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Examining Total Factor Productivity and Energy Intensity in the Landscape of Indian Manufacturing

Narayanan Kumar[a]

Abstract

In the contemporary discourse on climate change negotiations, the role of energy use patterns, efficiency, and productivity has gained paramount importance, particularly in the context of Indian manufacturing industries. Recognizing the critical interplay between these elements, the primary objective of this paper is to estimate the transcendental logarithmic production function. Moreover, the study aims to rigorously analyze the intricate relationship between energy intensity and total factor productivity within the Indian manufacturing sector. This research endeavors to shed light on the nuanced dynamics that underpin the efficiency of energy use and its consequential impact on the overall productivity of the manufacturing industries in India. The estimation of total factor productivity in this study relies on a comprehensive four-input model, encompassing labor, capital, material, and energy. The outcomes of the analysis indicate that labor and material inputs exert a significant influence, surpassing the impact of capital and energy inputs. This suggests that, within the context of the studied manufacturing industries, the efficiency and utilization of labor and material resources play pivotal roles in shaping overall productivity. Recognizing the relative importance of these inputs can inform targeted strategies for enhancing productivity and resource utilization in the pursuit of sustainable and efficient industrial practices. Additionally, the estimates from the study reveal several key relationships with total factor productivity in Indian manufacturing industries. The age of the firm, export intensity, and disembodied technology import demonstrate a positive association with total factor productivity. This implies that older firms, those with a higher proportion of exports, and those incorporating technology that doesn't require physical presence in the production process tend to exhibit higher productivity levels. Conversely, ownership, energy intensity, embodied technology import, and R&D intensity exhibit negative associations with total factor productivity. This suggests that firms with certain ownership structures, higher energy consumption, reliance on technology with physical presence, and those with lower investment in research and development may experience lower levels of overall productivity in the Indian manufacturing sector. These insights contribute to a nuanced understanding of the multifaceted factors influencing productivity within this industrial context. İn addition, energy efficient firms also found to have high levels of total factor productivity. This implies the need for fostering energy efficiency at firm level in Indian Manufacturing.

Keywords: production function, total factor productivity
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1. INTRODUCTION

During the initial stages of industrialization, the productivity of the Indian manufacturing sector faced constraints attributed to governmental policies. These policies, such as the reservation of production items for the small-scale sector, elevated customs tariffs leading to distorted resource allocation, and hindered the competitive capacity of the Indian industry on the global stage. Furthermore, the practice of shutting down industries in response to regular competitive market forces and the various distortions stemming from the structure of domestic trade taxes and excise duties further impeded the sector's growth. Nevertheless, a transformative shift has transpired since 1991, attributed to the implementation of liberalization policies. The Government of India has undertaken a series of strategic measures over the years to enhance industrial productivity. The journey of industrial liberalization in India spans over two decades, signifying a sustained commitment to fostering a more dynamic and competitive industrial landscape. One of the paramount objectives underlying policy reforms was to elevate the efficiency of industrial sectors, acknowledging that sustained advancements in productivity and efficiency constitute fundamental catalysts for the comprehensive development of any industry. By focusing on optimizing operational processes, resource utilization, and technological integration, these reforms sought to create a more robust foundation for industrial growth. The imperative recognition of the pivotal role played by efficiency enhancements underscores the government's commitment to fostering a competitive, adaptive, and resilient industrial framework conducive to long-term sustainability and prosperity. In this context, the present study places its emphasis on the estimation of total factor productivity, employing the transcendental logarithmic specification of the production function. Additionally, the research endeavors to ascertain the determinants influencing productivity within the Indian manufacturing industries. To achieve this, cross-sectional data for the year 2006-07 has been meticulously gathered from the Center for Monitoring Indian Economy (CMIE), forming the basis for a comprehensive analysis of the factors shaping productivity dynamics within this critical sector.

[a] Department of Humanities and Social Sciences, Chennai, India

2. LITERATURE REVIEW

Numerous studies have extensively delved into the trends characterizing total factor productivity growth within Indian industries. Concurrently, a considerable body of research has been dedicated to investigating the potential for substitution between key factors such as energy, capital, and labor within various industrial contexts. At the crux of this scholarly discourse lies the fundamental question of whether the relationships between energy and capital, as well as energy and labor, are characterized by substitutability or complementarity. This ongoing debate underscores the intricacies inherent in understanding the nuanced interplay among these critical factors and their implications for the broader economic landscape. Over the recent decades, there has been a proliferation of methodologies designed and employed to scrutinize shifts in productivity and technical advancements. Numerous studies have undertaken the estimation of total factor productivity in the Indian economy, employing statistical indices within the conventional growth accounting framework. Noteworthy contributions in this domain include the works of Mongia and Sathaye (1998, 1998a) as well as Ahluwalia (1991), who have employed rigorous methodologies to assess and analyze the multifaceted aspects of total factor productivity, thereby providing valuable insights into the evolving dynamics of India's economic landscape.

In the seminal work by Ahluwalia (1991), a comprehensive analysis is undertaken to scrutinize the long-term trends in both total productivity and partial productivity within the organized manufacturing sector in India, spanning the period from 1959-60 to 1985-86. The study intricately delves into the dynamics of factor input growth and the concurrent growth in value added, shedding light on their respective roles in shaping the overarching trends observed in the sector. By systematically examining this extensive time frame, Ahluwalia's research contributes valuable insights into the multifaceted determinants of productivity changes, providing anuanced understanding of the organized manufacturing landscape in India. The analysis undertaken in this study is characterized by a meticulous level of disaggregation, extending to 63 constituent industry groups identified at the three-digit level. Additionally, the investigation encompasses the four "use-based" sectors of manufacturing, namely intermediate goods, consumer non-durables, consumer durables, and capital goods. Notably, the scrutiny reveals that, across nearly all 63 industries, there is a discernible and statistically significant positive growth in capital intensity. This trend is particularly pronounced in a subset of industries, contributing to 64 percent of the total value added in the manufacturing sector. This insightful observation underscores the prevailing dynamics of capital deployment and its impact on value addition within the diverse landscape of manufacturing industries.

In some industries, a noteworthy decline in labor productivity has been observed. Addressing this challenge, the study conducted by Pradhan and Barik (1999) aims to provide a potential solution by investigating total factor productivity as an outcome of the interplay between economies of scale and technical change. Consequently, the study underscores the importance of effectively managing both scale economies and technical advancements to achieve the desired level of total factor productivity. Utilizing a translog cost function, the research empirically estimates total factor productivity. The empirical findings derived from the analysis of aggregate manufacturing sector data and data from eight specifically chosen industries in India reveal a discernible downward trend in both scale economies and technical change, contributing to an overall decline in total factor productivity in recent years. This underscores the pressing need for strategic interventions to address these diminishing factors and revitalize productivity dynamics within the manufacturing sector.

Goldar's (2000) study revealed a substantial increase in the growth rate of employment within the organized manufacturing sector in India from 1990-91 to 1997-98. During this period, the employment growth rate surged to 2.69 percent per annum, marking a notable improvement compared to the preceding decade where the growth rate was recorded at 0.53 percent per annum in the 1980s. This finding indicates a positive shift in employment dynamics within the organized manufacturing sector during the specified timeframe. Goldar (2000) attributed the notable growth in employment within the organized manufacturing sector to two key factors. Firstly, he identified a slowdown in the growth of real wages during the 1990s as a contributing factor. Secondly, the faster growth of small and medium-sized factories within the organized manufacturing sphere, which tend to be more labor-intensive compared to their larger counterparts, was highlighted as another significant influence on employment expansion. Additionally, Goldar underscored that the surge in employment during the 1990s was predominantly driven by private sector factories, emphasizing their pivotal role in shaping the employment landscape within the organized manufacturing sector.

Nagaraj (2004) highlighted that the accelerated employment generation observed in the organized manufacturing sector was predominantly confined to the initial half of the 1990s. However, with the subsequent economic downturn, there was a sharp decline in employment during the latter half of the decade. Interestingly, the relative cost of labor appeared to have minimal impact on employment decisions, as evidenced by the secular decline in the wage-rental ratio. According to Nagaraj's analysis, approximately 1.1 million workers, constituting 15 percent of the workforce in the organized manufacturing sector in the country, experienced job losses between the years 1995-96 and 2000-01. This underscores the complex dynamics and challenges faced by the labor market within the organized manufacturing sector during that period.

Roy et al. (1999) conducted a comprehensive analysis of productivity growth and input trends within six energy-intensive sectors of the Indian economy. Employing a growth accounting framework and econometric methods, the study utilized an econometric technique to estimate rates and factor price biases of technological change. This involved the application of a translog production model, with an explicit relationship defined for technological change. Notably, the study's estimates of own-price responses suggest that increasing energy prices could serve as an effective policy for carbon abatement in India, underscoring the intricate relationship between economic productivity, technological change, and environmental considerations in the energy-intensive sectors. Simultaneously, Roy et al. (1999) observed, akin to previous findings in the context of the US economy, that implementing such policies in India might result in adverse long-term effects on productivity within the targeted sectors. The study revealed that inter-input substitution possibilities were relatively weak, implying that such policies could potentially exert negative impacts on sectoral growth in the short and medium term. By shedding light on these dynamics, the research not only furnishes valuable insights into the potential repercussions of carbon abatement policies on Indian industries but also contributes significantly to the evolving realm of modeling and analysis of global climate policy. This information proves crucial for the nuanced examination of the costs and benefits associated with implementing carbon abatement strategies in the Indian context. Adopting a Translog specification of a four-input production function, Mongia et al. (2001) applied a growth accounting framework to dissect the expansion of output into the growth of inputs and a residual component, representing productivity growth. A key revelation from the study is that the overall productivity growth in the industries under consideration was notably modest during the period spanning 1973 to 1994. This finding underscores the challenges and constraints faced by these industries in achieving substantial productivity advancements over the specified timeframe. Nevertheless, noteworthy disparities in productivity growth were evident across industries during this period. These divergences can largely be elucidated by considering the nature and timing of policy changes specific to each sector. Employing the growth accounting framework, Mongia et al. (2001) conducted estimations for total productivity growth within five energy-intensive industries in India. The outcomes reveal that the overall total productivity growth in these industries from 1973 to 1994 was negligible, even though productivity growth exhibited considerable variation among the sectors. Specifically, it was markedly positive in the fertilizer industry, modestly positive in aluminum and cement, and conversely, negative for the iron & steel and paper industry. This underscores the sector-specific nuances in the impact of policies on productivity dynamics.

Productivity growth did not exhibit uniformity over time. Mongia et al. (2001) identified that the partial productivity growth of both capital and energy emerged as substantial determinants influencing total productivity growth. Crucially, these factors were significantly influenced by capacity utilization. The examination of results over two distinct sub-periods, namely 1973-1981 and 1981-1994, indicated that shifts in technologies and alterations in production conditions, instigated by policy reforms, played a pivotal role in significantly augmenting productivity growth in the cement and fertilizer industry. This underscores the dynamic interplay between policy changes, technological advancements, and capacity utilization in shaping the trajectory of productivity within specific industries over different time periods. The impact of policy changes was notably less pronounced in the aluminum industries, primarily due to the substantial lumpiness of investments and the inherent characteristics of the technology employed. However, the removal of market constraints and the introduction of a modern plant did result in a significant increase in the growth rate during the second sub-period. Conversely, in the case of the iron and steel as well as the paper industries, where a lack of a clear long-term perspective existed, the positive effects of policy reforms were overshadowed, at least temporarily, by prevailing institutional and market conditions. The study concludes that, despite the implemented policy reforms, they did not extend far enough to exert a substantial influence on productivity growth in India's energy-intensive manufacturing sectors. This underscores the complex and multifaceted nature of factors influencing productivity in these specific industries.

Berndt et al. (1998) demonstrated that, in major industries in Alabama, electricity exhibits weak substitutability for both capital and labor. Additionally, the study highlighted that regulatory constraints become binding, primarily attributed to the inelastic demand for electricity. This insight underscores the intricate dynamics between input factors and the regulatory framework in shaping the production processes within these industries in Alabama. Mahmud (2000) discovered that there is minimal substitution between energy and other inputs within the manufacturing sector in Pakistan. However, the study identified a weak substitution relationship between electricity and gas. This nuanced understanding of input substitution patterns in the Pakistani manufacturing context provides valuable insights into the complex dynamics of energy utilization within the industrial processes of the country. Chang (1994) observed little disparity between the Translog and constant elasticity production functions within the Taiwanese manufacturing sector. The study further reported that, in this context, energy and capital exhibit a relationship of substitutability. This finding contributes to the understanding of the production structure in Taiwanese manufacturing, shedding light on the interplay between energy and capital inputs. Yi (2000) discovered that the degree of substitution varies when comparing Translog and Leontief production functions in Swedish manufacturing industries. This observation emphasizes the importance of the chosen production function in modeling and analyzing the relationships and interactions among inputs within the manufacturing processes in Sweden. The nuanced understanding of substitution patterns contributes to a more comprehensive evaluation of the dynamics at play in the Swedish manufacturing sector.

3. METHODOLOGY AND ECONOMETRIC SPECIFICATION

Total factor productivity serves as a metric to quantify the growth in total output that cannot be attributed to the increase in total inputs. Essentially, it measures the shift in output resulting from changes in production efficiency over time, while keeping all inputs constant. Scholars such as Abramovitz (1956), Denison (1962, 1967, 1985), and Hayami et al. (1979) have contributed to the conceptualization and understanding of this crucial economic indicator. Indeed, the concept of total factor productivity implies a shift in the production or cost function, either upward or downward, resulting in a corresponding increase in output. The understanding here is that industrial growth, regardless of its magnitude, cannot be sustained without concurrent improvements in productivity. This perspective is widely recognized in economic literature, underscoring the pivotal role that productivity enhancements play in ensuring the long-term sustainability and success of industrial development.

3.1. TOTAL FACTOR PRODUCTIVITYG

This method involves decomposing the growth of output into contributions from the growth of inputs and a residual term representing total factor productivity growth.

This approach entails estimating production functions or cost functions through econometric methods, providing a quantitative analysis of the factors influencing productivity.

Utilizing methods like Data Envelopment Analysis (DEA), this approach evaluates productivity without specifying a functional form, offering flexibility in handling various inputs and outputs.

In the context of computing production functions, one method is to use the Translog production function. This function incorporates both linear and quadratic terms and allows for the incorporation of more than two inputs. The Translog production function can be approximated through a second-order Taylor Series, as proposed by Christensen et al. (1971). This mathematical model provides a versatile tool for capturing the complex relationships among inputs and assessing total factor productivity changes over time. In this study, the Translog production function is employed, incorporating four inputs denoted as KLEM (capital, labor, energy, and materials). It's noteworthy to recognize that the demand for industrial energy is essentially derived, as outlined by Berndt and Wood (1975). In this context, the firm's demand for energy serves as an input and is derived from the overall demand for the firm's output. This approach allows for a comprehensive analysis of the intricate relationships among capital, labor, energy, and materials, providing insights into the dynamics of industrial production and energy utilization. A constrained body of research has directed its focus toward estimating production functions that involve more than three inputs, particularly considering energy as a crucial component in the production processes of industries. The present study seeks to bridge this gap by making an endeavor to estimate the production function. This is achieved through the utilization of cross-sectional firm-level data specifically gathered for the Indian manufacturing industries. By undertaking this analysis, the study aims to contribute valuable insights into the multifaceted relationships among various inputs, with a particular emphasis on the role of energy within the production dynamics of the manufacturing sector in India. Additionally, this study extends its scope by delving into the determinants of Total Factor Productivity (TFP) using firm-specific variables beyond the traditional factors of labor, capital, and materials. The exploration of TFP drivers goes beyond the conventional inputs, aiming to uncover the nuanced factors influencing productivity in the manufacturing industries. Previous research has indicated a noteworthy trend: importing firms tend to outperform or demonstrate higher productivity levels compared to non-importing firms (Sachs and Warner, 1995). Building on this established insight, the study integrates these findings into the broader investigation, contributing to a comprehensive understanding of the factors shaping Total Factor Productivity in the context of Indian manufacturing. Indeed, higher-performing importing firms often benefit from technological transfers and access to superior inputs due to their engagement with foreign sources. This exposure has the potential to significantly enhance productivity and, consequently, improve export performance. The study recognizes that factors such as Embodied Technology Intensity (ETI), Disembodied Technology Intensity (DETI), and the efficient utilization of energy (cost minimization) can serve as key drivers in augmenting the overall productivity of a firm. By acknowledging the impact of these elements, the study aims to provide a nuanced understanding of the intricate relationships between technological intensity, energy efficiency, and productivity enhancement within the context of importing firms. The hypothesis posited in this study suggests that firms with higher productivity levels tend to exhibit lower energy intensity. This conjecture reflects the expectation that more productive firms can optimize their energy usage more efficiently.

The study employs specific metrics to quantify technological aspects. Embodied technology intensity is computed by taking the ratio of capital goods import expenditure to the net sales of the firm. On the other hand, disembodied technology intensity is determined by the ratio of royalty and technical fees payments to the net sales of the firm. These measures offer insights into the incorporation of technological elements within the production processes of the firms. Furthermore, the study assesses export intensity (EXPI) by calculating the ratio of export value to the net sales of the firm. This metric provides an indication of the significance of export activities within the overall operations of the firm. The analysis of these factors collectively contributes to a comprehensive understanding of the intricate relationships between productivity, energy intensity, and technological components in the context of the studied firms. The study aligns with the Learning by Exporting hypothesis, positing that engaging in foreign markets fosters positive learning effects for domestic firms. This involvement exposes these firms to advanced technological innovations from international buyers and competitors, ultimately enhancing their productivity. Griliches (1979) laid the foundation for this concept in the R&D Capital Stock Model, highlighting the direct impact of such exposure on firm performance. Subsequent empirical evidence by Lichtenberg and Siegal (1989) and Hall and Mairesse (1995) strongly supports Griliches's perspective. In capturing the R&D activities of the firms under consideration, the study adopts the ratio of R&D expenditure to the firm's net sales. This metric serves as a quantitative measure to assess the extent of research and development investments relative to the overall financial performance of the firm. By incorporating this factor, the study aims to shed light on the role of R&D in the context of learning through exporting and its potential influence on firm productivity. This variable is a measure of R&D intensity of firms and it is expected to have a positive impact on firms' productivity. Further to investigate the inter-industries difference of total factor productivity; we have defined 18 industries dummies ($ID_1, ID_2 \ldots ID_{18}$) from 19 sub-industries. Data for the empirical investigation is collected from the cmie prowess data base for 2008. The sample size is 2541 for 19 sub-industries in Indian manufacturing.

4. EMPIRICAL RESULTS

This section of the study provides empirical estimates for the Indian manufacturing sector. Table 1 offers descriptive statistics for selected variables within the sample of firms. The analysis encompasses a total of 2541 firms from Indian manufacturing industries for the fiscal year 2006-07. The mean output is computed at 7700.49 million, accompanied by a relatively higher standard deviation of 7133.29. These statistics provide a snapshot of the distribution and variability of key variables within the sample, laying the groundwork for a more in-depth empirical examination of the manufacturing sector in the specified period. The study computes the mean values for capital, labor, energy, and material inputs, which are found to be 401.90, 30.67, 26.04, and 372.33, respectively. This underscores the average levels of these crucial inputs across the sampled firms within the Indian manufacturing sector for the specified year. The research adopts a two-stage estimation approach to discern the determinants of productivity in the Indian manufacturing landscape. As previously outlined in Section-3, this methodology involves the inclusion of firm-specific variables in the second stage estimation. This nuanced approach allows for a comprehensive analysis that not only considers the core production inputs but also integrates additional firm-specific factors to better elucidate the drivers of productivity within the manufacturing sector. The variables considered in the analysis encompass the age of the firm, energy intensity, embodied technology import intensity, disembodied technology import intensity, R&D intensity, and export intensity. Examining Table-1, it is evident that the mean age of the firms is 31 years. Additionally, the mean values for energy intensity, embodied technology import intensity, R&D intensity, export intensity, and disembodied technology import intensity are calculated to be 0.07, 0.004, 0.003, 0.151, and 0.081, respectively. These figures provide a snapshot of the central tendencies and distributions of these key variables, forming the basis for a more detailed exploration of their impact on firm productivity in the subsequent stages of the study. Table-2 provides the estimation results of the Translog production function. The findings reveal that the elasticity of capital is positively correlated with output and is statistically significant at the 1% level. This implies that an increase in a firm's capital input is associated with a higher level of output. Similarly, the coefficient of the labor input carries a positive sign, indicating a significant and positive relationship with productivity. This suggests that an increase in labor input is associated with a higher level of output for the firm. The results provide valuable insights into the contributions of capital and labor to the production process and their impact on firm productivity. In the total factor productivity model, energy input is incorporated as the third input. The variable exhibits a positive sign and is statistically significant at the 1% level. This implies that an increase in energy consumption is associated with an increase in the output of firms, underscoring the positive impact of energy usage on productivity. The fourth input in the model is the material used for production, and this variable also maintains a positive relationship with the firm's output. A more detailed breakdown of the results for equation (0.1) is provided in Table-2, shedding light on the intricate dynamics of these inputs and their influence on overall firm productivity.

Table 1: Descriptive statistics of selected variables

Variable	Mean	Std. Dev.	Min	Max
Output	770.49	7166.29	0.01	270582.40
Capital	401.90	2956.63	-12182.80	107932.30
Labour	30.67	202.16	0.00	8069.15
Energy	26.04	138.40	0.01	3399.91
Material	372.33	3227.14	0.00	101494.60
Age of the firm	31.42	44.39	1.00	118.00
Energy Intensity	0.074	0.23	0.00	8.00
Embodied Technology Import Intensity	0.004	0.09	0.00	4.53
R&D Intensity	0.003	0.02	0.00	1.19
Export Intensity	0.151	0.24	0.00	1.09
Disembodied Technology Import Intensity	0.081	0.16	0.00	4.66
Number of Observations	2541			

Table 2: Estimation result of the Translog production function for Indian manufacturing

Variables	Coefficients	Standard Error	t Statistics
β_K	0.174	0.020	8.660***
β_L	0.220	0.026	8.470***
β_E	0.065	0.022	3.030***
β_M	0.515	0.020	25.540***
$^{\beta}KK$	0.000	0.000	3.370***
$^{\beta}KL$	0.040	0.007	5.570***
$^{\beta}KE$	-0.049	0.007	-7.010***
$^{\beta}KM$	0.009	0.006	1.450
$^{\beta}LL$	0.000	0.000	-0.590
$^{\beta}LE$	0.000	0.006	-0.070
$^{\beta}LM$	-0.046	0.007	-6.520***
$^{\beta}EE$	0.000	0.000	-0.560
$^{\beta}EM$	0.049	0.005	10.410***
$^{\beta}MM$	0.000	0.000	0.200
α_0	1.415	0.058	24.490
R^2	0.835		
Prob > F	0.000***		
Root MSE	0.493		
Number of observations	2541		

Once the total factor productivity is estimated based on a Translog specification, we tried to calculate the mean total factor productivity for 19 sub-industries. In addition, the mean energy intensity is also calculated for the full sample. From the result we can see that, the diversified manufacturing reported to be higher total factor productivity as compared to all other industries and the agricultural product industries have the least total factor productivity. Figure-1 presents the result where the horizontal line represents the mean total factor productivity and the bars represent the total factor productivity for each industry. We can observe from the figure that, only nine sub-industries out of 19 sub-industries have total factor productivity greater than the mean total factor productivity. The ranking of the sub-industries in terms of total factor productivity are given in table-3.

In an effort to examine the energy intensity of firms and its role as a determinant of productivity in the second stage regression, the study explores the mean energy intensity of 19 sub-industries and the mean energy intensity of the entire sample. The findings of this analysis are presented in Table-3, which also includes the ranking of sub-industries based on their energy intensity. By scrutinizing these results, the study gains valuable insights into the variation in energy intensity across different sub-industries, contributing to a nuanced understanding of the energy consumption patterns within the broader spectrum of the manufacturing sector. Figure-2 visually represents the mean energy intensity of each sub-industry along with the mean energy intensity of the entire sample. The horizontal line parallel to the X-axis in Figure-2 indicates the mean energy intensity across all sub-industries. Upon examination of the figure, a noteworthy observation is that the non-metallic mineral product industries exhibit higher energy intensity compared to the other 18 sub-industries. Conversely, the machinery and machinery product industries emerge as the least energy-intensive. This graphical representation provides a clear visual insight into the relative energy consumption patterns across different sub-industries, aiding in the identification of sectors with varying levels of energy intensity within the manufacturing landscape. The analysis reveals that seven out of the 19 industries exhibit energy intensity levels above the mean. However, in comparison to the mean total factor productivity, it is noteworthy that there is a higher degree of fluctuation in the case of energy intensity across the sub-industries. The subsequent step in this study involves an investigation into the determinants of total factor productivity, incorporating firm-specific variables beyond labor, capital, and material inputs. Consequently, the paper undertakes the estimation of factors contributing to inter-firm differences in productivity. This endeavor aims to provide a more comprehensive understanding of the multifaceted determinants influencing overall productivity levels within the diverse landscape of manufacturing sub-industries. The exploration of potential relationships between energy intensity and total factor productivity within the Indian manufacturing industries adds an intriguing dimension to the study. To delve into this aspect, the analysis includes an examination of the correlation coefficients between energy intensity and total factor productivity at the firm level. This statistical approach aims to uncover any discernible patterns or associations between the intensity of energy usage and the overall productivity levels of individual firms within the manufacturing sector. The correlation coefficients provide quantitative insights into the nature and strength of the potential relationship between these two critical variables. For a more detailed analytical examination, the sample has been categorized into three sub-classifications: (i) Classification based on the ownership pattern of the firms, (ii) Classification based on the aggregate industries classification (as in cmie), (iii) Classification based on the energy intensity.

Table 3: Mean Total factor productivity and energy intensity in Indian manufacturing

Symbol used	Sub-Industries	Number of observation	Mean Total Factor Productivity	Mean Energy Intensity	Ranking based on PO *	Ranking Based on Energy Intensity*
ID_1	Food Products	6	4.81	0.07	14	13
ID_2	Agricultural products	87	3.18	0.07	1	12
ID_3	Petrochemical	31	5.55	0.03	18	3
ID_4	Other Food Products	54	5.03	0.05	15	8
ID_5	Beverages and Tobacco Products	159	4.75	0.04	11	6
ID_6	Textile	321	4.53	0.11	10	17
ID_7	Lather and Lather Products	14	4.15	0.03	5	5
ID_8	Wood and Wood Products	14	3.58	0.08	3	15
ID_9	Paper and Paper Products	83	4.30	0.11	7	18
ID_{10}	Chemical and Chemical Products	390	4.49	0.09	9	16
ID_{11}	Rubber and Plastics Products	165	4.22	0.05	6	10
ID_{12}	Non-Metallic Mineral Products	129	4.80	0.15	12	19
$^{ID}13$	Basic Metal and Metal Products	283	5.19	0.06	16	11
ID_{14}	Machinery and Machinery Products	129	4.49	0.02	8	1
$^{ID}15$	Heavy Machinery	115	4.80	0.02	13	2
ID_{16}	Electronics	93	4.14	0.03	4	4
ID_{17}	Transport Equipments	181	5.32	0.04	17	7
ID_{18}	Other Miscellaneous Manufacturing Products	36	3.30	0.05	2	9
ID_{19}	Diversified Manufacturing	28	6.42	0.08	19	14
	Total	2318	4.63	0.07		

The analysis begins by exploring correlations within these sub-classifications, and subsequently, rank correlation coefficients between the set of variables are calculated. This comprehensive approach allows for a nuanced understanding of the interrelationships among ownership patterns, industry classifications, energy intensity, and various other key variables. By employing both correlation and rank correlation measures, the study gains a robust analytical foundation for exploring the intricate dynamics within these sub-classifications.

The outcomes of this analytical exercise are presented in Table-4. Notably, the results indicate that, with the exception of the non-metallic mineral product and diversified manufacturing industries, all other sub-industry classifications exhibit a negative relationship with total factor productivity. This suggests a potentially adverse impact of these sub-industry classifications on overall productivity levels within the Indian manufacturing sector. The findings contribute to a nuanced understanding of how different classifications, based on ownership patterns, aggregate industries, and energy intensity, are associated with the overall productivity performance of firms within the diverse manufacturing landscape.

Upon detailed observation of sub-groups, such as the distinction between foreign and domestic ownership of firms, the analysis reveals that domestic firms exhibit a higher correlation with total factor productivity compared to their foreign counterparts. This implies that, within the ownership classification, domestic firms are more strongly associated with overall productivity levels in the Indian manufacturing sector. Similarly, in the aggregate industries classification, there are discernible inter-industry differences in correlation coefficients. This suggests that the relationships between energy intensity, ownership patterns, and other variables with total factor productivity can vary significantly across different sectors within the manufacturing industry. These insights contribute to a more granular understanding of the nuanced dynamics at play within specific sub-groups and industry classifications.

In order to explore the relationship between energy intensity and total factor productivity further, the data has been segregated into two groups. One group comprises firms with energy intensity greater than the mean of the overall energy intensity in the sample, defined as less energy-efficient firms. The other group includes firms with energy intensity less than the mean, identified as energy-efficient firms. The correlation analysis reveals that firms classified as highly energy-efficient exhibit a higher and more significant correlation coefficient compared to their less energy-efficient counterparts. This finding underscores the potential impact of energy efficiency on overall productivity levels, emphasizing the relevance of energy considerations in the manufacturing sector.

Table-5 gives the detailed result of the estimates of equation (0.2). From the estimate of determinants of productivity we can observe that, age of the firm is positively significant with the total factor productivity of the firms. This suggests that older firms are more productive as compared to the younger ones. The positive relation between the age of the firm and the total factor productivity is as expected earlier and supports our hypothesis. Energy intensity has turned out to be negatively related to the total factor productivity. This result suggests that lesser energy intensive firms (higher energy efficiency firms) are more productive as compared to the higher energy intensive firms.

Table 4: Correlation coefficient of Energy intensity and total factor productivity across groups

SL No	Description of the sample	Sample Size	Correlation Coefficient	Rank Correlation Coefficient
1	Full sample	2318	-0.152	0.230
2	Foreign	89	-0.002	0.303
3	Domestic	2229	-0.151	0.230
4	Food Products	6	-0.807	0.770
5	Agricultural products	87	-0.127	0.252
6	Petrochemical	31	-0.593	0.600
7	Other Food Products	54	-0.305	0.593
8	Beverages and Tobacco Products	159	-0.316	1.000
9	Textile	321	-0.251	0.801
10	Lather and Lather Products	14	-0.251	0.864
11	Wood and Wood Products	14	-0.481	0.947
12	Paper and Paper Products	83	-0.020	0.830
13	Chemical and Chemical Products	390	-0.162	0.857
14	Rubber and Plastics Products	165	-0.018	0.927
15	Non-Metallic Mineral Products	129	0.081	0.867
16	Basic Metal and Metal Products	283	-0.048	0.913
17	Machinery and Machinery Products	129	-0.288	0.946
18	Heavy Machinery	115	-0.272	0.934
19	Electronics	93	-0.140	0.953
20	Transport Equipments	181	-0.269	0.877
21	Other Miscellaneous Manufacturing Products	36	-0.489	0.973
22	Diversified Manufacturing	28	0.218	0.860
23	Highly Energy Efficient	1886	-0.161	0.240
24	Less Energy Efficient	432	-0.080	0.362

This is as according to our hypothesis, as firms minimize energy input in producing output and energy is a derived demand for the industries, the higher energy efficient firms are more productive when compared to the less energy efficient firms. The embodied technology import intensity has a negative relationship with the total factor productivity of the firms. This result suggests that firms those import lesser embodied technology are more productive. Research and development intensity of the firms are positively related to the total factor productivity of the firms. Hence, higher the research and development expenditure of the firm higher productive they are. The export intensity has also turned out with a positive relation with the total factor productivity of the firms. Hence, export oriented firms are also more productive. As against the result of the embodied technology import, the disembodied technology import intensity of the firms is found to be positively related to the total factor productivity of the firms. This result suggests that firms importing higher disembodied technology are less productive as compared to their counterparts. To capture the industry specific characteristics in the inter-firm differences in total factor productivity, we have created 18 dummies in equation (0.2). Except Food Products industries all other industry dummies have turned out to be significant. As the coefficient of the constant has also turned out to be significant we can interpret the dummy coefficients and compared to the Diversified Manufacturing (the excluded industry in dummy). In addition to the industry dummy the MNE dummy is too significant in the result. Hence in addition to the constant coefficient the result suggests that the foreign owned firms are higher productive as compared to the domestic firms. The result of the dummied (17, except the Food Products industries) conform the estimation result. Further, we can observe that the total factor productivity is higher for the Diversified Manufacturing (as the benchmark) as compared to all other sub-industries.

5. CONCLUSION

The primary goal of this paper is to estimate the Translog production function and scrutinize the determinants of inter-firm variations in total factor productivity. A two-stage regression employing Ordinary Least Squares has been utilized to estimate the Translog production function, incorporating four inputs, for the Indian manufacturing industries specifically for the year 2008. This comprehensive methodology aims to provide insights into the production dynamics and factors influencing productivity levels within the manufacturing landscape in the specified period. Additionally, the study extends its focus to examine the determinants of total factor productivity by incorporating firm-specific characteristics and energy intensity. This approach allows for a more nuanced analysis, considering not only the core production inputs but also the influence of other factors and the energy efficiency of firms on overall productivity levels. The investigation aims to provide a comprehensive understanding of the intricate factors that contribute to inter-firm differences in total factor productivity within the context of the Indian manufacturing sector. The results of the study indicate that labor and material inputs exert a more significant influence compared to capital and energy inputs in the Translog production function. In the second stage regression, various factors such as the age of the firm, ownership structure, energy intensity, embodied and disembodied technology imports, research and development, and exports were explored as potential determinants of total factor productivity. These findings underscore the multi-faceted nature of factors influencing overall productivity in the Indian manufacturing sector, highlighting the importance of considering diverse inputs and firm-specific characteristics in the analysis of total factor productivity. The estimation results reveal that the age of the firm, export intensity, and disembodied technology import exhibit a positive relationship with total factor productivity in the Indian manufacturing sector. On the other hand, ownership, energy intensity, embodied technology import, and R&D intensity are found to be negatively associated with total factor productivity. These findings emphasize the diverse and complex nature of the determinants influencing productivity levels within the Indian manufacturing landscape, providing valuable insights for policymakers and industry stakeholders to enhance overall productivity. The analysis reveals that energy-efficient firms also demonstrate high levels of total factor productivity, suggesting a positive association between energy efficiency and overall productivity. Observing the mean total factor productivity, it becomes apparent that diversified manufacturing industries exhibit higher levels compared to the other eighteen sub-industries. In contrast, agricultural product industries emerge with the least total factor productivity within the Indian manufacturing sector. These insights underscore the potential impact of energy efficiency and the varying productivity levels across different sub-industries, offering valuable considerations for strategic planning and industry development. Beyond the quantitative assessment of total factor productivity, this study delves into the exploration of determinants influencing total factor productivity for the Indian manufacturing industries. A noteworthy aspect of this research is its comparative analysis across sub-industries, providing a nuanced understanding of variations in productivity drivers. Additionally, the paper contributes by incorporating energy as the fourth input in the production function, recognizing the significance of energy considerations in the overall productivity dynamics of the manufacturing sector. This comprehensive approach aims to offer valuable insights for policymakers, industry practitioners, and researchers in the realm of Indian manufacturing. In the context of ongoing climate change negotiations and discussions, the pivotal role of energy cannot be understated. The imperative to concentrate on both productivity and energy utilization within Indian industries, particularly in the manufacturing sector, is evident. The outcomes of this study carry significant policy implications, emphasizing the necessity to prioritize energy efficiency. One specific policy implication underscores the urgency to promote energy efficiency at the firm level across all manufacturing industries in India. The government could contemplate the introduction of fiscal incentives aimed at encouraging and rewarding higher energy efficiency achievements. Such proactive measures can not only enhance the sustainability of industrial operations but also contribute to broader environmental and economic goals.

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