−0.272*	−0.569**
	(0.237)	(0.125)	(0.420)	(0.134)	(0.162)	(0.187)
Capital intensity	0.933**	−0.234	0.369	0.168	1.915**	1.146
	(0.368)	(0.254)	(0.872)	(0.342)	(0.799)	(0.885)
Repair intensity	−4.396	3.084	−24.913	30.342***	−2.037	38.313**
	(14.908)	(5.795)	(25.163)	(11.313)	(8.087)	(13.182)
R&D intensity	6.351	114.905*	−150.287	12.037	−39.384	−114.065**
	(38.876)	(60.677)	(127.259)	(8.782)	(77.622)	(40.665)
Total energy cost	0.886***	0.704***	0.508**	0.673***	0.559***	0.417***
	(0.090)	(0.177)	(0.215)	(0.109)	(0.104)	(0.082)
Export intensity	−0.488	−3.258**	−1.847	0.186	−0.807	−0.634*
	(0.429)	(1.257)	(1.620)	(0.390)	(0.701)	(0.317)
Promoters	0.005	−0.013**	0.010	−0.001	−0.007**	0.014
	(0.007)	(0.005)	(0.018)	(0.005)	(0.003)	(0.015)
Constant	18.463***	12.897	−5.772	16.545***	28.992***	−8.282
	(3.914)	(13.972)	(19.797)	(3.897)	(8.310)	(68.837)
Observations	940	160	277	1069	464	67
R-squared	0.289	0.578	0.204	0.354	0.238	0.844
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

[1] The dependent variable is the natural log of Energy intensity. Treatment x Post is the primary interaction term. Treatment = 1 if a firm is subjected to the PAT scheme or 0 otherwise. Post is 0 for 2006–2011(pre-treatment period) and 1 for 2012–2015 (post-treatment period).
[2] Standard errors are clustered at the firm level in parentheses. All accounting ratios are winsorised at 1% and 99% levels. [*significant at 10%. **significant at 5%. ***significant at 1%.]

Appendix

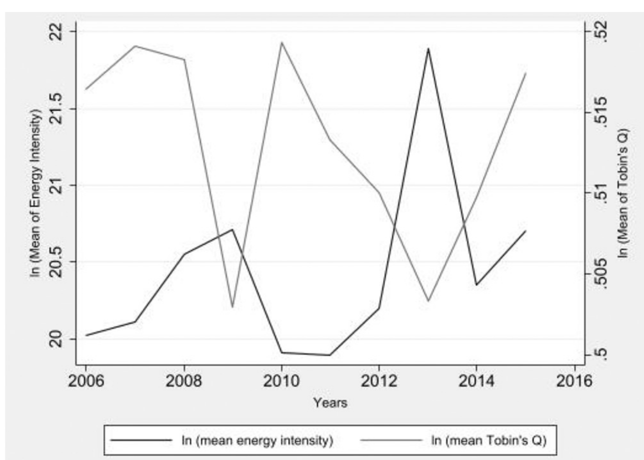
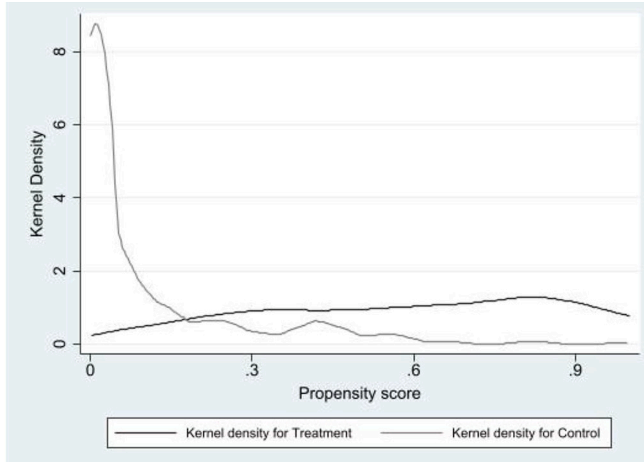


Fig. 1. Mean Distribution of Dependent Variables.
Source: Authors' calculations.



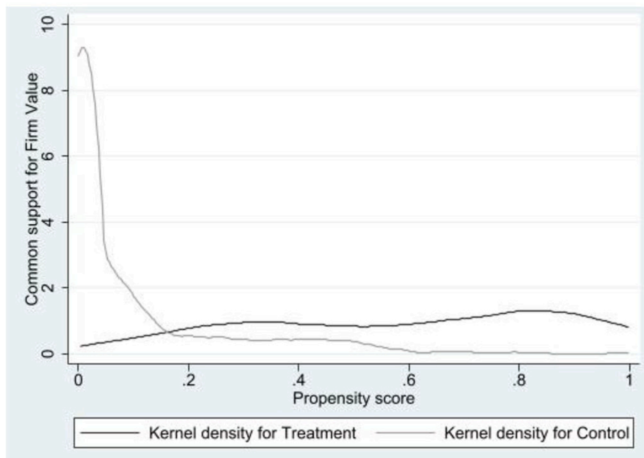


Fig. 2. a: Common Support for PSM (Kernel Matching).
Source: Authors' calculations.
Fig. 2**b:** Common Support for PSM (Kernel Matching).
Source: Authors' calculations.

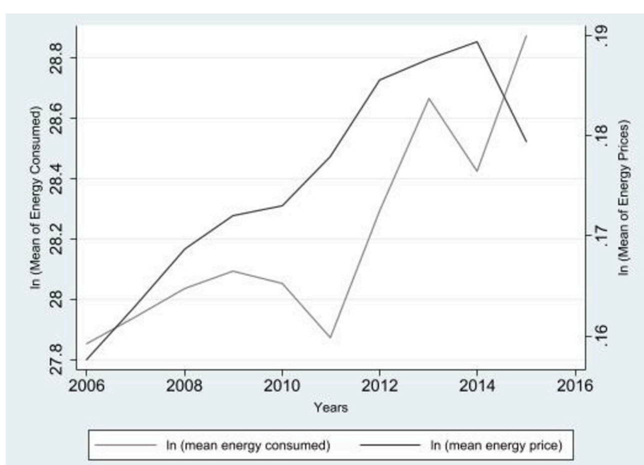


Fig. 3. Trend in Energy Consumption and Energy Price.
Source: Authors' calculations.

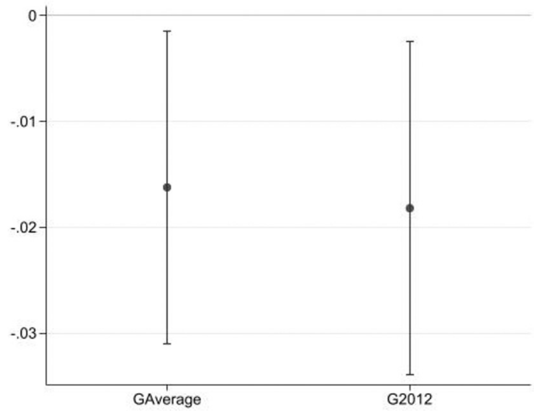


Fig. 4. Staggered DID.
Source: Authors' calculations.

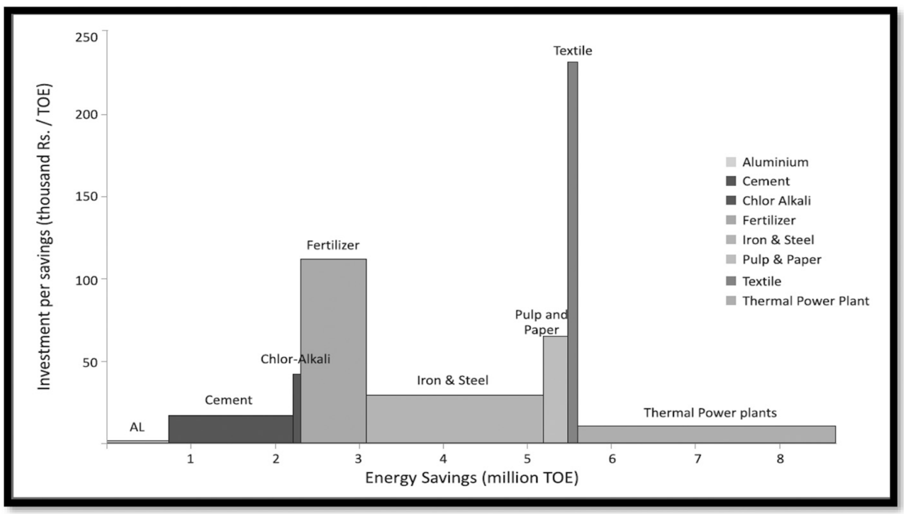


Fig. 5. Investment made by each industry for the savings made.
Source: BEE report "Enhancing energy efficiency through industry partnership (outcome and way forward)."

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2024.107581.

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