DECLINING ENERGY INTENSITY IN THE PULP AND PAPER INDUSTRY IN INDIA: DOES TRADITIONAL AND ADVANCED INPUTS USE MAKE A DIFFERENCE?

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Abstract: This study uses Annual Survey of Industries (ASI) Commodity Classification 2009 on ASI data and for the first time classifies the Pulp and Paper (P&P) industry in India into three different raw material-based sectors, namely Wood-based P&P sector, Agro-based P&P sector and Recycled paper-based P&P sector, and evaluates the intensity of energy use across these segments. The analysis reveals that the energy consumption per unit of output produced in the P&P industry and its different raw material based segments in India have been falling during 1999-2010. The declining energy intensity in this otherwise energy-intensive P&P industry and its different raw material based P&P sectors in India is examined employing the panel data econometric models. The analysis shows that the industry level determinants such as profit intensity, vertical integration and energy prices have significant and negative relationships with the declining energy intensity in all three segments of the P&P industry in India. However, owing to differences in the structure and nature of different raw material based P&P sectors in terms of differences in raw material consumption, scale of operation and the variation in production process followed, the effects of traditional inputs (capital, labour, indigenous material and imported material) and advanced inputs (services input, ICT and pollution control equipment) on declining energy intensity vary across these segments. The differential bearing of these variables on energy intensity in different raw-material based segments of the industry is also explained. The result may be useful for formulating proactive energy efficient and environmentally sustainable policies for energy-intensive traditional manufacturing in a developing country setting.

Keywords: Pulp and Paper industry, Energy intensity, Determinants of energy intensity and India.

JEL Classification: C33, D22, L67 and Q41.

"There is no favourable wind for those who do not know where they are going".
-Seneca[1]

1: Introduction

Globally, industry accounts for one-third of final energy used and for almost 40 percent of worldwide Carbon dioxide (CO_2) emissions.[2] In 2007, total final energy use[3] in industry amounted to 3019 Million tonnes oil equivalent (Mtoe) (Trudeau, Tam, Graczyk and Taylor, 2011). Between 2000 and 2010, the total industrial final energy use increased by 31 percent, from 103 Exajoule (EJ) to 135 EJ (Table 1). The observed growth in energy consumption has been mainly driven by increasing demand and production of industrial output in major countries like China and India. The shares of the Organization for Economic Co-operation and Development (OECD) regions' industrial energy consumption, however, declined from over 50 percent in 2000 to 36 percent in 2010.

Table 1: Global Industrial Energy Consumption by Region (in Percentage)

Region	2000 (103 EJ)	2010 (135 EJ)
China	14	28
India	5	6
Latin America	6	5
Africa and Middle East	7	8
Other Developing Asia	6	8
Other Non-OECD	11	9
OECD	51	36
All	100	100

Note:
EJ: Exajoule
Source: International Energy Agency (IEA), 2013

[1] As cited in The World Bank (2002).

[2] The industrial emissions are classified into two broad categories: direct emissions and indirect emissions. The direct emissions include fuel combustion and process-related CO_2 emission from within the industry. The direct emissions of CO_2 from the industry is 7.6 Gigatonnes of CO_2 (Gt CO_2). Indirect emissions are from the power generation sector due to electricity use in the industry. The indirect emission from the industry is 3.9 Gt CO_2 (Trudeau et al., 2011).

[3] The total industrial final energy includes energy used as a feedstock in the chemicals and petrochemicals sectors, as well as energy used in coke ovens and blast furnaces.

India is fourth largest energy user with 6 percent share of global industrial total energy use.[4] Up to 150 Mtoe of final energy was used for industrial purposes in 2007, accounting for 38 percent of the country's total energy used.[5] India's industrial energy use mix comprises coal, oil, natural gas, electricity, and biomass and waste (Table 2).[6] The biomass and waste constitutes a substantial portion of total industrial energy demand in India. The share of biomass and waste in total industrial energy demand in India is 19 percent compared to 6 percent of the world's mix of energy demand. Since the combustion of biomass is considered as carbon-neutral the large share of regenerative biomass use as a fuel makes the industry in India one of the least CO_2 intensive compared to the industry worldwide. As for total electricity consumed, about 30 percent of the electricity used by industry is generated by captive power plants which indicate the industry is becoming inventive, self-reliant, and less polluting.

Table 2: Industrial Final Energy Mix in India and in the World, 2007 (in Percentage)

Energy Type	India	World
Coal	33	27
Oil	23	23
Natural Gas	10	20
Electricity	15	20
Biomass and Waste	19	06
Other	-	04
Total	100	100

Source: Trudeau, Tam, Graczyk and Taylor, 2011

Globally, the energy consumption of five energy-intensive industries (iron and steel; chemical and petrochemical; non-ferrous metal; non-metallic minerals including cement; and paper, pulp and print) increased relative to the other industrial sectors between 2000 and 2010. These five sectors together accounted for more than 67 percent of the total final industrial energy use in 2010, compared with 58 percent in 1990 (IEA, 2013). In India, these

[4] For understanding the role of energy intensity in CO_2 emissions from Indian manufacturing industry, see Sahu and Narayanan (2013).

[5] Energy demand in the industry in India is projected to increase, so as to account for more than 50 percent of the country's total energy consumption by 2040 (IEA, 2015).

[6] About 30 percent of the electricity used by Indian industry is generated by captive power plants. Captive power stations are set up by industrial units for their exclusive supply (Trudeau et al., 2011).

five sectors accounted for about 56 percent of total industrial energy consumption in 2007. Among these energy-intensive sectors, the Pulp and Paper (P&P) industry was the fourth largest industrial energy user in the world in 2007, consuming 164 Mtoe of energy, which amounted to 5 percent of the total global industrial energy consumption (Trudeau et al., 2011). The P&P industry is also one of the energy intensive polluting industries in India [Schumacher and Sathaye, 1999; National Productivity Council (NPC), 2006; Tewari, Batra and Balakrishnan, 2009; Bureau of Energy Efficiency (BEE), 2011; Trudeau et al, 2011; Central Pollution Control Board (CPCB), 2016].[7] Though P&P industry in India is one of the energy intensive industries, its energy consumption has been declining over the last five decades. Table 3 and Table 4 shows decline in percentage share of P&P industry in the total energy use of the manufacturing industry as a whole, and falling share of energy in total inputs use in the P&P industry, respectively. It is against this background, this study evaluates the decline in energy consumption in the P&P industry in India.

Table 3: Percentage Share of Paper and Paper Products Industry in the Total Organized Manufacturing Industries in India

Variables	1961-62	2011-12
Value of Output	1.85	1.17
Gross Value Added	2.36	1.15
Total Persons Engaged	1.52	1.89
Fixed Capital	3.37	1.93
Fuels Consumed	4.20	2.95
Materials Consumed	1.60	1.18

Source: Author's Calculation based on Annual Survey of Industries (ASI) data.

The reminder of the study is organized as follows. Section 2 discusses the existing literature and identifies the research gaps. Section 3 described the data and methodology applied in the paper. The energy intensity in India's P&P industry is evaluated in Section 4. The econometric model specification and variable construction are presented in Section 5 while Section 6 discusses the results on determinants of energy intensity in the P&P industry and its three different raw material based sectors. The final Section 7 summarizes the findings.

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[7] This traditional P&P sector in India had some leverage, and played a pivotal role in laying the foundations for the country's social sector development, employment generation and economic growth. The P&P industry is one of the 17 basic industries in India [Centre for Science and Environment (CSE), 2004].

Table 4: Percentage Share of Different Inputs in Total Input Consumed by India's Pulp and Paper Industry

Inputs	1961-62	1971-72	1981-82	1991-92	2001-02	2011-12
Energy Consumed	14.36	13.75	19.88	20.61	18.28	12.68
Material Consumed	72.07	69.32	67.96	69.69	70.66	78.38
Other Inputs incl. Services	13.57	16.93	12.16	9.71	11.07	8.94
Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: Author's Calculation based on ASI data.

2: Review of Existing Literature

A few recent literature on energy demand have examined the determinants of energy intensity (EI) for different economies. The determinants of EI in the European Union-28 member states are studied by Filipovic, Verbic and Radovanovic (2015). Andersson and Karpestam (2013) examined the factors influencing EI in eight developed economies and two emerging economies. The determinants of EI in different individual countries are examined by Ma, Oxley and Gibson (2009), Wu (2012), Adom (2015a, 2015b), and Zhang, Cao and Wei (2016). There are also few recent studies discussing EI in different sectors. Mulder et al., (2014) analyzed the factors determining EI in the 23 service sectors in 18 OECD countries. Liu and Han (2009), and Fisher-Vanden, Hu, Jefferson, Rock and Toman (2013), and Cao and Karplus (2014) investigated the determinants of EI in Chinese industries. The determinants of EI in the Indian manufacturing industry have been examined by Kumar (2003), Goldar (2010), Sahu and Narayanan (2011) and Sahu and Mehta (2015). The determinants of EI in the P&P industry in India were analyzed by Narayanan and Sahu (2010). However, it is found that most of the studies were conducted at the national economy level and aggregate industry level. There are few studies that analyze the energy demand at the sub-sectoral level. They used firm-level annual data provided by PROWESS of the Centre for Monitoring Indian Economy (CMIE). The present study, however, uses an official data of Government of India- Annual Survey of Industries (ASI) at the 5-digit level and perhaps for the first time classifies the P&P industry in India into three different raw materials based sectors: wood-based P&P sector, agro-based P&P sector and recycled paper (RCP)-based P&P sector. It aims to analyse the energy used per unit of output produced in the P&P industry and its three different raw material based P&P

categories in India. It also seeks to understand the determinants of energy intensity in the P&P industry and its all raw material based sectors.

3: Data and Methodology

To fill the identified research gaps in the literature, this paper uses panel data models. Detailed expositions of these methodologies are provided in section 5, respectively. The data on total output, energy use, traditional input variables, advanced input variables, and industry level determining variables measured for the analysis of energy use in the P&P industry in India is drawn from Annual Survey of Industries (ASI) unit level factory data published by Central Statistical Office, Ministry of Statistics and Programme Implementation, Government of India. We apply ASI Commodity Classification (ASICC) - 2009 on ASI data to generate unit level database for different raw material based P&P sectors, namely, wood-based P&P industry, agro-based P&P industry and RCP-based P&P industry.[8] Using unit level data, unbalanced panel data was created for the P&P industry, wood-based P&P sector, agro-based P&P sector and RCP-based P&P sector.[9] The panel is unbalanced because not all units provide their annual reports for all the years.[10] However, due to insufficient unit-level panel observations, we aggregated unit-level information into a National Industrial Classification (NIC) 2008-based, seventeen 5-digit industry-level data.[11] Due to differences at the 5-digit level industrial classification in NIC-1998, NIC-2004 and NIC-2008, we harmonized the industry groups based on NIC-2008.[12] The unbalanced panel data of P&P industry in India consists of 204 observations of the seventeen 5-digit industry. In the unbalanced panel database, the wood-based P&P industry in India has 127 observations while the agro-based P&P industry has only 77 observations. The RCP-based

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[8] On how different raw material based P&P industry database was created, see Appendix- 1.

[9] The summary statistics of unit-level data of the P&P industry and its different raw material based P&P sectors is given in Appendix- 2.

[10] To learn how unbalanced panel data was created for the study, see Appendix- 3.

[11] The details as to why we aggregated ASI unit-level data for 1998-99 to 2009-10 into NIC 2008 based 5-digit industry level data (unbalanced panel) is given in Appendix- 4.

[12] The NIC 2008 based 5-digit industry-level harmonized classification of the P&P industry in India is given in Appendix- 5.

P&P industry in India has 191 observations for 1998-99 to 2009-10. The Wholesale Price Indices (WPIs) are obtained from Indiastat.com. The data set used in this study is purely based on it availability which runs from 1999 through 2010.

4: Energy required Per Unit of Output Produced in the P&P Industry in India

According to the Bureau of Energy Efficiency (BEE) (2011), the P&P industry in India ranked seventh among the high energy-consuming manufacturing sectors in 2007, using about 1.4 Mtoe of energy**.** The energy consumption in the P&P industry in India, however, has been falling over the years. The percentage share of energy use in the P&P industry in organized manufacturing industry in India declined from 4.20 percent in 1961-62 to 2.95 percent in 2011-12. The declining energy use in the P&P industry is also reflected in the falling share of energy in total input of the sector. It declined from 14.36 percent in 1961-62 to 13.75 percent in 1971-72. This proportion, however, increased to 19.88 percent in 1981-82, and to 20.61 percent in 1991-92. The share of energy consumption in total inputs declined again in 2001-02 to 18.28 percent, and in 2011-12, it further declined to 12.68 percent. Similarly, the energy intensity (EI) of this industry has been declining, more so after 1990. EI provides a single, simple and easy-to-compute summary measure of the efficiency with which energy is utilized (Freeman, Niefer and Roop, 1997). Typically, EI is computed as the ratio of energy input to the output.[13] The real value of 'fuels consumed' is estimated by deflating it by the composite 'energy price index' for India at 2004-05 base year prices. The value of 'total output' is deflated by the Wholesale Price Index (WPI) of paper and paper products in India at 2004-05 prices to get its real value.[14] The EI of India's P&P industry fell from 20.45 percent in 1961 to 14.81 percent in 1970. However, owing to establishment of medium- and small-sized input intensive mills, EI increased to 18.77 percent in 1980 and to 20.09 percent in 1990. The increasing EI of this industry started falling after 1990 and in 2000, it reached 15.86 percent, which declined further to 8.43 percent in 2011.

[13] Energy Intensity (%) = ((Real Value of fuels used / Real Value of Total output) * 100)

[14] The detail on the constituents of energy and output, and their estimation of real values are given in Appendix- 6.

As India’s P&P industry is highly fragmented and diversified in terms of raw material use and scale of operation, the energy consumption varies across different raw material based sectors. Table 5 demonstrates that this industry majorly uses wood-based, agro-based and recycled paper (RCP)-based raw materials for producing paper and paper products. There are 85 large scale wood-based P&P mills (about 11.20 percent of the total mills) in the country which produce around 36 percent of the total paper and paper products in 2011-12. These large sizes integrated P&P mills are owned by big business conglomerates and corporate groups. They have better financial capacity to carry out large expansion and modernization. These mills have also undergone significant modernization by installing input efficient technology in the production process and pollution controlling systems. These mills produce good quality high-grade paper and paper products. They are domestically competitive and also have a presence in the overseas market through exports [Jaakko Poyry Consulting (JPC), 2002, CPPRI, 2004; NPC, 2006]. The medium-sized agro-based P&P mills form 21.08 percent of the total factories and account for around 29 percent of the total production. The significant portion of the P&P factories in the industry (about 67.72 percent of the total mills) in the country is dominated by small-sized RCP-based mills, which account for 35 percent of the total production. Most of these small and medium-sized mills are owned and managed by local business groups or independent village producers running only one mill targeting their respective local markets (JPC, 2002; CPPRI, 2004). The second-hand imported machineries are installed in the production process in these mills, which are originally designed for large-sized wood-based P&P mills. This results in inefficient resource use leading to high production costs and huge environmental pollution (Mohanty ed., 1997; Mathur, Thapliyal and Singh, 2009). It is also uneconomical to install input-efficient equipment, effluent treatment plants, chemical recovery plants and pollution control systems in the small and medium size P&P factories (Trudeau et al., 2011). The lack of these results in the production of low quality paper and paper products (CPPRI, 2004; NPC, 2006). The industry, however, is dominated by medium sized agro-based and small sized RCP-based P&P mills. They constitute about 88.80 percent of total number of the P&P mills in the country, contributing 64 percent of the total production in 2011-12.

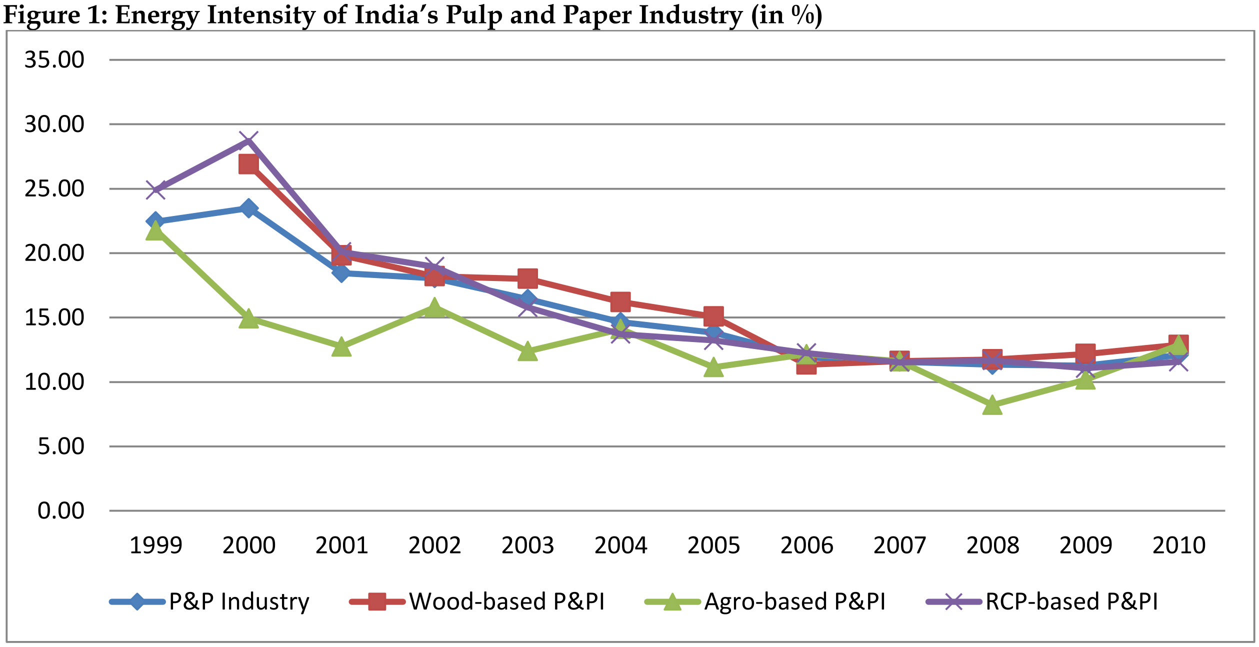
Table 5: The Scale of Operation of Different Raw-material based P&P Mills							
Type of Raw-material for Paper Industry	**Scale of Operation (TPD)**	**Number of Mills**			**Production Share (%)**		
	2011-12	**1991**	**2000**	**2011-12**	**1991**	**2000**	**2011-12**
Large Integrated Wood-based	100-1100	28 (8.62)	28 (7.37)	85 (11.20)	41	38	36
Medium Agro-based	50-100	87 (26.77)	111 (29.21)	160 (21.08)	32	36	29
Small Waste Paper-based	5-50	210 (64.62)	241 (63.42)	514 (67.72)	27	26	35
Medium Agro-based + Small Waste Paper-based	-	297 (91.38)	352 (92.63)	674 (88.80)	59	62	64
Total	-	325 (100.00)	380 (100.00)	759 (100.00)	100	100	100

Notes:
TPD: Tonnes Per Day
Figure in parenthesis refers to the percentage share in different raw material based sectors in total number of mills in the industry.
Sources:
1991: Indian Pulp and Paper Technical Association, 1992
2000: Central Pulp and Paper Research Institute, 2000a
2011-12: DIPP Annual Reports, 2010-11, 2011-12.

Owing to variation in the scale of operation, raw material usage and the differences in the production process followed in these mills, they produce different types of output. In contrast to the global trend where big mills specialize in producing single paper grades, in India, the large-sized mills produce multiple paper grades. Although these large scale wood-based mills produce multiple paper varieties predominantly, they produce cultural grades. Agro-based P&P mills in India are medium-sized and produce a combination of cultural and industrial paper. The largest segment in the P&P mills in India consists of small-scale mills using RCP material and produces industrial grade paper. Very few mills are involved in the production of special grade paper (CSE, 2004; NPC, 2006).

Considering the differences in raw material consumption, scale of operation and the variation in production process followed in different categories of the P&P industry which produce different types of final products, we looked at the EI of P&P industry in India and its three major raw material-based segments. We find that it has declined in all categories of the P&P sectors during the last one decade from 1999 to 2010. The EI in India's P&P industry fell from 22.46 percent in 1999 to 12.08 percent in 2010. Among different categories, wood-based P&P industry appears to be consuming slightly more amount of energy to produce one unit of output compared other two sectors (Figure 1) because of its use of high energy consuming fibrous raw material (Jaakko Pyory Consulting, 2002).[15] In the wood-based P&P sector, EI reduced from 26.89 percent in 2000 to 12.88 percent in 2010. The agro-based P&P sector witnessed a fall in EI, from around 21.77 percent in 1990 to 12.86 percent in 2010 while during the same period in RCP-based P&P sector, it declined from 24.90 percent to 11.56 percent.

Figure 1: Energy Intensity of India's Pulp and Paper Industry (in %)



Source: Author's Calculation based on ASI data.

[15] The improvement of energy efficiency provides benefits at multiple levels. At the sectoral level, the benefits include high productivity and competitiveness, better energy service by the energy provider, and infrastructure benefits that reduce the operating cost and increase asset value. The high energy efficiency at the sectoral level in turn, provides gains at the national level by offering new employment opportunities, reducing energy-related public expenditures, and ensuring energy security. There are also positive macroeconomic impacts, including increase in GDP. The effort for energy efficiency also provides benefits at the international level by reducing greenhouse gas emission, moderating international energy prices, and natural resource management for sustainable development (Ryan and Campbell, 2012).

The decline in EI (energy required per unit of output produced) in the P&P industry in India could be attributed to three major reasons occurring simultaneously, such as, change in energy use policy, technological improvement, and change in raw material use. These are discussed below.

Change in Policy for Increasing Energy Efficiency: The first of these is the systematic policy initiatives by the government to make the sector energy efficient. Yang (2006) collated the various industrial energy policies modulated by different government agencies to achieve higher energy efficiency. This includes the policies of 1980s which gave high priority to energy efficiency and related environmental improvement. The government set up the National Energy Efficiency Program to promote indigenous capabilities for design and manufacture of energy efficient equipment. It made energy and environment management mandatory. In 1989, the government introduced the disclosure of company-level energy use information, and established the Energy Management Centre under the Ministry of Energy to promote and support the energy efficiency program. In 1991, the government introduced several reforms in energy prices and liberalized the regulatory regime. Further reforms were undertaken in energy pricing for the development of market-based-prices to guide energy efficiency initiatives and promote international competitiveness in 1993. Import of low quality coal was allowed in 1994. The accelerated depreciation of energy efficiency and pollution control equipment was allowed in 1995. The Bureau of Energy Efficiency (BEE) under Ministry of Power was set up under the provisions of the Energy Conservation Act, 2001 which made mandatory provisions of energy consumption norms and energy audit, and establishing energy efficiency standards and labelling. The Electricity Act, 2003 pays specific attention to energy conservation and captive Combined Heat and Power (CHP) cogeneration.[16] The Integrated Energy Policy 2008, the first comprehensive energy policy by the Indian government, deals with energy security, access and availability, affordability and pricing. It also addresses multifaceted

[16] Captive stations are units set up by industrial plants for their exclusive supply. It burn fuel inputs to generate electricity (Trudeau et al., 2011).

energy efficiency and environmental concerns by emphasising on the application of energy efficient technologies and demand side management and conservation (Ahn and Graczyk, 2012). The National Mission for Enhanced Energy Efficiency was set up in 2010 under the Ministry of Power and BEE with the mission to usher in four new initiatives to significantly scale up the implementation of energy efficiency in India. The flagship of the Mission is the Perform, Achieve and Trade (PAT) mechanism, which is a market-based mechanism to make improvements in energy efficiency in energy-intensive large industries and facilities more cost-effective by certification of energy savings that could be traded. The PAT mechanism is designed to allow designated consumers to not only achieve their legal obligations under the Energy Conservation Act, 2001, but to also provide them with necessary market-based incentives to overachieve the targets set for them. In March 2007, the Ministry of Power notified units consuming energy more than the threshold in nine industrial sectors, namely Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron and Steel, Aluminium, and Railways as energy intensive industries' designated consumers. The designated consumers are required to submit the annual energy consumption report to the designated authority of the state as well to BEE, comply with the energy conservation norms and standards prescribed, purchase energy saving certificates for compliance, allow monitoring and verification of compliance by designated energy auditors. It incentivizes the excess achievement of the target set by issuing energy saving certificates. It also has provision of penalty for non-compliance (BEE, 2011). These institutional monitoring might have instigated the industry to improve energy efficiency through the use of energy-saving technologies in production processes.

Technological Improvement in the Production Process: The second factor which could have contributed to the improvement in energy efficiency is the technological change. The technological improvements in the P&P industry in India is reflected in the increasing total factor productivity growth, shown in the studies by Virmani and Hashim (2011), Kathuria, Raj and Sen (2013), Chakraborty and Dasgupta (2014). The increasing adoption of energy-saving modern technology in the major production process (raw material preparation, pulping, pulp washing and bleaching, stock preparation, and paper making) of different raw material based P&P sectors over the years have increased the energy efficiency of the P&P industry in India (CPPRI, 2000a, 2000b, 2004; Panda, 2005, 2007).[17] For instance, the increasing consciousness for environmental pollution and consumer preference of good quality products pressures the P&P industry to use sophisticated bleaching sequences.[18] Over the years, there has been a substantial improvement in the bleaching technology from conventional batch digester to Ozone bleaching, which reduces the capital costs and operation costs, making bleaching sequences more economical. The improvement in bleaching technology reduced the pulp Kappa number from about 25 in 1975 to 8 in 2005. The decline in Kappa number indicates the reduction in the use of energy, water and chemicals in the bleaching sequences and thereby corresponding decline in waste water effluent parameter such as Adsorable Organic Halide (AOX) (Panda, 2007).

Switch to Energy Efficient Raw Material: The third important reason for the decline in total energy use in the P&P industry in India could be shift in the usage of raw material. The industry moved away from using energy-intensive conventional wood-based raw material to energy efficient and environment friendly unconventional RCP-based material (Jaakko Pyory Consulting, 2002). The share of RCP in total raw material use in the P&P industry in India increased significantly from around 35 percent in 2000 to 47 percent in 2011 (DIPP, 2011, Kulkarni, 2013).

Though declining EI could be hypothetically attributed to simultaneous occurring of change in energy use policy, technological improvement, and change in raw material use, the decline in EI could be determined by various industry-specific factors. To that end, the present study analyses the determinants of changing EI in the P&P industry in India and its different raw material based sectors.

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[17] For in-depth discussion on the emerging energy-efficiency and greenhouse gas mitigation technologies for the P&P industry, see Kong, Hasanbeigi and Price (2012).

[18] Bleaching sequences are used to deliginify the pulp in the early stages and employ chemical agent to destroy the residual color in later stages. The entire bleaching process is carried out in such a manner that strength characteristics and other papermaking properties are preserved, and environmental pollution is curbed (CPPRI, 2004).

5: Determinants of Energy Intensity: Model Specification and Variable Construction

Energy intensity (EI) reflects the energy required to produce one unit of output. It also indicates the level of energy efficient technology used in the production process. Lower the EI higher will be the energy efficiency and vice versa. The observed decline in EI in India's P&P industry could have been affected by the use of various traditional inputs, advanced inputs or industry level determinants. This study examines the factors that influence EI of India's P&P industry using panel data econometric models such as pooled Ordinary Least Squares (OLS), Fixed Effect (FE) and Random Effect (RE). Similar exercise has been carried out to analyse the determinants of EI of the wood-based P&P industry, agro-based P&P industry, and RCP-based P&P industry. We assume that there is unobserved heterogeneity across the industry captured by α_i. If the individual specific α_i are correlated with the regressor, we use a FE model; if they are not correlated, we use a RE model.

The FE model for the P&P industry in India is as follows:

$$\mathrm{EI_{it}} = \alpha_\mathrm{i} + \beta_1\mathrm{KI_{1it}} + \beta_2\mathrm{LI_{2it}} + \beta_3\mathrm{DMI_{3it}} + \beta_4\mathrm{MMI_{4it}} + \beta_5\mathrm{SI_{5it}} + \beta_6\mathrm{ICTI_{6it}} + \beta_7\mathrm{PCEI_{7it}} + \beta_8\mathrm{PIlag1_{8it}} + \beta_9\mathrm{VI_{9it}} + \beta_{10}\mathrm{EP_{10it}} + \mathrm{u_{it}} \quad (1)$$

Where, β's = Coefficient of variables, α = Individual effect of ith industry assumed to be constant over time, u = Between entity error, i = Cross-section unit, i = 1, 2……,N; t = Time period, and t = 1, 2……,T.

We use the Hausman (1978) test to arrive at the appropriate model between the FE and RE models. The Breusch and Pagan (1980) Lagrangian multiplier test is performed to choose the right model between the RE and pooled OLS regression estimators. All panel data models are estimated with option 'cluster panel identity' that control heteroscedasticity and autocorrelation in the data.

Variable Construction

The increasing use of service input, information and communication technology (ICT) in the manufacturing sector, and the growing importance of pollution control equipment (PCE) for input-efficient pollution neutral production, makes it necessary to divide the input used in the industry into traditional inputs (capital, labour, indigenous material and imported material) and advanced inputs (services, ICT and PCE) for a better understanding about their impact on EI. Non-input industry-level determining variables such as profit intensity and vertical integration, and intermediate input price variables such as energy price have been considered for the analysis. The variables used for the analysis are constructed in following ways.

Energy Intensity (EI): EI is considered as a proxy for energy efficiency. Increase in energy efficiency occurred either when energy consumption is reduced for a given level of output or enhanced output for a given amount of energy use. In this study, EI is defined as the ratio of real value of fuels used to the real value of output.

Capital Intensity (KI): The fragmented P&P industry in India consists large scale wood-based, medium scale agro-based and small-scale RCP-based P&P mills. The medium-sized agro-based and small sized RCP-based capital saving P&P mills use second-hand imported machinery and equipment in the production process, which are originally designed for large-scale wood-based P&P mills (Mohanty ed., 1997; Mathur, Thapliyal and Singh, 2009), resulting in the huge consumption of energy. Thus, we expect that the setting up of a large number of small and medium-sized labour-intensive P&P factories to increase the production means higher application of obsolete technology in the production process, which increases the EI of the agro-based P&P sector and RCP-based P&P sector. Since the P&P industry is dominated by technologically inefficient medium-sized agro-based P&P mills plus small sized RCP-based P&P mills, we expect that the rise of KI in the P&P industry will raise its EI. However, with the formulation of several policies for promoting industrial energy efficiency, especially after the 1990s, the government encourages the application of energy saving technology and equipment in the production process to promote an energy efficient production system. This has been responded well by the large scale wood-based P&P mill by adopting energy efficient technology in the production process (JPC, 2002: CPPRI, 2004; National Productivity Council 'NPC', 2006). In this context, we hypothesize a negative relationship between KI and EI in the large-sized wood-based P&P industry.

KI is measured as the ratio of the value of fixed capital stock to the real value of total output, as applied in Kumar (2003), Narayanan and Sahu (2010), and Sahu and Narayanan (2011, 2013), and Sahu and Mehta (2015).[19] The estimation of capital stock series is a controversial issue both in theory and empirics. Since there is no perfect way of measuring capital stock, we follow the standard practice of using the Perpetual Inventory Method (PIM) as used in the literature, although it is not free from caveats.[20] We consider Net fixed capital stock (as given in ASI) at constant prices in 2004-05 as the measure of capital input. Using the PIM method for the industry-level developed by Hashim and Dadi (1972), we estimate capital stock as done by Balakrishnan and Pushpangadan (1994), Pradhan and Barik (1999a), Veermani and Goldar (2004), and Banga and Goldar (2007). The real value of output is measured by deflating the total output by the WPI of paper and paper products in India at 2004-05 prices.

Labour Intensity (LI): In India, the medium-sized agro-based plus small-sized RCP-based P&P mills forms large share in the total number of P&P mills, indicating the dominance of small- and medium-sized labour intensive units in the P&P industry. The increase in labour use is also reflected in terms of labour employment in the P&P industry in India. With the growing numbers of P&P factories, the total number of persons engaged in the P&P industry to the total manufacturing in India increased from 1.73 percent in 1991-92 to 1.89 percent in 2011-12. These capital-saving mills rely more on labour to expand economic activity. Hence, increase in LI, in turn raises their EI. With the clear dominance of small- and medium-sized labour-intensive agro-based and RCP-based P&P sectors, we expect that increased LI will push up the EI of the P&P industry in India. LI is measured as the ratio of total number of persons engaged to the real value of total output, as done in Narayanan and Sahu (2010) and Sahu and Narayanan (2011, 2013), and Sahu and Mehta (2015).

[19] We use this measure of KI to normalize the variables in the model. Though we tried to use the K/L ratio as a measure of KI as used in various studies, the results were not on the expected lines. The results are also not consistent because of the high K/L ratio compared to other estimated independent variables.

[20] The problem of PIM is explained in detail by Ray (2002).

Material Intensity (MI): The scarce supply of raw material and energy leading to rise in their market prices, pressure the manufacturers to reduce the cost of production by substituting the intermediary inputs. The P&P industry in India being one of the material, energy and water intensive polluting industries (Ramaswamy et al., 1996; Schumacher and Sathaye, 1999; Pradhan and Barik, 1999b; NPC 2006; Tewari et al., 2009; BEE, 2011), it is likely that there could be substitution between intermediary inputs such as material and energy. So, we expect a negative relationship between MI and EI.

The material consumed by the P&P industry in India is derived both from indigenous and imported sources (Table 6). As the agro-based P&P sector obtains a large chunk of the material required from indigenous sources (about 94 percent), we use MI instead of indigenous material intensity (DMI) and imported material intensity (MMI) for the analysis. However, for the analysis of other segments such as the P&P industry, wood-based P&P sector and RCP-based P&P sector, we use DMI and MMI.

Table 6: Sources of Material used in the P&P industry in India (1999-2010)

Sector	Indigenous Materials (%)	Imported Material (%)	Total Material (%)
P&P Industry	78.75	21.25	100
Wood-based P&P sector	74.91	25.09	100
Agro-based P&P sector	93.60	6.40	100
RCP-based P&P sector	77.48	22.52	100

Source: Source: Author's Calculation based on ASI data.

MI is the value of material consumed divided by the value of total output. The real value of material is estimated by deflating the value of material with the material price index. The material price index in India, base 2004-05, is constructed using a method similar to that used for the energy price index. The value of total output is deflated by the WPI of paper and paper products in India at 2004-05 prices to arrive its real value.

Indigenous Material Intensity (DMI): Since a large proportion of the material used is indigenously sourced, we hypothesize that DMI has a negative impact on EI. The DMI is estimated as the value of indigenous materials used divided by value of total output. The real value of indigenous material is estimated by deflating with the composite material price index with base year 2004-05. The real value of output is measured by deflating the total output by the WPI of paper and paper products in India at 2004-05 price base.

Imported Material Intensity (MMI): Goldberg, Khandelwal, Pavcnik and Topalova (2010) found the imported intermediate inputs enabled the production of new output in Indian firms. Considering the positive impact of intermediate inputs on output, we expect that increase in MMI would reduce the EI. The MMI is estimated as the value of imported materials divided by the value of total output. The nominal value of imported material is deflated by material price index in India at 2004-05 price base to get its real value.

Services Intensity (SI): The use of services input such as inward freight, transport charges, bank charges, advertisement costs, and so on in the manufacturing sector has been established in recent literature. Banga and Goldar (2007) found the contribution of services input to output and productivity growth in the Indian manufacturing sector increased during 1980-81 to 1997-98, mainly on account of trade reforms undertaken in the post-1990 period. Arnold, Javorick, Lipscomb and Mattoo (2012) observed that services sector (banking, telecommunications, insurance, and transport) reforms had significant and positive effects on productivity growth in Indian manufacturing firms during 1993-2005. Bas (2013) found that the reforms of energy, telecommunications and transport services in the mid-1990s increased the profitability of exporting firms and export shares of firms producing downstream manufacturing industries in India during the period 1994 to 2004. Considering the positive impact of services input on the industry's performance, we hypothesise that the increase in services input use will reduce EI.

The SI is estimated as the actual value of services input divided by the actual value of total output. We use implicit service deflator at 2004-05 base price as done in Banga and Goldar (2007) to get the real value of services input. The real output is obtained by deflating the value of output by the WPI of paper and paper products in India at 2004-05 prices.

Information and Communication Technology Intensity (ICTI): The rising importance of ICT in Indian economic growth in general and the manufacturing sector in particular has been established in the literature. A study by Joshi (2009) shows the high contribution of the information technology (IT) sector and IT-enabled services to the total value added in the Indian economy. Other studies such as Sharma and Singh (2012) found that the higher use of IT raised value added growth in the Indian manufacturing industry. Joseph and Abraham (2007), and Commander, Harrison and Menezes-Filho (2011) found that ICT has had a positive effect on productivity growth in the country's manufacturing industry. Goldar (2010) found that the use of IT promotes energy use efficiency in the Indian manufacturing industry. In India's P&P sector, ICT was earlier used only in non-critical areas of operation such as the administration of a factory. However, in recent times, ICT has been used in critical areas of the production process and marketing of the P&P industry. For example, the development of imaging technology facilitates the online measurement of fibre characteristics to assess pulp quality (Uniya and Nigel, 2013). The use of On-Time-In-Full (OTIF) technology in marketing division tracks ascertains the delivery of products, and makes marketing efficient by integrating the producer with market channels (Kujur and Panda, 2013). We, therefore, assume that the increasing use of ICT reduces EI.

ICTI is measured as the ratio of value of ICT to the value of total output. The real value of ICT is arrived at by deflating it with the nearest possible price index available, which is the WPI of machinery and machine tools in India at 2004-05 prices. We deflated the value of total output by WPI of paper and paper products in India at 2004-05 prices.

Pollution Control Equipment Intensity (PCEI): International agencies such as the IEA and national agencies such as the CPCB and BEE emphasize the importance and measures to reduce environmental pollution in manufacturing. In India, various legislations have been effected which offer regulatory and fiscal policy instruments to control and prevent water and air pollution, and environmental protection in Indian industry (Kathuria and Haripriya, 2000).[21] India's P&P sector is among the 17 'Red Category' high polluting industries identified by the Ministry of Environment and Forest, Government of India (Ali and Srikrishnan, 2001; Tewari et al., 2009). The effect of environmental regulations on the performance of the P&P industry in India has been analyzed by Pradhan and Barik (1999b).

[21] For India's water and air prevention and pollution control Acts, environment protection Act., see CPCB (2010). It also outlined rules and notifications pertaining to pollution control.

They showed that the implementation of environmental regulations encourages environmental-friendly behaviour, which improves the competitiveness of the P&P industry. In order to promote environmentally benign behaviour, the P&P industry invests in PCE by setting up the oxygen delignification, chemical recovery, lime re-burning and effluent treatment plants, in addition to major production process such as raw material preparation, pulping, bleaching, stock preparation and paper making (CPPRI, 2004). The establishment of pollution controlling plants to oblige environmental norms raises its total energy use and we therefore expect a positive relationship between PCEI and EI.

The PCEI is measured as the ratio of the value of PCE stock to the value of total output. The PCE stock is constructed using the PIM as pollution control plants in the P&P industry constitute fixed capital by nature. We deflated the value of total output by WPI of paper and paper products in India at 2004-05 prices.

Profit intensity (PI): We hypothesize that the rise in PI should increase the availability of funds for installation of energy-efficient technology and equipment in the production process, which will reduce the EI. Considering the lag effect of PI on EI we take one lag of PI, which is the PIlag1.

PI is measured as the ratio of value of profit to the value of total output. The real values of profit and output are calculated by deflating them with the WPI of paper and paper products in India at the 2004-05 price base.

Vertical Integration (VI): VI is defined as a decentralized pattern of diversification that enhances, supplements, complements, and accentuates the value-added margin for a particular chain of processing in the forward linkages and backward linkages of the industry from raw-material production to the ultimate consumers (Harrigan, 1985; Heimler 1991; Langlois and Robertson, 1989). VI reduces asymmetry in the input and output market structures, making it cost advantageous to become specialized and produce high-quality products (D'Aveni and Ilinitch, 1992; Riordan, 1998). Besides this, it facilitates adaptation and adjustment in a complex inter-stage production process by sharing technological information. It also increases the ability of firms to implement the new process or the new products (Langlois and Robertson, 1989; Armour and Teece, 1980). In this framework, we expect that increasing VI would improve energy efficiency.

This is measured as the ratio of value of gross value added (GVA) to the value of total output. The real GVA and real output are estimated by deflating them with WPI of paper and paper products in India at 2004-05 prices.

Energy Price (EP): The role of EP on the EI of the industry has been studied. Goldar (2010) found that the rise in the real price of energy prompts its judicious use, leading to a decline in the EI. Panda (2007) also argued that increasing EP prompted most of the large- and medium-sized P&P mills to process improvement and install captive cogeneration power plants that use organic waste and produce power. This has reduced the demand for power from external sources such as the state power grid, and also helped lower the industry's environmental impact. Thus EP is one of the important and direct measures of government intervention on input use and pollution generation in the P&P industry. The inclusion of EP in the model helps us understand its effect on energy efficiency and its influence on energy-related emissions by the P&P industry. We hypothesize that the energy demand responds negatively to a hike in EP. The composite price index of energy in India at constant 2004-05 prices is used as a measure of EP.[22]

6: Results and Discussion

The estimated results of the determinants of EI of the P&P industry in India and its three different raw material based sectors are discussed below. Although we present the results of all panel models, we interpret only one model as recommended by the Hausman test and Breusch-Pagan test.

[22] Details on the construction of variables used in the study are presented in Appendix- 6.

6.1: Aggregate Pulp and Paper Industry in India

The RE model is used to explain the determinants of energy intensity of India's P&P industry.[23] The independent traditional input variable KI is found to be not significant. LI is, however, significantly positive. The DMI is significantly negative with EI at the 1 percent level, as one point increase in DMI leads to decline in EI by -.38 points. The other traditional input variable MMI is not significant. The advanced input variables such as SI, ICTI and PCEI are not significant. The industry-level determinants such as PIlag1, VI and EP are observed to be significantly negative (Table 7).

Table 7: Estimation Results of Determinants of Energy Intensity in India's Aggregate Pulp and Paper Industry (1999-2010)

Dependent Variable: EI

Independent Variables	Pooled OLS (Robust) (Coefficient: t-value)	FE Model (Robust) (Coefficient: t-value)	RE Model (Robust) (Coefficient: z-value)
KI	.0057543 (.0081619)	.0091714 (.0052774)	.0069556 (.0063103)
LI	42018.69** (16643.16)	41684.94*** (11954.78)	41237.02*** (14724.5)
DMI	-.5061812*** (.1417903)	-.2860332* (.0983036)	-.3845732*** (.1210404)
MMI	-.2521688 (.2389274)	-.1920025 (.1144794)	-.2057658 (.1777485)
SI	-.5943123 (.3780819)	-.2007613 (.3132042)	-.3542322 (.3343042)
ICTI	-2.326993 (2.052918)	-1.656261 (2.285396)	-2.139608 (2.09032)
PCEI	-.0057553 (.0081622)	-.0091742 (.0052781)	-.0069575 (.0063109)
PIlag1	-.0608156* (.0553863)	-.0122103 (.0467899)	-.0284695* (.0494286)
VI	-.1139923* (.1826021)	-.1555202* (.0854811)	-.1358726** (.1283108)
EP	-.0008292*** (.0002731)	-.0011546*** (.0002548)	-.0010124*** (.0002538)
No. of Observations	203	203	203
F-Statistics	86.27	56.20	-
Prob > F	0.0000	0.0000	-
Wald $\chi 2$	-	-	741.51
Prob > Chi2	-	-	0.0000
R^2	0.6105	-	-
R^2 Within	-	0.6058	0.5868
R^2 – between	-	0.5541	0.7898

[23] In the Hausman test, the Chi^2 statistics is negative (-1.09). The test does not provide its p-value. We might interpret this result as strong evidence that we cannot reject the null hypothesis. Such a result is not an unusual outcome for the Hausman test, particularly when the sample is relatively small (STATA, 2013, pp. 770).

R^2 – overall	-	0.5153	0.5893
Rho	-	.57352612	.15374004
Hausman Test	-	-	chi2(2) = -1.09
Breusch & Pagan LM Test	-	-	chibar2(01) = 80.53 Prob > chibar2 = 0.0000
Notes: (1) Robust standard errors are given in parentheses. (2) *, ** and *** indicate significance at the 10 percent, 5 percent and 1 percent levels respectively. Source: Author's estimate based on ASI data.			

6.2: Wood-based Pulp and Paper Industry in India

The result of the Pooled OLS estimate is analyzed to understand the determinants of EI of the wood-based P&P industry. The traditional input variable KI is significant and negatively associated with EI. In the capital intensive wood-based P&P sector, the LI is found to be not significant. The intermediate input variable DMI and MMI are significant. The DMI and MMI display a negative relationship with EI. The advanced input variables such as SI and ICTI are not significant. The other advanced input variable PCEI, is significantly positive. The industry-level determinants such as PIlag1, VI and EP are significant, which reduces the EI of the wood-based P&P industry (Table 8).

Table 8: Estimation Results of Determinants of Energy Intensity in Wood-based Pulp and Paper Industry in India (2000-2010)

Dependent Variable: EI

Independent Variables	Pooled OLS (Robust) (Coefficient: t-value)	FE Model (Robust) (Coefficient: t-value)	RE Model (Robust) (Coefficient: z-value)
KI	-.0000503** (.0000207)	-.0000322 (.0000197)	-.0000503** (.0000207)
LI	8116.31 (5545.652)	9061.828 (7275.743)	8116.31 (5545.652)
DMI	-.4852754*** (.1268646)	-.4406156** (.1871306)	-.4852754*** (.1268646)
MMI	-.526183*** (.1173867)	-.5270425*** (.169364)	-.526183*** (.1173867)
SI	.0177247 (.3913409)	.0985166 (.5430787)	.0177247 (.3913409)
ICTI	-2.958312 (2.844408)	-2.025532 (3.573757)	-2.958312 (2.844408)
PCEI	.0000477** (.0000199)	.0000302 (.0000189)	.0000477** (.0000199)
PIlag1	-.0674871* (.0335362)	-.0678674* (.0317715)	-.0674871** (.0335362)
VI	-.3494717*** (.1127142)	-.3223687** (.1396633)	-.3494717*** (.1127142)
EP	-.0009559*** (.0002646)	-.0009672*** (.0002942)	-.0009559*** (.0002646)
No. of Observations	123	123	123

F-Statistics	152.87	134.34	-
Prob > F	0.0000	0.0000	-
Wald χ2	-	-	1528.69
Prob > Chi2	-	-	0.0000
R^2	0.7254	-	-
R^2 Within	-	0.6814	0.6713
R^2 – between	-	0.8014	0.9195
R^2 – overall	-	0.7105	0.7254
Rho	-	.14467308	0
Hausman Test	chi2(2) = 2.60 Prob>chi2 = 0.2727	-	-
Breusch & Pagan LM Test	chibar2(01) = 0.00 Prob > chibar2 = 1.0000	-	-
Notes: (1) Robust standard errors are given in parentheses. (2) *, ** and *** indicate significance at the 10 percent, 5 percent and 1 percent levels respectively. Source: Author's estimate based on ASI data.			

6.3: Agro-based Pulp and Paper Industry in India

The FE model is applied to understand the determinants of EI in agro-based P&P industry. The result reveals that the traditional input variable KI is not significant. The LI, however, is significant and positively associated with EI. Though MI is not significant it is negatively related to EI. The advanced input variables such as SI and ICTI are found to be significantly negative. The PCEI, as another advanced input variable, is not significant. Though the industry-level determinant PIlag1 is not significant, VI and EP are observed to be significant, which reduces its EI (Table 9).

Table 9: Estimation Results of Determinants of Energy Intensity in Agro-based Pulp and Paper Industry in India (2000-2010)			
Dependent Variable: EI			
Independent Variables	**Pooled OLS (Robust) (Coefficient: t-value)**	**FE Model (Robust) (Coefficient: t-value)**	**RE Model (Robust) (Coefficient: z-value)**
KI	-.0003925 (.0006814)	-.0000706 (.0011271)	-.0005625 (.000789)
LI	9605.52 (11592.72)	26085.03* (13406.83)	14998.9 (10870.97)
MI	-.0832348 (.067068)	-.0322516 (.0243493)	-.0395092 (.0371575)
SI	-.1836842 (.1071668)	-.2213906** (.0880561)	-.1979153** (.0944312)
ICTI	1.323567 (8.724968)	-14.01521* (7.872498)	-7.231321 (6.379887)
PCEI	.000392 (.0006813)	.0000706 (.001127)	.0005623 (.000789)
PIlag1	.015323 (.0554328)	-.0033665 (.034796)	.0177482 (.0382749)
VI	-.173254*	-.2497955**	-.2570648***

	(.0855011)	(.0965204)	(.0761144)
EP	-.0025849*** (.0007788)	-.00116** (.0005022)	-.0017966*** (.0006304)
No. of Observations	76	76	76
F-Statistics	10.65	9.46	-
Prob > F	0.0002	0.0003	-
Wald χ2	-	-	164.47
Prob > Chi2	-	-	0.0000
R^2	0.3325	-	-
R^2 Within	-	0.4938	0.4393
R^2 – between	-	0.0593	0.2236
R^2 – overall	-	0.1074	0.2570
Rho	-	.71295494	.30893562
Hausman Test	-	chi2(2) = 16.45 Prob>chi2 = 0.0003	-
Notes: (1) Robust standard errors are given in parentheses. (2) *, ** and *** indicate significance at the 10 percent, 5 percent and 1 percent levels respectively. Source: Author's estimate based on ASI data.			

6.4: Recycled Paper-based Pulp and Paper Industry in India

The RE model is used to understand the determinants of EI in RCP-based P&P industry in India.[24] The EI of the RCP-based P&P sector is not significantly influenced by the traditional input variable KI. Rather, it is significant and positively affected by LI. Traditional input variable DMI is significantly negative with EI. The other traditional intermediate input variable MMI is, however, not significant. Advanced input variables such as SI, ICTI and PCEI are found to be not significant. All industry-level determinants such as PIlag1, VI and EP are observed to be significant to reduce EI in RCP-based P&P industry in India (Table 10).

Table 10: Estimation Results of Determinants of Energy Intensity in RCP-based P&P Industry in India (1999-2010)			
Dependent Variable: EI			
Independent Variables	**Pooled OLS (Robust) (Coefficient: t-value)**	**FE Model (Robust) (Coefficient: t-value)**	**RE Model (Robust) (Coefficient: z-value)**
KI	.006419 (.0067088)	.0131126 (.0084308)	.0100206 (.0070212)
LI	21842.14* (10998.96)	34697.6*** (11088)	26587.61** (10575.61)
DMI	-.416671*** (.1284073)	-.2533045*** (.0866582)	-.3210897*** (.1037716)

[24] In the Hausman test, the Chi^2 statistics is negative (-45.24). The test does not provide its p-value. We might interpret this result as strong evidence that we cannot reject the null hypothesis. Such a result is not an unusual outcome for the Hausman test, particularly when the sample is relatively small (STATA, 2013, pp. 770).

MMI	-.0595956 (.2056358)	-.1682551 (.1050497)	-.1167382 (.1499838)
SI	-.2831079 (.240197)	-.1045076 (.2022186)	-.1557533 (.213251)
ICTI	-3.033638* (1.685272)	-1.497083 (2.202248)	-2.365656 (1.896759)
PCEI	-.0064227 (.0067098)	-.0131187 (.0084324)	-.0100249 (.0070227)
PIlag1	-.1337379*** (.0251238)	-.1296475*** (.0272546)	-.1280996*** (.0211641)
VI	-.4093815*** (.099066)	-.2809821*** (.0669699)	-.3278811*** (.0792276)
EP	-.0009253*** (.0002774)	-.0010262*** (.0002475)	-.00099*** (.0002577)
No. of Observations	190	190	190
F-Statistics	121.67	43.21	-
Prob > F	0.0000	0.0000	-
Wald $\chi 2$	-	-	1045.81
Prob > Chi2	-	-	0.0000
R^2	0.6632	-	-
R^2-within	-	0.6714	0.6533
R^2-between	-	0.5338	0.8156
R^2-overall	-	0.5238	0.6284
Rho	-	.6363662	.23044392
Hausman Test	-	-	chi2(2) = -45.24
Breush-Pagan LM Test	-	-	chibar2(01) = 63.33 Prob > chibar2 = 0.0000

Notes:
(1) Robust standard errors are given in parentheses.
(2) *, ** and *** indicate significance at the 10 percent, 5 percent and 1 percent levels respectively.
Source: Author's estimate based on ASI data.

6.5: Discussion

The energy intensity of the different raw material based sectors of the P&P industry in India is influenced by different industry-level factors. The traditional input variable KI is not significant in all the raw material based sectors except in wood-based P&P industry. The KI in the agro-based and RCP-based P&P sector is not significant to affect their respective EI because these sectors consist of capital saving (or labor intensive) small- and medium-sized factories using second-hand imported technology in the production process. The KI in the whole P&P industry is also not significant as this industry is dominated by capital saving agro-based and RCP-based P&P mills. The KI however is significant and negatively associated with the EI of the wood-based P&P sector, because wood-based P&P factories in India are large in scale, and equipped with modern machinery and machine tools. In the capital-intensive wood-based P&P sector, the labor variable LI is not significant to determine the EI. The traditional input variable LI, however, is significant and positively related to EI in the agro-based and RCP-based P&P sectors. The higher use of labor in these capital-saving sectors to increase production raises their EI. Since the whole P&P industry is dominated by labour-intensive P&P mills, the LI of the P&P industry is expectedly significant and positively related to its EI.

The traditional intermediate input materials have a varied impact on EI of the industry. The DMI is significant in the P&P industry, wood-based P&P sector and RCP-based P&P sector, because the indigenous material use per unit of output has been increasing in all three segments. The MMI is significant only in the wood-based P&P sector. Owing to increase in the imported material consumption per unit of output, the MMI is significant in the sector. The MMI is not significant in the P&P industry, agro-based P&P sector and RCP-based P&P sector, because the share of imported material in total material consumption and imported material use per unit of output in these segment is low. Although the significance of MI, DMI and MMI is different for the different sectors, the relationship with EI is seen to be negative, which indicates the substitution of intermediary input between material and energy in the P&P industry in India.

The advanced input variable SI is not significant in all the segments of the industry except in the agro-based P&P sector. The SI does not affect EI in the P&P industry, because the use of services in producing one unit of output has been declining. It fell from 6.96 percent in 1999 to 5.55 percent in 2010. In the wood-based P&P sector, SI fell from 8.30 percent in 2000 to 5.86 percent in 2010 while in RCP-based P&P sector it declined from 5.20 percent in 1999 to 4.88 percent in 2010. The SI of the agro-based P&P industry, however, is significant because the sector has seen an improvement in the use of services in producing one unit of output, which increased from 4.51 percent in 2000 to 6.00 percent in 2010.

Like SI, the advanced input variable ICTI is observed to be significant only in the agro-based P&P sector, which reduces its EI, whereas in other segments of the industry, this variable is not significant. The ICTI in the agro-based sector is significant because the use of ICT in producing one unit of output has increased considerably from 0.0013 percent in 2000 to 0.36 percent in 2010 at a CAGR of 46.45 percent. On the other hand, the rise in the use of

ICT in other segments of the industry is low, thus having no significant impact on their respective EI. In the wood-based P&P sector, the use of ICT per unit of output declined from 0.36 percent in 2000 to 0.23 percent in 2010. In the RCP-based P&P industry, it marginally increased from 0.16 percent in 1999 to 0.17 percent in 2010. Similarly, in the P&P industry, the use of ICT per unit of output fell from 0.24 percent in 1999 to 0.21 percent in 2010.

PCEI, another advanced input variable, is significant and that increases the EI of the wood-based P&P industry. The PCEI however is not significant in other segments. The PCE is the capital investment made in addition to basic fixed capital to comply with the pollution control norms of the government. In India, unlike the medium-sized agro-based and small-sized RCP-based P&P sectors, the wood-based P&P industry constitutes large-scale factories owned and run by large corporate houses. They inherit the advantages of economies of scale and have better financial capability to invest in pollution controlling systems to meet environmental pollution regulations. The PCEI in the wood-based P&P industry grew at a CAGR of 8.76 percent between 2000 and 2010. The installation of number of pollution control plants in addition to basic production processes within the factory has increased the EI of the wood-based P&P sector. On the other hand, PCEI is not significant in the agro-based P&P industry and RCP-based P&P industry because most of the small and medium sized mills in these sectors do not have pollution control systems such as chemical recovery plant and lime re-burning plant, and so on. It is also not economical for these small- and medium-sized mills owned by local producers to install pollution control plants. In fact, the CAGR of the PCEI in the agro-based P&P industry was -13.99 percent during 2000-2010 while in RCP-based P&P industry, it grew at -8.25 percent during 1999-2010. For the whole P&P industry, the PCEI is not a significant variable because the P&P industry in India is dominated by small and medium sized agro-based and RCP-based P&P mills, and these are not adequately equipped with PCE. The CAGR of PCEI in India's P&P industry also grew by only 2.29 percent.

The industry-level determinant (PIlag1) is significant to reduce the EI of the P&P industry, wood-based P&P sector and RCP-based P&P sector. The increase in profits prompted the industry to invest in energy efficient technology in the production process, which reduced their EI. However, due to highly fluctuating trends the PIlag1 is found to be not significant in agro-based P&P industry.

The significant negative relationship between VI and EI in the P&P industry and its all three different raw material based sectors indicate that the presence of VI in the industry helps reduce their intermediate input costs by making the industry energy efficient.

As energy intensive manufacturing the P&P industry in India is directly affected by EP. Rise in EP induced the industry to adopt modern energy efficient technologies in the production process and install captive CHP plants that reduced the EI of the P&P industry and its three different raw material-based sectors.

7: Summary and Conclusion

Since this is an energy-intensive manufacturing industry, the study analyzes energy use in the P&P industry and its different raw material based P&P sectors in India, a new addition to the literature. The study identified the different levels of energy intensity exhibited by the different raw material based P&P sectors, namely the wood-based P&P sector, agro-based P&P sector and RCP-based P&P sector, suggesting differential energy efficiency policies for the different raw material based P&P sectors.

Since the energy intensity is found to be declining we examined the determinants of energy intensity using 5-digit industry level panel data. It also assessed the determinants of energy intensity in different raw material based sectors of the industry, namely, the wood-based P&P sector, agro-based P&P sector and RCP-based P&P sector. The traditional input variable capital intensity is not significant to determine the energy intensity in all segments of the P&P industry, except in the wood-based P&P sector. Capital intensity is significant and negatively related to energy intensity in the wood-based P&P industry because the sector is comprises large scale and technologically efficient factories which reduce its energy intensity. However, capital intensity is not significant in the agro-based and RCP-based P&P sectors as these sectors composed small- and medium-sized factories equipped with second-hand imported technology in the production process. Since P&P industry in

India is dominated by capital saving agro-based and RCP-based P&P mills and their capital intensities are not significant, the capital intensity of the entire P&P industry is also not significant. Contrary to the capital intensity effects on energy intensity, labour intensity is found to be significant and positive in all segments of the P&P industry, except in the wood-based P&P sector. Labour intensity is not significant to affect energy intensity in the wood-based P&P sector because of its capital intensive nature. The medium sized agro-based and small sized RCP-based capital saving P&P factories apply second-hand imported technology in the production process relying on higher use of labour to expand the production, which in turn raises their energy intensity. Therefore, the traditional input variable labour intensity is significantly positive with the energy intensity of the agro-based and RCP-based P&P sectors. Since the whole P&P industry is dominated by labour intensive P&P mills, the labour intensity of the P&P industry is also significant and positively related to its energy intensity.

The traditional intermediate input variable indigenous material intensity is significant that it reduces energy intensity in the P&P industry, wood-based P&P sector and RCP-based P&P sector. The imported material intensity is significantly negative with energy intensity in the wood-based P&P sector. Though imported material intensity is not significant, it displays a negative relationship with energy intensity in the P&P industry and RCP-based P&P sector. The material intensity in the agro-based P&P sector is observed to be insignificant. Although the significance of material intensity, indigenous material intensity and imported material intensity are different in different sectors it shows the negative relationship with energy intensity, indicating the substitution of intermediary input between material and energy use in the P&P industry in India.

The advanced input variables such as services intensity and ICT intensity are significant in reducing energy intensity only in the agro-based P&P sector, whereas in other segments of the industry, they are not significant. The pollution control equipment is the capital investment made within the factory in addition to the basic fixed capital to control pollution, and therefore, increase in pollution control equipment intensity raises the energy intensity. Since the large scale wood-based P&P sector is equipped with pollution control system the increase in pollution control equipment intensity raises its energy intensity. On the other hand, pollution control equipment intensity is not significant in the agro-based P&P industry and RCP-based P&P industry because these small and medium sized mills are rarely equipped with pollution control equipment. Since the large majority of the P&P factories in India are not fully equipped with pollution control system, the pollution control equipment intensity is not significant in the P&P industry.

The profits earned by the industry is reinvested in energy efficient technology for use in the production process, which reduces the energy intensity of the P&P industry, wood-based P&P sector and RCP-based P&P sector. However, profit intensity is not significant in agro-based P&P industry. Another industry level determinant, vertical integration, is significantly negative with the energy intensity of P&P industry and its all three different raw material based sectors. Energy price directly affects the energy use of this energy-intensive industry. The rise in energy prices reduced the energy intensity of P&P industry and its all raw material-based P&P sectors. The evidence on the effect of traditional inputs, advanced inputs and industry level determinants on energy intensity could very well serve to identify appropriate policy measures for the different raw material based sectors of the P&P industry in India to further reduce its energy use and enhance sustainability.

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Appendix- 1

Identification of Different Inputs Consumed by the P&P Industry in India

To identify different types of inputs consumed by National Industrial Classification (NIC)-2008 based Manufacture of Paper and Paper Products factory (17011-17099) in India mentioned in Block-H (Indigenous Input Items) and Block-I (Imported Input Items) in the unit level data of Annual Survey of Industries (ASI) given for 1998-99 to 2009-10, we follow below mention steps using Stata/S.E. 11.2.

Step 1: To find out the maximum amount of a particular input consumed by the factory, we used the 5-digit input code given by ASI Commodity Classification (ASICC)-2009. We measured the input coefficient of all ten major basic indigenous items reported in Block-H and all five major basic imported items reported in Block-I of ASI data separately. Input coefficients are measured as follows:

Input coefficient 1 = Purchase Value of input 1 / Total basic items

Input coefficient 2 = Purchase Value of input 2 / Total basic items

Input coefficient 10 = Purchase Value of input 10 / Total basic items

We used the same technique to find out the input coefficients of Block I, which has the five major basic imported inputs consumed by the unit.

Since purchase value (in □.) has been used to measure material and energy consumption in the ASI Tabulation Plan, we considered purchase value to estimate the input coefficient. Lack of data due to under-reporting on quantity consumption for all inputs is another important reason for considering purchase value.

Step 2: In the same file, we traced the ASICC codes of these basic inputs of Block-H and Block-I separately. The steps followed for this are:

First, we identified the ASICC codes of input cases of Block-H and Block-I using the ASICC code Manuals for different years given by the ASI.

Secondly, we clubbed some of the related ASICC codes to identify the broader classification of raw material-based industries. For example, the wood-based pulp and paper (P&P) factory uses wood and bamboo as its primary inputs; therefore, we clubbed wood, forestry and logging products, and bamboo to form a wood-based input. Appendix Table 1 shows how we identified the ASICC coded inputs.

Appendix Table 1: Harmonization of ASICC

S.No.	ASICC-2009 Code	Item Descriptions	Harmonised item code for the study	Harmonised Item for the study
1	51101 –54129	Wood, corck and thermocol	1	1 + 2 + 3 = Wood-based inputs = 1
2	14401 –14489	Forestry and logging products	2	
3	12935	Bamboo	3	
4	11101 – 4389	Animal, vegetable, horticulture, forestry products, beverages	4	4 + 5 +6 = Agro-based inputs = 2
5	14501 –15619	Produce or sericulture and beverages, tobacco and pan masala	5	
6	16301 –17299	Misc. Non-edible substances of animal/vegetable origin n.e.c. and Services and processes relating agricultural activities and animal husbandry	6	
7	54108	Waste paper	7	7 + 8 = Recycled paper-based inputs = 3
8	55101 – 7339	Paper and paperboard	8	
9	16101 – 16129:	Natural water & ice for industrial use	9	Water consumption = 9
10	21101 –29899	Ores, minerals, minerals fuels, lubricants, gas, electricity	10	Ores, minerals & fuels = 10

11	31102 – 39089	Chemicals & allied products	11	Chemicals = 11
12	54107	Sludge, ETP	12	Sludge = 12
13	41101 – 49899	Rubber, plastic, leather and products thereof	13	Rubber, plastic and leather products = 13
14	61101 – 69189:	Textile and textile articles	14	Textile materials =14
15	71101 – 79589	Base materials, products thereof and machinery and equipments, and parts thereof, excluding transport equipments	15	Machinery & equipments = 15
16	81101 – 85299	Railways, airway, ships and road transport equipment and related equipments and parts	16	Transport equipments = 16
17	91101 – 99221:	Other manufactured articles & services	17	Other manufactured articles = 17
18	97101 – 97989	Service related items	17	Services = 17
19	.	Other inputs	18	Other inputs = 18
Source: Author's Compilations				

Step 3: We dropped the input coefficient if its value was less than the other coefficients in all ten cases of Block-H and all five cases of Block-I. Thus, the maximum value of the input coefficient and its respective ASICC codes are retained while others are deleted. In this way, we kept only the maximum value of input coefficients and its respective ASICC codes in all cases.

Step 4: Knowing the maximum value of input coefficients and its ASICC codes, we dropped all other ASICC if it does not belong to the specified ASICC code in all cases. Hence, we created a database where only the above-mentioned ASICC codes and their input coefficients in all ten cases in Block-H and all five cases in Block-I are retained.

Step 5: Finally, we clubbed some of the predetermined ASICC codes (given in Appendix Table 4.1.1) to generate data on different raw material-based P&P sectors. For instance, we clubbed item 1, 2 and 3 to trace the wood-based P&P factories.

Step 6: We estimated the total quantity of consumption and total purchase value of different inputs combining those from indigenous as well imported sources.

Appendix- 2

Summary Statistics of ASI Unit Level data of P&P Industry in India and its Different Raw Material based P&P Sectors

We have used NIC-2008 based 5-digit industry mentioned in Block-A of the ASI unit level data (A_Ind_5digit) for summarizing simple statistics of the P&P industry in India and its different raw material based P&P sectors (Appendix Table 2).

Appendix Table 2: Summary Statistics of P&P Industry in India and its different raw material based P&P sectors

Variable	Observations	Mean	Std. Dev.	Min	Max
P&P Industry in India					
A_Ind_5digit	10907	17039.21	31.29214	17011	17099
Wood-based P&P Industry in India					
A_Ind_5digit	463	17055.69	38.46855	17011	17099
Agro-based P&P Industry in India					
A_Ind_5digit	185	17037.4	33.62747	17011	17099
Recycled paper-based P&P Industry in India					
A_Ind_5digit	8607	17037.51	30.03508	17011	17099

Source: Author's Calculation based on ASI data.

Appendix- 3

The Steps followed to create a Panel database are:

(1) We used the Dispatch Serial Number/Dispatch Schedule Number (DSL) number, which is a unique code of information given in Block-A to identity particulars for every factory for all year in ASI. Using the DSL number, we created a panel database for the P&P industry in India and its different raw material based P&P sectors.

(2) Sorting database by DSL: We considered only those factories for which data was available for 3 years (continuous observations at least for 3 years is essential for the estimation of capital stock). Also, the minimum time length in the sample is three as we have taken lagged values for the estimation of variable such as profit intensity.

(3) While aggregating unit level data up to the 5-digit industry level, we omitted units reporting zero or negative fixed capital, zero output, zero labour, zero energy, zero material, zero ICT, zero PCE, zero profit and zero GVA from the database.

Appendix- 4

Why we aggregated ASI Unit Level data for 1998-99 to 2009-10 to NIC 2008 based 5-digit Industry Level data

DSL numbers are unique across the regions for a particular year of survey. However, the same factory may have different DSL numbers in different years of survey. A discussion with CSO statistician at the 5th National Conference on "Industrial Statistics" organized by Central Statistical Office, Industrial Statistics Wings, Ministry of Statistics and Programme Implementation, Govt. of India, held at Kolkata during October 29-30, 2014, brought to light the fact that factories got a different DSL number every year because they keep changing their type of products (product mix). A same DSL number belong to different NIC 5-digit factory means it is representing different factory. The change in the NIC 5-digit factory is also cross-checked with its 'Year of Initial Production' reported in Block-B of the database. Therefore, while filtering the data to make the panel, we confirmed that the DSL had at least three years of continuous series data and also ensured that the particular DSL number belongs to the same NIC 5-digit factory.

In fact, we observed the frequency of DSL number in the database is mostly 1 to 4. And this resulted in very small number of observations in the unit level panel database. Owing to above-mentioned reason, we aggregated ASI factory level unit data to NIC 2008 based 5-digit industry level database for the study. The NIC 2008 based 5-digit industry classification is the maximum disaggregated industry level data given by ASI.

Appendix- 5

Harmonised Classification of NIC 5-digit Manufacture Paper and Paper Products Industry in India

Appendix Table 4: Classification of 5-digit Manufacture of Paper and Paper Products Industry in India

S.No.	NIC 2008	5-digit Industry	NIC 1998 & 2004	NIC 2008	Harmonization of NIC 1998, 2004, & 2008
1	17011	Manufacture of pulp	21011	17011	17011
2	17012	Manufacture of newsprint	21013	17012	17012
3	17014	Manufacture of packing paper	21014	17014	17014
4	17015	Manufacture of special purpose paper/paper products for computers	21017	17015 + 17091	17015
5	17016	Manufacture of paperboard, strawboard	21015	17016	17016
6	17017	Manufacture of hardboard including false board & chipboard	21016	17017	17017
7	17019	Manufacture of other primary paper material including composite paper & paperboard, n.e.c.	21019	17019	17019
8	17022	Manufacture of corrugated paper ,	21023	17021 +	17022

		paperboard & containers		17022	
9	17023	Manufacture of cardboard boxes	21022	17023	17023
10	17024	Manufacture of sacks & bags of paper	21021	17024	17024
11	17029	Manufacture of other containers of paper & paperboard n.e.c	21029	17029	17029
12	17092	Manufacture of paper cups, saucers, plates, hoops, cones & other similar products	21091 + 21092	17092	17092
13	17093	Manufacture of paper, including printing, writing & photocopying ready for use	21012	17013 + 17093	17093
14	17094	Manufacture of paper pulp articles other than containers (such as egg trays, dolls, mache articles, wall paper)	21093 + 21094 + 21095 + 21096	17094 + 17096	17094
15	17095	Manufacture of file cover/file board & similar articles	21097	17095	17095
16	17097	Manufacture of carbon paper & stationary items	21098	17097	17097
17	17099	Manufacture of other pulp & paper products n.e.c.	21099	17099	17099
Source: Author's Compilations					

Appendix- 6

Estimating the Real Value of Variables used

Value of Output: The value of 'Total output' is the sum of value of products and by products including variation in stock of semi-finished goods and value of own construction; and other output or receipts from services, value of electricity generated and sold, and sale value of goods sold in the same conditions as purchased during the accounting year. To get the real value of output, we deflated total output with Wholesale Price Index (WPI) of 'Paper and paper products' in India, base 2004-05 from Indiastat.com.

Measurement of Capital Stock at Industry Level: The ASI database provides information about the net value of fixed capital. The fixed assets includes net value of land, buildings, plant and machinery, transport equipment, computer equipment including software (CES), pollution control equipment (PCE), others, and capital work in progress. Due to the increasing use of CES in the manufacturing sector and growing importance of PCE to pursue pollution free production system, it is important to analyze the effect of these two variables separately. Therefore, we subtracted the value of CES and PCE from fixed capital, which will also avoid the problem of double counting.

The fixed capital stock series of the P&P industry was constructed at 2004-05 prices for the period of 1998-99 to 2009-10. The construction of fixed capital stock is based on the following notation:

$$K_T = K_0 + \sum_{t=1}^{T} I_t$$

Where,

K_T = Fixed capital stock in year T

K_0 = Benchmark capital stock

I_t = Net investment series

Let's now discuss on the estimation of each of these variables mentioned above.

1. Benchmark capital stock $(K_0) = \text{Factor} * B_0$

Where, Factor = Net Fixed Capital Stock (NFCS) in registered manufacturing from National Account Statistics (in 2004-05 prices) for base year 1998-99 is divided by book value of Net Fixed Capital (NFC) for all manufacturing industry from ASI for the year 1998-99, as followed in Veermani and Goldar (2004) and Banga and Goldar (2007).

B_0 = Book Value of NFC of Manufacture of Paper and paper products industry from ASI in the benchmark year, that is 1998-99.

For this, first we converted NFCS and Book values of ASI into a common value (Appendix Table 5).

Appendix Table 5: Measurement of Value of Factor and Benchmark Capital Stock for different Base Year

Base Year	NFCS in Registered Mfg. from NAS in 2004-05 Prices (□.)	Book value of NFC of All Mfg Industry at 3-digit level from ASI (□.)	Factor	Book value of NFC of Paper & Paper Products Industry at 3-digit level from ASI (□.)	Benchmark Capital stock
1961	828080000000	14742613250	56.17	496167858	27869324989
1998-99	12698940000000	3911514500000	3.25	74357204222	241404620891
1999-00	13624070000000	4018647300000	3.39	89188254852	302367173970
2000-01	14314530000000	3996042200000	3.58	98305338214	352147110214
2001-02	14886630000000	4319601300000	3.45	99498217176	342900430361
2002-03	15337390000000	4447593800000	3.45	109253042651	376755746855

2003-04	15968240000000	4733314000000	3.37	112136760755	378302962482
2004-05	17135240000000	5130692500000	3.34	102970599685	343896255437
2005-06	19017460000000	6069402800000	3.13	123986172591	388489964417
2006-07	21320650000000	7151313900000	2.98	146686924436	437326709358
2007-08	24330180000000	8451320900000	2.88	176268108198	507451421081
2008-09	26563270000000	10559661900000	2.52	212293762343	534033814893
2009-10	29015010000000	13521837400000	2.15	260238322623	558416530973
Source: Author's estimate					

2. Net investment series $(\mathrm{I_t}) = \mathrm{GI_t} - \delta \mathrm{K_{t-1}}$

Here, $\mathrm{GI_t}$ = Gross fixed investment in year t. To estimate this following method is used.

$$\mathrm{GI_t} = \frac{(\mathrm{B_t} - \mathrm{B_{t-1}} + \mathrm{D_t})}{\mathrm{P_t}}$$

Where,

$\mathrm{B_t}$ = Book value of fixed capital in year t.

$\mathrm{B_{t-1}}$ = Book value of fixed capital in year $t - 1$

$\mathrm{D_t}$ = Depreciation of fixed capital in year t as reported in ASI

$\mathrm{P_t}$ is the price index for capital goods (base year 1998-99), for which we used WPI of machinery and machine tools.[25]

δ = Rate of depreciation. For this, we follow Unel (2003) and assume the average life of fixed capital to be 20 years with a depreciation rate of 5 percent of the fixed capital of year $(\mathrm{K_{t-1}})$. The 5 percent depreciation charge is also applied in Goldar (2004), Veermani and Goldar (2004) and Banga and Goldar (2007), and Madheswaran et al. (2007).

Starting from the benchmark fixed capital stock and adding real investment for successive years, the net fixed capital stock series was constructed.

[25] Like Ahluwalia (1991), Balakrishanan and Pushpangandan (1994), Pradhan and Bark (1998a, 1998b, 1999), Madheswaran et al. (2007), Kathuria et al. (2011), we also use WPI of machinery and machine tools as the fixed capital deflator. However, other studies such as Unni et al. (2001), Goldar (2004), Veermani and Goldar (2004), Trivedi (2004) and Banga and Goldar (2007) used the implicit deflator (current/constant prices of GFCF for registered manufacturing taken from NAS) instead of WPI.

Labour Engaged: The ASI database reports the 'Average number of persons engaged'. This reflects the total number of employees in the unit, which is an aggregation of total persons directly employed, workers employed through contractors, supervisory and managerial staff, other employees, and unpaid family members or proprietors during the accounting year.

Value of Energy Use: ASI gives data on total fuel use (in □.), which is the summation of the purchase values of electricity purchased and consumed; petrol, diesel, oil and lubricants consumed; coal consumed; gas consumed; and other fuel consumed by the factory during the accounting year except those which directly enter into products as material consumed. It excludes the fuels produced and consumed by the factory in the manufacturing process, that is, all intermediate products and also fuels (such as electricity own generated through in-house power plant) consumed by employees as part of the amenities.

The nominal value of 'fuels consumed' is deflated by composite 'energy price index' for India at the 2004-05 price base to get its real value. The energy price index is constructed using weights obtained from the Input-Output Transaction Table of India for 1993-94, 1998-99, 2003-04, 2006-07, and 2007-08 published by the Central Statistical Organisation (CSO). Appropriate Wholesale Price Indices (WPI) (electricity, mineral oils, and coal and lignite) are collected from the Index Number of Wholesale Prices in India, base 2004-05, from Indiastat.com.

Value of Material Consumed: ASI provides data on the value of material consumed. The material consumed by industry is derived from indigenous and imported sources. ASI's estimate of 'materials consumed' is the sum of major ten basic items, other basic items (raw materials, components), all kinds of non-basic chemicals, packaging items and consumable stores derived from indigenous sources, and major five items and imported items that enter the production process in the factory during the accounting year. It also includes the cost of all the materials used in the production of fixed assets, including construction work for the factory's own use. Components such as accessories that go into producing the finished product during the accounting year are also included. The ASI estimate excludes intermediate products, meaning all those products produced by the factory and consumed for further manufacturing. In this study, however, to estimate 'materials consumed', we have deducted some indigenous and imported input components from the estimate of 'materials consumed' as they are already mentioned in fixed capital, energy, and services. The indigenous plus imported 'machinery and equipment' and 'transport equipment' are already part of 'fixed capital.' The indigenous plus imported 'ores, minerals, mineral fuels, lubricants, gas and electricity' are present in 'energy'. The indigenous plus imported 'services' has been analyzed as a separate variable. Therefore, we subtracted these inputs items from the estimate of 'materials consumed', which also avoids double counting between material, and fixed capital, energy and services.

The nominal value of 'materials' was deflated by the composite material price index. The material price index, 2004-05 price base, was constructed using a method similar to that used for the energy price index. The material price index was constructed using weights obtained from the Input-Output Transaction Table of India for 1993-94, 1998-99, 2003-04, 2006-07, and 2007-08 published by the CSO. Appropriate WPIs (wood and wood products; non-metalic mineral products; cotton textiles; textile; jute, hemp an mesta textiles; paper and paper products; synthetic resins; chemicals and chemical products; and paints, varnishes and lacquers) in India were collected from the Index Number of Wholesale Prices in India, base 2004–05, from Indiastat.com.

Value of Indigenous Material: The indigenous material input in the ASI database constitutes ten major basic indigenous items, all kinds of non-basic chemicals, packing items, and consumable stores, which enters into the production process during the accounting year. To estimate 'indigenous material', we deducted some elements of indigenous inputs from the estimate of 'indigenous material' as these components are already mentioned in other estimated variables such as fixed capital, energy and services. Unlike the estimate of 'materials consumed' where we deducted the components from both domestically produced and imported inputs, we exclude only indigenously sourced inputs from the estimate of 'indigenous material'. The components excluded from 'indigenous material' are indigenously sourced 'machinery and equipment' and 'transport equipment' which are part of 'fixed capital'. We exclude indigenous inputs such as 'ores, minerals, minerals fuels, lubricants, gas and electricity' from 'indigenous material' as these are already part of 'Energy'. We also deducted 'service input' from 'indigenous material' to consider it as a separate variable for the analysis. This helps avoid double counting between indigenous material, and fixed capital, energy and services. The indigenous material is deflated by the material price index of India at 2004-05 prices to get its real value.

Value of Imported Material: ASI gives information on five major imported input items and other imported items. We estimated 'imported material' using a method similar to that used for 'indigenous material'. To estimate 'imported material' we excluded imported inputs such as 'machinery and equipment', 'transport equipment', which are already a part of 'fixed capital'. We excluded imported items such as 'ores, minerals, minerals fuels, lubricants, gas and electricity' from 'imported material' as they are already part of 'Energy'. We also deducted 'services input' as it is a separate variable considered for analysis. This helps avoid double counting between imported material, and fixed capital, energy and services. The value of imported material is deflated by the material price index of India at 2004-05 prices to arrive at its real value.

Value of Services Input: The 'total input' used by the Indian manufacturing industry reported in the ASI database is a composed of 'fuels consumed', 'material consumed' and 'other inputs'. The 'other inputs' used in the industry are in the form of different types of services that enter into the production process during the accounting year. These services are: work done by others on material supplied by the industrial undertakings; repairs and maintenance of buildings and other construction, other fixed assets; operating expenses (such as inward freight, transport changes, inspection fees, road tax, sales tax renewal fees, administrative changes and so on); non-operating expenses (payment for postage, telephone, accounting, bank charges, legal services, advertisement, printing and stationary); insurance changes; and rent purchase value of goods sold in the same condition as purchased.

The nominal value of 'services input' was deflated by the implicit service deflator in India at 2004-05 price base to arrive at its real value. Following the method used in Banga and Goldar (2007), the implicit services deflator was constructed from the NAS. The input-output table provides information on purchase of services (transport, banking, insurances, etc.) made by the industry during that year. The implicit deflator was computed using current and constant prices of various service sectors reported in National Account Statistics. The input-output table indicates the weights to be used for combining them; these are the flows from the service sector to the manufacturing industry. Thus, a weighted average of implicit deflators of different service sectors has been taken and a deflator of services purchased was developed.

Value of Information and Communication Technology (ICT): We used computer equipment including software (CES) used in the industry during the accounting year as a proxy of ICT. We subtract the value of ICT from the value of fixed capital to analyze its influence on the industry's performance.

Value of Pollution Control Equipment (PCE): The value of PCE was subtracted from the value of fixed capital to analyze it separately. The PCE stock was estimated using PIM as discussed above.