International Journal of Economic Research

ISSN : 0972-9380

available at http: www.serialsjournals.com

Volume 14 • Number 15 (Part 3) • 2017

Production and Environmental Performances of Selected Steel Plants in India: An Empirical Investigation

Babita Das Paul[1], Madhabendra Sinha[2], Sebak Kumar Jana[3] and Partha Pratim Sengupta[4]

[1]*Department of Hospital Management, NSHM Knowledge Campus - Durgapur, West Bengal 713212, India, babita.das@nshm.com*
[2]*Department of Humanities and Social Sciences, National Institute of Technology Durgapur, West Bengal 713209, India, madhabendras@gmail.com*
[3]*Department of Economics with Rural Development, Vidyasagar University, Midnapore, West Bengal 721102, India, sebakjana@yahoo.co.in*
[4]*Department of Humanities and Social Sciences, National Institute of Technology Durgapur, West Bengal 713209, India, parthapratim.sengupta@hu.nitdgp.ac.in*

ABSTRACT

The steel industry becomes one of the largest industrial energy consumers and plays an important role in economic growth in India. Post-Economic reform scenario of Indian steel industry has changed remarkably and a rapid progress in steel industry aggravates the environmental management problems. The major causes of environmental pollution and energy inefficiency include traditional technology and infrastructures, coal dominated energy structures and lack of managerial skills. It is an established view in India that emphasis given to environment related issues is much lesser than the production performance issues by steel plants. In this context, we try to explore dynamic relationships among various production and environmental factors for some selected steel plants in India over the period from 2000 to 2015. We form a balanced panel on collecting data from various annual reports published by Ministry of Steel, Government of India and employ panel unit root tests followed by panel cointegration test. Our findings imply significant cointegrating relationships among variables measuring production and environmental performances.

Keywords: Steel Industry, Production, Environment, India, Panel Data Econometrics.

1. INTRODUCTION

Steel is world's one of the most important, valuable and essential engineering and construction material used all over the world. Steels, used in India, need not be necessarily produced in India. Because of the improved communication system, reduced international freight cost and the ease of International trade, India can meet its high demand of steel through importation. India already has affluence of coal and iron ore, and due to which, the country enjoys a comparative advantage in the arena of steel. India has been the eleventh largest importer of steel in the world, but with the growth in the country's steel demand, India cannot remain dependent solely on external supplies. There's a high demand for steel in the country, almost 600 metric ton, every year. And this huge demand cannot be satisfied by external supply. So to increase the country's production capacity, to reach the benchmark of 720 metric ton steel production every year, as per the necessary requirement by the year 2050, we need a capacity-production ratio to be stagnant at 1.2 and a zero BOT in Steel sector.

The implications of growing India and the country's production of steel are of immense significance. Currently, the country has the capacity to produce 100 metric tonne steel every year. To reach its 2050 goal of 720 metric ton, India has to grow its production capacity by more than about 600 metric ton. In other developed countries like USA, UK, France, Japan and China steel industry is growing at a modest rate. In this scenario, India poses to be an attractive marketplace for Steel producers and also for the raw material suppliers in this sector. There lies a significant risk with Indian Steel Industry, as it has a potential for environmental degradation. But despite this, Indian Steel industry has huge potential for recycling too. As per the suggestions of World Steel Association, Life Cycle Assessment (LCA) approach should be given proper attention in this context. Since, LCA approach properly identifies the areas of potential consequences throughout the life cycle, from manufacturing product usage to its life's end, and also including the re-use, recycling and also the disposal stages. The approach of LCA is the most useful way to assess the inter-linkage between the steel sector and environment measures. The LCA approach takes into consideration emissions both from the products of steel, from the modern-day usage of steels and also the lighter products which actually reduce energy consumptions.

For every tonne steel scrap, about 740 kg of coal, 1400 kg iron ore and about 120 kg of limestone can be stored. Greenhouse gases (GHG) emissions should be a step in recycling steel products to address their concerns about the rising concern of the world and the high rate of CO2 emissions. Also, there may be an internal use of the manufactured industry in this industry to reduce emissions such as steel making slogans or bursts of bombs. As it can help to reduce emissions at important levels and there is no adverse effect on the environment. Despite the long-term prospects, the current state of Indian steel industry is not satisfactory due to the environmental perspective, according to the report of the Center for Science and Environment (CSE) (2012), Delhi. Indian steel is covered under the Environmental Protection Act (EPA) and Environmental Protection Rules and Regulations and published by the Ministry of Environment and Forest, Government of India. Entrepreneurs need to get authorization approved by the government under the EPA for establishing a new iron and steel plant or their significant expansion. In addition, steel companies are required to install certain pollution control facilities and work well in the regulations regarding water, air and noise pollution, and therefore, under the supervision of pollution control boards.

Fuel cost is one of the many Integrated Indian steel plants. 6-6.5 is generally higher 4.5-5.5 Giga Calorie per ton of crude steel foreign steel plants. The main reason for the high quality of low-cost electricity consumption of raw materials such as the replacement of the old plant's modern technology, the store floor and operating practices, high coal, high aluminum iron mining. However, due to the gradual reduction of electricity demand in steel plants, due to the upgrade of the technology, the use of waste heat, the use of improved quality inputs etc. Energy and environment conservation are directly related to technology adopted by the Indian steel plant. Although steel plants are solving the energy and environmental problems through a technological transformation, and the expansion of skilled energy and environmentally friendly technologies is being done in plants. Government supports the improvements in the energy and environment scenario in this sector through different mechanisms like Charter on Corporate Responsibility for Environment Protection (CREP), UNDP-AUSAID-MOS Steel Project, and NEDO Model Projects with Government of Japan, Global Superior Energy Performance Partnership (GSEP), and National Action Plan on Climate (NMEEE) etc.

Against this backdrop, we can argue that a study must be carried out to look into the matter of overall sustainability of steel industry in India, which is almost under-investigated. In this context, our basic objective is to investigate the inter-linkage between production and management of environment measure by some related parameters in Indian Steel plants. To fulfil our objective, we take five Indian steel plants namely Durgapur Steel Plant, Bhilai Steel Plant, Bokaro Steel Ltd., Raurkela Steel Plant and Indian Steel Plant in this study and their production and environment performances measured by Blast Furnace production, Energy Consumption, Coke Rate and Water Consumption over the period 2000 to 2015, and also apply some appropriate econometric tools for empirical investigation. The rest of the chapter is organized as follows. We briefly interpret a note on some economic and environmental indicators as considered in Indian steel plants. After discussing the methodological issues, we mention hypothesis and data base. Before drawing the conclusion in the final section, we analyse the empirical results.

2. BRIEF DESCRIPTIONS OF SELECTED STEEL PLANTS IN THE STUDY

2.1. Steel Authority of India Limited (SAIL)

Steel Authority of India Limited (SAIL), the largest producer of Steel in India, is a Government of India undertaking. SAIL is based in New Delhi. SAIL is India's premier steel manufacturing company. Founded in 1954, since then the company has been the principal driving force behind the industrial rejuvenation of modern India. The company holds a place among the seven 'Maharatnas' of India's Central Public Sector Enterprises. The SAIL is a coherent iron and steel maker. And the company produces iron and steel at three special steel plants and at five integrated plants, scattered across the eastern and central parts of the country, mainly situated close to the captive iron ore, dolomite mines and limestone.

Table 1
Production Performance of SAIL in Rupees Crore

Key Performance Indicators	*2013-14*	*2014-15*	*2015-16*
Hot Metal	14.45	15.41	15.72
Crude Steel	13.58	13.91	14.28
Total Saleable Steel	12.88	12.84	12.38
Finished Steel	10.12	9.84	9.33

Source: Steel Authority of India Limited (SAIL) (www.sail.co.in)

SAIL is the producer of basic and also special steels that are used for domestic construction, power, automotive, engineering, railway, and defence industries. The company manufactures and also sells a wide and varied range of steel products, such as hot and cold rolled sheets and coils, galvanized sheets, railway products, electrical sheets, structural, plates, bars and rods, stainless steel and other alloy steel. The above-mentioned table includes the different plants and units that fall under SAIL.

2.2. Bhilai Steel Plant

Bhilai Steel Plant, another significant name in Indian Steel Industry, is located in Bhilai, Chhattisgarh. The plant was established in 1955, as an outcome of an agreement between Indian Government and USSR. It is India's first and one of the principal producers of Steel rails, steel plates and also a variety of other steel products. From its Coal Chemical plants and its Cove ovens, Bhilai Steel Plant also produces different chemical by-products. Bhilai Steel Plant has won the 'Prime Minister's Trophy for best-integrated steel plant in the country' consecutively for eleven times. The plant is the country's sole producer of heavy steel plates, railway steel and structural steel. In addition to this, the plant is also India's sole supplier of longest rail tracks, spanning over 260 meters (850 ft.). Bhilai Steel Plant also produces merchant products and also wire rods.

Table 2
Production Performance of Bhilai Steel Plant in Rupees Crore

Key Performance Indicators	*2013-14*	*2014-15*	*2015-16*
Hot Metal	5.4	5.1	5.3
Crude Steel	5.1	4.8	5.1
Saleable Steel	4.6	4.3	4.2

Source: Steel Authority of India Limited (SAIL) (www.sail.co.in)

In September 1967, Bhilai Steel Plant was expanded to 2.5 million ton and again to 4 million tons in 1988. The expansion mainly focused on the 'Continuous Casting Unit' and the 'Plate Mill', which was a new technology in the sphere of steel casting and shaping in the country. A new Rs 1200 crore Universal Rail Mill at SAIL's Bhilai Steel Plant has been inaugurated on 22nd January 2017. With this, SAIL has commenced commercial production of world's longest single rail of 130 meters from the new Universal Rail Mill. The new URM will take BSP's total capacity to produce rails at two million tonnes per annum. It will be the largest production capacity for rails in any single location for a plant world over.

2.3. Durgapur Steel Plant

Durgapur Steel Plant was set up in the late fifties with an initial production capacity of 1 million tonne per annum crude steel which was increased to 1.8 million tonnes during the last modernization in nineties with the prime objective of achieving higher level of production, improvement in productivity and quality, conservation of energy, reduction in cost of production & minimization of environmental pollution. Situated in an advantageous position, on the riverside of Damodar, and at a distance of only 158 km from the metropolitan city, Kolkata, DSP has got the privilege of better communication, ease of transportation etc.

Table 3
Production Performance of Durgapur Steel Plant in Rupees Crore

Key Performance Indicators	*2013-14*	*2014-15*	*2015-16*
Hot Metal	2.2	2.3	2.2
Crude Steel	2.0	2.1	2.0
Saleable Steel	1.9	2.0	1.9

Source: Steel Authority of India Limited (SAIL) (www.sail.co.in)

The Plant is equipped with CO-BF-BOF process of steel making. New facilities have been added after the last modernization in the nineties - two new rebuilt coke oven batteries, CDI in Blast Furnaces, three Ladle Furnaces, one Bloom caster, one bloom- cum-round caster and a new Medium Structural Mill (MSM). The Plant is poised for crude steel production almost 100% through Concast route. The unique feature of DSP is its Wheel and Axle Plant for making forged wheels and axles catering to Indian Railways. Wheels are tested in International Test House and found of the higher standard. Over the years, the plant has developed various types of wheels as per requirements of Indian Railways.

2.4. Bokaro Steel Plant

Bokaro Steel Plant, based in Bokaro, Jharkhand, is India's fourth largest steel plant, which was established in 1964 with the cooperation of Soviet Union (USSR). Initially, Bokaro Steel Plant was initially embodied as only a limited company, but laterwards, it was merged with SAIL, as a subsidiary at the initial stage and afterwards, as a unit, through the 'Public Sector Iron & Steel Companies (Restructuring & Miscellaneous Provisions) Act 1978'. On 6th April, 1968, the merging process began. Bokaro Steel Plant has been acknowledged as India's first Swadeshi steel plant, which was constructed with maximum indigeneity in respect of equipment, material, technology and what not. The first Blast Furnace of Bokaro Steel Plant started functioning on 2nd October 1972 and it completed its first phase of about 1.7 million tonnes ingots steel on 26th February 1978. And in the same year, the plant got the sanction for constructing the plant's third Blast Furnace. By the early 90's, the plant got all of its four units sanctioned, upgraded and modernized and further extended to 4.5 million tonnes.

Table 4
Production Performance of Bokaro Steel Plant in Rupees Crore

	2013-14	*2014-15*	*2015-16*
Hot Metal	4.1	4.2	3.7
Crude Steel	3.8	3.8	3.4
Saleable Steel	3.5	3.4	2.6

Source: Steel Authority of India Limited (SAIL) (www.sail.co.in)

The modernization or expansion of Bokaro Steel Plant included the new features, such the two twin-strand slab casters and also a Steel Refining Unit. On 19th September, 1997, the Steel Refining Unit of Bokaro Steel Plant was inaugurated, and on 25th April, 1998, the Continuous Casting Machine was inaugurated. On the other hand, the Hot Strip Mill modernization included the features like work roll bending, high pressure de-scalers, hydraulic automatic gauge control, laminar cooling, quick work roll change, etc. In addition to these, the less-efficient pusher-type furnaces got replaced by the new 'walking beam reheating furnaces'. Two of the existing hydraulic coiler has been refurbished and a new coiler has also been added. With the completion of the modernized construction of the Hot Strip Mill of the Bokaro Steel Plant, the plant is currently producing high quality hot rolled products, which are in high demand in the global market.

At the initial stage, Bokaro Steel Plant was designed to produce flat products, such as Hot Rolled Coils, Hot Rolled Plates, Hot Rolled Sheets, Cold Rolled Coils, Cold Rolled Sheets, Tin Mill Black Plates (TMBP) and Galvanised Plain and Corrugated (GP/GC) Sheets. In addition to these productions, the plant also provides strong raw materials to a number of modern engineering industries, like automobile, LPG cylinder, pipe and tube, barrel and drum producing industries so on and so forth.

2.5. Rourkela Steel Plant

Rourkela Steel Plant, based in north-west Orissa, is India's first integrated steel plant. The steel plant was established in 1955, in collaboration with a German private firm. At the initial stage, the plant had the installed capacity of about 1 million tonnes. Afterwards, the plant's capacity was increased to almost 2 million tonnes of Hot Metal, 1.9 million tonnes of Crude Steel and 1.67 million tonnes of Saleable Steel. The plant got modernised and expanded further. And at present, the plant has the capacity to produce about 4.5 million tonnes of Hot Metal and 4.2 Million tonnes of Crude Steel.

Rourkela Steel Plant or RSP tops the list of Indian Steel industries in a number of aspects. First of all, RSP was the country's first Steel plant adopts LD Technology in Steel sector. Secondly, RSP, at present, is the only Steel plant and the sole plant under SAIL, which produces all of its slabs using the continuous casting route. This method is cost-effective and subsequently, quality-centric. RSP provides India's power sector with silicon steels, and the oil and gas sector with high quality pipes. RSP is the sole plant under SAIL that can produce silicon steels. Besides these, RSP also produces flat and tubular products and also varied sophisticated coated products.

Table 5
Production Performance of Rourkela Steel Plant in Rupees Crore

Key Performance Indicators	*2013-14*	*2014-15*	*2015-16*
Hot Metal	2.5	3.1	3.0
Crude Steel	2.3	2.9	2.7
Saleable Steel	2.2	2.5	2.4

Source: Steel Authority of India Limited (SAIL) (www.sail.co.in)

Like other Indian Steel plants, RSP or Rourkela Steel Plant has also undergone significant changes. The plant has witnessed a historic modernization and expansion process. With the completion of its modernization and expansion, the plant has now doubled its production capacity, for hot metal and has reached the level of 4.5 million tonnes, compared to the previous 2.0 million tonnes. A steep growth could also be observed in the plant's crude steel making capacity, which has risen to 4.2 million tonnes from the rough 1.9 million tonnes per year.

The production of Saleable Steel is also supposed to increase to about 3.99 million tonnes from 1.671 million tonnes per year. Besides increased production capacity, RSP's modernization and expansion program have reaped other fruits as well. For example, RSP's customer base has enlarged, the product quality has been enhanced, while the expenditure for the same has been minimized, labour productivity has also been improved, the economy of scale has been increased and market compatibility has been enhanced. And finally, the plant's strict observation of the environment norms has led to reduced environmental degradation.

2.6. Indian Iron and Steel Company

Located at Burnpur, West Bengal, IISCO or The Indian Iron and Steel Company (IISCO), another integrated steel plant of the country, was established in 1918. IISCO is one of the oldest Steel plants of India. The company merged with SAIL in 2006. Initially it was envisioned only as an industrial enterprise, and the plant first produced iron at Hirapur in 1922.

Table 6
Production Performance of IISCO Steel Plant in Rupees Crore

Key Performance Indicators	*2013-14*	*2014-15*	*2015-16*
Hot Metal	0.2	0.6	1.4
Crude Steel	0.1	0.1	0.9
Saleable Steel	0.2	0.1	0.9

Source: Steel Authority of India Limited (SAIL) (www.sail.co.in)

The plant had the capacity of producing 2.5 million tonnes crude Steel per year. Afterwards, the plant upgraded its production capacity. And now, IISCO has the capacity of producing about 4.26 lakh tonnes saleable steel and pig iron about 2.54 lakh tonnes per annum. IISCO produces a varied range of products, in some of which it even holds exclusive market dominance. Almost 16,000 crores have been spent for IISCO's modernization and expansion. And after its modernization and expansion, the plant has increased its crude steel production capacity to about 2.5 million tonnes per annum.

3. NOTES ON ECONOMIC AND ENVIRONMENTAL INDICATORS IN STEEL INDUSTRY

3.1. Blast Furnace Production in the Steel Industry

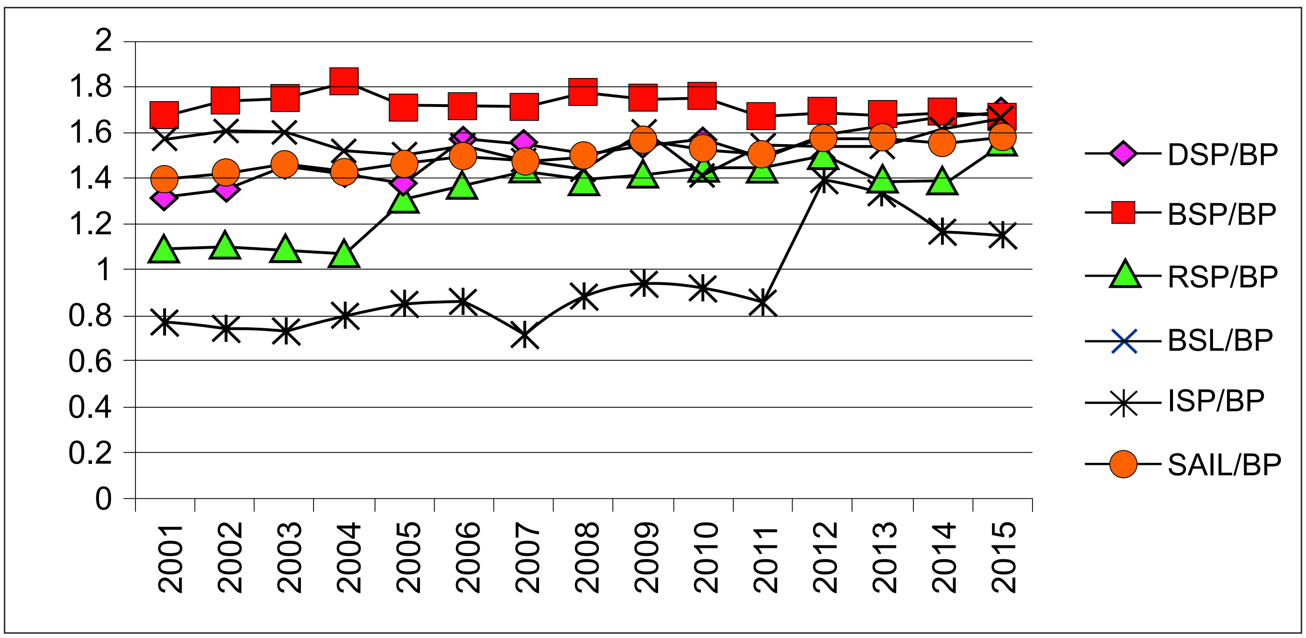

Figure 1: Pattern of Blast Furnace Production across Steel Plants

Source: Combined from Various Annual Reports of Ministry of Steel, Govt. of India

Steel is actually produced from iron ore and scrap. And the very first step in the process of steel-making is Blast Furnace (BF). Approximately, over 70% of the steel-making processes across the world include the use of Blast Furnaces. The principal equipments of Blast Furnaces are in a countinuous process of evolution. These equipments continue changing for betterment and improvement, as these improvements actually lead to a rise in the production of Steel. Although the Blast Furnace equipments go on changing, the actual process or designs inside them remain the same always. Blast Furnaces have better future prospects as these large furnaces can produce steel efficiently and in a cost-effective way, in comparison to other steel-making technologies.

The complete process of Blast Furnaces includes a multivariate system, a system that is influenced by a large number of inter-dependent variables. These variables significantly influence the performance of the Blast Furnaces. In addition to these variables, there are several other parameters too, which influence the performance of the Blast Furnaces. Among these parameters, productivity is important. The productivity of the Blast Furnaces is usually expressed in 'tons of hot metal produced /day/cum of working volume (T/*m*3/day)'. Useful volume in place of working volume is usually considered in some countries.

3.2. Water Consumption in the Steel Industry

Water plays a very significant role in the manufacturing operations of Iron and Steel. Steel industries use huge quantities of water. In integrated water plants, water is used in cooling operations, in descaling and dust scrubbing etc. Although a high percentage of water in steel industries return to source. And thus, the proper management of water resource is an important sustainability challenge faced by the Steel industries. We assume that fresh water is abundant; there will never be any scarcity of fresh water in this world. This assumption is totally wrong, since water, especially fresh water is a valuable commodity, probable to lessen in quantity in the future. The percentages of water being recycled vary across plants. While the water recycling percentage is as high as 98% in some plants, in certain other plants, water is recycled through system just once.

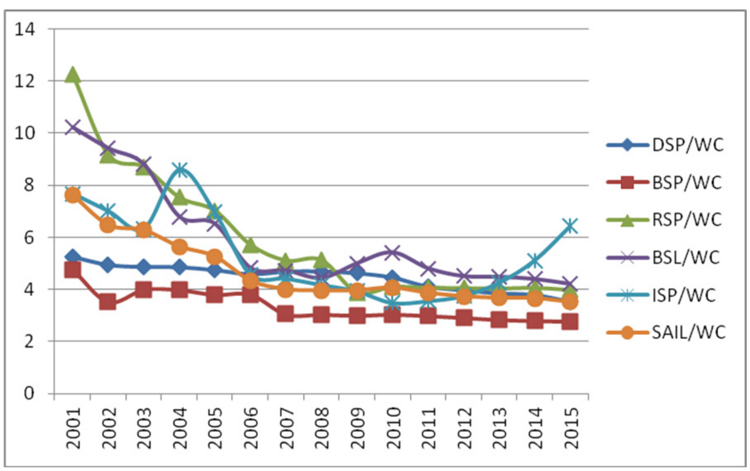

Figure 2: Pattern of Water Consumption across Plant

Source: Combined from Various Annual Reports of Ministry of Steel, Govt. of India.

Water is a commodity that can be recycled a number of times. Since water is one of the most important substances in the production and manufacturing process of steel, the production cost of Steel largely depends on the efficiency enhancement of water usage and also on the reduction in its demand. Increased recycled water usage has led to a reduction in water usage and consumption in the Integrated Steel Plants. Although the steel plants use all types pf water, fresh water is a preferred choice in these steel plants. However, the availability of fresh water and the quality of the water is a serious concern in a number of steel plants.

Almost about 85% to 90% of the water, which is generally used in a Steel Plant, is wasteful, non-consumptive in nature, a study says. 80% of the remaining 10% to 15% water returns to source through evaporation and in the form of rain. In an integrated steel plant, only 2% to 3% of water gets consumed and then get discharged from the plant with other waste products. In an integrated steel plant, the Blast furnaces consume the maximum quantity of water in the production process of Steel. In a steel plant, water is primarily used in the colling operation, cooling of different parts of the Blast furnace, and its various auxiliaries, like tuyeres, stove valves, hearth staves, bosh and stack cooling plates etc. Besides these, water is also used in an integrated steel plant for furnace moisture injection (steam), dust control, and slag granulation.

3.3. Coke Rate and Blast Furnace Production

Blast furnace (BF) is a counter-current reactor in which the reduced gas is produced by the glass of air cavity, and the injected hot explosion oxygen through the towers in the bottom. Encouragement to reduce the burden load bearing loads above the furnace below the gas decreasing. BF cock is a main ingredient for making iron, working as a major energy source (fuel), and a carburization agent. Coke rate is the parameter for BF coke consumed per ton of hot metal produced and measured in kilograms.

BF coke is the most important raw material fed into the Blast Furnace. Blast furnace operation and hot metal quality depend on the quality of coke. A high quality BF coke supports a smooth descent from the burden of bomber as the smallest submerge as possible. A high quality BF coke provides the lowest amount of impurities, maximum thermal power, maximum metal reduction and optimum permeability for the flow of gases and melted products. Introduction of high quality BF coke to a Blast Furnace results in lower coke rate, higher productivity and lower hot metal cost.

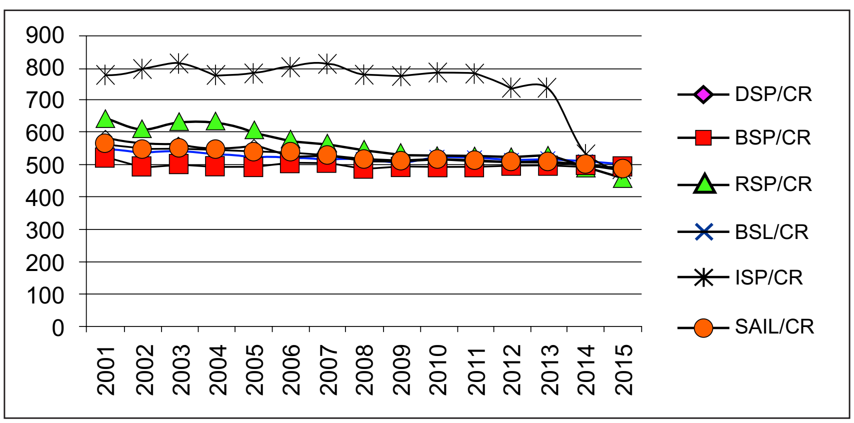

Figure 3: Pattern of Coke Rate across Steel Plants

Source: Combined from Various Annual Reports of Ministry of Steel, Govt. of India

In order to ensure good BF performance, the crow should be slightly larger with a narrow size range and there should be a high mechanical strength to prevent carbon dioxide and weak reaction with alkali, friction and heat shock inside bombs. Impurities such as moisture, volatile matter, ash, sulphur, phosphorous, and alkali contents present in BF coke affect its performance in the blast furnace by decreasing its role as a fuel in terms of amounts of carbon available for direct and indirect reduction roles and also its role as a permeable support. An efficient BF works at a low coke rate and it increases the flow of gas, thereby improving the reactor permeability and reducing the amount of specific gases on the other, which reduces the specific use of BF coke.

3.4. Coke Rate and Environment

Most of the iron and steel industries use coal as the main source of energy. During the production of coal, some coal was converted to coke oven gas during the production of coke and in BF, where iron ore coal was produced from metal and BF gas. These gases can be used to recover and be used as fuel for various installations. This is a direct way to increase the overall efficiency of the combustion process, but raises a variety of problems such as high emission of NOx due to the high amount of nitrogen present in the Blast Furnace - gas, high emission of SO2 due to the high amount of Hydrogen sulphide (H_2S) in the coke-oven gas and relatively high CO2 emission, if compared with other hydrocarbon fuels like natural gas.

Basic air pollutants found in the iron and steel industry are CO, CO_2, NOx, SOx etc. Depending on the source point, these pollutants are spread throughout the atmosphere in the sensor. A steel plant, natural gas and coke oven gas (residual gas from the steel plant BF) pollution results polluted. The residual gases of blast furnace and coke oven are characterized by reduced lower heating values (LHV) and high content of carbon monoxide (CO), Carbon dioxide (CO_2), Nitrogen (N_2) and Hydrogen sulphide (H_2S). Combustion of these fuels leads to increased emission of pollutants into the air.

3.5. Energy Consumption in Steel Industry

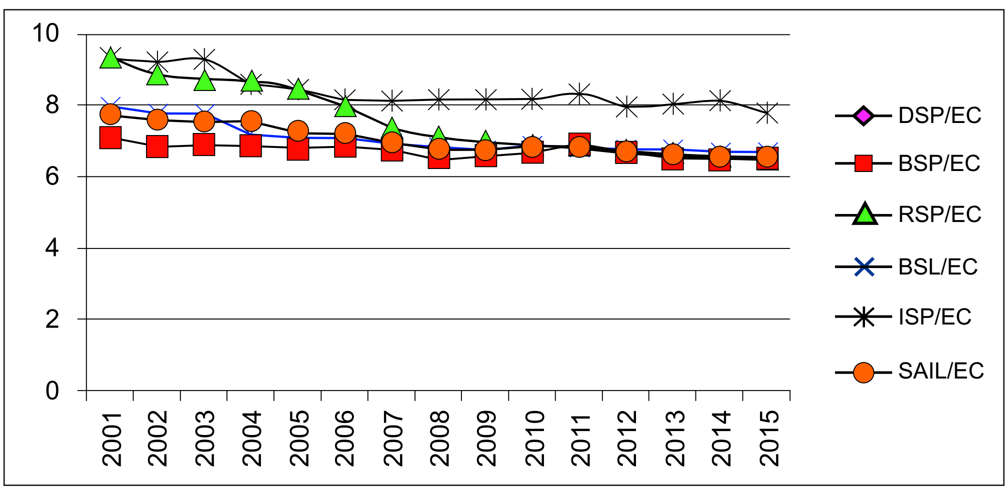

Figure 4: Pattern of Energy Consumption across Steel Plants

Source: Combined from Various Annual Reports of Ministry of Steel, Govt. of India

Steel production involves a lot of heating, cooling, melting and solidification cycles. The specific energy consumption of Indian steel plants ranges from 8 to 12 Gcal/tcs (giga calories per tonne of crude steel) whereas those of developed countries range from 4 to 6 Gcal/tcs. The developed countries mostly use electric arc sculptures to make steel, such as oxygen plants, Coca-Cola oven etc., cannot be liable for the convenience, because these supplies are purchased. The initial energy inputs for integrated steel plants are for steam coal and electricity for the use of coke coal, boilers, liquid petroleum fuel. Coking coal and boiler coals account for more than 90% of the total energy input. Indian coals generally have high ash contents from 15 to 55%. The average ash contents of Indian coking coals are 20-25%, while those of foreign coals are less than 10%. The specific energy cost of an integrated steel plant is largely determined by the coke rate of iron making, where the coke rate is directly related to the additives. More than 50% of the ashes are silica. In addition to technology and process related issues, there are some other factors that affect the specific energy cost of steel plants. For example, the production mix, has an impact on the use of energy.

In addition to increasing the overall energy intensity of more complex and high quality product manufacturing, there are specific reasons in India that should be considered when Indian steel plants are trying to try higher power consumption higher. They include economic and political stimulus structures and energy saving for the production of raw materials, operation scale, plant size and size coke oven, plant use functions, technology updates and modernization for the Indian industry and recovery system.

3.6. Energy Consumption and Environment

One of the most significant negative impacts of Industrialization across the globe is the increased demand and consumption of energy. Industries across the globe satisfy their demand for energy through the usage of fossil fuels. The excessive consumption and burning of fossil fuels have resulted in environmental degradation through air, since the burning of fossil fuels emits carbon dioxide in large quantities into the atmosphere. This emission increases the risk of global warming. Energy consumption, especially unregulated usage of non-renewable energy sources significantly impacts our environment. Non-renewable energy sources, such as Fossil fuels coal, oil and natural gas are more harmful to our environment than the renewable energy sources. The unregulated usage of non-renewable energy sources causes water pollution, air pollution, global warming and serious health issues for people.

4. ECONOMETRIC METHODOLOGY

4.1. Panel Unit Root Tests

The method of unit root tests in panel data models has become very popular nowadays to solve the problem of low power of a test for a single time series data. Besides the conventional testing of unit root namely Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test, the study also employs the unit root tests for panel data as developed by Levin-Lin and Chu (LLC) (2002) and Im-Pesaran-Shin (IPS) (2003) to explore the stochastic properties of the panel variables. The tests of panel unit root are almost same, but not identical to single time series unit root tests. To test panel unit roots, the basic specification of ADF can be expressed by following equation:

$$\Delta y_{it} = \rho y_{i,t-1} + \sum_{i=1}^{p_i} \eta_{ij} \Delta y_{i,t-1} + X_{it}^{'}\delta + \varepsilon_{it} \quad (1)$$

LLC allows examination intermediation, time trend, residual and self-reliance orders to be freely separated from the cross-section unit. But it requires a series of time independently generated with a generic sample size and with all the usual auto-regressive of order one or the AR(1) series, with a general interconnection. The order of lag of p_i will be allowed to differ across variables. The fitting order of lag is selected through permitting the maximum order of lag and then by following the t-statistics for η_{ij}. The estimated value of the autocorrelation coefficient, ρ, cannot be obtained directly by estimating equation (1). The use of proxies for Δy_{it} and y_{it} are to be standardised and also free of deterministic components and autocorrelations, the coefficient of autocorrelation is estimated.

4.2. Panel Cointegration Test

To explore the long run cointegrating relationship among variables, we employ the tests of panel cointegration as recommended by Pedroni (1999 and 2004). Pedroni (1999) panel cointegrations test is used, since the test can determine the suitability of the test, which has to be applied to the estimated residuals of the cointegration equation on normalizing the statistics of panel with the correction terms. The test procedures use the estimated residual from the hypothetical equation of long run regression as follows:

$$y_{i,t} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \ldots + \beta_{Mi} x_{Mi,t} + e_{i,t} \tag{2}$$

for $t = 1,\ldots..,T;$

$i = 1,\ldots.,N;$

$m = 1, \ldots., M,$

where T represents the number of observations vary over time, N is the number of cross-sectional units used in the panel, and M represents number of regressors. Within the above mentioned set-up α_i represents the intercept specific to members or parameter of fixed effects varying across the individual cross-section units. The same thing is applied in case of the slope coefficients as well as the time effects specific to member, $\delta_i t$.

Pedroni (1999 and 2004) has proposed the test statistics of the panel of heterogeneous and panel of heterogeneous group mean to the panel cointegration and has defined the statistics for two different sets. The first set containing three statistics namely $Z_{\hat{r},N,T}$, $Z_{\hat{\rho}N,T\nu 1}$ and $Z_{tN,T}$, is based on residuals' pooling along with the panel dimensions, and the statistics are as follows:

$$Z_{\hat{r},N,T} = T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{i=1}^{N} \hat{L}_{11i}^{\nu 2} \hat{e}_{i,t\nu 1}^{2} \right)^{\nu} \tag{3}$$

$$Z_{\hat{\rho}N,T\nu 1} = T\sqrt{N} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{\nu 2} \hat{e}_{i,t\nu 1}^{2} \right)^{\nu 1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{\nu 2} \left(\hat{e}_{i,t\nu 1} \Delta \hat{e}_{i,t} \nu \hat{\lambda}_i \right) \tag{4}$$

$$Z_{tN,T} = \left(\tilde{\sigma}_{N,T}^{2} \sum_{I=1}^{N} \sum_{T=1}^{N} \hat{L}_{11i}^{\nu 2} \hat{e}_{i,t\nu 1}^{2} \right)^{\nu 1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{\nu 2} \hat{e}_{i,t\nu 1}^{2} \left(\hat{e}_{i,t\nu 1} \Delta \hat{e}_{i,t} \nu \hat{\lambda}_i \right) \tag{5}$$

Where $\hat{e}_{i,t\nu 1}$ is the residual vector of the least square estimation of the equation (2) and the other notations are properly defined by Pedroni.

The second set of the above mentioned statistics is based on the pooling of the residuals along with the between dimensions of the panel, which allows us for an autocorrelation of heterogeneous parameter across variables, can be expressed as follows:

$$\tilde{Z}_{\hat{\rho}N,T^{\nu 1}} = \sum_{i=1}^{N} \left(\sum_{i=1}^{T} \hat{e}_{i,t\nu 1}^{2} \right)^{\nu 1} \sum_{t=1}^{T} \left(\hat{e}_{i,t\nu 1} \Delta \hat{e}_{i,t} \nu \hat{\lambda}_i \right) \tag{6}$$

$$\tilde{Z}_{t\,N,T^{\nu 1}} = \tilde{Z}_{t\,N,T^{\nu 1}} = \sum_{i=1}^{N}\left(\sum_{i=1}^{T}\hat{e}_{i,t\nu 1}^{2}\right)^{\nu 1/2}\sum_{t=1}^{T}\left(\hat{e}_{i,t\nu 1}\Delta\hat{e}_{i,t}\,\nu\hat{\lambda}_{i}\right) \qquad (7)$$

The above mentioned statistics calculate the group mean of the all individuals and conventional statistics of time series. The asymptotic distribution of all statistics can be represented by following:

$$\frac{X_{N,T}\nu\mu\sqrt{N}}{\sqrt{v}} \Rightarrow N(0,1) \qquad (8)$$

Where $X_{N,\,T}$ represents the corresponding form of the test statistics, whereas μ and ν represent mean and variance of the test respectively. In case of the alternative hypothesis, the panel *v* statistics will be diverging to the positive infinity. So, this is a one tail test, where the large positive values will reject the null hypothesis of no cointegration relation between variables. The remaining statistics will move away to the negative infinity, which replies the rejection of the null by large negative values.

4.3. Hypothesis and Data Base

On the basis of above mentioned background, the basic hypothesis, which is to be tested to fulfill our objective, which is to look at the dynamic inter-linkage between production and management of environment measured by some suitable parameters in case of Indian steel plants, categorized as follows:

There is no inter-linkage between blast furnace production and various measures of environmental related issues like energy consumption, coke rate and water consumption.

The scope of the study is limited to five major public steel plants covering a significant period starting from the year 2000 to 2015. The secondary data on the variables namely Blast Furnace (BP) production, Energy Consumption (EC), Coke Rate (CR) and Water Consumption (WC) have been collected from annual reports published by the plants namely Durgapur Steel Plant, Bhilai Steel Plant, Bokaro Steel Ltd., Raurkela Steel Plant and Indian Steel Plant. All the data on the variables taken in our study are in index form as provided by the plants.

5. EMPIRICAL FINDINGS

5.1. Panel Unit Root Tests

The main purpose is to validate long run dynamic relationship among production and different environmental measure across various steel plants in India. Our study applies the panel econometric techniques for the justification of the propositions. This study attempts to explore the presence of the cointegrating relationships among the specified variables. Our first step is to check the stationarity of the data series. The panel unit root tests have been carried out by using the methodology proposed by Levin Lin and Chu (LLC) (2002) and Im-Pesaran-Shin (IPS) (2003). We also employ the unit root tests of ADF-Fisher as well as PP-Fisher.

Table 7
Estimated Statistics of Panel Unit Root Tests

Variables	*Results of Panel Unit Root Tests at Level*							
	Constant				*Constant and Trend*			
	ADF Test	*PP Test*	*IPS Test*	*LLC Test*	*ADF test*	*PP test*	*IPS Test*	*LLC Test*
BP	-0.19	-0.25	-0.51	-1.11	-0.61	-0.83	-0.89	-0.88
EC	-1.21	-1.03	-1.19	-0.57	-0.59	-0.73	-0.69	-1.09
CR	-0.67	-0.59	-0.97	-0.39	-0.71	-0.91	-0.91	-0.97
WC	-0.91	-1.01	-1.23	-0.71	-0.89	-1.02	-1.05	-0.82
	Results of Panel Unit Root Tests at First Difference							
BP	-6.21*	-5.36*	-7.05*	-7.22*	-6.83*	-6.06*	-6.11*	-7.23*
EC	-6.32*	-5.27*	-6.79*	-6.59*	-6.09*	-6.28*	-6.26*	-7.51*
CR	-7.61*	-5.91*	-6.48*	-6.66*	-7.00*	-6.07*	-6.18*	-7.09*
WC	-7.59*	-5.73*	-5.92*	-6.09*	-6.69*	-6.73*	-6.97*	-6.85*

Source: Authors' own estimation by using E-views 8

The Table 7 shows the results of unit root tests both at level and first difference with constant and constant with time trend. The panel variables of BC, EC, CR and WC are found to be non-stationary at level, which is supporting the hypothesis of the presence of panel unit root in both with and without time trend respectively. The lower part of the Table 7 shows the results of the tests at first difference including both with and without time trend respectively. So the results refer that all panel variables are stationary at first difference. Additionally the results supply a strong verification that the variables are integrated of order one (I(1)) across the steel plants.

5.2. Panel Cointegration Test

Table 8
Estimated Results of Pedroni Panel Cointegration Test

Test Statistics	*Within Dimension*			
	Individual Intercept		*Individual Intercept and Constant Trend*	
	Statistic	*Prob.*	*Statistic*	*Prob.*
Panel rho-Stat	-3.15*	0.00	-2.88*	0.01
Panel v-Stat	-3.76*	0.00	-4.10*	0.00
Panel PP Stat	-3.01*	0.00	-3.81*	0.00
Panel ADF Stat	-3.22*	0.00	-3.45*	0.00
	Between Dimension			
Group rho Stat	-4.06*	0.00	-3.79*	0.01
Group PP Stat	-5.13*	0.00	-5.91*	0.00
Group ADF Stat	-5.26*	0.00	-4.15*	0.00

Source: Authors' own estimation by using E-views 8

To explore the long run dynamic relationship between the considered panel variables, we have to look for the panel cointegration test. We can justify our exercise since all the variables are found to be integrated of same order (I(1)). The test porposed by Pedroni (2001) has been conducted to verify the presence of cointegrating relationship with the existence of the individual intercept and also the intercept with constant trend. The findings of Pedroni panel cointegration test are reported in Table 8.

The Pedroni cointegration model states that BP is a function of EC, CR and WC respectively. At the level of intercept without trend, all test statistics provide the strong evidence of the existence of cointegration among the panel variables. The results are strongly rejecting the no-cointegration in the heterogeneous panels for within and between dimensions tests respectively. After including the trend, all test statistics have rejected hypothesis of no-cointegration among variables. Hence our study makes sure the presence of long run relationships among the considered variables.

6. CONCLUDING REMARKS

The study tries to explore the inter-relationships between steel production measured by Blast Furnace production and various environment measures like Energy Consumption, Coke Rate and Water Consumption in five Indian steel plants namely Durgapur Steel Plant, Bhilai Steel Plant, Bokaro Steel Ltd., Raurkela Steel Plant and Indian Steel Plant for the period from 2000 to 2015. On forming a balanced panel, the technique panel cointegration technique has been applied for our empirical investigation after checking the unit roots of the data series. The empirical findings clearly state that there exists panel cointegrating relation between variables. The findings also support the view that Indian steel plants are not so called advanced at least in terms of maintaining and managing environment for the sustainability not only in the industry but also for the entire economy, because we find significant long run relationships.

Our exploratory study highlights the high potential of the Indian steel plants over post reform period. The capacity expansion prospects in many developed and developing countries seem to be limited. There should have a chunk investment for replacement and new techniques. India has a high probability to need million tonnes of additional steel capacity. The policymakers in this regard have to strive to understand the bright future of this industry. It is also found in the study that the steel industry is not limited by natural supply, such as land, minerals, environmental approvals, but insufficient demand and limited by macroeconomic reasons. We see the rise of industrial stall plants as an obstacle on the production side and we see inadequate progress in meeting the expected environmental standards of a modern steel industry. So the government has to introduce a transitional program for the industry. There will not be much to achieve with the current policy and to make more efforts. The research proposes some elements of a policy framework that could be the basis of a revival Indian steel industry.

7. BIBLIOGRAPHY

Centre for Science and Environment. (CSE). (2012). *Annual Reports*. New Delhi.

Dickey, D. A. and Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association*, 74: 427–431.

Im, K. S., Pesaran, M. H., and Shin, Y. (2000). Testing Unit Roots in heterogeneous panels. *Journal of Econometrics*. 115: 53-74.

Levin, A., Lin, C. F., and Chu, C. (2002). Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. *Journal of Econometrics*, 108: 1-24.

Ministry of Steel. (2000-2015). *Various Annual Reports*. Government of India, New Delhi.

National Council of Applied Economic Research. (NCAER). (2015). The Indian Steel Industry: Key Reforms for a Brighter Future. New Delhi.

Pedroni, P. (1999). Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors. *Oxford Bulletin of Economics and Statistics*, *Special Issue* 61: 653-678.

Pedroni, P. (2001). Purchasing Power Parity Tests in Cointegrated Panels. *The Review of Economics and Statistics*, 83(4): 727-731.

Pedroni, P. (2004). Panel Cointegration: Asymptotic and Finite Samples Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis. *Economic Theory,* 20: 597-625.

Phillips, P. C. B., and Perron, P. (1988). Testing for a Unit Root in Time Series Regression. *Biometrika*, 75(2): 335–346.

Steel Authority of India Limited. (SAIL). (2000-2015). *Various Annual Reports*. New Delhi.