Environmental Certification and Technical Efficiency: A Study of Manufacturing Firms in India

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Abstract

Obtaining environmental (as per ISO 14001) certification has become a status symbol for adopting greener practices for the corporate sector in emerging economies. Such certification can help improve the global visibility of firms and is mandated in international trade. This paper attempts to examine the impact of such certifications on technical efficiency of firms belonging to the manufacturing sector in India. In analysing the impact of ISO Certification on technical efficiency, this paper uses data from the CMIE Prowess for the period 2007-2012. In the first step, the paper estimates technical efficiency for the sample firms and then examines the determinants of inter-firm differences in technical efficiency using firm specific characteristics. The results of this study conclude that there are substantial inter-firm differences in technical efficiency and they are systematically different based on firm age, firm size, debt capital, MNE affiliation, and ISO certification. ISO certification, especially maintaining the standards associated with it, turned out to be an important factor in making the firms achieve higher technical efficiency. In addition, the results of this study also confirms that firms that are ISO certified and doing R&D are better off in technical efficiency as compared to the others.

Key Words: ISO certification, R&D, Efficiency, Manufacturing Firms, India

JEL Classifications: L11, L22, Q57

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1 Introduction

Dominant thinking in economic theory holds that regulation imposes a cost burden on firms, causing them to reallocate their spending away from investments in innovation to meet the standards set by the regulations. On the other side, the environmental movement along with greater public concern about social health and safety has fuelled arguments that economic

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efficiency is a necessary sacrifice for improved social welfare. The "*Porter Hypothesis*[3]" goes even further, arguing that environmental, health, and safety regulation regularly induces innovation and may even enhance the competitiveness of the regulated industry. Schumpeter (1942) distinguished innovation, the commercially successful application of an idea, from invention, the initial development of a new idea, and from diffusion, the widespread adoption of the innovation (Ashford and Heaton, 1981[4]). Based on this Schumpeterian definition of innovation, at the highest level of analysis, there are two competing ways in which government regulation impacts innovation. First, regulation places a compliance burden on firms, which can cause them to divert time and money from innovative activities to compliance efforts. Counter to this, and second, firms may be unable to achieve compliance with existing products and processes and thus, assuming that the firms do not shut down, regulation may spur either compliance innovation or circumventive innovation. Circumventive innovation occurs when the scope of the regulation is narrow and the resulting innovation allows the firms to escape the regulatory constraints. Compliance innovation occurs, when the scope of the regulation is broad and the resulting product or process innovations remain within the scope of the regulation. Firms' R&D efforts create new technologies, products, and solutions designed to satisfy customer needs that are not easily imitated by competitors and hence gain competitive advantages. This behaviour of a firm enables it to differentiate itself from other firms. This motivates a firm to focus more on innovation activity to survive in the global competitive markets.

In the debate of global climate change and contribution to GHGs emission from firms; so far number of research and policy papers has been published. Most of the papers deal with the implication of greenhouse gases emission on the behaviour of firms. However, studies that relate regulation or policy instrument such as ISO certification that might enhance the quality of product and minimise the output at firm level are few. ISO develops new standards in response to sectors and stakeholders that express a clearly established need for them. ISO standards are voluntary, and based on a solid consensus of international expert opinion. ISO standards are among the leading objective tools that assist policymakers in decisions related to public incentives, regulations, and use of standards to foster energy-efficiency and new

[3] According to the Porter hypothesis, strict environmental regulations can induce efficiency and encourage innovations that help improve commercial competitiveness. The hypothesis was formulated by the economist Michael Porter in an article in 1995. The hypothesis suggests that strict environmental regulation triggers the discovery and introduction of cleaner technologies and environmental improvements, the innovation effect, making production processes and products more efficient. The cost savings that can be achieved are sufficient to overcompensate for both the compliance costs directly attributed to new regulations and the innovation costs. In the first mover advantage, a company is able to exploit innovation by learning curve effects or patenting and attains a dominating competitive position compared to companies in countries where environmental regulations were enforced much later.

[4] According to Jaffe et al. (2002), "A firm can innovate without ever inventing, if it identifies a previously existing technical idea that was never commercialized, and brings a product or process based on that idea to the market".

green technologies. Out of a total of over 18500 ISO standards and related documents, over 570 are directly related to environmental subjects, including environmental management systems, climate change, energy management, and many more that can help in reducing environmental impacts. Offering business, government and society a complete portfolio of practical tools for tackling environmental challenges, they range from standards for sampling, testing and analytical methods, through environmental management and environmental aspects of product design, to new work on ship recycling.

The ISO 14000 family of standards for environmental management is firmly established as the global benchmark for good practice in this area. ISO has been a leader in preparing climate change relevant standards that help streamline procedures and unify definitions and requirements for the climate mitigation and related actions of corporations, organizations and governments. ISO not only helps streamline GHG accounting with its policy-neutral tools, but it also develops climate change monitoring tools. ISO International Standards can also make essential contributions to realizing the full potential of energy efficiency measures based on existing technology and good practice, as well as to disseminating innovative technologies particularly for renewable and carbon-neutral energy sources.

In the case of innovative technologies, standards can reduce the time to market of products and services based on them, create global interest and develop a critical mass of support to ensure the economic success of such technologies. ISO has already developed standards with an impact on climate change for areas such as building environment design, energy efficiency of buildings and sustainability in building construction, intelligent transport systems, solar energy, wind turbines, nuclear energy and hydrogen technologies. ISO’s proactive stance on energy and climate change matters has resulted in the initiation of ISO work on energy. As one indicator of the use of ISO 14000, up to the end of December 2009, more than 223149 ISO 14001 certificates of conformity had been issued to private and public sector organizations in 159 countries and economies. The ISO 14000 family of standards also includes supporting tools for environmental management and designing environmentally friendly products and services. A well-defined environmental management system is essential for an organization to manage environmental aspects like emission and handling of waste. It is important for the efficient utilization of resources and energy (Whitelaw, 2004). Some of the benefits of the ISO 14001 certification are:

1. Reduction in insurance premiums: waste handling costs; water and air permitting fees;
2. Improved corporate image: strategic investment; improved regulatory relations; and

3. Evaluates system performance through management review and correct management system deficiencies

Technology acquisition has traditionally been viewed as a source of techniques necessary for initiating production and hence is considered as substituting domestic R&D. In the absence of the inflows of new and advanced technologies, however, there has been little incentive, direction and capability to update the existing technologies. Technology continues to be sourced from other nations, but the firm-level technology absorption is low. Sound product design and engineering work could have greater impact on ultimate product cost, value and quality than comparable efforts undertaken further down the manufacturing chain (Indian Manufacturing Industries: Technology Status and Prospects, UNIDO[5]). India has the technical ability to achieve a high level of precision, yet Indian firms are unable to produce quality products due to lack of supporting technologies, such as precision measuring, material engineering and process control. The defect rates of final products are many times 5-10 time than that of Japan and those of USA. In addition, about 20 percent of the firms have equipment, which is more than 20 years old and therefore, obsolete. Most Indian firms are vertically integrated and rely far less on subcontracting arrangements, although such trend is beginning to emerge (Point of view: National Manufacturing Policy, 2012[6])

During the early 1990s the Indian policy makers acknowledged that improved performance and efficiency is supposed to be a prerequisite for growth. The liberalization policy created a technological paradigm shift in various forms which encouraged competition in a number of ways like increased import and entry of new firms etc. After the liberalization, firms are putting in particular efforts to acquire technological capabilities through rigorous investments in various sources of technology such as in-house R&D, import of capital goods, import of designs, drawings and blueprints, and import of raw materials. Given the newly industrialized and globalized economy and increasing emphasis on technology and in-house R&D in a developing country such as India, whether technical efficiency is related to firms' decision on certification remains empirical question in manufacturing firms in India.

Based on the discussion above, this study looks at the impact of regulations for the Indian manufacturing firms. The ISO certification is defined in terms of ISO 14001 families of certification that is energy saving technologies and firms that are involved in the energy saving technologies through the clean development mechanism in India. This paper estimates technical efficiency in the first step and further it tries to identify the differences in

[5] https://www.unido.org/fileadmin/user_media/Publications/Pub_free/Indian_manufacturing_industrytechnology status_ and_prospects.pdf

[6] https://www.pwc.in/en_IN/in/assets/pdfs/industries/industrial-manufacturing/national-manufacturing-policy-pov.pdf

technical efficiency between ISO and Non-ISO certified firms. The analysis tries to find out the inter-firm differences in technical efficiency between ISO and Non-ISO certified firms. The structure of the paper is as follows. The next section of the paper discusses the review of literature, section three describes the methodology and definition of variables, section four describes the results and final section concludes with a discussion.

2 Literature Review

Cohen (1979) reviews NRC power plant licensing procedures and finds that they negatively impact market innovation through compliance uncertainty due to regulatory delay, although she suggests that this may be worth the social benefit of improved safety and quality. Marcus (1988) studied the effect of regulation on social innovation in the nuclear power industry. Marcus finds that flexibility helps promote social innovation. Through examining the safety regulations implemented by the Nuclear Regulatory Commission (NRC) following the 1979 Three Mile Island accident, he finds that regulations affected plants differently depending upon their prior safety records. The NRC took a less flexible approach to plants that had a poor safety record before the accident, while it took a more flexible approach to those with good safety records. By regressing human error events on the compliance implementation strategy undertaken by each plant, Marcus finds that poor safety records resulted in less flexible regulation, which restricted plants' implementation choices, and this in fact perpetuated poor safety performance in the future. On the other hand, a good safety record allowed for a "zone of discretion" in implementation, which resulted in continued strong safety performance. Marcus goes on to note, "If poor performers are given more autonomy, their safety record is likely to improve.

Griliches (1981) constructed the Tobin's q measure to examine the impact of R&D on firm market value. A total sample of 157 firms from US for the period of 1968 to 1974 was drawn for the analysis. His empirical results reveal that there is a positive and significant relationship between R&D intensity and Tobin's q. Prior to 1990, most new plants were required to install a scrubber with a 90 percent [sulfur] removal efficiency rating. As a result, there were no incentives for R&D that would increase the ability of scrubbers to control pollution. However, there were incentives to perform R&D to lower the costs of operating these scrubbers, and thus lower the costs of complying with the regulation. In contrast, the [sulfur dioxide] permit market established by the 1990 Clean Air Act provided incentives to install scrubbers with higher removal efficiencies, and thus led to more R&D designed to improve the removal efficiency of scrubbers. Hence, although innovative activity still occurred, the benefits of the innovative activity were redirected from the firm to society and the environment.

Sickes and Streitwieser (1991) use statistical analysis to examine the impact of the Natural Gas Policy Act of 1978, which altered existing well-head price controls such that gas prices could rise more rapidly to curtail shortages in the wake of the 1973 oil price shock. Sickles and Streitwieser find that both the technical efficiency and the productivity of gas transmission firms fell over the period 1977-1985, which is indicative of flagging innovative activity. They attribute these results to a lack of flexibility in economic regulations that "could neither anticipate changing market conditions nor rapidly adjust to those changes".

Jaffe and Palmer (1996) use regression analysis to analyze the relationship between the stringency of environmental regulations and innovation in U.S. manufacturing industries, and their results are mixed. While they find no relationship between environmental compliance costs (as a proxy for static stringency) and patent counts, they do find a statistically significant relationship between compliance costs and R&D expenditures. Noting that these results are somewhat contradictory, and the difficulty in classifying patent data by industry, the authors warn that their results cannot be considered conclusive. Furthermore, the authors cannot distinguish whether the increase in R&D activity is an indicator of market innovation or social innovation-they are unable to discern whether the regulation has caused firms to "wake up and think in new and creative ways about their products and processes," or whether firms are increasing R&D to comply with regulation at the expense other, potentially more profitable R&D investments.

Lyon (1996) finds that compliance uncertainty caused by economic regulation has a negative impact on market innovation. He examines the regulatory "hindsight reviews" that were adopted by regulators in the 1980s in response to a series of poor investments made by electric utilities. Hindsight reviews assess whether a utility's investment was "used and useful" and is a cost-effective source of power, from which the regulator determines whether the utility's investment should be disallowed. Lyon runs a simulation using data from coal-burning steam plants and finds that hindsight reviews can cause a utility to forgo investing in risky innovation and instead utilize more costly conventional technologies. Furthermore, utilities may cease making technological investments at all and instead switch to purchasing power from third-party producers.

Pickman (1998) performs a test similar to that of Jaffe and Palmer (1996) and finds that social regulation causes firms to change the direction of innovation, from market innovation to social innovation. She employs a more complex regression analysis and limits her innovation proxy to environmental patents thus she focuses exclusively on "environmental innovation" Pickman finds a statistically significant positive relationship between environmental compliance costs and environmental patenting, indicating that regulation does indeed spur environmental innovation. Her findings may go some way toward answering the question posed by Jaffe and Palmer (1996): to comply with social regulation, firms tend to divert R&D expenditures from market-oriented innovation to compliance-oriented social innovation.

Bellas (1998) finds evidence that the moving target of continuously revised social regulations is not conducive to market innovation in the energy industry. Using cost data as a proxy for innovation, he performs a regression analysis to examine whether the desulfurization (scrubbing) units utilized by coal power plants underwent technological improvement during the regulatory regimes specified by the environmental performance standards of the Clean Air Act and the Power-plant and Industrial Fuel Act of 1978 importantly, the stringency of Sulfur emissions regulation is subject to increase as soon as costs fall. Bellas finds little evidence that the cost of scrubber units fell since their introduction, indicating that there had been little technological progress. Importantly, he observes that the market innovation of scrubbers is greater when power plants are subject to regulations that do not change in response to innovation, rather than moving-target regulations that increase in stringency as soon as costs fall.

Through regression analysis, Majumdar and Marcus (2001) find that incentives-based regulation of electric utilities leads to higher productivity "a proxy for market innovation" compared to command-and-control regulation. They analyze the time period around the 1990 Clean Air Act Amendments, which established the system of tradable permits for pollution control. Their productivity measure includes total sales and energy disposition as outputs, and total production, transmission, distribution, employees, and purchasing power as inputs. Their results show that the productivity of electric utilities was lower during the prior command-and-control regime. Additionally, their results indicate that regulations that are stringent but flexible in terms of the firm's path to implementation are more effective at promoting market innovation.

Brunnermeier and Cohen (2003) also examine the impact of environmental regulation on environmental innovation, but they also include the degree of enforcement as an explanatory variable. They find a small but statistically significant effect of compliance costs on environmental innovation, as measured by environmental patent activity. They also test enforcement's effect on innovation using pollution inspection data from the EPA, but they find no significant relationship between enforcement and innovation. Instead of cost data, Popp (2003) examines scrubber innovation using patent counts. Through estimating a regression model, he finds that, contrary to Lange and Bellas (2005), the level of market innovation decreased following the incentives-based social regulation of the 1990 Clean Air Act Amendments, but that social innovation increased:

Lange and Bellas (2005) apply the model of Bellas (1998) to the system of tradable permits established by the 1990 Clean Air Act Amendments and find more flexible incentives-based regulation to be somewhat more effective at inducing market innovation than the previous command-and-control regulatory regime. The amendments established a system of tradable permits for sulfur dioxide emissions. The authors' results show a significant drop in the cost of scrubber units following the legislation; however, when they looked at the rate of change in costs over time, it was no different than the rate before the regulation. In other words, the tradable permit system induced a sudden flurry of innovation, but the innovation then subsided, occurring at a lower rate than it did prior to the system, offsetting the increased innovation from the sudden flurry. The authors suggest that market-based policies may be useful for inducing sudden breakthrough innovation, but less suited for stimulating incremental innovation over time, although they offer little explanation for this theory.

Taylor et al. (2005) take a more qualitative look at the Clean Air Act's effect on the market innovation of scrubber units. Using patent counts as well as R&D investment figures and expert interviews, they find that government regulation precipitated by policy uncertainty can stimulate market innovation. And contrary to Popp (2003), they find that the incentive-based standards of 1990 did not lead to more innovation than the prior regime of performance standards. However, this does not refute incentives-based regimes in general, they argue; rather, the incentives system simply came too late in the maturation of scrubber technology to have an effect. Huang and Liu (2005) examined the relationship between innovation capital and firm performance for top 1,000 Taiwan firms using a multiple regression model. The authors included both R&D intensity and its squared term in their regression equation to examine the existence of nonlinear relationship between R&D investment and firm performance. Their analysis found that R&D intensity has a curvilinear inverted U-shape relationship with firm performance measured by return on assets as well as return on sales.

Popp (2006) employs a regression model with patent data from the United States, Japan, and Germany to measure the impact of sulfur dioxide and nitrogen oxide emissions standards on pollution control innovations among electric utilities. He finds that more stringent U.S. emissions standards resulted in greater innovation in the United States but had no effect on innovation in Japan and Germany. Popp concludes that U.S. firms innovate in response to domestic regulations, but not foreign regulations. Furthermore, he finds that domestic firms innovate even for technologies that have already experienced significant innovative activity abroad, although his results also show that earlier foreign patents serve as an important building block for U.S. nitrous oxide emissions innovations.

Feng and Rong (2007) measured firms profitability efficiency and tried to examine the association among firm's profitability efficiency, innovation capacity and firm value (Tobin's q) using a sample of 228 firms listed in Japanese Electricity machinery industry for the period of 2000 – 2005. They conducted a regression model based on fixed effect and random effect to investigate the association between Tobin's q and the R&D expenditure along with firm efficiency measure and advertisement. Their findings reveals that R&D intensity is basically negative and significantly related to Tobin's q whereas the Cumulative R&D intensity (representing long run impact) is positive and significantly related to Tobin's q. This suggests that R&D intensity is positively related to firm value in the long run but not in short run.

Johnstone et al. (2008) examine the effect of various economic regulations on the market innovation of renewable energy technologies in OECD countries, and they find that the effect of different regulatory regimes varies across energy sources. Their regression models specify a relationship between renewable energy patent counts, as a proxy for innovation, and policy instruments, including public R&D support, investment incentives, tax incentives, voluntary programs, quantity obligations, and tradable permits. Regressing the patent counts for each renewable on an aggregate policy variable representing the effect of regulation in general, they find that, in general, economic regulation has a positive effect on the innovation of all energy sources. Regressing an aggregate patent count representing all renewable on each policy instrument, they find that only tax incentives, quantity obligations, and tradable certificates have a positive effect on renewable energy innovation overall. Then, they regress each energy source on each policy instrument. These estimations show that investment incentives stimulate innovation on solar and waste-to-energy technologies, that tariff structures spur biomass energy innovation, and that production obligations (often linked to tradable certificates) support wind technology innovation. Only tax incentives stimulated innovation for a wide range of renewable energy sources. Because the study uses a wide array of patent data, it is unclear whether their results indicated market innovation or social innovation.

3 Methodology

Technical efficiency is the effectiveness with which a given set of inputs is used to produce an output. A firm is said to be technically efficient if a firm is producing the maximum output from the minimum quantity of inputs, such as labour, capital and technology. For example, a firm would be technically inefficient if a firm employed too many workers than was necessary or used outdated capital. Here the concept of technical efficiency is related to productive efficiency. Productive efficiency is concerned with producing at the lowest point on the short run average cost curve. Thus productive efficiency requires technical efficiency.

3.1 Measuring Technical Efficiency

The actual production function of a firm is expressed as

$$Q_{it} = f\left(X_{it};\beta\right) + v_{it} - u_{it} \qquad (1)$$

The potential production function of a firm can be written as

$$Q_{it}^{*} = f\left(X_{it};\beta\right) \qquad (2)$$

Where,

Q_{it} = actual output for $_i$th firm in the $_t$th period,
Q_{it}* = potential output for $_i$th firm in the $_t$th period,
X_{its} = inputs
β_s = parameters that describes transformation process,
v_{its} = random noise components in the model which are assumed to be independent and identically distributed (iid) N (0, σ^2_v) distribution and independent of the u_{its}
u_{its} = non negative random variables associated with inefficiency in the firms and assumed to be truncation of the N ($\mu_{it,}$ σ^2_u) distribution.

If the firm is efficient, the actual output is equal to potential output.

Thus,

$$TE_{it} = Q_{it} - Q_{it}^{*} = u_{it}$$

Where,

TE_{it} = Technical Efficiency;
u_{it} = inefficiency

The error term representing technical inefficiency is specified as; $u_{it} = \exp(-\eta(t-T))$ (3)

Under this specification, inefficiencies in periods prior to T depend on the parameter η. As t tends to T, u_{it} approaches u_T. Inefficiency prior to period T is the product of the terminal year's inefficiency and exp $(-\eta(t-T))$. If η is positive, then exp $(-\eta(t-T))$ = exp $(\eta(t-T))$ and it is always greater than 1 and increases with the distance of period t from the last period T. The positive value of η indicates inefficiencies fall overtime, whereas negative value of η indicates inefficiencies increase overtime.

The above model can be estimated by the maximum likelihood estimates (MLE). Restricting $\mu = 0$ in the model, it reduces the model to the traditional half normal distribution. If μ is not restricted then μ follows truncated normal distribution. If $\eta = 0$, then technical efficiency is time-invariant i.e., firms never improve their efficiency. The value of $\gamma = \sigma^2_u/\sigma^2$ (where $\sigma^2 = \sigma^2_u + \sigma^2_v$) will lie between 0 and 1. If u_{it} equals zero (which indicates full technical efficiency) then γ equals zero and deviations from the frontier are entirely due to noise v_{it}. If γ equals one all deviations from the frontier are due to technical inefficiency. Besides on the above rationality, the following Cobb-Douglas specification of functional form is employed to specify the parameters of the model to estimate the efficiency since it is widely used one in efficiency studies. The functional form in present case is:

$$\ln Q_{it} = \beta_{1t} + \beta_{2t} \ln C_{it} + \beta_{3t} \ln L_{it} + \beta_{4t} \ln M_{it} + \beta_{5t} \ln E_{it} + v_{it} - \eta_{it} u_{it} \quad (4)$$

Where, Q = Output; C = Capital; L = Labour; M= Material; and E = Energy,

The parameters of the stochastic frontier model, defined in equation (4), is estimated by using the FRONTIER 4.1 computer program under the 'production function' option, developed by Coelli (1996). For estimating productive efficiency and technical change specified above we have used data drawn from the Center for Monitoring Indian Economy. In this study, gross output at constant prices is used as a measure of real output. Prowess reports gross output data in value terms (Rs. Lakh). Nominal values of gross output are deflated by the wholesale price indices for industrial goods. Wages and salaries of employees are considered for the labour input. Unlike other factors of production, capital is used beyond a single accounting period and measuring capital stock input is rather problematic. For capital stock we have followed, perpetual inventory method (PIM), as followed in Goldar et al. (2004) and many other studies on Indian manufacturing sector.

4 Empirical Results

Table 1 presents maximum likelihood estimates. The coefficients of σ^2 and γ are positive and statistically significant in all cases. It reveals that estimated levels of all outputs considerably differ from their potential levels due to factors, which are within the control of firms. The estimated values of γ indicate the efficiency gap that existed between actual and potential level of performance which is mainly due to technical inefficient performance of firms. The statistically significant of coefficient μ term indicates it follows truncated normal distribution whereas the significant of η indicates that inefficiency of firms change over time. The negative of η in advances case indicates that inefficiency increase in producing advances overtime, whereas the positive value of η in other output cases indicates that inefficiencies decrease in production of outputs overtime. The estimated technical efficiency are presented in figure 1. We can observe that there are firms which are having higher technical efficency and also lower technical efficency, however maximum number of firms lies in the mean area of technical efficency.

The mean Technical efficiency (TE) is higher for the ISO certified firms and less for Non-ISO firms, and this result not only holds true for the full sample but also for the years 2007, 2011 and 2012. For the Non-ISO firms technical efficiency continued to increase for three years from 2007 and hereafter TE has declined, however the ISO firms are steady in terms of Technical efficiency. If we observe the minimum value for technical efficency on Non-ISO certification category, we can see that the minimum value for regulated firms always lies above the ISO firms. If we observe the maximum value for technical efficency on ISO certification category, we can see that the maximum value for these regulated and ISO firms always lies above the non-regulated firms. Table 2 presents time-variant average technical efficiency of ISO and Non-ISO firms. The ISO Certified firms achieved highest level of technical efficiency followed by Non-ISO firms.

Table 1: Maximum Likelihood Estimates

Variables	Capital	Labour	Material	Energy
Ln E	0.021 (3.074)*	0.039 (3.859)*	0.024 (1.887)***	0.015 (0.844)
Ln L	0.009 (0.799)	0.074 (4.090)*	0.113 (5.195)*	0.150 (5.766)*
Ln C	0.732 (53.175)*	0.747 (36.012)*	0.611 (27.078)*	0.491 (17.172)*
Ln M	0.155 (20.674)*	0.060 (6.462)*	0.065 (4.542)*	0.415 (8.821)*
σ^2	4.210 (3.712)*	0.142 (10.153)*	0.308 (8.709)*	0.539 (8.227)*
γ	0.975 (138.368)*	0.390 (12.123)*	0.437 (7.164)*	0.588 (19.207)*
μ	-4.052 (-6.808)*	0.470 (6.692)*	0.734 (4.175)*	1.126 (6.275)*
η	-0.197 (12.498)*	0.060 (9.449)*	0.015 (2.703)*	0.084 (1.641)***
Constant	0.749 (12.197)*	0.969 (8.438)*	-0.696 (-3.866)*	-1.446 (-8.405)*

Figure 1: Frequecy Distribution of Technical Efficency

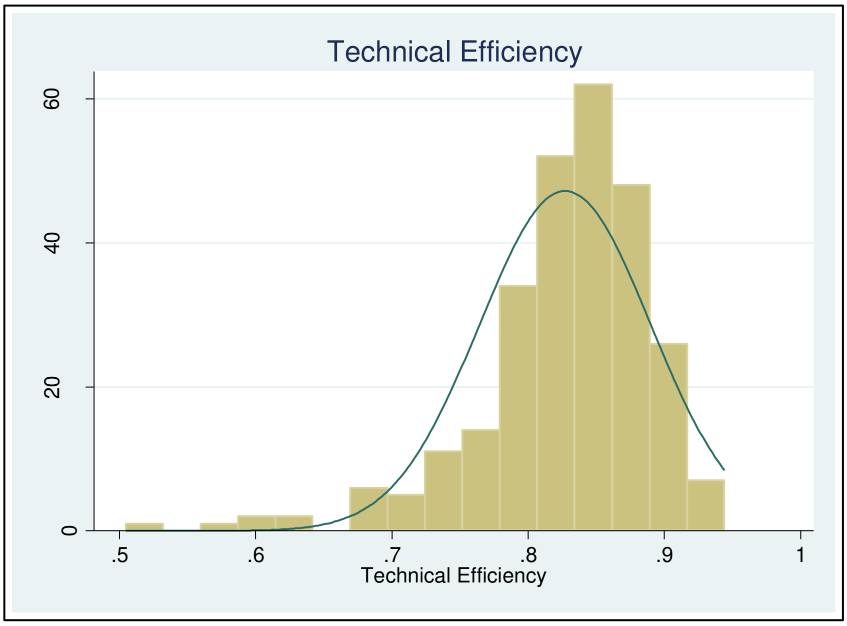

Table 2: Time Varying TE by ISO Certification and Non-ISO Certified Firms

	Non-ISO			ISO		
Year	Mean	Minimum	Maximum	Mean	Minimum	Maximum
2007	0.781	0.749	0.813	0.832	0.566	0.925
2008	0.836	0.823	0.849	0.834	0.504	0.944
2009	0.830	0.813	0.846	0.823	0.603	0.918
2010	0.834	0.830	0.838	0.826	0.631	0.924
2011	0.787	0.756	0.818	0.823	0.670	0.921
2012	0.757	0.731	0.782	0.826	0.599	0.908

The following observations can be derived from the above tables. (1) There are higher variations in terms of technical efficiency for Non-ISO firms than the ISO firms; (2) The minimum value of technical efficiency for ISO certified firms lies above the Non-ISO certified firms; and (3) Firms that are ISO certificated exhibits similar of technical efficiency, whereas the distribution of non-ISO firms in terms of technical efficiency has a wide range.

Table 3: Mean Differences of Technical Efficiency and R&D Intensity

Certification	Technical Efficiency	t-stat	R&D Intensity	t-stat
ISO	0.828	t = 1.867*	0.615	t = 2.882***
Non-ISO	0.806		0.420	

Now we compare the TE and R&D intensity of firms categorised as ISO and Non-ISO. From the tabulated result (table 3) we can see that on an average Non-Regulated firms are technically less efficient than the Regulated Firms and Firms (Regulated) report higher R&D intensity and higher technical efficiency. The above table on the mean difference between the technical efficiency and Research and Development intensity statistically establish that ISO firms are better off than that of Non-ISO firms. However, it should be noted that R&D intensity is down scaled by net sales. Table 4 reports for descriptive statistics of the sample. From the descriptive statistics we can observe that higher standard deviation is found for the share of debt capital, profit margin and firm age. This indicated that inter-firm differences are higher for the indicators such as debt capital, profit and firm age. Other statistical indices of the sample are presented in table 6 in detail.

Table 4: Descriptive Statistics (full sample)

Variable	Mean	Std. Dev.	Min	Max
Technical Efficiency	0.827	0.063	0.505	0.944
Share of Debt Capital	1.019	2.564	0.001	29.829
Export Intensity	0.031	0.288	0.101	0.994
R&D Intensity	0.201	0.004	0.010	0.339
Profit Margin	0.689	2.264	-5.817	21.465
Firm Size	1.958	0.752	0.201	3.937
Firm Age	31	21	1	82
No. of Observations	271			

Before estimating we have tried to understand the correlation among the variable of interest. The result is reported in table 5. From table 5 we can observe that R&D is positively related to firm age and negatively related to profit margin, firm size, share of debt capital of firm, and technical efficiency. Technical efficiency (TE) is positively related to profit margin, firm age, firm size and share of debt capital of firm. To check for the multicolinearity in the sample we have estimated the variance inflation factor (VIF) and the mean VIF of 3.89 suggests that the sample is not suffering from the multicolinearity problem.

Table 5: Correlation Matrix (full sample)

	R&D	Profit Margin	Firm Age	Firm Size	Debt capital	TE
R&D	1					
Profit Margin	-0.016	1				
Firm Age	0.006	0.037	1			
Firm Size	-0.089	0.156	0.127	1		
Debt capital	-0.008	0.010	-0.153	0.043	1	
TE	-0.096	0.047	0.099	0.489	0.008	1

Review of literature suggests that because of regulations in regulated market there are several benefits on which the firm that operate in a domestic setup is one of the benefits of the firm. It increases the productivity and efficiency in general to the extent we can also assume that regulated markets with policy as the instrument can also help firms in increasing the technical efficiency. Product or process, research or development through

R&D expenditure for any given firm stimulates the capacity and hence the efficiency. The estimation of technical efficiency confirms that technical efficiency is different for firms classified on the ISO certification. The ISO firms are technically efficient as compared to the Non-ISO firms however; dispersion in terms of the technical efficiency for ISO and non-ISO is not homogenous. The sample consists of firms which are highly technically efficient in either of this group. To understand the inter-firm difference of technical efficiency along with the ISO certifications and other firm's characteristics we estimate the following regression equation.

$$\begin{aligned} TE_{it} &= \alpha_{it} + \beta_1 FS_{it} + \beta_2 EXPI_{it} + \beta_3 DC_{it} + \beta_4 RD_{it} + \beta_5 AGE_{it} + \beta_6 PM_{it} \\ &\quad + \beta_7 MNE_{it} + \beta_8 ISO_{it} + \beta_9 IS_{it} + \mu_{it} \end{aligned} \tag{5}$$

The description of the variables used equation 5 and definitions are given in table 6 below.

Table-6 Definition of Variables

SL No.	Variable	Symbol Used	Definition
1	Firm Size	FS	Natural log of net sales
2	Export Intensity	EXPI	Ratio of export to net sales
3	Debt Capital	DC	This variable is constructed as the ratio between the borrowings of the firm to net sales.
4	Research and Development Intensity	RD	R&D intensity is measured as the ratio of R&D expenses to net sales.
5	Profit Margin	PM	Ratio of profit after tax to net sales
6	Firm Age	AGE	As a measure of age, we subtract the year of incorporation from the year of the study.
7	MNE	MNE	Multinational enterprise dummy, takes the value one for domestic firm and zero for the multinational affiliated firms.
8	ISO certifications	ISO	ISO certification relates to the certification of firm where in 2007 firms attend ISO certificates therefore this dummy captures zero for the non-certified firm and one for the certified firms.
9	ISO and R&D	IS	Interaction dummy takes the value 1 if firm is ISO certified and doing R&D else, 0

The estimates of technical efficiency are given in table 7. The initial estimate is based on the OLS and OLS robust procedure. However, as the data is an unbalanced panel; we have used the panel data econometrics of fixed and random effects models. The efficiency of the model is based on the Hausman statistics, and the Hausman statistics confirms that fixed effects model is efficient as compared to the random effects estimates. Except model (M1) and (M2) other two models are the estimates with time and firm effects. As stated earlier, the objective of the paper is to find out the determinants of technical efficiency and relate it with ISO certification. In understanding the determinants of technical efficiency and ISO certification, we have considered firm characteristics. Firm characteristics include (1) Profit Margin, (2) Share of debt capital, (3) Export Intensity, (4) R&D Intensity, (5) Firm Size and Firm Age. We have also used dummy capturing the foreign affiliation (MNE dummy), ISO certification dummy and interaction dummy between ISO certified firms and doing R&D.

The result indicates that debt capital is negatively related and statistically significant with technical efficiency, meaning firms with less debt capital are technically more efficient. Export intensity is positively related to technical efficiency. This result indicates that firms that are exporting more in proportion to their sales are also having higher technical efficiency. Higher expenses in research and development also make firms technical efficient. This result is confirmed with a positive and statically significant result of R&D intensity. A non linear relationship is found between technical efficiency and firm size. The result suggests that technical efficiency and firm size are non-linearly related and they exhibit an inverted U shape relation. This indicates that medium sized firms are more technical efficient when compared to the small and large firms. Further, firm age is negatively related to technical efficiency, indicating younger firms are technical efficient as compared to the older firms. ISO certification has played a major indicator in determining technical efficiency. The result suggests that ISO certified firms are higher technically efficient compared to the Non-ISO firms. Further, we have tried to create an interaction dummy that captures certification (ISO) of the firms and R&D. In this case we have considered the participation of R&D and ISO certification. The result of such an exercise indicates that firms that are ISO certified and doing R&D are technically efficient as compared to the rest of the sample. The detail result is presented in table 7.

5 Conclusion

The objective of this research is to check the impact of ISO certifications on technical efficiency for a sample of manufacturing firms in India. We have used firm level data from CMIE PROWESS database for the period 2007-2012 (unbalanced panel data). We have first estimated the technical efficiency for the sample firms and analysed the determinants of technical efficiency using firm characteristics. We conclude from the study that there are inter-firm differences in technical efficiency and they are systematically different based on firm age, firm size, debt capital, MNE affiliation, and ISO certification. Specifically, meeting the requirements of ISO certification has helped firms to achieve higher technical efficiency. Therefore ISO certification has become an important factor in making the firms improve their technical efficiency. In addition, the result of this study also confirms that firms that are ISO certified and doing R&D are better off in technical efficiency when compared to others. Hence, ISO certification, especially because of the conditionalities attached to maintaining the standards, appears to positively enhance the efficiency of firms in the manuraturing setor of India. The policy implications from the findings of this paper are clear and not too difficult to be implemented.

Table 7 Determinants of Technical Efficiency

	OLS (M1)		OLS Robust (M2)		Random-effects (M3)		Fixed-effects (M4)	
Independent Variables	Coefficient	t	Coefficient	t	Coefficient	z	Coefficient	t
Debt capital	-0.002	-2.088***	-0.002	-2.742***	-0.002	-2.180***	-0.002	-2.846***
Export Intensity	0.004	0.412	0.004	0.357	0.011	2.773***	0.017	1.871**
R&D Intensity	1.405	2.204***	1.405	3.558***	0.943	1.459	0.134	1.917***
Profit Margin	-0.004	-0.327	-0.006	-0.629	-0.001	-0.646	0.002	1.237
Firm Size	0.161	12.205***	0.161	9.062***	0.162	6.410***	0.155	5.660***
Firm Size^2	-0.029	-8.971***	-0.029	-7.458***	-0.029	-5.019***	-0.026	-3.340***
Firm Age	-0.023	-2.103***	-0.022	-2.357***	-0.019	-1.720***	-0.004	-2.300***
MNE Dummy	-0.034	-4.199***	-0.034	-4.082***	-0.028	-2.920***	-0.006	-2.369***
ISO certification Dummy	0.009	0.696	0.009	1.078	0.023	1.669	0.023	2.667***
Interaction between ISO and firm doing R&D	0.987	0.435	0.983	0.422	0.007	0.469	0.011	1.989**
Constant	-0.749	-1.175	-0.749	-1.894**	-0.297	-0.458	0.895	1.139
R^2 within					0.499		0.518	
R^2 between					0.652		0.231	
R^2 overall	0.536		0.536		0.533		0.259	
sigma_u					0.029		0.077	
sigma_e					0.039		0.039	
Rho					0.207		0.795	
Corr (u_i, X)					0 (assumed)		-0.698	
Wald chi^2(10)					291.630***			
F(9,196)							23.450***	
F(9, 261)	33.460***		26.080***					
Number of observations	271		271		271		271	
Firm Effect and Year Effect	No		No		Yes		Yes	

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