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EVIDENCE ON THE FUTURE PROSPECTS OF INDIAN THERMAL POWER SECTOR IN THE PERSPECTIVE OF DEPLETING COAL RESERVE

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ABSTRACT

Increasing industrial growth throughout the world largely depends on availability of electricity. The overall situation in the power sector provides an optimistic view. However, insight into the thermal power industry provides a bleak picture. Thermal power stations mostly depend upon coal as a basic raw material. Economists project that India has a little over 250 billion metric tons of coal reserve to sustain continued and progressive demand for thermal power generation in the next 40-50 years. Indian thermal stations have started importing expensive coal from other countries to maintain generation and supply. Every thermal power station emits CO_2. Suspended Particulate Matter (SPM), fly ash and effluents create health hazards and contribute to global warming. This paper develops a model based on Auto Regressive Integrated Moving Average (ARIMA) to depict the future prospects of coal based thermal power sector of India. The evidence shows that India needs to identify alternative sources of power generation to grow without damaging world and maintaining sustainability.

JEL: E23; E27

KEYWORDS: Insight; CO_2; SPM; Fly ash; Global warming; ARIMA Model; Sustainability

INTRODUCTION

Since independence, India's population has grown from 300 million to more than one billion today. Increased population and changing lifestyle along with rapid economic growth has accelerated energy requirement of the country. Since 1990s, India's Gross Domestic Product (GDP) has been increasing rapidly and is expected to increase at a similar pace for several decades. The rise in GDP implies an increase in expenditures on key energy sectors, namely electricity. Thermal power is the basic source of the country's energy production. In the beginning of 2010 the country produces 157,229 MW of electricity out of which 100,598 MW was generated from thermal plant. Coal is the basic primary fuel in thermal power plants, although there are other natural resources available like hydro-electricity, nuclear, solar and wind powered. These alternative sources of power are either highly technology oriented, capital intensive or demand highly skilled human capital. Moreover, commissioning a power plant based on these alternative sources of energy is time consuming.

As an alternative to the critical demand for power, country planners have concentrated more on commissioning of thermal power plants. Coal happens to be the basic fuel of any thermal power plant and India had a plentiful supply of this basic raw material until recently. Unfortunately, the stock of coal in India is not unlimited. The share of coal in electricity generation declined from 98% in 1950-51 to 62.3% in 2009-10. Even then, it accounts for more than one-half of the electricity generation of the country. Coal mining in India commenced in the 18th century when much of the stock was exported to the UK due to limited requirement for thermal power in industries and in the domestic sector. The coal industry was in the hands of private entrepreneurs. In 1923, the India Government developed a regulatory framework and in 1972-73 nationalized the coal industry.

Coal India Ltd (CIL) was incorporated as a holding company for seven coal-producing subsidiaries. Today CIL is engaged in mining coal from 495 working coal mines, accounting for nearly 88% of total coal production in the country. It is estimated that total coal reserve in India are 267 billion tons. At present, the Government of India has plans to add more than 50 gigawatts of new coal-fired generating capacity during its 11th power plan. In the recent five-year plan period ending in March 2007, only about 12 of 20 gigawatts of new coal-fired generating capacity were planned and completed.

India is the third largest coal producing country. Unfortunately, Indian coal is of poor quality with high ash content and low caloric value i.e. gross heat of combustion. A major portion of this ash is inherent in the coal, aggravating the difficulty in removing it before combustion. High ash content of Indian coal and inefficient combustion technology contribute to emission of suspendable air particles and other trace gases which are responsible for the greenhouse effect. Thus, the vicinity of thermal powerhouse in India are highly polluted causing health hazards and damage to agriculture. In consideration of depleting stocks of quality coal, India has started importing coal from countries like Indonesia, Australia and South Africa. However, cost of imported coal is high. Moreover, the ability to continue importing coal from these countries is uncertain, as there is likely to be worldwide shortage of coal in the near future. The remainder of the paper is organized as follows. Section 2 briefly discusses the relevant literature. Data selection, research methodology, and empirical models are described in Section 3. Section 4 provides analysis and interpretations of the empirical findings and Section 5 concludes the paper.

LITERATURE REVIEW

According to Dresner (2002), "Sustainability is a concept which combines post-modernist pessimism about the domination of nature with almost Enlightenment optimism about the possibility to reform human institutions." Since the conclusion of the Brundtland Commission (World Commission on Environment and Development, 1985), in itself something of a political compromise, two competing notions of *strong* and *weak* sustainability have dominated the theoretical debate on sustainable development. Loosely speaking, *strong* sustainability argues that we must live within the environmental and ecological limits that the planet has. *Weak* sustainability argues that humanity will replace the natural capital we use and depend upon with human-made capital. Theorists virtually unanimously agree that the latter has formed the conceptual basis for sustainable development.

The all-pervasive nature of neo-classical economics has also come to permeate thinking on sustainable development, with a broad acceptance that intra-generational and inter-generational equity can only be achieved within the confines of economic growth. Brandon and Lombardi (2005) focus on policy integration, as a central tenet for the evaluation of sustainable development. They claim an integrating mechanism or framework is required to obviate the interconnectedness and interdependence of systems. In the existing literature of Econometric models and forecasts on coal consumption and production, a single equation time series model is frequently used. In economic data commonly used forecasts are normally non-stationary and it have a high correlation coefficient (R2) due to the presence of trend between the dependent and independent variable.

Huntington (1994) shows that the forecasting performance of ten structural models was problematic since the errors in structural models were due to factors such as exogenous GNP assumptions, resource supply conditions outside OPEC, and demand adjustments to price changes. Lynch (2002) arrives at a similar conclusion by comparing the theory and practice of oil supply forecasting. Koomey et al (2003) point out that factor like technological innovation and inaccuracy of coal reserve forecasts may also contribute to forecast errors. Pindyck (1999) points out that structural models may not be always accurate in long run forecasts. Structural models are better for understanding the short run fluctuation of dependent and other variables. Areepong (1999) proposed methods to forecast the nonrenewable product by using forecasting techniques of regression analysis including the exponential smoothing method. The forecasting technique is regression analysis or moving averages. Moving averages work better with stationary data. For a time series that contains a trend or seasonal or non-stationary data, the forecasting technique should be the Auto Regressive Integrated Moving (ARIMA). ARIMA models have been applied to forecast commodity prices, such as oil. The ARIMA models has been used in different applications and has demonstrated more flexible than other simple models. The purpose of ARIMA analysis is to find a model that accurately establishes past and future patterns in the time series data and is able to capture a wide variety of realistic phenomena regarding the uncertainty about the future risk.

DATA AND METHODOLOGY

The present research focuses on time varying trends of future production of coal with the help of a benchmark time series Auto Regressive Integrated Moving Average (ARIMA) model. The study is based on the past twenty-six years of secondary data on coal consumption and production for the world and India. The data were published by Energy Information Administration, International Energy Annual 2006, etc. We analyze the result by using ARIMA model to predict future coal production and consumption in the Indian and world economy. After describing the ARIMA (p, d, and q) where p is the order of the auto regressive model, d is the number of differentiations to accomplish stationarity; and q is the order of moving average, we follow a parameter estimation procedure for the ARIMA model and an adaptive prediction scheme is then used to allow capturing the non-stationary characteristics. The authors expect that electricity demand will continue to grow at high rates as a natural consequence of industrialization in India, which will require coal alternative sources of fuel in order to expand the country's power generation capacity and maintain sustainability.

EMPERICAL RESULTS

Future Projection of Coal Consumption and Production in World and India

Coal is a nonrenewable resource for thermal power production. It has depleted over time at an increasing rate and its demand has increasing over time at an increasing rate. Therefore, the future projection of coal production and its demand become necessary homework for decision makers to achieve sustainable devolvement in respect to energy production. On the basis of the past 26 years (1980 to 2006) of data collected from Energy Information Administration, International Energy Annual 2006 we analyze the future trend of coal demand and supply and find a situation where coal production will be saturated with by demand. We apply a general time series regression model described as:

$$Y_t = X_t\beta + \varepsilon_t$$

Where Y_t = production of coal, X_t = Year, ε_t= White noise, with zero mean and constant variance.
We estimate the time series regression equations for world coal consumption and production as follows:

World Coal Production: $Y_t = 4301.36 + 59.36X_t$

World Coal Consumption: $Y_t = 4280.63 + 60.94X_t$

On the basis of the above time series regression equation we predict the future trend of coal production and consumption and draw a diagram which gives us a saturation point where supply and demand intersect each other. After the point of saturation, the world is faced with a big question regarding coal supply and the alternative sources of energy. The above model is a basic time series regression where we do not consider the random walk model as well as the stationary property of time series inherent in the problem of moving average and autoregressive problems. In order to avoid the problem of autoregressive and moving average we consider the ARIMA (autoregressive integrated moving average) model for prediction of consumption and production of coal.

AR-model: $Y_t = PY_{t-1+} \varepsilon_t$

It can be shown that $E(y_t) = 0;\ V(y_t) = \dfrac{\sigma^2}{(1-\rho^2)};\quad corr(y_t, y_{t-k}) = \rho^k.$

MA-models: $y_t = \varepsilon_t + \theta\varepsilon_{t-1}.$

It can be shown that

$$E(y_t) = 0;\ V(y_t) = \sigma^2(1+\theta^2);\quad corr(y_t, y_{t-1}) = \frac{\theta}{(1+\theta^2)},$$

$$corr(y_t, y_{t-k}) = 0,\ k > 1.$$

<u>ARIMA Model:</u>

$$y_t = \alpha x_t + \rho_1 y_{t-1} + \cdots + \rho_p y_{t-p} + \varepsilon_t + \theta_1\varepsilon_{t-1} + \cdots + \theta_q\varepsilon_{t-q}.$$

Here x_t represents different years, ε_t is the error term at time t and $\varepsilon_{t-1}......\varepsilon_{t-q.}$ represent error terms in previous time periods that are incorporated in the response of y_t .We estimate the ARIMA model for production and consumption of coal, where we apply Box-Jenkins (B-J) methodology for ARIMA (p, d, q) models with time series data. In practical applications of the B-J procedure, the most difficult part is to determine the values of p, d, and q. According to the Box- Jenkins method we determine whether the series is stationary or not by considering the graph of Autocorrelation Function (ACF).

The Autocorrelation Function is defined as $\rho_k = \dfrac{\gamma_k}{\gamma_0} = \dfrac{\text{cov}\,ariance.at.lag.k}{\text{var}\,iance}$. Based on the autocorrelation function we can determine the lag length and the value of p, q and d. If an ACF graph of the time series values either cuts off quickly or dies down fairly quickly, then the time series values should be considered stationary. If the ACF graph dies down extremely slowly, then the time series values should be considered non-stationary. If the series is not stationary, it can often be converted to a stationary series by differencing. In B-J procedure p and q can be determined by the ACF and PACF. From the characteristics of the ACF, it describes the correlation between current states of the time series with the past. Using ACF, we determine the moving average (MA) parameters order q straight. From the characteristics of the PACF, it describes the correlation between current state innovation of the time series with the past. Using ACF, we can determine the auto-regressive (AR) parameters order p directly. In such a model, we use the maximum likelihood method (MLE) to estimate the parameters. After estimating the model, we check for adequacy by considering properties of the residuals. The residuals from an ARIMA model must have the normal distribution and should be random. An overall check of model adequacy is provided by the Ljung-Box Q statistics. The test statistic Q is

$$Q = n(n+2)\sum_{k=1}^{m}\left(\frac{\hat{p}_k^2}{n-k}\right)$$

The model with the highest value of Q is preferred. The estimate ARIMA equations are as follows:

World Coal Production:

$$y_t = 4158.57 + 71.22x_t + 1.87y_{t-1} - 0.97y_{t-2} + 0.92\varepsilon_{t-1}$$

World Coal Consumption:

$$y_t = 4199.66 + 69.66x_t + 1.68y_{t-1} - 0.88y_{t-2} + 0.12\varepsilon_{t-1}$$

India Coal Production:

$$y_t = 103.45 + 13.94x_t + 0.87y_{t-1} + 0.13\varepsilon_{t-1}$$

India Coal Consumption:

$$y_t = 94.46 + 15.85x_t + 0.14y_{t-1} + 0.68y_{t-2} - 0.45\varepsilon_{t-1}$$

An Akaike Information Criterion (AIC) is defined as $\ln AIC = (\frac{2k}{n}) + \ln(\frac{RSS}{n})$. In comparing two ARIMA models, the model with the lowest AIC value is preferred. On the basis of Akaiki Information criteria and Ljung –Box statistics, (where all t-values for different regression parameter are statistically significant) we can accept the ARIMA model for different dependent variables. The results show the selection of an ARIMA (p=1, d=0, q=1) model for World Coal Production, ARIMA (p=2, d=0, q=1) model for World Coal Consumption, ARIMA (p=1, d=0, q=1) model for India Coal Production, and ARIMA (p=2, d=0, q=1) model for India Coal Consumption. It can be used to predict the future trend based on past data.

Table 1 shows ARIMA estimation of the world's coal production and consumption. The first series of rows show ARIMA Estimation for World's Coal Production. The first row of Panel A shows ARIMA (p=1, d=0, q=1) an in Panel B shows ARIMA (p=2,d=0,q=1). The first column of Panel A and Panel B shows the Log likelihood ((Ljung-Box Q Statistics) and the Akaiki Information Criteria. The second column shows Log likelihood ((Ljung-Box Q Statistics) and the Akaiki Information Criteria respectively. The third rows shows estimates of analysis of variance for Panel A and B. The second column of the fourth row of Panel A shows the degree of freedom. The third column shows the adjusted sum of squares and the fourth shows residual variance. The first column of the fourth row of Panel B shows the degree of freedom. The second column shows adjusted sum of squares, and third shows residual variance. The fifth row of Panel A and B shows the degree of freedom, adjusted sum of squares and the residual variance respectively. The sixth row of Panel A and B show estimated parameters for ARIMA estimation of world coal production. First column of seventh row of panel A shows parameters, second column shows estimated values, third column shows t-statistics and fourth column shows p-values. First column of seventh row of panel B shows estimated values, the second column shows t-statistics and third column shows p-values. The first column of the eight, nine, ten, eleven, twelfth and thirteenth row shows the parameters of AR1, AR2, MA1, years and constant. The second through thirteenth rows show the estimated value of different parameters.

Similarly, the second series of rows show the ARIMA Estimation for the world's coal consumption. The first series of rows show the ARIMA estimation for world's coal consumption. The first row of Panel A shows the ARIMA (p=2, d=0, q=1). Panel B shows the ARIMA (p=1,d=0,q=1). The first column of Panel A and B shows the Log likelihood ((Ljung-Box Q Statistics) and the Akaiki Information Criteria and the second column shows the values of Log likelihood ((Ljung-Box Q Statistics) and the Akaiki Information criteria respectively. The third row estimates the analysis of variance for panel A and panel B. The second column of the fourth row of Panel A shows degrees of freedom, the third column shows adjusted sum of squares and the fourth column shows residual variance. The first column of the fourth row of Panel B shows degree of freedom, the second column shows adjusted sum of squares, and the third column shows residual variance. The fifth row of panel A and B shows the degree of freedom, adjusted sum of squares and residual variance respectively. The sixth row of Panel A and B show estimated parameters for the ARIMA estimation of world coal consumption. The first column seventh row of Panel A shows parameters, the second column shows estimated values, the third column shows t-statistics and the fourth column shows p-values. The first column of the seventh row of Panel B shows estimated values, the second column shows t-statistics and the third column shows p-values. The first column of rows eight through thirteenth shows the parameters of AR1, AR2, MA1, years and constant. The second through seventh columns of the eighth through thirteenth rows show the estimated value of different parameters.

Table 1: ARIMA Estimation for World's Coal Production and Consumption

ARIMA Estimation for World's Coal Production						
Panel A: ARIMA (p=1,d=0,q=1)				**Panel B: ARIMA (p=2,d=0,q=1)**		
Log likelihood (Ljung-Box Q Statistics)			-169.93	Log likelihood (Ljung-Box Q Statistics)		-174.89
Akaiki Information Criteria			349.85	Akaiki Information Criteria		357.77
Analysis of Variance				**Analysis of Variance**		
	Degree of Freedom	**Adj. Sum of Squares**	**Residual Variance**	**Degree of Freedom**	**Adj. Sum of Squares**	**Residual Variance**
Residuals	22	462875	17359	23	666331	26708
Estimated Parameters				**Estimated Parameters**		
Parameters	**Estimated value**	**t-Statistics**	**p-values**	**Estimated value**	**t-statistics**	**p-values**
AR1	1.86	23.15*	0.000	0.87	7.11*	0.000
AR2	-0.96	-13.11*	0.000			
MA1	0.93	3.89*	0.000	-0.39	-1.91**	0.068
YEARS	71.22	6.90*	0.000	88.98	3.71*	0.001
CONSTANT	4158.58	27.72*	0.000	4028.73	9.23*	0.000
ARIMA Estimation for World's Coal Consumption						
Panel A: ARIMA (p=2,d=0,q=1)				**Panel B: ARIMA (p=1,d=0,q=1)**		
Log likelihood (Ljung-Box Q Statistics)			**-162.97**	Log likelihood (Ljung-Box Q Statistics)		-166.84
Akaiki Information Criteria			335.93	Akaiki Information Criteria		341.68
Analysis of Variance				**Analysis of Variance**		
	Degree of Freedom	**Adj. Sum of Squares**	**Residual Variance**	**Degree of Freedom**	**Adj. Sum of Squares**	**Residual Variance**
Residuals	22	275892	10880	23	368006	14215
	Estimated parameters				**Estimated parameters**	
Parameters	**Estimated value**	**t-Statistics**	**p-values**	**Estimated value**	**t-statistics**	**p-values**
AR1	1.68	9.54*	0.000	0.88	8.73*	0.000
AR2	-0.83	-4.44*	0.000			
MA1	0.11	0.41	0.684	-0.69	-4.52*	0.000
YEARS	69.65	4.62*	0.000	91.93	4.09*	0.000
CONSTANT	4199.64	17.39*	0.000	3978.84	9.53*	0.000

This table shows summary statistics of ARIMA Estimation for world's coal production and consumption. *We consider the values of different parameters of ARIMA model for world's coal production and consumption. As the value of AIC is lower in ARIMA (p=1,d=0,q=1) compared to ARIMA (p=2,d=0,q=1) in our model of world's coal production, we accept the ARIMA (p=1,d=0,q=1) to predict the future of world's coal production. Similarly, as the value of AIC is lower in ARIMA (p=2,d=0,q=1) compared to ARIMA (p=1,d=0,q=1) in our model of world's coal consumption, we accept the ARIMA (p=2,d=0,q=1) to predict the future of world's coal consumption. We also accept the alternative hypothesis for each parameter based on t-statistics where the test statistics is described as follows: * t- statistic are significant at 1% level of significance i.e., t-values are more than 2.51 at 22 degree of freedom and t-values are more than 2.50 at 23 degree of freedom. ** t- statistic are significant at 5% level of significance i.e, t-values are more than 1.72 at 22 degree of freedom and t-values are more than 1.71 at 23 degree of freedom.*

Table 2 shows the ARIMA estimation of India's coal production and consumption. The first series of rows show the ARIMA Estimation for India's Coal Production. The first row of Panel A shows the

ARIMA (p=1, d=0, q=1) and Panel B shows the ARIMA (p=2,d=0,q=1). The first column of Panel A and B show the Log likelihood ((Ljung-Box Q Statistics) and the Akaiki Information Criteria. The second column shows the Log likelihood **(**(Ljung-Box Q Statistics) and the Akaiki Information Criteria respectively. The third rows estimate the value of analysis of variance for Panel A and B.

Table 2: ARIMA Estimation for India's Coal Production and Consumption

ARIMA Estimation for India's Coal Production						
Panel A: ARIMA (p=1,d=0,q=1)				**Panel B: ARIMA (p=2,d=0,q=1)**		
Log likelihood (Ljung-Box Q Statistics)			-95.02	Log likelihood (Ljung-Box Q Statistics)		-94.42
Akaiki Information Criteria			198.04	Akaiki Information Criteria		198.85
Analysis of Variance				**Analysis of Variance**		
	Degree of Freedom	**Adj. Sum of Squares**	**Residual Variance**	**Degree of Freedom**	**Adj. Sum of Squares**	**Residual Variance**
Residuals	23	1789.4	74.55	22	1704	73.85
	Estimated parameters			**Estimated parameters**		
Parameters	**Estimated value**	**t-Statistics**	**p-values**	**Estimated value**	**t-statistics**	**p-values**
AR1	0.87	5.11*	0.000	0.23	0.38	0.709
AR2				0.57	1.19	0.244
MA1	0.14	0.51	0.618	-0.42	-0.61	0.546
YEARS	13.93	17.64*	0.000	13.95	17.16*	0.000
CONSTANT	103.45	7.31*	0.000	103.63	7.02*	0.000
ARIMA Estimation for India's Coal Consumption						
Panel A: ARIMA (p=2,d=0,q=1)				**Panel B: ARIMA (p=1,d=0,q=1)**		
Log likelihood (Ljung-Box Q Statistics)			**-102.57**	Log likelihood (Ljung-Box Q Statistics)		-103.67
Akaiki Information Criteria			215.14	Akaiki Information Criteria		215.35
Analysis of Variance				**Analysis of Variance**		
	Degree of Freedom	**Adj. Sum of Squares**	**Residual Variance**	**Degree of Freedom**	**Adj. Sum of Squares**	**Residual Variance**
Residuals	22	3119	134	23	3399.98	141.21
	Estimated parameters			**Estimated parameters**		
Parameters	**Estimated value**	**t-Statistics**	**p-values**	**Estimated value**	**t-statistics**	**p-values**
AR1	0.14	0.25	0.803	0.88	5.91*	0.000
AR2	0.68	1.56	0.131			
MA1	-0.45	-0.76	0.451	0.15	0.52	0.601
YEARS	15.86	13.90*	0.000	15.88	13.99*	0.000
CONSTANT	94.46	4.44*	0.000	93.23	4.51*	0.000

*This table shows summary statistics of ARIMA estimation for India's coal production and consumption. We consider the values of different parameters of the ARIMA model for India's coal production and consumption. As the value of AIC is lower in ARIMA (p=1,d=0,q=1) compared to ARIMA (p=2,d=0,q=1) in our model of India's coal production, we accept the ARIMA (p=1,d=0,q=1) to predict the future. Similarly, as the value of AIC is lower in ARIMA (p=2,d=0,q=1) compared to ARIMA (p=1,d=0,q=1) in our model of India's coal consumption, we accept the ARIMA (p=2,d=0,q=1) to predict the future. In our model, we accept the alternative hypothesis for each parameter based on t-statistics where the test statistics is described as follows: * t- statistic are significant at 1% level of significance i.e., t-values are more than 2.51 at 22 degree of freedom and t-values are more than 2.50 at 23 degree of freedom. ** t- statistic are significant at 5% level of significance i.e., t-values are more than 1.72 at 22 degree of freedom and t-values are more than 1.71 at 23 degree of freedom.*

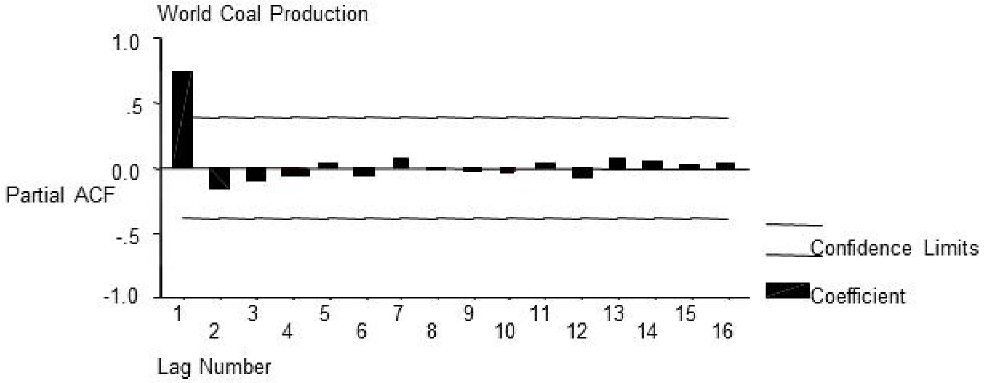
The second column, fourth row of Panel A shows degree of freedom, the third column shows adjusted sum of squares and the fourth column shows residual variance. The first column fourth row of Panel B shows the degree of freedom, the second column shows adjusted sum of squares, and the third column shows residual variance. The fifth row of Panel A and B shows the degree of freedom, adjusted sum of squares and the residual variance respectively. The sixth row of Panel A B shows estimated parameters for the ARIMA estimation of India coal production. The first column seventh row of Panel A shows parameters, the second column shows estimated values, the third column shows t-statistics and the fourth column shows p-values.

The first column seventh row of Panel B shows estimated values, the second column shows t-statistics and the third column shows p-values. The first column of the eighth through thirteenth rows shows the parameters of AR1, AR2, MA1, years and constant. The second through thirteenth rows show the estimated value of different parameters.

Similarly, the second series of rows show the ARIMA Estimation for India's coal consumption. The first series of rows show the ARIMA estimation for India's coal consumption. The first row of Panel A shows ARIMA (p=2, d=0, q=1) and panel B shows ARIMA (p=1,d=0,q=1). The first column of Panel A and B shows the Log likelihood ((Ljung-Box Q Statistics) and Akaiki Information Criteria and the second column shows the values of Log likelihood ((Ljung-Box Q Statistics) and Akaiki Information Criteria respectively. The third rows estimate the analysis of variance for Panel A and B. The second column fourth row of Panel A shows degrees of freedom, the third column shows adjusted sum of squares and the fourth column shows residual variance. The first column fourth row of Panel B shows degrees of freedom, the second shows adjusted sum of squares, and the third shows residual variance. Refer to Figures 1 through 7 for additional results.

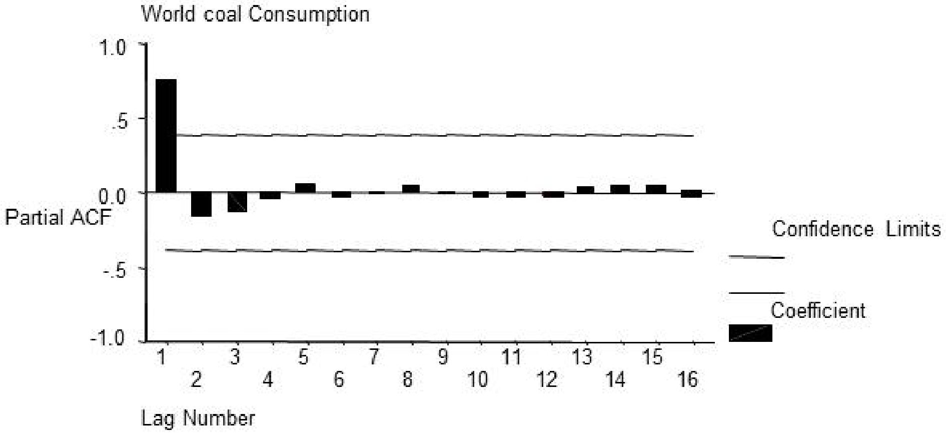
The fifth row of Panel A shows the degrees of freedom, adjusted sum of squares and residual variance respectively. The sixth row of Panel A and B shows estimated parameters for ARIMA estimation of India's coal consumption. The first column seventh row of Panel A shows parameters, the second shows estimated values, the third shows t-statistics and the fourth shows p-values. The first column seventh row of Panel B shows estimated values, the second shows t-statistics and the third shows p-values. The first column of the eighth through thirteenth rows shows the parameters of AR1, AR2, MA1, years and constant. The second through thirteenth rows show the estimated values of different parameters.

Figure 1: Partial Autocorrelation Function of the Differentiated Time Series of World's Coal Production



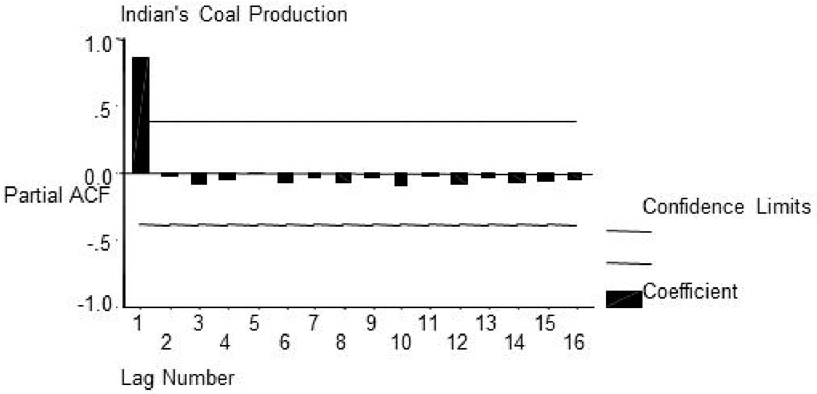
The analysis of partial auto-correlation function (PACF) depicted in figure 1 demonstrate that the ARIMA model for world coal production to be evaluated by (p=1, d=0, q=1) as PACF exhibits a peak much different from zero.

Figure 2: Partial Autocorrelation Function of the Differentiated Time Series of World's Coal Consumption



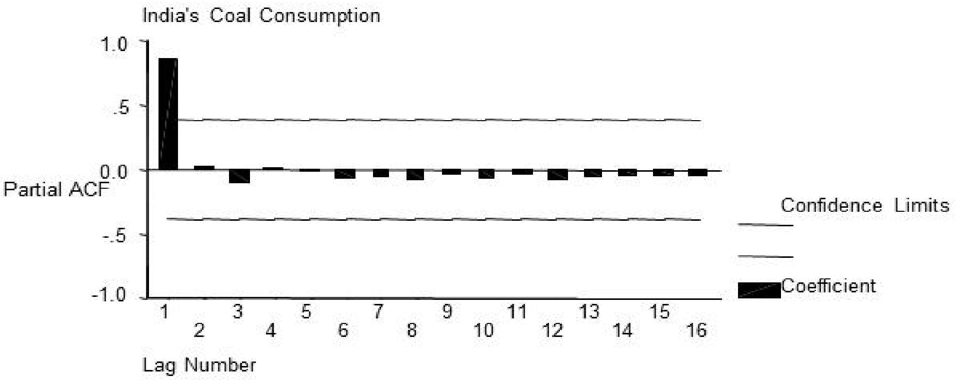
The analysis of partial auto-correlation function (PACF) depicted in figure 2 demonstrate that the ARIMA model for world coal consumption to be evaluated by (p=2, d=0, q=1) as PACF exhibits a peak much different than zero and exponential fall in negative values.

Figure 3: Partial Autocorrelation Function of The Differentiated Time Series of India's Coal Production



The analysis of partial auto-correlation function (PACF) depicted in figure 3 demonstrate that the ARIMA model for Indian coal production to be evaluated by (p=1,d=0, q=1) as PACF exhibits a peak much different from zero.

Figure 4: Partial Autocorrelation Function of the Differentiated Time Series for India's Coal Consumption



The analysis of partial auto-correlation function (PACF) depicted in figure 4 demonstrate that the ARIMA model for Indian coal consumption to be evaluated by (p=2, d=0, q=1) as PACF exhibits a peak much different than zero and exponential fall in negative values.

Figure 5: Prediction of World Coal Production and Consumptions

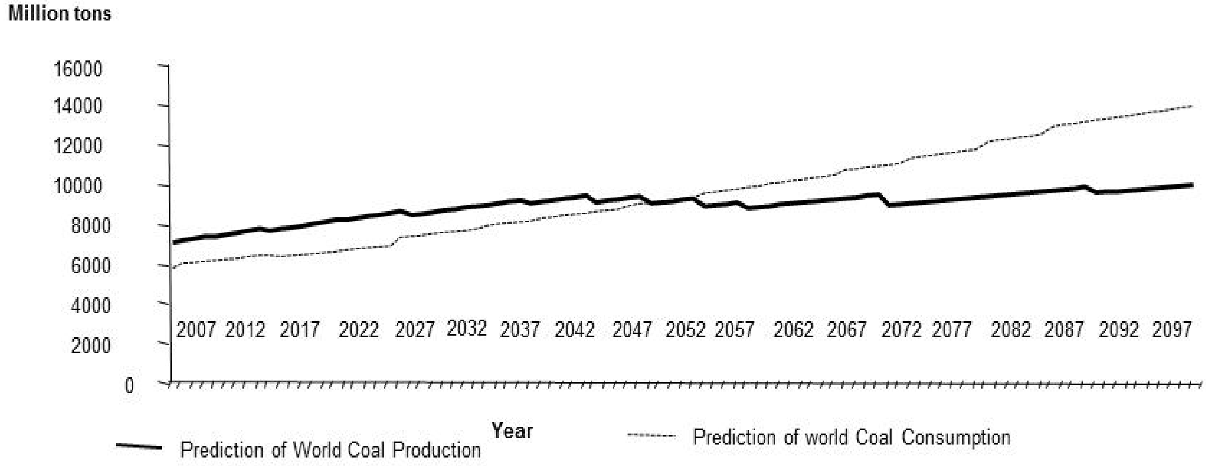


Figure 5 shows the prediction results of world foal production and consumption. It is observed that after 2050 a saturation point is reached for coal demand and supply in world.

Figure 6: Prediction of Indian Coal Production and Consumptions

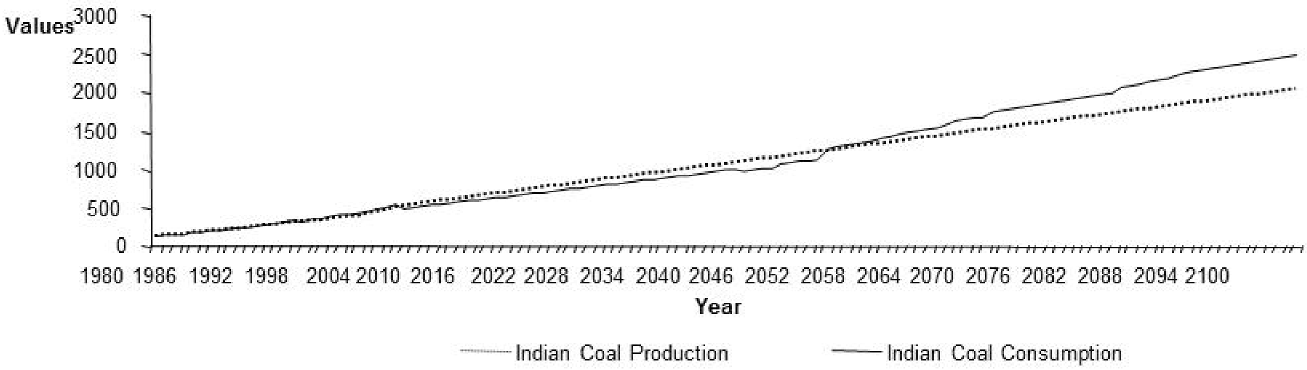


Figure 6 shows the prediction results of India coal production and consumption. It is observed that after 2055 a saturation point is reached for coal demand and supply in India.

Figure 7: Coal Consumption by Different Industries in India ('00000 Tonnes).

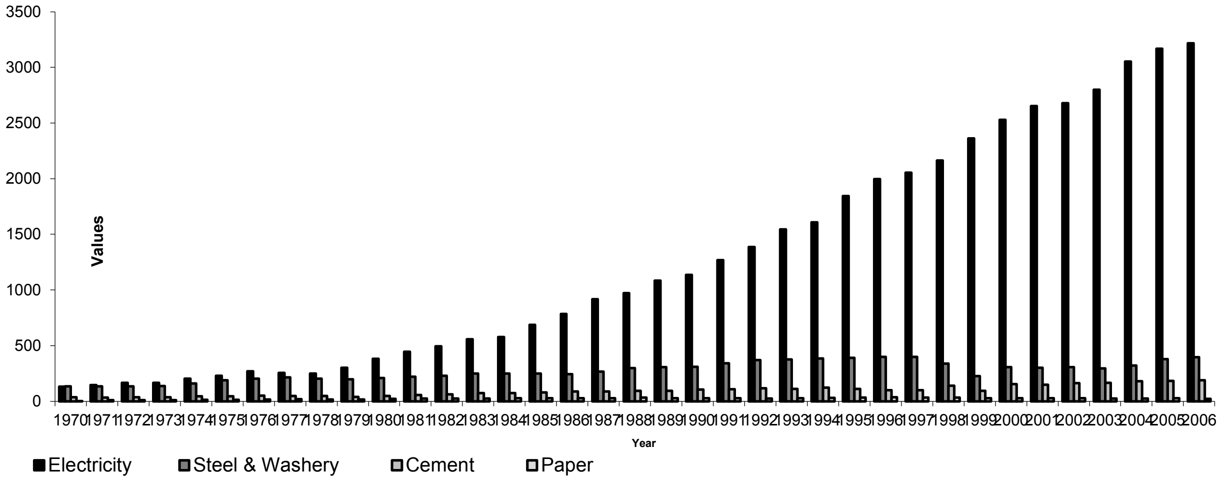


Figure 7 shows the consumption of coal by different Indian industries. It is observed that the demand for coal as a raw materials for the power sector increased over time where as the demand of coal as raw materials for other industries is constant but at a high rate.

CONCLUSION

Indian economic growth has stabilized at around 8 to 9 percent per annum, attributed largely to the industrial sector. We have observed that thermal power generating units use substantial quantity of coal. Further, consumption of coal has increased, as other major industries are also dependant on coal. While consumption of coal in the thermal power sector is increasing daily, it is more or less stable in other industries. In this scenario if the trend of coal consumption in the power sector continues to increase, other industries will starve for want of coal. The shortage of coal will push raw material costs of other industries high and they will face the question of survival. Therefore, in order to maintain the sustainable development and economic growth of the country, India needs to reduce coal use by the thermal power sector. This also leads us to the conclusion that in the near future thermal power generation with coal will not be possible because of shortages of this basic raw material

In the context of economic globalization, no country has any boundary with the neighboring country. Every country is looking towards foreign markets to achieve its target and combat international competition. Competition never leaves the price war, which is affected by raw material costs. Therefore, to be a market leader in both domestic and global markets, the Indian government should aid the industry in terms of cost of basic raw materials at an affordable cost. One of the basic costs of industrial production is electricity for which the country largely depends upon thermal power. The cost of thermal power is high due to factors noted above. Thus, India needs to explore alternative sources of energy.

The study also indicates that coal consumption will exceed production and the saturation point of coal consumption & production will reached by the mid 21st century. This holds true not only in India but all over the world. Therefore, decision makers must be concerned with uncertainty and non-availability of coal for generation of thermal power. Decision makers need to explore avenues for generation of electricity through alternative sources for sustainability of the country's economy.

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