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Diversity of Primary Energy Production in India- A Study for the Period 1970-2022

Khushboo Singh[1], and Sebak Kumar Jana[2]

[1] Research Scholar, Department of Economics, Vidyasagar University, Rangamati, Midnapore, West Bengal, India
[2] Professor, Department of Economics, Vidyasagar University, Rangamati, Midnapore, West Bengal, India

Correspondence should be addressed to Khushboo Singh; khushboosinghkhushi006@gmail.com

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ABSTRACT- The diversity of energy production is vital for India's sustainable development. It enhances energy security, economic stability, environmental sustainability and resilience to climate change. By investing in a variety of energy sources and technologies, India can ensure a reliable, affordable, and sustainable energy supply for its growing population and economy. India is mostly dependent upon coal for its energy production and consumption. When we consider only primary energy sources, India produced 79.6 % of energy from coal and consumed 52.89 % of energy from coal in 2020. In this paper we have studied about the energy diversity of India based on primary energy sources using data for 53 years (from 1970 to 2022). We have used the four types of primary energy sources i.e., coal, lignite, crude oil and natural gas. We have used different indices [Shannon-Weiner Index (SWI), Herfindahl-Hirschman Index (HHI), Weighted_SWI (D_SWI) and Weighted_HHI (D_HHI)] to find the Energy Diversity Index of India. From the result, we have found that energy diversity of India is very low due to high dependency upon coal and also the index is falling which is of concern in regard to energy security of India.

KEYWORDS: Energy Diversity, Energy Security, Shannon-Weiner Index (SWI), Herfindahl-Hirschman Index (HHI).

I. INTRODUCTION

The primary concern of any country is to bring energy security at sustainable level and to meet energy demand, created by different sectors of that country. Due to geographical condition and limited reserves of energy sources, country could not help in reducing the energy dependence upon import and increase its energy security. According to the target of Sustainable Development Goals, many countries have taken steps towards different policy implementation for energy security [1][2]. The trend shows the increase in growth and rapid population increment pushes the consumption of crude oil, coal, natural gas etc. [3]. This increased energy demand did not meet by energy production of India. So, India had to rely on energy import and its energy import dependency increases over time even energy import ratio of India increases throughout the period and energy security for primary energy sources decreases [3]. The best solution for above all problems is improvement in energy diversity, optimum finance distribution for development of energy sector and increase in reliable energy supply etc. [4]. International Energy Agency (IEA) suggested that diversity, equity and inclusion (DEI) is the key solution for energy access, energy security and energy efficiency by 2030 [5]. Energy security of any country can be restored by diversification of energy supply and selection of energy sources for consumption, collectively these are affecting the economy of that country. There has four 'D' instrumentalise for energy transition which are democratisation, decentralisation, digitalisation and decarbonisation [6]. Joshua Atkins has added a fifth 'D'- Diversity. He suggested that there is requirement of energy diversity for effective and advance energy transition [7]. The high generation diversity push for low electricity consumption per person [8]. As India has huge population and also large potential for different renewable energy resources like solar, wind, small hydro, biomass and cogeneration bagasse [9], hence diversification process for energy would be easy for India. We can also focus upon energy import dependence and energy diversity for increasing energy security of any country [10]. Many countries like Japan and South Korea have been diversifying their energy sources to perceive energy security of their country [11]. Shannon- Weiner Index (SWI) and Herfindahl-Hirschman Index (HHI) are two famous and well-known indices for measuring diversity index. It is a biological index for measurement of diversification of species. Chung and Ma have used it as a measurement of diversity in energy supply [12]. The SWI and HHI are fully quantitative in nature because they are express in proportion or share of their own. So, to bring the qualitative scenario in this frame we have used Weighted_SWI and Weighted_HHI. These indices bring energy import dependence with SWI and HHI [12].

In our study, we have studied about energy diversity of India to understand the energy security of it. Here, we have taken four primary energy sources like coal, lignite, crude oil and natural gas. As India has been using abundantly conventional energy sources for production and consumption till now. The dominance of coal in energy mix also creates problems in controlling pollution [13]. For example, electricity production from solar power emits only 54-60 grams of CO_2 for one unit (kWh) electricity whereas power plant based on coal creates 950-1000 grams CO_2/kWh [14]. Among conventional energy sources, coal has used for 52.89 % of energy consumption in 2020 and it has been using for almost greater than 65 % of energy production from very early period (1970-2020) [15]. The collective contribution of renewable energy sources, nuclear energy and other sources in energy production was only about 20 % which is very low [16].

II. OBJECTIVES, METHODOLOGY AND DATA SOURCES

- ***Objectives of the study***

In this paper we have studied about status of energy security of India from 1970 to 2022 through energy diversity index of primary energy sources.

- ***Methodologies***

For energy diversity measurement, we have used SWI and HHI which are traditionally used for measurement of diversity index of different species. As SWI and HHI are quantity-based indicator so result for major import or export country can be biased. So, we have used weighted indices of energy diversity and energy import dependence to get a relevance result. The methodologies have used are categories into two groups: (A) Energy Diversity Indices
(B) Weighted of energy diversity indices and energy import dependence. These are discussed as follows.

A. Energy Diversity Indices

- The Shannon- Weiner Index (SWI): SWI is thoroughly used for measuring the diversity of species. Now a days after exploration of different energy sources, we can apply it for finding disorder and uncertainty in energy sources. In our study we have used to measuring diversity of energy sources. High value of SWI represent high diversity i.e., higher uncertainty of energy sources.

This index is simple calculation of share of each primary energy resources.

$$SWI = -\sum_{i=1}^{N} p_i ln p_i \,, \qquad p_i = \frac{ES_i}{ES_T}$$

Where, $p_i =$ share of ith primary energy sources in total primary energy production (ES_T) or it is ratio of production of ith primary energy sources to total production of primary energy sources.
Minimum value of SWI can be 0 (if only one option of energy resources will present) and SWI value be maximum when $p_i = 1/N$

$$SWI_{max} = -\sum_{i=1}^{N} \frac{1}{N} ln \frac{1}{N} = -N.\frac{1}{N}.ln\frac{1}{N} = lnN$$

- The Herfindahl – Hirschman Index (HHI): It calculates the concentration of each primary energy resources in that country. It has denoted as the sum of square of the percentage contribution of each primary energy resources in total primary energy resources of that country.

$$HHI = \sum_{i=1}^{N} P_i^2 = \sum_{i=1}^{N} (p_i \times 100)^2$$

Where, $P_i =$ % contribution of ith primary energy resources ES_i in total primary energy resources ES_T
As this index is measuring by square of proportion of energy, so it highlights the bigger sources. So, we can say that HHI edify abundance energy sources in that country. This is just opposite to SWI, smaller value of HHI shows high diversity of energy sources.

B. Weighted of Energy Diversity Indices and Energy Import Dependence

SWI and HHI considering the proportion of each energy resources over total primary energy sources so these are taken the quantitative aspects only. If any country highly dependent upon import energy or lower dependent upon import energy then the efficacy of these methodologies becomes lesser. In weighted methodologies two indices have been used for calculating energy diversity of any country, we have multiplied the energy import dependence with energy diversity indices (SWI and HHI). Weighted of Energy Diversity Indices and Weighted of Energy Dependence gave relatively unbiased result. It can be calculated as below:

$$D\_SWI = -\sum_{i=1}^{N} (1 - \frac{EI_i}{ES_i}) p_i ln p_i$$

$$D\_HHI = \sum_{i=1}^{N} (1 + \frac{EI_i}{ES_i}) p_i^2$$

Where,
ES_i = ith primary energy resources
EI_i = import of ith primary energy resources
$p_i = ES_i / EI_i$
i = value of i denotes the type of energy sources index
N = number of types of energy resources

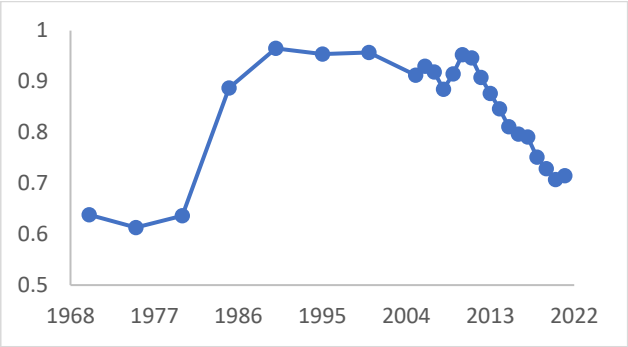
- ***Data Sources***

We have collected data from Energy Statistics- Ministry of Statistics and Programme Implementation (MoSPI) [17]zq. The data belongs to production, consumption, availability and gross import of primary energy sources of India from 1970 to 2022.

III. RESULTS AND DISCUSSION

A. The Shannon- Weiner Index (SWI)

This diversity indices measures the import ratio indices for the energy which is rare in country and the country largely dependent upon import. From early period there was energy production from conventional sources are always high and among them contribution of coal has been always in top. From calculated result we can see between 1970 to 1985 the SWI decreases as the coal's participation was highest in production (almost 80 %) [13]. Almost in 1980_s crude oil and natural gas got major share in production of conventional energy sources and after 1990 New Economic Policy implementation, energy demand increases continuously. From Figure 1, we can see that SWI has been increasing for that period which means diversification of energy increases with time. The highest value of SWI was found in 1990 i.e., 0.97. There was some fluctuation in 2008 due to fluctuation in world economy. So, SWI curves has been increasing for some period but after 2013 again contribution of coal in production of conventional energy has been continuously increasing as a result SWI decreases afterward till 2022. The minimum value of SWI has been found 0.61 in 1977, which indicate lower diversity i.e., only one energy source (coal) took major participation in production.

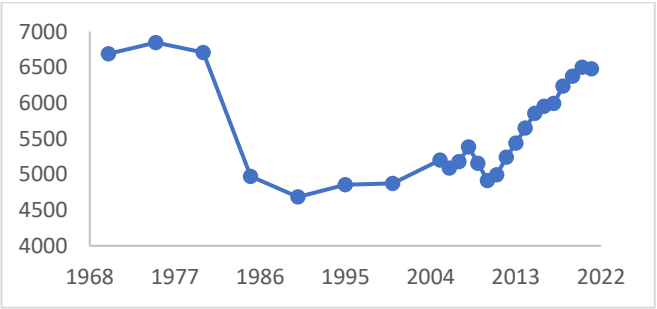


Source: Estimation from MoSPI (data from 1970 to 2022)

Figure 1: The Shannon- Weiner Index (SWI) for India from 1970 to 2022

B. The Herfindahl – Hirschman Index (HHI)

HHI curve is just image of SWI. As we know the higher value of SWI represent the higher diversity and lower value of HHI represent higher diversity. So, from Figure 2, HHI curve from 1970 to 1980 represents lower energy diversity because energy production has mostly depended upon coal. The highest value of HHI was found in 1975 i.e., 6846.32. As the share of crude oil and natural gas increases in energy production, the HHI started to decrease for the period 1980 to 2005. Lowest value of HHI has found in 1990 i.e., 4683.83. Again, when coal's share started to increase in energy production, HHI has been started increasing after 2010 till 2022. So, we can say energy diversity decreases for that period. SWI shows the rare sources of country and HHI shows the abundant energy sources. In India no primary energy sources are in abundance so, SWI and HHI interpretation are equally likely. For more accuracy we have to see the result of Weighted_SWI (D_SWI) and Weighted_HHI (D_HHI).

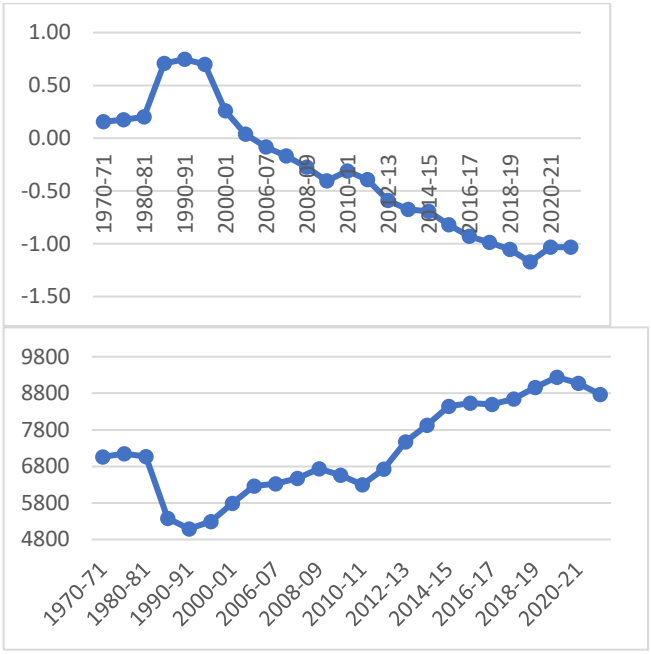


Source: Estimation from MoSPI (data from 1970 to 2022)

Figure 2: The Herfindahl – Hirschman Index (HHI) for India from 1970 to 2022

C. *Weighted of Energy Diversity Indices and Energy Import Dependence*

To get accurate scenario we have used import dependence index and energy diversity index simultaneously which will give us weighted value. When we will use energy import dependence with SWI and HHI, it will give D_SWI and D_HHI respectively. In Figure 3, D_SWI is maximum in 1980_s when import dependence is at lowest level. After 1990, D_SWI is continuously decreasing till 2020 which means country strongly dependent upon energy import.



Source: Estimation from MoSPI (data from 1970 to 2022)

Figure 3: D_SWI and D_HHI for India from 1970 to 2022

After 1995 the energy import dependence has always greater than 35% in all primary energy sources [15]. D_HHI trend value follows the trend of HHI. From Figure 3 we can see after 1990 D_HHI continuously increases. D_HHI value shows the collectively result of energy import dependence and diversity indices, which clearly states that India is largely import dependent country and so, energy security of India is under question.

IV. CONCLUSION

In our study we have found that country India is mostly dependent upon primary energy sources for its energy demand. When we considered the primary energy sources, its energy diversification has found to be very low according to Shannon -Weiner Index and Herfindahl-Hirschman Index, which indicates that energy security of India is under threat for future. As SWI and HHI are completely quantitative because they have based on ratio and numbers of energy share. We have used Weighted-SWI and Weighted-HHI to find the actual scenario of energy security. From the calculation we have found that India is strongly energy import dependent country. So, energy security of India has been also declining according to Weighted_SWI and Weighted_HHI.

India is largely dependent upon primary energy sources specially coal and crude oil. Between coal and crude oil, contribution of coal solely captures the most part of energy production. As India is dependent upon unidirectional energy sources for their energy demand [18]. So, diversification is very low due to less contribution of different energy sources. We have to make sure that we will use diversified energy resources in future i.e., renewable energy sources- solar, wind, biomass, tidal, waste to energy, small hydro power etc. For this government should encourage and promote uses of renewable energy resources. Government should implement effective policy for renewable energy promotion and should encourage public-private-partnership for improvement in investment in renewable energy.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest between them and with any third party

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