

## RISE OF INDIA AND CHINA AMIDST CLIMATE CHANGE: QUEST FOR A NEW DEVELOPMENT PARADIGM

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### ABSTRACT

*Climate change is the biggest challenge before the policy planners today but focusing on it alone could be highly misleading, especially in case of the two Asian giants, China and India, which continue to experience a revolution of rising socio-developmental expectations among more than two billion people. The emerging economies of India and China also need to balance their domestic imperatives of development and poverty alleviation with that of international obligations of cutting down their carbon emissions. India and China are the largest developing countries of the world. Both have the same development needs and both face the same development dilemma of balancing the economic growth with environmental concerns. These similar imperatives can offer them good opportunity to cooperate with each other. But at the same time both need energy resources to sustain their economy and meet their other human development goals which can lead to a kind of resource war between the two. The present paper will focus on the rise of India and China and the impact of climate change on their growth trajectories. It also brings to light the dilemma of development and sustainability and the dependency factor into dynamics of climate change.*

**Keywords:** IPCC, developing nations, geopolitics.

### INTRODUCTION

Climate change is one of the most complex and compelling challenge before the states and societies today. The question as to whether we are experiencing widespread 'global' climate change is now beyond doubt ; graphically revealed for example through the dramatic decline in the Arctic Sea ice ,the melting of Himalayan as well as Antarctic glaciers, cloud-bursts in Ladakh, winter flood in England. Much more detailed and country/region specific studies are needed however to understand and approach the impacts and implications of climate change in terms of their varied geographies.

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According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the warming of the earth climate system is unequivocal and well supported by observations of increase in global average air and ocean temperature, widespread melting of snow and ice and rising global average sea level. While highlighting the fact that developing countries are most vulnerable to climate change, the report reveals that climate change will have an adverse impact on availability of food, water and resilience of many ecosystems, industries, settlements, society and health of the citizens of these countries (IPCC Fourth Assessment Report, 2007).

Williams (2005) in his study highlighted an emerging geopolitical development related to climate change. He mentions how the climate change has geopolitical fallout in conceptualization by making relevant the category of 'developing countries' as a concept, which in some ways seemed to be losing its significance after the fall of the Berlin wall and the growing focus on globalization. The role and responsibility of developing countries, many of which have much less per capita emissions in comparison to the affluent, industrialized countries of the global north, have started receiving far more attention in the context of the rise of Asia. It is a truism that 21<sup>st</sup> century is in many ways Asia's century and the growth stories of countries like India, China, Japan, South Korea, Taiwan and Singapore is causing remarkable shifts in global geopolitical equations (Niraj Kumar, 2015). No doubt Asia is rising and changing at the same time in several ways and at a fast pace. Most populated of all the continents, Asian countries are facing some of the most difficult environmental and socio-economic challenges. Land and ecosystems are already being degraded, threatening to undermine food security. Water and air quality are deteriorating while continued increases in consumption and associated waste have contributed to the exponential growth in the region's existing environmental problems. Many environmental and developmental problems in Asia are likely to be multiplied due to climate change.

This is more so in the case of large and fast developing countries like India and China. For many analysts both India and China are better understood and approached as economies in transition rather than as developing countries. Although both India and China have achieved tremendous progress in many fields in last few decades, the environmental damage caused by economic growth oriented, fossil-fuels driven model of development continues to undermine the progress made by these countries. It appears neither feasible nor desirable to divorce climate change issues that India and China are likely to face from the long standing histories of environmental unsustainability in these countries. Both face the development dilemma of balancing the much sought after high rates of economic growth with several negative fallouts in terms of environmental sustainability. The strategies that India and China are likely to adopt in order to mitigate climate change while ensuring energy security and high growth rates need attention and critical examination. It also becomes important to understand that how Asia, because of its rising economies, is enjoying a new development paradigm but at the same time this development is creating a new dependency paradigm firstly because of higher vulnerability of developing countries and secondly due to less capability of these countries to deal with the crisis of climate change.

## **THE RISE OF INDIA AND CHINA AND CLIMATE CHANGE**

According to Kishore Mahbubani “*Indo China relationship is the most important bilateral relationship of the 21<sup>st</sup> century*” (cited in Dipankar Banerjee, 2010). “This is the relationship that will shape the geopolitics of the region” (Arvind, 2008). India China relationship has a long history which has seen both ups and down during the last six decades. But the present era of globalization and resource conflict have resulted in the “speedy emergence and intensification of dilemmas of common interest and aversion” (Yu Hongyuan, 2008, p.16). It is, therefore, expected that both India and China will try to overcome their mutual challenges and climate change issue is such an opportunity for India and China. It is a golden chance for these countries to turn the threat of climate change into an opportunity. Their disputes are many; but both share an interest in avoiding overt conflict and rivalry as there is sufficient space for both of them to grow or develop together. There are many dimensions of Indo-China relationship like the political, economic, strategic and security aspects of their relationship. But the focus should be on their environment- related issues particularly their approach on issue of climate change.

The IPCC report states that Asia is potentially more susceptible to climate change than many other regions of the world. It also concludes that developing countries of Asia are highly vulnerable, and their adaptability is also low. India and China both are the victims of climate change resulting from global warming. Both are having the same development imperatives like poverty alleviation, unemployment and improving the living standards of their people. For all this, they need to consistently maintain their economic growth for which they need energy resources. Their dependence on non-renewable sources of energy increases their carbon emissions level. This will put them under higher pressure to change their energy strategy. The dilemma of sustainable growth has been in global focus for more than two decades.

United National Framework Convention on Climate Change (UNFCCC) was created on 9<sup>th</sup> May 1992. Before that IPCC was convened by the United Nations in 1988 to provide an authentic summary of our present understanding of the climate change induced by human beings and indicate the ways to mitigate this climate change or adapt to it. Since the adoption of UNFCCC, parties have continued in order to agree on the decisions and conclusions that advance its implementation. India and China’s climate approach can be traced back to the formation of UNFCCC only, because since then environmental issues have got a prominent place in policy discussions of almost all the countries.

Both India and China recognized some environmental problems and began addressing them way back in 1950s. However by the 1980s, increasing damage to their natural environment and adverse environmental impacts on economic development led to greater government concern. New environment laws were instituted in the areas of solid waste, noise, air and water pollution and by the mid 1990s the government was becoming more serious about the environmental issues. The present paper will focus on the climate approach of India and China since 1990s and more specifically since the signing of Kyoto protocol on December 11, 1997. India and China consider UNFCCC as the only platform to discuss environment related issues and they believe that only in the framework of UNFCCC, the deadlock between the developed and developing countries can be resolved.

Predictions are being made that the center of gravity of power is indeed shifting from west towards east especially because of the simultaneous rise of India and China to global prominence.(Niraj Kumar,2015) But the problem is how to sustain this growth especially because of the threat of climate change. The focus is now on the indicators which point toward this rise along with highlighting the impact of climate change upon rise of Asia and vice-versa. Another focus area is the Energy-climate interface taking place in India and China. Climate change and global energy are so strongly related to each other that they can no longer be discussed in isolation. The provision of energy is at the core of the climate change issue. The growing energy needs of the various sectors of India and China and the increase in carbon emissions as a result of this reflect the growing development as well as dependency phenomenon happening at the same time. Their environmental diplomacy has sought to further several goals: protect their sovereignty, acquire foreign aid and technical assistance, and promote economic development.

It is of paramount importance to know what have been their stands on climate change issue during various environmental negotiations and what are their key priorities which they keep in mind while taking any decision on this issue?

The rate of environmental degradation in China and India has aggravated with the rapid rate of economic growth in these countries. The key purpose of the paper is to examine the environmental condition of these countries and the level of environmental pollution and degradation in the world's two largest economies of India and China. The various steps which have been taken or which should be taken for the mitigation of climate change especially focusing on their national action plans on climate change also become an important area of study.

India and China can adopt new clean development strategies to circumvent the crisis caused by the Climate change upon the current model of development. Many other believe that climate change may also lead to resource war between the two neighbours given the limited stock of energy sources and the over-reliance of these countries on energy import. The world is watching with eagerness policies of India and China with respect to their development policies.

### **DILEMMA OF DEVELOPMENT AND CLIMATE CHANGE**

The threat of global warming has become a serious environmental security issue. The study of climate change also becomes important because of its serious impact on every aspect of human life be it economic, cultural, political and social. This problem gets worse because of the deadlock between the developed and developing countries which revolve around the question that who is to be blamed for present crisis of climate change and who should take the responsibility in this regard? No doubt, co-operation of all the countries is needed to resolve the crisis but question arises who should take the initiative as lot of issues such as the sovereignty, ethics, morality, justice, security are involved that makes this whole issue very complex.

This paper raises an important question – Can billions in the East develop the same way millions in the west developed? Climate change resulting from global warming is basically the result of industrialization of developed countries and developing countries are least responsible

for this crisis but according to the IPCC 4<sup>th</sup> Assessment Report, developing countries are the most vulnerable to its adverse consequences. At the same time they are least capable of dealing with it. All this make their position more vulnerable. Developed countries are shirking from taking the initiative in mitigation of climate change but these countries instead of doing something to bring the situation under control, are demanding that developing countries should also take the concrete responsibilities in this regard. It means developing world will have to compromise with their development needs in order to deal with the adverse effects of climate change. In this way developing countries are being denied the right to develop.

Developing countries believe that limiting their carbon emissions level will limit their economy's growth. Climate change is a matter of grave concern to these countries due to their higher vulnerability and lower adaptability. Few developing countries have the necessary financial, technical and institutional capacities. There are some critical perspectives which call these tactics of developed countries as '*environmental colonialism*' and argue that climate change as post-industrial and post-colonial discourse is likely to result in new kinds of dependencies.

This is being discussed in the latest round of climate change negotiations also. Developing countries argue that difference should be made between the luxury emissions of developed countries and subsistence emissions of developing countries. They are of the opinion that developed countries have already achieved very high levels of development and their emissions are byproduct of their luxuries but for developing countries it is the question of their survival.

The emerging economies of India and China also need to balance their domestic imperatives of development and poverty alleviation with that of international obligations of cutting down their carbon emissions. India and China are the largest developing countries of the world. Both have the same development needs and both face the same development dilemma of balancing the economic growth with environmental concerns. These similar imperatives can offer them good opportunity to cooperate with each other. But at the same time both need energy resources to sustain their economy and meet their other human development goals which can lead to a kind of resource war between the two.

India and China are the largest developing countries of the world. Both are the top five emitters of greenhouse gases. China comes second and India comes last in this group. In terms of population, both countries also belong to top five. Both countries also belong to the top five countries with respect to economic size. When measuring their gross domestic product in term of purchasing power parity, China comes first and India comes third (IMF, 20147). On one hand, both countries are relatively vulnerable to adverse impacts of climate change, on the other, with a large population, in pursuing accelerated growth, carbon emissions will inevitably increase in the short and medium term. Both will have to make difficult decisions to keep a balance between climate protection and meeting the needs of economic development and poverty alleviation.

The question is whether India and China will cooperate to give a strong voice to the developing countries bloc as well as to come out with a better negotiating strategy for themselves in all the climate change negotiations or will they lose this opportunity by drifting

apart because of the many unresolved issues between them. A comparative analysis of their approach in all the climate change negotiations can help in resolving this dilemma.

Climate change and energy security are interwoven to such a great extent that both cannot be studied in isolation. Therefore, in the face of rising energy needs, India and China would try to take advantage of all the energy resources in the best way possible. But at the same time they are under pressure to reduce the level of their carbon emissions resulting from fossil fuel consumption. These countries will be called upon to change their energy strategy. Besides this the impact of climate change will force these countries to adopt a sustainable growth model. There is a need to balance their energy security needs with the compulsions of climate change.

### **THEORETICAL APPROACHES TO ADDRESS THIS DILEMMA**

Yu Hongyun writes, "*Like many global issues, such as Global financial crises issues, the risk of nuclear proliferation, the threat of terrorism, environmental degradation within an increasingly interwoven global economy and so forth, climate change is also becoming more and more important for all people. All this resulted in the speedy emergence and intensification of dilemmas of common interest or aversion*" (Yu Hongyuan, 2008, p.16). Every country is required to collaborate on this issue but the saddest part is that they all do not stand together on this issue. The world is divided into developed and developing world on the issue of climate change. As shown by various reports of IPCC, developed countries are principally responsible for changes in climate conditions but these countries by not doing anything are denying their historical responsibility and by asking the developing countries to take concrete responsibility are making them more dependent on them.

For the analytical purpose of this study we intend to draw upon a few critically informed approaches and theoretical arguments. First and foremost is a Critical Geopolitical approach to environmental sustainability issues and climate change (Dalby, 2009, Doyle and Chaturvedi 2010) in order to examine the complex and dynamic political geography of climate change and the nature of its space. A key puzzle here relates to simultaneously happening processes of deterritorialisation and reterritorialisation of climate change. The two seem to be operating in conjunction, and perhaps do not so much question the system of sovereign spaces as they reproduce it. Climate as a geopolitical space, therefore, as pointed out by Doyle and Chaturvedi (2010) "*is constantly moving in and out of physical-material geography and the spaces of climate change are always in the making and intermittently assume territorial or non-territorial forms depending upon the strategic convenience of the actors and their agendas concerned.*"

We are also inclined to use the Dependency Theory. The basic premise of the Dependency Theory is that the rich develop at the cost of the poor nations. Poor nations provide natural resources and cheap labor. They are the export destinations for obsolete technology and markets for the wealthy nations, without which, the latter could not have the standard of living that they enjoy. Poor are at a disadvantage in their market interactions with wealthy nations. For the purpose of the proposed thesis, we take Dependency theory as the rhetorical form of reasoning to explain the stand of powerful developed countries on climate change in all the climate negotiations wherein they justify the exercise of power in the pursuit of so-called *vital*

*national security interests.*

Climate change is essentially a consequence of the industrialization process of the developed countries at the development cost of developing countries. But it is basically these developing countries only which will be hit hard by the changes taking place in the climatic conditions. They are also least capable of dealing with the climate change crisis which makes them more vulnerable as well as more dependent on developed countries. It can be said that developed countries made progress at the expense of developing countries and today when it is their turn to develop, developed countries by moving away from their responsibility are denying the developing countries the right to develop. Huge technological gap between developed and developing countries also make developing countries heavily dependent on the developed countries for the transfer of technology and finances.

The second main principle of Dependency theory is that wealthy nations actively perpetuate a state of dependence by various means as in the case of climate negotiations. Heavy emphasis has been placed on carbon dioxide production due to deforestation and methane production from rice fields and livestock as compared to carbon dioxide emissions from the use of fossil fuels like oil and coal. Since the developing countries are more responsible for the former, heavy emphasis on deforestation and methane generation tends to overplay their contribution while underplaying that of the developed countries (Navroz K. Dubash, 2012).

Then there is a demand from the side of developed countries that carbon emissions reductions should be legally binding for developing countries also but developing countries believe that by making carbon emissions reduction legally binding for them, they are being denied the right to development and they call all this as 'Environmental Imperialism' or 'Environmental Colonialism' ( Navroz K. Dubash, 2012). The main thrust of developing countries has always been on the principle of '*common but differentiated responsibility and respective capabilities*'. Developing countries have always been united in their quest to be able to pursue their economic development without undue constraints. They believe that they should be internally as well as externally sovereign while making decisions in this regard. They also believe that mechanisms like Clean Development Mechanism (CDM), Joint Implementation (JI) etc. are the instruments in the hands of rich nations to further perpetuate the existing inequality. By emphasizing more on adaptation than on mitigation they are denying their historical responsibility in this regard.

The reason to focus on this aspect is the rising emissions of emerging economies of India and China. Pressure is increasing on all the developing countries to cut their carbon emissions level particularly on India and China as these are the largest developing countries of the world.

India is currently one of the fastest growing emitters of Green House Gases and contributes 5% of global emissions. India should be concerned about climate since the phenomenon might have substantial adverse impacts on various aspects of its economy. China is also an important country in the international climate change regime because of two reasons; first, it is the world's second largest emitter of greenhouse gases after the United States. Second, its status and influence in the G-77 of third world give it prominence in climate negotiations.

All this has led to the strong feeling that China and India has no reasonable argument for refusing binding reduction targets for their future emissions but India and China refuse to commit to any legally binding emissions. They argue that they cannot be blamed even for a single kg of carbon dioxide or methane that is accumulating in the earth's atmosphere as the accumulation of these gases is mainly the result of industrialization process of developed countries. No doubt climate change is a pressing problem that needs to be solved but for countries like India and China prime goal is that of development and securing a good standard of living for large number of poor and vulnerable people. Their message is clear – *Development First*.

Of particular importance for us in today's time is the notion of Game theory. Game theory is all about a unit's behavior in a strategic situation. As we see in all the climate negotiations, every country wants to protect its own national interest. But at the same time common threat of climate change force them to co-operate with each other. "On the one hand the pursuit of rational common goods leads to co-operation; on the other hand, the pursuit of rational self-interest or preference among different states often frustrates international cooperation"(Yu Hongyuan, 2008, p.70). The theory of Game has a special attraction for climate change negotiations as it basically deals with how decisions are taken by all the countries especially when objectives (climate change mitigation) and rules are clear and the only problem is to find the most logical strategy for an individual country to pursue.

The context in which the discourse on climate change finds itself situated is of utmost importance to a thorough and accurate discourse analysis (Jorgensen & Phillips, 2002). This is the reason for the extensive structure of this proposal which considers the implications of this discourse well beyond the realm of the discourse itself. As noted earlier, identity provides an important foundation for action. Social relations are also important to the issue of tackling global climate change as those interest groups who attempt to influence policy are forced to interact with one another in their efforts to exert influence, be it to uphold or to change the status quo. Lastly, systems of knowledge and meaning are critical for action on climate change (national or otherwise), because the object of understanding (here, climate change) must be known to have a potential to affect the realities in which the subjects exist. To put it more plainly, climate change will not be addressed if it is not understood as something that seriously threatens the well being of humanity.

Discourse analysis as associated with the methodology of Fairclough (also referred to as *Critical Discourse analysis*) recognizes that "discursive practices contribute to the creation and reproduction of unequal power relations between social groups" (Jorgensen & Phillips, p. 63). Therefore, this method of analysis is useful in revealing "the role of discursive practice in the maintenance of the social world" (Jorgensen & Phillips, p. 63); a social world that is not making headway on climate change quickly enough to ensure the threat of climate change is mitigated for all. This type of discourse analysis is meaningful, even if the solutions to the inequalities uncovered through its application may need to be conceived of outside the boundaries of the analysis. Defining the problem, be it climate change, or stagnant political situations, is a vital first step towards finding solutions. This methodology is therefore not politically neutral, but rather "politically committed to social change." (Jorgensen & Phillips 2002).

## CONCLUSION

There is no doubt that climate is changing the world over. But climate is not the only thing that is changing and a number of transitions and transformations (socio-cultural and political-economic) are visible in different parts of the globe including Asia particularly in India and China. Whereas China and India acknowledge that their cumulative emissions are increasing with each passing day, they would point out with all emphasis at their command that their per capita emissions in comparison to Global North are still much lower. The counter-argument on the part of the developed countries is put forward that the developing countries should also be included in the fold of Kyoto Protocol and emissions reductions to some extent should be legally binding for them as well. Developed countries argue that no doubt climate change is the result of their industrial activities but the large developing countries like India and China too are repeating the same mistake. There are some critical perspectives which call these tactics of developed countries as environmental colonialism and argue that climate change as post-industrial and post-colonial discourse is likely to result in new kinds of dependencies.

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# MEASURING TECHNICAL, SCALE, COST AND ALLOCATIVE EFFICIENCY IN THE MANUFACTURE OF BASIC METALS IN INDIA USING DATA ENVELOPMENT ANALYSIS

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## ABSTRACT

*There are two approaches for estimation of efficiency, viz., the Stochastic Frontier Approach (SFA) and Data Envelopment Approach (DEA). While the SFA (econometric approach) estimates the efficiency of the firms by estimating the production function, the DEA technique involves the use of mathematical programming to estimate the efficiency of the firms / industry. For the period 2002-3 to 2011-12, the calculations on the efficiency of Decision Making Units (DMUs) in the manufacture of basic metals in India have been done. The paper demonstrates that the technical, scale, cost and allocative efficient DMUs were more under Variable Returns to Scale (VRS) production technology in comparison with Constant Returns to Scale (CRS) production technology.*

**Keywords:** Allocative efficiency, BCC MODEL , CCR Model , cost efficiency, Decision Making Units(DMU), scale efficiency, Variable Returns to Scale (VRS).

## INTRODUCTION

India's manufacturing sector is vital for its economic progress. The contribution of manufacturing to overall GDP is meager 17.2 per cent (2014-15). The government has realized the importance of this sector to the country's industrial development, and has taken a number of proactive steps to further enhance the industry. Manufacturing Industry in India has gone through various phases of development over the period of time.

Since independence in 1947, the Indian manufacturing sector has traveled from the initial phase of building the industrial foundation in 1950's and early 1960's, to the license-permit Raj during the period of 1965-1980, to a phase of liberalization of 1990's, emerging into the

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current phase of global competitiveness. It has grown at a robust rate over the past ten years and has been one of the best performing manufacturing economy. Studies have estimated that every job created in manufacturing has a multiplier effect, creating 2–3 jobs in the services sector. In a country like India, where employment generation is one of the key policy issues, this makes manufacturing a critical sector to achieve inclusiveness in growth.

The metal sector is a key part of manufacturing. It is highly sensitive to changes in the business cycle. It is considered a capital- (basic metals), labour- (fabricated metal products) and energy-intensive industry, producing a wide range of products e.g. basic metals, tanks, steam generators, cutlery, tools, light metal packaging, wires etc. The metal industry is an important component of the world economy when measured by its share of GDP worldwide. In sub-branches such as metal production, non-electrical machinery, electrical machinery and transport equipment, it employs some 70 million workers worldwide, who account for nearly half of the goods produced in the manufacturing sector and more than half of all merchandise exported worldwide (in terms of value). Consequently, the metal industry is both a driving force of the world economy and is influenced to a large extent by the overall world economic climate.

## **METHODOLOGY**

### **1. Data Base of the Study**

The basic data source of the study on fixed capital, wages, net value added and number of workers was Annual Survey of Industries (ASI) published by the Central Statistical Organisation (CSO), Government of India. All the referred variables were normalised by applying Gross State Domestic Product (GSDP) deflator. The GSDP at current and constant prices were obtained by referring to the Economic Survey, published by the Government of India, Economic Division of the Ministry of Finance, New Delhi. The reference period chosen for the study covers post- liberalization period between 2000-01 and 2011-12. The availability of data is confined only up to this period.

### **2. Tools of Analysis**

#### **DEA Model**

There are basically two approaches for estimation of efficiency, viz., the Stochastic Frontier Approach (SFA) and Data Envelopment Approach (DEA). While the Stochastic Frontier Approach (econometric approach) estimates the efficiency of the firms by estimating the production function, the DEA technique involves the use of mathematical programming to estimate the efficiency of the firms / industry. DEA is a non-parametric, deterministic methodology for determining relatively efficient production frontier, based on the empirical data on chosen inputs and outputs of a number of entities called Decision Making Units (DMUs). From the set of available data, DEA identify reference points (relatively efficient DMUs) that define efficient frontier (as the best practice production technology) and evaluate the inefficiency of other interior points (relatively inefficient DMUs) that are below the frontier (Saon Ray, 2004).

The DEA provides a measure of efficiency that allows intra-firm comparison, as the

efficiency measure is a pure number. The main advantage of DEA is that unlike SFA, it does not require a priority assumption about the analytical form of the production function. Instead, it constructs the best practice production solely on the basis of observed data and therefore the possibility of mis-specification of the production technology is minimized. In the case of SFA, the parameter estimates are sensitive to the choice of the probability distribution specified for the disturbance term.

There are two approaches to estimating the efficiency of the firm in the DEA approach viz., the output-oriented efficiency and the input-oriented efficiency. In the output-oriented approach, efficiency is determined by maximum output that can be produced from an input bundle. In the input-based measure, the technical efficiency of the firm is evaluated by the extent to which all inputs could be proportionally reduced without a reduction in the output. Among number of DEA models, the two most frequently used ones (input-oriented) are, CCR model (after Charnes, Cooper, Rhodes, 1978) and BCC model (after Banker, Charnes and Cooper, 1984), both of which are used in the study. The DEA model is used to estimate the technical, scale, cost and allocative efficiency of the industries under study.

**I. TECHNICAL EFFICIENCY**

**(i) CCR Model ( based on constant returns to scale)**

Charnes, Cooper and Rhodes(1978) introduced a measure of efficiency for each DMU that is obtained as a maximum of ratio of weighted outputs to weighted inputs. The weights for the ratio are determined by a restriction that the similar ratios for every DMU have to be less than or equal to unity, thus reducing multiple inputs and outputs to single “virtual” output without requiring pre-assigned weights.

The efficiency measure is then a function of weights of the “virtual” input-output combination. Formally, the efficiency measure for the DMU can be calculated by solving the following mathematical programming problem:

$$\max h_0(u,v) = \frac{\sum_{r=1}^s u_r Y_{r o}}{\sum_{i=1}^m v_i x_{i o}} \dots\dots\dots(1)$$

$$\text{Subject to } \frac{\sum_{r=1}^s u_r Y_{r j}}{\sum_{i=1}^m v_i x_{i j}} \leq 1, j = 1,2,\dots,j_o,\dots,n \dots\dots\dots(2)$$

$$u_r \leq 0, r = 1,2,\dots, s \dots\dots\dots(3)$$

$$v_i \geq 0, i = 1,2,\dots, m \dots\dots\dots(4)$$