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Article

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An Assessment of the Relationship between Profitability and Energy Intensity for Technology Oriented Manufacturing Firms in India

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ABSTRACT

The hypothesis put forth by Porter and Linde (1995) suggests imposing regulation to promote energy efficiency can lead to improved innovation and performance among firms. This study seeks to explore this theoretical premise in the Indian manufacturing sector by analysing the influence of energy intensity on profitability of firms belonging to the Perform Achieve and Trade (PAT) regulated sectors, with a particular focus on classifying technology oriented firms. The study examines seven manufacturing industries from the first cycle of the PAT policy. Two measures of energy intensity indicators, namely the physical economic indicator and the economic indicator, are included in the study. The empirical analysis is divided into two categories: Firms that import technology (714 firms) and firms that do not import technology (752 firms). The study employs panel data analysis with a fixed effect model to conduct the analysis for the time period 2011-2020. Based on empirical analysis, it appears that firms that import technology exhibit a negative relationship between energy intensity and firm performance. Non-technology importing firms exhibit a similar relationship but with a higher coefficient value for energy intensity. The study also includes control variables such as firm size, age, capital intensity, raw material imports, and market concentration. The results show that relatively small to medium-sized firms, which are also young and striving to expand their market size, achieve energy efficiency gains. This highlights the reluctance of established players to improve their performance efficiency through technological up gradation.

Keywords: Energy Intensity, Energy Efficiency, Regulation, Technology, Firm Performance
JEL Classifications: L1, L25, Q4

1. INTRODUCTION

Energy is a vital resource that drives the industrial sector. Right from the production technique to the final product distribution, every process relies on energy. Considering the rising climate change issues, there has been a growing emphasis on reducing fossil fuel consumption and achieving energy efficiency. In these circumstances, however, a trade-off exists between a firm's environmental and economic performance (Porter and Linde, 1995). According to the International Energy Agency, India's Gross Domestic Product (GDP) is expected to rise from \$9 trillion in 2018 to \$49 trillion in 2050, with an average annual growth rate of 5.4%. However, this growth will come with a significant increase in energy consumption, doubling from 5.7% in 2018 to 13.2% in 2050 (IEA, 2020). Despite efforts to diversify, coal, oil, and solid biomass remain India's primary sources of fuel consumption, accounting for 80% (IEA, 2021). It is also worth noting that India's manufacturing industry has one of the highest energy consumption rates globally. Against this backdrop, this study examines the relationship between energy intensity and the economic performance of manufacturing firms operating in India. Manufacturers can drive sustainable change in the manufacturing sector by adopting clean technology solutions that enhance their energy inputs, optimise processes, and improve logistics. Some prior studies have identified technological advancements and input prices as critical drivers of industry energy demand shifts that can reduce energy consumption, improve energy production efficiency, and replace fossil fuels with renewable energy sources; Ethridge (1973), Roy et al. (1999), Fischedick et al. (2014), and Lund (2007). Hence, our unit of analysis is the technology-oriented manufacturing firms. Precisely, we attempt to analyse the impact of the economic and physical economic measurements of energy intensity on profitability of these manufacturing firms.

In 2010, the Bureau of Energy Efficiency (BEE, 2020) introduced the perform achieve and Trade (PAT) policy as a market-based approach to boost the cost-effectiveness of energy efficiency improvements in energy-intensive industries. Oak and Bansal (2022) and Misra (2019) report improved energy efficiency due to PAT policy in the Cement, Fertiliser, Iron, and Steel industries. We therefore examine the firms belonging to the seven manufacturing industries that are part of the first PAT cycle, namely, Aluminium, Cement, Chemical (Including fertiliser and Chlor Alkali), Paper and Pulp, Iron and steel, Textile and Thermal Power plants. An unbalanced panel of 714 firms is examined for the time period 2011-2020.

The paper is organised as follows. Section 2 provides the literature review and development of our hypotheses. Section 3 presents the descriptive statistics. Section 4 describes the estimation methods and highlights the empirical findings. Finally, Section 5 summarises the paper.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

There has been theoretical and empirical debate over the balance between environmental and economic performance. According to neo-classical theorists such as Palmer et al. (1995), environmental regulations may stimulate innovation. However, these new developments may not completely cover the financial costs of pollution control. Another argument suggests that improved environmental benefits lead to an increase in costs. This view is based on the premise that pollution abatement and environmental improvements have decreasing marginal net benefits (Walley and Whitehead, 1994). Contrary to the above argument, Porter (1991) proposed that stringent environmental regulation helps in higher productivity and innovation, enhancing competitiveness in the sector; also see, Cohen et al. (2018). Porter and Linde (1995) further explored and developed this concept. The authors identify the following benefits of well-designed regulation. First, it suggests that environmental regulations must be stringent; this creates pressure and helps companies to become more efficient. Second, environmental regulation promotes innovation. Together, these two effects neutralise the cost of stringent regulation and improve firms' competitiveness.

However, empirical studies provide inconclusive findings. King and Lenox (2001) found a positive association between environmental control and financial performance, but the relationship is conditional on firm-specific characteristics and their strategic positioning in the market. Another study by Russo and Fouts (1997) reports a positive relationship between environmental performance and profitability claiming that this relationship is stronger among high-growth industries. On the other hand, Cordeiro and Sarkis (1997) studied the relationship between a firm's proactiveness on environmental actions and firm performance. Results reported a negative relationship suggesting that environmental practices may incur short-term costs and hinder forecast earnings. Stakeholders may not fully value the long-term benefits of environmental performance. The study results of Jaggi and Freedman (1992) also report a negative association between pollution control and economic performance and highlight the need for stricter environmental regulation to encourage firms to prioritise pollution reduction.

Similar to environment performance studies, energy efficiency studies also provide mixed evidence. Pons et al. (2013) examine the impact of Energy Saving Technologies (EST) and Material Saving Technologies (MST) on environmental performance and firm performance. The study finds that EST and MST adoption improves environmental performance. However, they have no impact on economic performance. Chinese energy-intensive firms show a positive relationship between energy efficiency and financial performance (Fan et al., 2017). A study by Moon and Min (2020) finds variations in improvement in energy efficiency across industries. However, there is no significant relationship between financial performance and energy efficiency. Undertaking energy-efficient technological practices depends on government regulation, policies, and firm-level sustainable production techniques. With added financial costs, such practices may be viewed as a burden rather than an opportunity for technological upgradation and improved productivity; see, Subrahmanya (2006); Bunse et al. (2011); Pons et al. (2013).

We individually analyse existing literature on the dependent, independent, and control variables to support our hypotheses development.

2.1. Firm Performance

According to prior research by Sahu and Sharma (2016), Soni et al. (2017), Fan et al. (2017), Feng et al. (2018), Sharma et al. (2019), and Kumar et al. (2023), there is a negative relationship between energy intensity and firm performance. For instance, Kumar et al. (2023) found that firms can reduce energy consumption by investing in the latest technical know-how, machinery and plants. Feng et al. (2018) suggest that firms with better access to financing may be able to invest in more fuel-efficient technologies or processes, thereby reducing their energy intensity and potentially improving profitability.

2.2. Energy Intensity

Energy intensity is a proxy measure of energy efficiency, often defined as fuel consumption per unit of output. Energy efficiency, on the other hand, refers to reducing energy consumption while maintaining the same output level (Bhattacharyya, 2019). Studies have shown an inverse relationship between energy intensity and energy efficiency (Zhang, 2016). Following Patterson (1996), we measure energy intensity using the physical-economic and economic indicators. The former measures energy input in physical units and output in economic units, such as electricity consumption in kilowatts and output in terms of net sales. The economic indicator is derived using the energy cost and net sales information. Given the existing empirical works, our first hypothesis is that there exists a negative relationship between energy intensity and firm performance.

2.3. Import Intensity of Raw Materials

We identify that the import of raw materials is embodied with the latest upgraded technical prowess and may contribute towards improving firm performance. Studies conducted on the manufacturing sectors in India, Chile and Germany exhibit a positive correlation between imported intermediated inputs and productivity (Sharma, 2014; Kasahara and Rodrigue, 2008; Vogel and Wagner 2010). Few others suggest that trade in intermediate goods and other inputs can enhance energy performance. A study by Imbruno and Ketterer (2018) reports that importing intermediate goods enhances energy efficiency in Indonesian firms. Similarly, Zhao and Lin (2020) found that importing textiles or efficient machinery in China's textile industry can incentivize domestic firms to innovate and adopt energy-efficient technologies. Our second hypothesis aims to test this positive impact of import intensity (raw materials goods) on firm performance.

2.4. Firm Size

Hall and Weiss (1967) highlight the complexity of the relationship between firm size and profitability as it is influenced by firm characteristics and the industry specifics in which the firms operate. For instance, in an imperfect market structure, firm size positively impacts profitability, as economies of scale plays an important role in these industry structures. In the recent empirical literature, we identify mixed evidence with respect to the relationship between firm size and firm performance. Fan et al. (2017) estimate a positive relationship between firm size and performance in the case of Chinese energy-intensive firms. In the context of India, Sahu and Narayanan (2014) report a nonlinear relationship (inverted-U) between profitability and firm size, indicating that bigger and smaller firms are less profitable than medium-sized firms. Singla (2011) measures the relationship between profitability and firm size in the Indian textile industry and finds a positive relationship between the variables. With respect to energy performance of firms, Golder (2011) and Mandal and Madheswaran (2011) find a positive relationship between firm size and energy intensity. Considering the mediating role of firm size in influencing the relationship between energy intensity and firm performance we hypothesize (third hypothesis) a significant relationship between the interaction effect of firm size and energy intensity on profitability of firms.

2.5. Firm Age

In the Indian context, Majumdar (1997) finds a negative relationship between firm age and profitability. Similarly, Sahu and Narayanan (2014) reports a negative relationship between profitability and firm age, indicating that older firms are less profitable than younger firms. Macharia et al. (2022) finds a positive relationship between firm age and performance for the manufacturing firms in Kenya, suggesting older firms might have accumulated knowledge, developed skills, and established networks. With energy intensity as the dependent variable, Jain and Kaur (2023) found that younger firms tend to be more energy-intensive, indicating an inverse relationship between age and energy intensity. Considering the moderating role of firm age in influencing the relationship between energy intensity and firm performance we hypothesize (fourth hypothesis) a significant relationship between the interaction effect of age and energy intensity on profitability of firms.

2.6. Market Concentration

We have measured market concentration using the Herfindahl-Hirschman Index (HHI). According to Harrison (1994), market competition significantly influences how firms behave and perform. In highly competitive markets, firms are constantly pressurized to innovate, improve efficiency, and lower prices to remain competitive. Shaurav and Rath (2023) report that firms with high market concentration (measured by the HHI) showed better performance in terms of profitability. This suggests that concentrated markets offer advantages like economies of scale, bargaining power, and reduced competition, leading to improved performance. However, there exist inconclusive evidences as regards the role of market structure. While some suggests a linear relationship between firm performance and market structure variables, others provide evidences of a non-linear association between the two. We test for this non-linearity in our econometric model specification and hypothesise (fifth hypothesis) a significant relationship between HHI and profitability.

2.7. Capital Intensity

Capital-intensive firms may experience increased risk due to significant fluctuations in profitability (Shapiro and Titman, 1986). This is because a business with more fixed assets incurs a high level of fixed costs in generating profits, which do not vary with sales volume and can lead to more significant fluctuations in profits; Myers (1984). As a result, high capital intensity can increase cost of capital and lower firm value.

Our sixth hypothesis aims at testing the negative relationship between capital intensity and firm performance.

To recall, our empirical study is based on classifying firms based on technology imports. In order to understand the role of technology imports in embodied form vis-à-vis the net fixed assets at the firm level (used for generating the capital intensity variable), we include the import intensity of capital goods as a control variable in one of our econometric models. Notably, Coe and Helpman (1995) reported that imports incorporating foreign R&D have a considerable effect on the productivity growth of the home country. Furthermore, they suggested that this impact is even more pronounced in economies more open to international trade. Additionally, Hasan (2002) observed a significant positive impact from both embodied and disembodied technology purchased in the manufacturing sector. Hence, we expect that technology imported in embodied form boosts firm performance. At the same time, we also examine the sign and significance of technology imports interacting with firm level capital intensity as these are pertinent for augmenting the technological capability of firms; Teece (2007); Teece (2018).

3. DATA AND DESCRIPTIVE STATISTICS

Data for the study is collected from the Centre for Monitoring Indian Economy (CMIE) Prowess Database. Data collection is based on the National Industrial Classification at the three-digit level. Initial data extraction generated 5425 firms belonging to the following seven industries—Aluminium, Cement, Chemical (Including fertiliser and Chlor Alkali), Paper and Pulp, Iron and steel, Textile and Thermal Power plants, see Appendix 2 for industry groups details. Out of these, 3977 firms reported net sales data.[1] Further data cleaning based on the availability of information for all the control variables used in the final econometric model gave us a maximum of 714 firms (that reported their import of capital goods) and 752 firms not importing capital goods. Details of variable measurement are provided in Table 1.

Table 2 includes summary statistics for technology-importing firms. As mentioned earlier, this data set consists of 714 firms. The average deflated energy intensity for a physical economic indicator of all seven industries combined is 2028.54, see Appendix 3 for energy sources classification. Individually, the average energy intensity for electricity in the textile industry is 1415.90; for the paper industry, it is 3914.54; the cement industry reports 1065.936, chemical industry is 2152.14; the iron and steel industry, 752.616; for aluminium, it is 980.588; and for the thermal power plants, it is 4439.648.

The average deflated energy intensity in terms of cost, as mentioned in Table 2, is 0.000842. The textile industry has 0.000107; the paper industry has 0.000188; the chemical industry has 0.000353; the cement industry has 0.00569; the iron and steel industry reports 0.0000817; the aluminium industry reports 0.0000779, and the thermal industry reports 0.000245. Firm age ranges from 1 year to 136 years old firms. Summary statistics of HHI and firm size suggest that a perfectly competitive industry structure defines the firms operating space, with a majority of small fringe firms. The average HHI is 38.984, and average market share is 0.082.

Table 3 presents summary statistics for non-technology importing firms. The average deflated energy intensity (electricity) combined for seven industries is 519981.8. The textile industry's average is 22554.88; the pulp and paper industry's average intensity is 1699361.42; the chemical industry is 269388.02; the cement industry's average is 546949.89; the iron and steel industry is 11558017.75; the aluminium industry is 53520.09 and for the thermal power industry calculated average is 53520.09.

For energy cost intensity, the combined average for seven industries is 0.193. The pulp and paper industry average is 2.581; the textile industry is 0.138; the Chemical industry average is 0.329; the cement industry is 0.003; the iron and steel industry average is 0.602; the aluminium industry average is 0.011, and the thermal power industry average is 0.002.

Figure 1 presents the trend for physical economic indicators of energy intensity. The figure indicates non-technology importing firms are more energy intensive than technology importing firms. This suggests that technology import helps in achieving energy efficiency.

Figure 2 shows that non-technology-importing firms are more energy intensive (with respect to the economic indicator of energy intensity) than technology-importing firms.

Figure 3 presents average net sales of firms belonging to the two groups of firms (technology importing vis-à-vis technology non-importing). The bar graph suggests technology importing firms have higher net sales than non-technology importing firms for the time period 2011-2020.

4. EMPIRICAL MODEL

Our econometric model is based on the time period 2011-2020. The model in Equation 1 presents the base model, which includes technology-importing and non-technology-importing firms. EI stands for the alternate energy intensity indicators. The number of observations differs for each energy intensity indicator, and the dataset includes an unbalanced panel.

1. As we are looking into the technological orientation of firms, we further screen our dataset based on the reporting of information on import of capital goods. We find that 1,566 firms report import of capital goods information, whereas the remaining 3,864 did not report such imports. To note, there are firms that import capital goods in some years from 2011 to 2020, whereas, they may not import in other years.

Table 1: Details of variable measurement

Variable	Measurement of variable	Symbol
Profitability	Profit after tax divided by net sales	FP
Electricity intensity: Physical Economic indicator of energy intensity (ln)	Electricity consumption in quantity (Kilowatt) divided by deflated net sales	EI
Energy cost intensity: Economic indicator of energy intensity (ln)	Deflated energy cost (Rs million) divided by deflated net sales.*	EI
Firm size	Market share in the respective industry (%).	FS
Firm age	Year of incorporation minus study period	FA
HHI	HHI is the sum of squared market shares for all n firms at the three-digit industry group level.	HHI
Capital intensity (ln)	Net fixed assets divided by net sales	CI
Import Intensity (Raw materials)	Import of raw materials divided by net sales	IRI
Import Intensity (Capital goods)	Import of capital goods divided by divided by net sales	ICI

ln signifies the variables in natural log form. *Energy cost is constructed as the sum of cost for all fuel types divided by net sales. These fuel types includes, Coal, Coal gas, steam coal, High-speed diesel, furnace oil, electricity, Briquettes, light diesel oil, Liquefied petroleum gas, firewood, natural gas, coke, and lignite, HHI: Herfindahl-Hirschman index

Table 2: Summary statistics of technology importing firms

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Profitability (FP)	5,765	−0.019	1.062	−43.509	3.32104
Deflated Energy Intensity[2] (Electricity) (EI)	2,761	2028.541	26799.84	0.0016	929054
Deflated Energy Intensity (Cost) (EI)	2,770	0.0008	0.033863	6.40E-10	1.77743
Herfindahl Hirschman Index (HHI)	5,765	38.984	22.949	0.00017	164.375
Firm Age (FA)	5,765	29.859	19.630	1	136
Capital Intensity (CI)	5,762	1.820	26.457	0.003	1126.36
Import Intensity (Raw Materials- RMI)	4,526	0.169	0.497	0.000021	28.9344
Import Intensity (Capital Goods - CI)	5,765	0.609	16.089	6.70E-06	845.6
Firm Size (FS)	5,765	0.082	0.271	3.03E-06	5.403

Author constructed table, data source CMIE prowess

Table 3: Summary statistics of non-technology importing firms

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Profitability	22,194	−0.65427	20.14956	−1726	978.5
Deflated energy intensity (Electricity)	6,113	519981.8	2.13E+07	0.000528	1.40E+09
Deflated energy intensity (Cost)	6,345	0.193685	9.737	3.90E-10	741.758
Herfindahl hirschman index	22,194	40.39441	21.275	0.000171	164.944
Firm age	22,180	25.51181	16.951	1	143
Capital intensity	22,080	10.892	419.222	−0.01471	40037
Import intensity (raw materials)	5,170	0.209	1.547	7.20E-06	88.3333
Firm size	22,194	0.021	0.093	3.03E-07	4.135

Author constructed table, data source CMIE prowess

$$PF_{it} = \beta_0 + \beta_1 EI_{it} + \beta_2 IRI_{it} + \beta_3 FA_{it} + \beta_4 HHI_{it} + \beta_5 HHI_{it}^2 + +\beta_6 FS_{it} + \beta_7 CI_{it} + \mu_{it} \tag{1}$$

To understand the impact of firm size on improving energy efficiency and its overall impact on firm performance, we introduce the interaction terms of firm size and energy intensity.

$$FP_{it} = \beta_0 + \beta_1 EI_{it} + \beta_2 IRI_{it} + \beta_3 FA_{it} + \beta_4 HHI_{it} + \beta_5 HHI_{it}^2 + +\beta_6 FS_{it} + \beta_7 CI_{it+} + \beta_8 FS_{it} EI_{it} + \mu_{it} \tag{2}$$

Equation 3 presents an equation for interaction term of firm age and energy intensity.

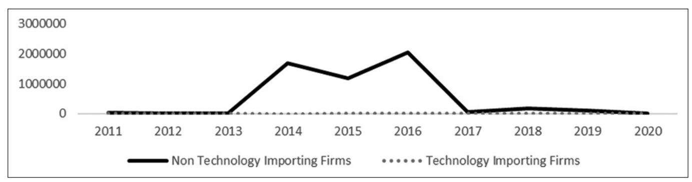
$$FP_{it} = \beta_0 + \beta_1 EI_{it} + \beta_2 IRI_{it} + \beta_3 FA_{it} + \beta_4 HHI_{it} + \beta_5 HHI_{it}^2 + +\beta_6 FS_{it} + \beta_7 CI_{it+} + \beta_8 FA_{it} EI_{it} + \mu_{it} \tag{3}$$

Model Specification is based on Hausman (1978) test results. For technology importing firms, χ^2 values is 69.95 (with P = 0.000). Our initial hypothesis that the individual-level effects are adequately modelled by a random-effects model is rejected. Fixed effect model is used for the analysis based on the mentioned results. For non-technology importing firms the computed χ^2 value is 31.44 (with P = 0.000). Therefore, we report and interpret the fixed effect models in the following subsection.

4.1. Empirical Findings

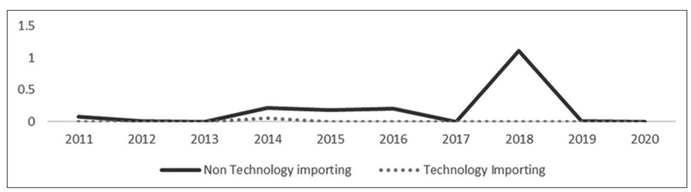
Interplay of a series of firm-specific and industry-specific attributes determines the relationship between energy intensity and firm performance at the firm level. This study focuses on the role of some crucial factors, such as firm experience, the market structure in which a firm operates, their reliance on the import of embodied technology along with other raw material and intermediate inputs, and firm-level investment towards building up fixed assets. Further, the empirical analysis attempts to address the theoretical contention concerning the role of technology adaptation in augmenting energy efficiency and thereby boosting firm performance.

Figure 1: Physical economic indicator of energy intensity



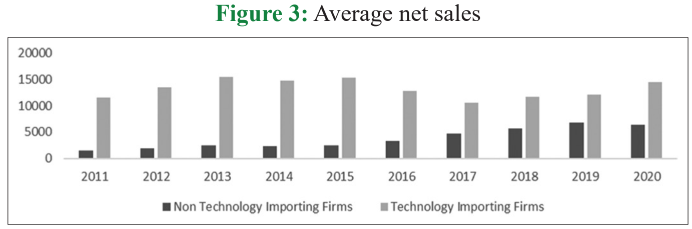
Author constructed graph, data source: CMIE Prowess, Values presented in the graph are of deflated energy intensity

Figure 2: Economic indicator of energy intensity



Author constructed diagram, Data Source: CMIE Prowess, values presented in the graph are of deflated energy intensity

Figure 3: Average net sales



Author constructed diagram, Data Source: CMIE Prowess

2. Values are deflated based on the Wholesale Price Index (WPI) provided by the Office of Economic Advisory, Government of India. Details are provided in Appendix 2 and 3.

The results clearly illustrate the positive influence that embodied technology has on the energy efficiency of manufacturing firms operating in India. As can be seen from models 1 and 5 in Tables 4 and 5, the coefficient of energy intensity for technology importing firms is relatively lower than for firms not importing technology. For instance, the statistically significant coefficient of electricity intensity for firms importing capital goods is −0.075, whereas for the non-importing firms, it turns out to be −1.924. Hence, while the technology importing and non-importing firms appear to be efficient the efficiency is higher for the former. Graphical representation of average energy intensity (Figures 1 and 2) for the period 2011-2020 reveals a similar pattern. The average electricity consumption per unit of deflated net sales for technology importing firms is 1740.55 compared to 530748.9 for non-importing firms. The average deflated energy cost per unit of deflated net sales for technology importing firms is 0.0005 compared to 0.180 for technology non-importing firms.[3]

As we include the control variables, while energy intensity remains a statistically significant coefficient for the technology-importing firms, it loses its significance for the firms not importing technology.

Import intensity of raw material has a negative coefficient and is statistically significant at 1% significance level, while the variable is not significant for the technology non-importing firms. As can be seen from Figure 3, the average net sales of technology-importing firms are higher compared to the technology-nonimporting firms.

3. Author's calculation based on the CMIE Prowess database.

The results suggest that the technology importing firms may have financial constraints and funds inadequacy for importing raw material. Concomitantly, the finding also point towards the development of complementary in-house technology by these technology importing firms by undertaking in-house R&D activities (To note, the average R&D intensity of technology importing firms hovers around 2.28% compared to the average R&D intensity of 1.57% for firms not importing capital goods, standard deviation being 0.36% and 0.82% respectively; Authors calculation from CMIE Prowess Database). The average import intensity for the time period 2011-2020 for the technology importing firms is 16.63% compared to 21.07% for the technology non-importing firms. A high import intensity of raw materials for technology non-importing firms can be attributed to their low firm size (Figure 3) as the average import of raw material in Rs. Million stands at 2532.35 for technology importing paper vis-a-vis 552.599 for the non-importing firms.

An interesting finding is with respect to the role of market structure in which these firms are operating. While competitiveness remains irrelevant in influencing firm performance of technology non-importing firms, it turns out to be an important variable in influencing profitability of firms importing capital goods. In fact, this sensitivity of the firm performance of technology-oriented firms to market structure exhibits a non-linear relationship. It appears that an optimal number of firms exists that maximises firm performance, as illustrated by a statistically significant inverted U-shaped relationship between HHI and profitability of firms importing capital goods.

Table 4: Fixed effects empirical estimates for the econometric model with the physical economic indicator of energy intensity

Variables	Embodied technology firm				Non-embodied technology firms			
dependent variable profitability	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Energy Intensity (EI)	−0.075**	−0.023**	−0.031**	−0.052**	−1.924**	−0.106	−0.116	−0.198
	(−2.13)	(−2.06)	(−2.12)	(−1.90)	(−2.10)	(−1.24)	(−1.30)	(−1.42)
Import Intensity (raw		−1.084***	−1.076***	−1.075***		−0.292	−0.295	−0.288
materials)		(−2.42)	(−2.40)	(−2.39)		(−0.63)	(−0.64)	(−0.63)
Firm Age (FA)		−0.004	−0.004	−0.008**		−0.001	0.002	−0.023
		(−0.97)	(−0.99)	(−2.32)		(−0.36)	(0.49)	(−1.39)
Herfindahl-Hirschman		0.002***	0.002***	0.002***		0.001	−0.001	0.0008
Index (HHI)		(3.00)	(2.69)	(2.96)		(0.56)	(−0.84)	(0.47)
HHI^2		−0.00002**	−0.00001**	−0.00002***		−4.27e−06	0.00001	−3.06e−06
		(−2.37)	(−2.17)	(−2.36)		(−0.24)	(0.90)	(−0.17)
Firm Size (FS)		−0.057	−0.125*	−0.050		−0.512	−4.654	−0.396
		(−1.33)	(−1.77)	(−1.19)		(−0.60)	(−1.56)	(−0.49)
Capital Intensity (CI)		−0.188***	−0.183***	−0.183***		−0.185*	−0.172*	−0.181*
		(−3.18)	(−3.18)	(−3.20)		(−1.69)	(−1.70)	(−1.69)
EI*FS			0.056*				1.760*	
			(1.77)				(1.79)	
EI*FA				0.0009*				0.003
				(1.66)				(1.44)
Constant	0.411**	0.190	0.231	0.344**	12.263**	0.418	0.372	0.976
	(2.24)	(1.20)	(1.44)	(2.11)	(2.03)	(0.72)	(0.68)	(1.14)
No. of observations	2,761	2210	2210	2210	6,113	2033	2033	2033
No. of groups	862	705	705	705	1,577	723	723	723
R^2 Within	0.0368	0.2012	0.2028	0.2038	0.0576	0.0462	0.0500	0.0500
R^2 Between	0.0538	0.1360	0.1439	0.1367	0.0206	0.1263	0.1022	0.1022
R^2 Overall	0.0413	0.1388	0.1470	0.1386	0.0277	0.0501	0.0452	0.0452
F statistics	4.53**	3.62***	3.16***	3.18***	4.41**	4.05***	3.39***	3.39***

Data Source, CMIE Prowess. Values within the parentheses are the t-values *, **, *** stands for 10%, 5%, and 1% significance level respectively

Table 5: Fixed Effects Empirical Estimates for the econometric model with the economic indicator of energy intensity

Variables	Embodied technology firms				Non-embodied technology firms			
dependent variable profitability	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Energy Intensity (EI)	−0.102** (−2.32)	−0.065** (−2.33)	−0.075*** (−2.42)	−0.117*** (−2.54)	−1.519** (−2.07)	−0.137 (−1.63)	−0.161* (−1.67)	−0.146 (−1.07)
Import intensity (raw materials)		−1.061*** (−2.44)	−1.053*** (−2.45)	−1.044*** (−2.41)		−0.240 (−0.60)	−0.237 (−0.60)	−0.240 (−0.61)
Firm Age (FA)		−0.007** (−2.17)	−0.006* (−1.79)	0.014 (1.38)		−0.007 (−1.08)	−0.005 (−0.90)	−0.004 (−0.22)
Herfindahl-Hirschman Index (HHI)		0.002*** (2.94)	0.002** (2.31)	0.002*** (2.88)		0.002 (0.82)	0.0004 (0.25)	0.002 (0.79)
HHI^2		−0.00002*** (−2.41)	−0.00001** (2.01)	−0.00002*** (−2.36)		−0.00001 (−0.57)	−1.38e-06 (−0.07)	−0.00001 (−0.55)
Firm size (FS)		−0.075 (−1.55)	2.221*** (2.78)	−0.066 (−1.45)		−1.037 (−0.52)	26.189* (1.80)	−1.053 (−0.51)
Capital intensity (CI)		−0.158*** (−3.38)	−0.153*** (−3.38)	−0.156*** (−3.38)		−0.156 (−1.44)	−0.143 (−1.44)	−0.155 (−0.51)
EI*FS			0.160*** (2.80)				2.099* (1.69)	
EI*FA				0.001*** (2.39)				0.0003 (0.13)
Constant	−1.10** (−2.28)	−0.513 (−1.47)	−0.674* (−1.71)	−1.103** (−1.99)	−15.177** (−2.15)	−1.415* (−1.86)	−1.714* (−1.86)	−1.504 (−1.19)
No. of observations	2770	2213	2213	2213	6345	2074	2074	2074
No. of groups	876	714	714	714	1739	752	752	752
R^2 Within	0.0581	0.2148	0.2203	0.2209	0.0433	0.0561	0.0624	0.0561
R^2 between	0.0553	0.1202	0.1354	0.1231	0.0352	0.0834	0.0935	0.0814
R^2 overall	0.0491	0.1214	0.1360	0.1214	0.0319	0.0405	0.0463	0.0398
F statistics	5.37**	3.64***	3.27***	3.39***	4.29**	3.58***	2.54***	3.21***

Data Source, CMIE Prowess. Values within the parentheses are the t-values *, **, *** stands for 10%, 5%, and 1% significance level respectively

In literature, HHI, along with other similar indicators such as the four-firm concentration ratio, amongst others, are considered an important measure of competitiveness and market concentration. A study by Tuyet and Ninh (2023) suggests a moderate level of competition is more conducive to firm performance. The average HHI being 41.24 with the maximum lying around 164 over the period 2011-2020, reflects the perfectly competitive environment in which the firms belonging to the seven industries are operating. An inverted U-shaped function spanning this data set clearly illustrates that firm-level profitability improves at high levels of competition.

Firm size is negatively associated with profitability in models capturing the physical economic indicator of energy intensity. However, an increase in market power diminishes the efficiency effect of the manufacturing firms, as implied by the positive coefficient of the interaction of market share and energy intensity. This is contrary to the Schumpeterian contention that a concentrated industry structure is more conducive to enhancing technological efficiency at the firm level. However, considering the economic cost indicator (Table 5), firm size is relevant with a positive coefficient in the presence of the interaction term. The value of the positive coefficient of firm size and the interaction term is high and statistically significant at a 1% significance level.

Firm experience is statistically significant, with a negative coefficient for the technology importing firms. Introducing the interaction term of firm age and energy intensity generates a positive and statistically significant coefficient for these firms. This relationship reflects that efficiency gains are more for relatively young firms, as suggested by existing literature.

Capital intensity turns out to be an important control variable with a negative and statistically significant coefficient. Significance is obtained at a 1% level for the technology-importing firms compared to the 10% significance level for the technology non-importing firms. A negative coefficient of capital intensity for technology-importing firms may indicate the substitution of building indigenous assets with the technical know-how imported in the embodied form, thereby improving one's technical prowess, and enhancing profits. Introducing the interaction between capital intensity and import of capital goods illustrates this substitutability between these two avenues for technological upgradation (Appendix 1). While capital intensity per se has a negative coefficient, import intensity of capital goods is significant with a positive sign. The negative and statistically significant coefficient of the interaction term may point towards barriers to the development of in-house technical know-how and, hence, the reliance on importing such knowledge and assets from the outside.

5. CONCLUSION

The current body of literature in the context of the Indian manufacturing industries predominantly centres on the determinants of energy intensity. However, limited literature exists that looks at the impact of energy consumption on firm performance and its wider implications. This study attempts to look at the likely impact of technological capabilities of manufacturing firms on their energy-performance relationship.

To sum up, for all the firms, irrespective of their technology import status and with profitability as our dependent variable, the empirical results suggest a negative coefficient for energy intensity for firms belonging to the seven sectors that came under the ambit of PAT policy Cycle 1. However, the absolute value of the coefficient is lower in the case of firms importing technology in embodied form. This indicates their relative efficiency with respect to electricity usage and other sources of energy used in production. Additionally, descriptive statistics reveal that firms not importing embodied technology consume more energy than their technology-oriented counterparts. A significant dissimilarity is also found in the characteristics of firms using embodied technology and for firms not reporting such imports. For instance, while import intensity of raw materials and market structure appear to be important control variables in explaining profitability variation, they are insignificant in firms not importing embodied technology.

While a possible limitation of the study is that it does not explicitly analyse the PAT-regulated firms, we apprehend that selected firms operating under regulation and achieving energy efficiency may induce the other non-regulated firms to function towards achieving a similar efficiency level in order to survive and remain viable incumbents in the market. In particular, the negative coefficient of electricity intensity and energy cost intensity support the strong version of Porter's hypothesis.[4] Also as mentioned in section 4.1, firms importing embodied technology have a higher R&D intensity compared to those that do not undertake similar imports. This supports the weak version of the Porter hypothesis, which suggests the positive influence of regulation on firm level innovation.[5] As technology imports along with investing in in-house R&D capacity, provide an edge to the firms in lowering both their physical economic and economic indicators of energy intensity, policy makers can promote practices towards the indigenous development of technology along with assimilating and adopting efficient practices from the outside in order to boost energy efficiency and augment the performance of firms.

According to our study results, firms that have lower energy consumption or adopt imported technology tend to achieve higher profitability. This implies that by embracing both indigenous and imported technology, companies can maintain and enhance their competitive edge in the global market. However, the viability of such technological developments at the in-house level may be a challenging issue in the wake of financial constraints and other barriers to undertaking such huge investment. Hence, an immediate policy implication point towards increasing investment in indigenous development of technology. With the rise of global warming and climate change issues, international organisations and government institutes are considering various measures to achieve energy efficiency. The study suggests development of in-house research and development capability in order to absorb and assimilate the technology in embodied form imported from outside.

4. Jaffe and Palmer (1997) decomposed the Porter hypothesis (PH) into three premises: the narrow version of PH, the weak version of PH, and the strong version of PH. The strong version of PH states that returns to undertaking innovation outweighs its costs; hence, environmental regulation enhances firm's competitiveness. However, Cohen et al. (2018) emphasized that the positive effect of environmental regulations on productivity are more significant at the country level than at the firm level.
5. For instance, the study by Jaffe and Palmer (1997) finds that environmental regulation has a positive effect on R&D expenditures.

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APPENDIX

Appendix 1: Results with import of capital goods as a control variable

Dependent variable profitability	Physical economic indicator of energy intensity	Economic Indicator of Energy Intensity
Energy intensity (EI)	−0.022** (−1.99)	−0.064** (−2.28)
Import intensity (raw materials)	−1.115*** (−2.52)	−1.099*** (−2.57)
Firm age (FA)	−0.002 (−0.66)	−0.006* (−1.87)
Herfindahl-Hirschman Index (HHI)	0.002*** (3.17)	0.002*** (3.13)
HHI^2	−0.00001*** (−2.39)	−0.00002*** (−2.44)
Firm Size (FS)	−0.052 (−1.23)	−0.070 (1.46)
Capital Intensity (CI)	−0.190*** (−3.09)	−0.162*** (−3.29)
Import of Capital Goods Intensity (ICI)	0.477*** (2.63)	0.492*** (2.70)
CI*ICI	−0.176*** (−3.28)	−0.179*** (−3.34)
Constant	0.133 (0.86)	−0.562 (−1.55)
No. of observations	2210	2213
No. of Groups	705	714
R^2 Within	0.2200	0.2338
R^2 Between	0.1464	0.1352
R^2 Overall	0.1547	0.1419
F statistics	4.20***	4.22***

Data Source, CMIE Prowess. Values within the parentheses are the t-values *, **, *** stands for 10%, 5%, and 1% significance level respectively

Appendix 2: Industry groups

Sectors	NIC classification	WPI classification
Aluminium NIC code - 242	1. Manufacture of Aluminium from alumina and by other methods and products of aluminium and alloys 2. Manufacturing of lead, zinc and tin products and alloys 3. Manufacture of other non-ferrous metals 4. Manufacture of Copper from ore, and other copper products and alloys.	1. Manufacture of non-ferrous metals incl. precious metals 2. Castings 3. Manufacture of other fabricated metal products 4. Manufacture of other electronic and electric wires and cables.
Cement NIC Code -239	1. Manufacture of clinkers and cement 2. Manufacture of articles of concrete, cement, or artificial stone (tiles, bricks etc.) 3. Manufacture of asbestos sheets 4. Manufacture of hume pipes and other pre-fabricated structural components of cement and/or concrete for building or civil engineering 5. Manufacture of other cement and asbestos cement products n.e.c. 6. Manufacture of portland cement, aluminous cement, slag cement and similar hydraulic cement 7. Manufacture of quicklime, slaked lime and hydraulic lime excluding chewing lime 8. Manufacture of R.C.C. bricks and blocks	1. Manufacture of refractory products 2. Manufacture of clay building materials 3. Manufacture of other porcelain and ceramic products 4. Manufacture of cement, lime and plaster 5. Manufacture of articles of concrete, cement and plaster 6. Manufacture of other non-metallic mineral products
Chemical Industry NIC code- 201 (Includes Patricides, Fertiliser and Chlor Alkali)	1. Manufacture of liquefied or compressed inorganic industrial or medical gases (elemental gases, liquid or compressed air, refrigerant gases, mixed industrial gases etc.) 2. Manufacture of associated nitrogen products (nitric and sulphonitric acids, ammonia, ammonium chloride, ammonium carbonate, nitrites and nitrates of potassium) 3. Manufacture of basic chemical elements manufacture of dyes and pigments from any source in basic form or as concentrate 4. Manufacture of inorganic acids except nitric acid 5. Manufacture of organic and inorganic chemical compounds n.e.c. 6. Manufacture of other fertilizers n.e.c.	1. Manufacture of basic chemicals 2. Manufacture of fertilizers and nitrogen compounds 3. Manufacture of plastic and synthetic rubber in primary form 4. Manufacture of pesticides and other agrochemical products 5. Manufacture of paints, varnishes and similar coatings, printing ink and mastics 6. Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations 7. Manufacture of other chemical products

(*Contd...*)

Appendix 2: (*Continued*)

Sectors	NIC classification	WPI classification
Iron and Steel Industry NIC Code - 241	1. Manufacture of pig iron and spiegeleisen in pigs, blocks, or other primary forms 2. Manufacture of direct reduction of iron (sponge iron) and other spongy ferrous products 3. Manufacture of steel in ingots or other primary forms, and other semi- finished products of steel 4. Manufacture of ferro-alloys 5. Manufacture of hot-rolled and cold-rolled products of steel 6. Manufacture of tube and tube fittings of basic iron and steel 7. Manufacture of wire of steel by cold drawing or stretching 8. Manufacture of other basic iron and steel n.e.c	1. Inputs into steel making 2. Metallic iron 3. Mild Steel - Semi Finished Steel 4. Mild Steel -Long Products 5. Mild Steel - Flat products 6. Alloy steel other than Stainless Steel- Shapes 7. Pipes and tubes
Paper Industry NIC Code-170	1. Manufacture of pulp 2. Manufacture of news print 3. Manufacture of paper and paper rolls not further processed 4. Manufacture of packing paper 5. Manufacture of other special-purpose paper (excluding computer stationary) 6. Manufacture of paper board, straw board 7. Manufacture of other primary paper materials including composite paper and paper board n.e.c. 8. Manufacture of corrugated paper and paperboard 9. Manufacture of computer paper 10. Manufacture of printing, writing and photocopying paper ready for use 11. Manufacture of other paper products n.e.c	1. Manufacture of pulp, paper and paperboard 2. Newsprint 3. Paper for printing and writing 4. Paper bag including craft paper bag 5. Base paper 6. Kraft paper 7. Laminated Paper 8. Card board 9. Tissue paper 10. Press board 11. Hard board 12. Bristle paper board 13. Poster paper 14. Pulp board 15. Manufacture of corrugated paper and paperboard and containers of paper and paperboard 16. Corrugated sheet box 17. Corrugated paper board 18. Card board box 19. Paper carton/box
Thermal power industry Nic Code – 351	1. Electric power generation by coal based thermal power plants 2. Electric power generation by non-coal based thermal (e.g. diesel, gas)	1. Fuel and Power
Textile NIC Code- 131, 139	1. Weaving of jute, mesta and other natural fibers including blended natural fibers n.e.c. 2. Preparation and spinning of man-made fiber including blended* man-made fiber 3. Finishing of cotton and blended cotton textiles. 4. Preparation and spinning of cotton fiber including blended* cotton 5. Activity related to screen printing 6. Finishing of jute, mesta and other vegetable textiles fabrics 7. Manufacture of knitted and crocheted cotton fabrics	1. Preparation and spinning of textile fibres 2. Weaving and Finishing of textiles 3. Manufacture of knitted and crocheted fabrics 4. Manufacture of made-up textile articles, except apparel 5. Manufacture of cordage, rope, twine and netting 6. Manufacture of other textiles

Appendix 3: Energy Sources classification used for deflating energy intensity

Sectors	NIC classification	WPI classification
Energy Consumption	1. Coal 2. Briquettes 3. Steam coal 4. Process steam 5. Coal and coke 6. Coke breeze 7. Coal and lignite 8. Diesel 9. Furnace oil 10. Light diesel oil 11. Superior kerosene oil 12. Natural gas 13. Liquefied petroleum gas 14. HSD and LDO 15. Electricity (purchased) 16. Electricity (through diesel generator) 17. Electricity (through steam generator)	1. Coking Coal 2. Non-Coking Coal 3. Non-Coking Coal G1 to G6 [GCV exceeding 5500 Kcal/kg.] 4. Non-Coking Coal G7 to G14 [GCV 3100 Kcal/kg. to 5500 Kcal/kg.] 5. Non-Coking Coal G15 to G17 [GCV<3100 Kcal/kg.] 6. Lignite 7. LPG 8. Petrol 9. Kerosene 10. ATF 11. HSD 12. Naphtha 13. Bitumen 14. Furnace Oil 15. Lube Oils 16. Petroleum Coke 17. Electricity 18. Crude Petroleum 19. Natural Gas