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# Allocating a Cumulative Carbon Budget to India – Results from Different Budgeting Periods and Sharing Principles

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***Authors' contributions***

*Author SS the first author is responsible for the design and structure of the study. Data collection, interpretation, analysis and manuscript writing is the work of the first author. Author IS the second author provided the intellectual inputs investigated the design of the study and supervised the preparation of manuscript.*

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## ABSTRACT

**Introduction:** Paris Agreement, aiming to limit global warming to 2°C, has stipulated a global discussion regarding allocating a fair share of world's cumulative carbon emissions to countries. Thereafter, different theories proposing various sharing principles are being proposed. The present study estimates the future cumulative carbon budget allocation to India using these sharing principles.
**Aims:** The aim is to explore India's share in the world's carbon budget for different budgeting periods using different sharing principles, and find out which sharing principle is in the *best interest* of the country.
**Methodology:** Using the four different sharing principles (equity, inertia, blended and inclusion) proposed in previous studies, India's share in carbon budget has been calculated. Calculations are done for three budgeting periods (1970-2012; 1990-2012; 2005-2012) in order to find a concrete result. Observations are made to find the different conditions in which various budgets may allocate a high carbon budget to India.

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**Results:** Inclusion sharing principle has been found to allocate the highest carbon budget to India in all the three budgeting periods. It has been found that the higher the number of historical emissions years taken into calculations, the higher is the budget allocation to India. Historical accountability factor is deduced to be the reason. A new sharing disparity trend has also been observed in which the inclusion principle is allocating a higher budget to India in stricter warming limits while a lower budget is allocated in case of less strict warming limits.
We have also found that the principles of inertia, equity and blended sharing allocate high budget to India when lesser number of years and more recent years are taken into calculations.
**Conclusion:** We argue that for a developing country like India, historical accountability is an important factor for budget sharing decisions and inclusion sharing principle has been claimed to be in the *best interest* of the country.

*Keywords: Warming limit; inertia sharing; equity sharing; blended sharing; inclusion sharing; historical accountability.*

## 1. INTRODUCTION

Kyoto protocol was the first legally binding effort that the countries took in unison to meet the stipulated climate targets. While the final commitment period of the protocol is to end in 2020, the world is still far from meeting the targets [1,2,3,4,5,6,7]. At this end, the Paris Agreement [8] is being seen as the new roadmap to achieve these targets [9,10,11,12,13,14]. This agreement aims to limit global warming to 2°C and pursue efforts to limit it further to 1.5°C. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) [15] has observed a close relationship between global temperature and carbon emissions which is being called 'the transient climate response to cumulative carbon emissions (TCRE)'[16]. In addition to that, several studies have observed a near linear relationship between the two [17,18,19,20]. This states that global temperature increases with increase in the global emissions; which emphasizes the requirement of putting an absolute cap on the world's cumulative emissions. Acknowledging this fact, IPCC has been invited by the United Nations Framework Convention on Climate Change (UNFCCC) to translate this 'safe limit' into carbon budget count [21].

Meanwhile, several principles and ideas for the sharing of global emission among countries have been proposed in last two and there has been an extensive discussion about the 'inertia' and 'equity' based sharing principles. Inertia sharing (formerly known as grandfathering is based on the theory that the countries should be allocated future emissions based on their historical emissions trajectories [22,23,24]. Equity sharing is based on the theory that each person on Earth has an equal right over emissions and hence, future emissions should be allocated based on the population share of the countries [25]. Since these two principles are seen as the two ends of justice spectrum [26,27,28], many more alterations, modifications of them have been proposed, but¸ by the time the 24$^{th}$ meeting of Conference of Parties was held in December 2018, none of the sharing principles have been accepted globally. Efforts including research for the determination of a justifiable sharing principle that serves the interests of all countries most fairly are still.

This study aims to determine the sharing principle which is fair for all countries, and serves the interests of India (which is currently in the list of top emitters of the world [29,30,31]) most effectively. It estimates the allocation of future cumulative carbon budget to India using the different sharing principles. Other than the inertia and equity sharing principles, the 'blended sharing' proposed by Raupach [32], which introduces a *sharing index (w)* to maintain a balance between equity and inertia extremes, and the 'inclusive sharing' proposed by Neumayer [33]¸ which introduces a factor of 'historical accountability' in the equity sharing were also used in the estimation. The importance of the roles of four fundamentals: (i) period of total budgeting defined by the start year and end year; (ii) the year when the emission distribution is to start; (iii) probability of the estimations; (iv) demographic reference year in the calculating of the national emission budget raised by Messner [34] was also considered in this study. Accordingly, in this study, calculations are done for three different budgeting periods – 43 year period (1970-2012), 23 year budgeting period (1991-2012) and 8 year budgeting period (2005-2012), 2020 is the start year and two warming limits; 2°C and 3°C with 66% and 50%

probabilities are considered. Again, Alcaraz [35] specifies that global temperature changes are dependent on all the years in which emissions have occurred until now. Accordingly, the demographic reference year is superseded by the budgeting period, and instead of using one year as the reference year, 'reference periods of years' have been used in calculations and are termed 'the periods of total budgeting' in this study.

There is an elaborate literature on *when* should we start considering the countries accountable for their historical emissions. Some studies argue that the period of start of UNFCCC should be identified as the start year for historical accountabilities which is the beginning of 1970s [36,37,38,39]. Others argue that the year when official text of UNFCCC was published should be identified as the start of the year for historical accountability which is the beginning of 1990s [40]. And, in 2005, the process to discuss future emission reduction commitments from the Annex-I countries started under Kyoto protocol- the first binding agreement. Hence, all these 3 years; 1970, 1990 and 2005 are used as the start years of the budgeting periods assessed for clearer picture in this study. 2012 has been chosen as the end year of budgeting period because the data for emissions calculation is available only up to the year 2012 (details are given below). 2020 is chosen as the start year because the second and final commitment period of Kyoto Protocol is to officially end in 2020 and a new Climate Protocol with a new commitment period is to commence in this year.

## 2. METHODS

### 2.1 Data

Historical emissions of India are calculated using the European Database for Global Atmospheric Research (EDGAR) v 4.3.2, available in the form of global grid-maps per sector per country at a resolution of 0.1 x 0.1 degrees [41]. The corresponding world's historical emission data (fossil fuel and industrial) is compiled from the Carbon Dioxide Analysis and Information Centre (CDIAC) [42], UNFCCC [43] and Global Carbon Project [44]. It includes emissions from fossil fuel combustion, oxidation and cement production and bunker fuels. For the prediction of future emissions of the world, there is an elaborate literature available. Representative Concentration Pathway (RCP) 2.6 scenario [16] provides prediction for future emissions and is widely used in similar studies. However, it includes the factor of negative emissions for future consideration [45,46], in which the credibility of climate response to cumulative emissions is yet to be explored [47,48]. Although, efforts are being taken in this direction, for this study, future cumulative emission data is taken from [49] where, future emissions are calculated using projected growth rate of Gross Domestic Product (GDP) combined with the carbon intensity of world economy which is assumed to be persistent in trend. The time duration of exhausting the cumulative emissions is open ended; depending on the previous emission trends, 'equitable emission years' have been calculated. The data on committed future emissions is obtaine from other studies [50,51]. The data on global population is obtained from The World Bank [52]. India's population data is taken from Census of India [53]. Since demographic data of India is collected on a 10-year basis, exact population data was only available for the years 1961, 1971, 1981, 1991, 2001, and 2011. The population data of the non-census years was extrapolated using available data. We understand that most of the studies related to the distribution of carbon budget take the emission and population data from The World Bank or UN Population database. But those studies are mostly done for all the countries of the world which are party to UNFCCC and hence there is a strong requirement of maintaining similarity in the survey methods, calculation methodology, assumptions, and data formats etc. But in the present study, since we are dealing with only one country, it is more practical to use the national level database which is definitely more accurate than the global database for one nation.

### 2.2 Budget Calculations

The following equations are employed for allocation of future carbon budget for three different budgeting periods:

***Equation 1***

$$E^t_c = (E^b_c / E^b_w) \cdot E^t_w \qquad \text{(inertia sharing)}$$

***Equation 2***

$$E^t_c = (P^b_c / P^b_w) \cdot E^t_w \qquad \text{(equity sharing)}$$

where,

$E^t_c$ ( $E^b_c$) = Emission of country C in target year t (base year b)

$E^t_w$ ($E^b_w$) = Emission of the world in target year t (base year b)
$P^b_c$ = Population of the country C in base year b
$P^b_w$ = Population of the world in base year b

Studies have proved that the effect of emissions on climate is not conditioned on the location and time of emission occurrences [54], hence, the base unit in each budgeting period is the mean of the factor in question. For example, in the case of 43 years of budgeting period (1970-2012), the mean of 43 years (1970-2012) has been assumed to be the base unit for each value. Hence, the population of base year ($P^b_c$) is the mean of population of India (or world) for 43 years and the emission of base year ($E^b_c$) of is the mean of emission of India (or world) for 43 years. Same follows for the other two budgeting periods; 1990-2012 and 2005-2012. 2020 is the start year for emission budget calculations.

**Equation 3**

$$E^t_c = [(1-w).\ (E^b_c/\ E^b_w) + w.(P^b_c/\ P^b_w)]\ E^t_w \quad \text{(blended sharing)}$$

As mentioned above, the concept of sharing index (w) has been proposed in the blended sharing principle which can vary between 0 and 1. The sharing index w = 0 will signify the case of inertia sharing while w = 1 will signify the case of equity sharing. Hence, the blended principle can potentially be placed somewhere between the two extremes of carbon sharing justice. For this study, and also as demonstrated by Raupach [32], the calculations are done using w = 0.5.

Calculations based on the principle of inclusion are more elaborate [33]. This principle takes into account the historical emission debt (or credit) of the country and compensation that the country deserves (or owes) to other countries. Following are the equations:

***Equation 4***

$$HED_c = \Sigma\ [E_c - (P^b_c/\ P^b_w)\ .\ E_w]$$

***Equation 5***

$$C^n_c = (1/N)\ .\ HED^n_c$$

***Equation 6***

$$E^t_c = [(P^b_c/\ P^b_w)\ .\ E^t_w] - C^n_c \quad \text{(inclusion sharing)}$$

where,

$HED_c$ = Historical emission debt (or credit) of the country C
$C^n_c$ = Compensation that the country C agreed in N years (where n = 1,…..N)

Here, the calculations are being done for future cumulative emissions, hence we assume that the country is to be compensated for all the years in each case. This numerically means that for this study, we assume that 100% of HED is to be compensated to the country. Therefore, we dissolve the factor N from our equation in order to make compensation factor ($C^n_c$) = Historical emission debt ($HED^n_c$).

Using the above equations, cumulative remaining carbon budget of India is calculated to meet the global warming limit of 2°C and 3°C with 66 % and 50% probability.

## 3. RESULTS AND OBSERVATIONS

Table 1 shows the future carbon budget allowed to the world in order to stay under the 'safe limit' [49] and Table 2 shows the share of cumulative carbon budget to India calculated by us using 4 different sharing principles for four different periods of total budgeting. The results bring forth some interesting observations. Fig. 1 is a graphical illustration of the carbon budget to the world (a) and India (b to c). We found that inclusion sharing allocates highest emission budget to India', followed by equity sharing and blended sharing, while inertia sharing allocates lowest budget to the country, which was very much expected owing to the low historical emissions of India. This outcome stands true for all the cases irrespective of the different periods of budget estimation. We also found that, the percentage share is changing drastically; showing a dramatic decline in share when the budgeting years are less. Also, the more recent is the budgeting period, the lower is the share allocated to India. The pattern can be easily observed in Fig. 1 (b to d) where the declining shares are inevitable. The details are elaborated in the following sections.

### 3.1. India's Carbon Budget

#### 3.1.1 Observations from different periods of budgeting

In the 1970-2012 period of budgeting, the total number of historical years included are 43. This is the longest period of consideration in all the 3 cases taken in this study. It contains highest number of years in which Indian historical emissions have been very low compared to the world average. We found that inclusion sharing allocates highest share, followed by equity, blended and inertia sharing. Fig. 2 shows the historical emission debt of the country from 1970 to 2012. The negative emission debt (which means credit) which the country deserves is highest in 1970s, after which there is a gradual decrement in the credit. In this period of budgeting, inertia sharing allocates 9.58% share of the world emissions to India, blended sharing allocates 12.81 while equity sharing allocates 16.03% share through both 2°C and 3°C scenario for 66% and 50% probabilities' which is the lowest compared to the other budgeting periods in this study. However, the inclusion sharing allocates 18.10% to 22.46% share in the world emissions to India, which is the highest share compared to the other sharing principles and also higher than the share in other budgeting periods. Hence, allocation through inclusion sharing in 43 year period is the highest in all the cases observed in this study.

The 23 year budgeting period (1990-2012) allocates higher emission budget to India compared to the 43 year budgeting period for inertia, equity and blended sharing principles, while for the inclusion sharing, the emissions budget has decreased in this period. The increased population, increased past emissions and less number of years for historical accountability is the obvious reason. Specifically, the increased emissions increased the allocation through inertia share. Increased population is responsible for increased allocation through equity sharing. Blended sharing which lies in the middle of inertia and equity also has an increased share because of high population and emission. While in case of inclusion, the credible years of historical accountability have decreased and hence, the allocation has decreased too. Inertia sharing allocates 12.08% of world emission share to India which is significantly higher (2.5%) than the 43 year budgeting period. Equity sharing allocates 16.60% emission share which is 1.04% higher than the 43 year budgeting period. Blended sharing allocates 14.34% which is also higher than 43 year budgeting period by 1.53% while, inclusion sharing allocates 17.51% to 19.42% emission share which is lower than the share allocated through inclusion sharing in the 43 year of budgeting period. This can also be observed from Fig. 3 which shows the yearly emissions allotted to India using different sharing principles for 3 budgeting periods. The yearly emission budget in case of inertia, equity and blended sharing is higher than 43 year budgeting period while that of inclusion sharing is lower.

The 2005-2012 period which has 8 budgeting years follows the same path. The highest allocation is through inclusion sharing followed by equity, blended and then inertia sharing principles. Also, inertia, equity and blended sharing principles allocate higher results to India as compared to the previously discussed 43 years and 23 years case of budgeting years while inclusive sharing allocates lower results. Fig. 3 gives a clearer picture of this comparison where the yearly emissions for each budgeting period can be compared with each other for all the sharing principles. It can be seen that the 8 year budgeting period does follow the previous trend and again, although the inclusion sharing is allocating lowest share to India compared to the other budgeting periods, its share is still higher than allocation through inertia, equity and blended sharing. Inertia sharing allocates 14.02% of world emissions to India which is 1.94% higher than 23 year of budgeting period and 4.44% higher than 43 years of budgeting period. Similarly, equity sharing allocates 17.11% share to India which is 0.52% higher than 23 years period and 1.08% higher than 43 years period. Blended sharing allocates 15.57% which is 1.23% higher than 23 years period and 2.76% higher than the 42 year period. On the contrary, inclusion principle allocates 17.37% to 17.91% share to India which is significantly low compared to the allocation through 23 year period and 43 year period of budgeting.

**Table 1. World's future cumulative carbon budget starting from 2020 for 2°C and 3°C warming limits**

| **Warming limit** | **2°C** | | **3°C** | |
|---|---|---|---|---|
| Probability | 66 % | 50 % | 66 % | 50 % |
| | **Future cumulative carbon budget of the world** | | | |
| | 1,000,000,000 | 1,300,000,000 | 2,700,000,000 | 3,100,000,000 |
| emission years | 22 (15-30) | 28 (19-38) | 58 (49-75) | 67 (60-86) |

*Source: [49]*

**Table 2. India's future cumulative carbon budget starting from 2020 for 2°C and 3°C warming limits**

| **Warming limit** | **2°C** | | **3°C** | |
|---|---|---|---|---|
| Probability | **66 %** | **50 %** | **66 %** | **50 %** |
| | **Future cumulative carbon budget of the world** | | | |
| | 1,000,000,000 | 1,300,000,000 | 2,700,000,000 | 3,100,000,000 |
| Emission years | 22 (15-30) | 28 (19-38) | 58 (49-75) | 67 (60-86) |
| | **43 years budgeting period (1970-2012)** | | | |
| **Inertia sharing** | 95,793,331.782 | 124,531,331.317 | 258,641,995.812 | 296,959,328.525 |
| **Equity sharing** | 160,308,798.879 | 208,401,438.543 | 432,833,756.973 | 496,957,276.525 |
| **Blended sharing** | 128,051,065.331 | 166,466,384.930 | 345,737,876.392 | 396,958,302.525 |
| **Inclusion sharing** | 224,584,819.623 | 272,677,459.287 | 497,109,777.717 | 561,233,297.269 |
| | **23 years budgeting period (1990-2012)** | | | |
| **Inertia sharing** | 120,775,134.894 | 157,007,675.362 | 326,092,864.214 | 374,402,918.172 |
| **Equity sharing** | 165,961,374.093 | 215,749,786.321 | 448,095,710.051 | 514,480,259.688 |
| **Blended sharing** | 143,368,254.494 | 186,378,730.842 | 387,094,287.133 | 444,441,588.930 |
| **Inclusion sharing** | 194,177,351.702 | 243,965,763.930 | 476,311,687.660 | 542,696,237.297 |
| | **8 years budgeting period (2005-2012)** | | | |
| **Inertia sharing** | 140,186,541.512 | 182,242,503.966 | 378,503,662.083 | 434,578,278.687 |
| **Equity sharing** | 171,125,156.087 | 222,462,702.914 | 462,037,921.436 | 530,487,983.871 |
| **Blended sharing** | 155,655,848.800 | 202,352,603.440 | 420,270,791.759 | 482,533,131.279 |
| **Inclusion sharing** | 179,137,654.048 | 230,475,200.874 | 470,050,419.396 | 538,500,481.831 |

#### 3.1.2 Observations from different sharing principles

The results confirm that inertia sharing is allocating the lowest share to India in each case while, inclusion sharing is allocating highest share to India. Blended sharing allocates higher share than inertia but lower then equity sharing principle. If only the principle of inertia is followed, the allocation is 9.58%, 12.08% and 14.02% in 43, 23 and 8 year period of total budgeting respectively. It allocates highest in the shortest period of budgeting which is 2005-2012. This is because the 8 year period of budgeting comprises of highest emissions years; which implies that the historical accountability is low. This is the reason for lowest allocation through inclusion sharing in the 8 year period. Inclusion sharing is allocating 22.46% to 18.10%, 19.42% to 17.51% and 17.91 to 17.37% in the 43, 23 and 8 year period of total budgeting respectively. Also, the population count is highest in this period in India which has made allocation through equity sharing highest in this period compared to the other budgeting periods. It allocates 16.03%, 16.60% and 17.11% share to India in 43, 23 and 8 year period of total budgeting respectively. The same reasons (high population and emissions) have also made the allocation through blended sharing the highest in this period (and lowest in 43 year period). Blended sharing allocates 12.81%, 14.34% and 15.57% for 43, 23 and 8 year period of total budgeting respectively. An interesting observation has come out from these results. Firstly, unlike the other sharing principles, the emissions allotted by inclusion sharing vary for different warming limits and different probabilities. Secondly, the emission share allotted to India through inclusion sharing principle in stricter target scenarios (2°C and 66% probability) is surprisingly higher than its share in less strict emission scenarios. This is an unexpected outcome because the world's total emission budget for 2°C target and 66% probability is 32.22 % less that the world share in 3°C target with 50% probability, hence a higher share in less strict targets could be expected. In contrast to that, emission share allotted to India through inclusion sharing in 2°C target and 66% probability scenario is 4.35% higher than the 3°C target and 50% probability scenario for the 43 year budgeting period, 1.91% higher for the 23 year budgeting period and 0.54% high in the 8 year budgeting period. We are calling it '*sharing disparity trend*'. This trend is also observable in Fig. 3, which shows that inclusion sharing in the 43 year period in 2°C target allocates 10,208,400.89 and 9738480.69 Gg $CO_2$ per year to India for 66% and 50% probability respectively, while for 3°C target; 66% and 50% probability, an yearly budget of 8,570,858.24 and 8,376,616.38 Gg $CO_2$ is allotted. The same trend is followed in the 23 year and 8 year budgeting period to, however, the difference has sharply decreased.

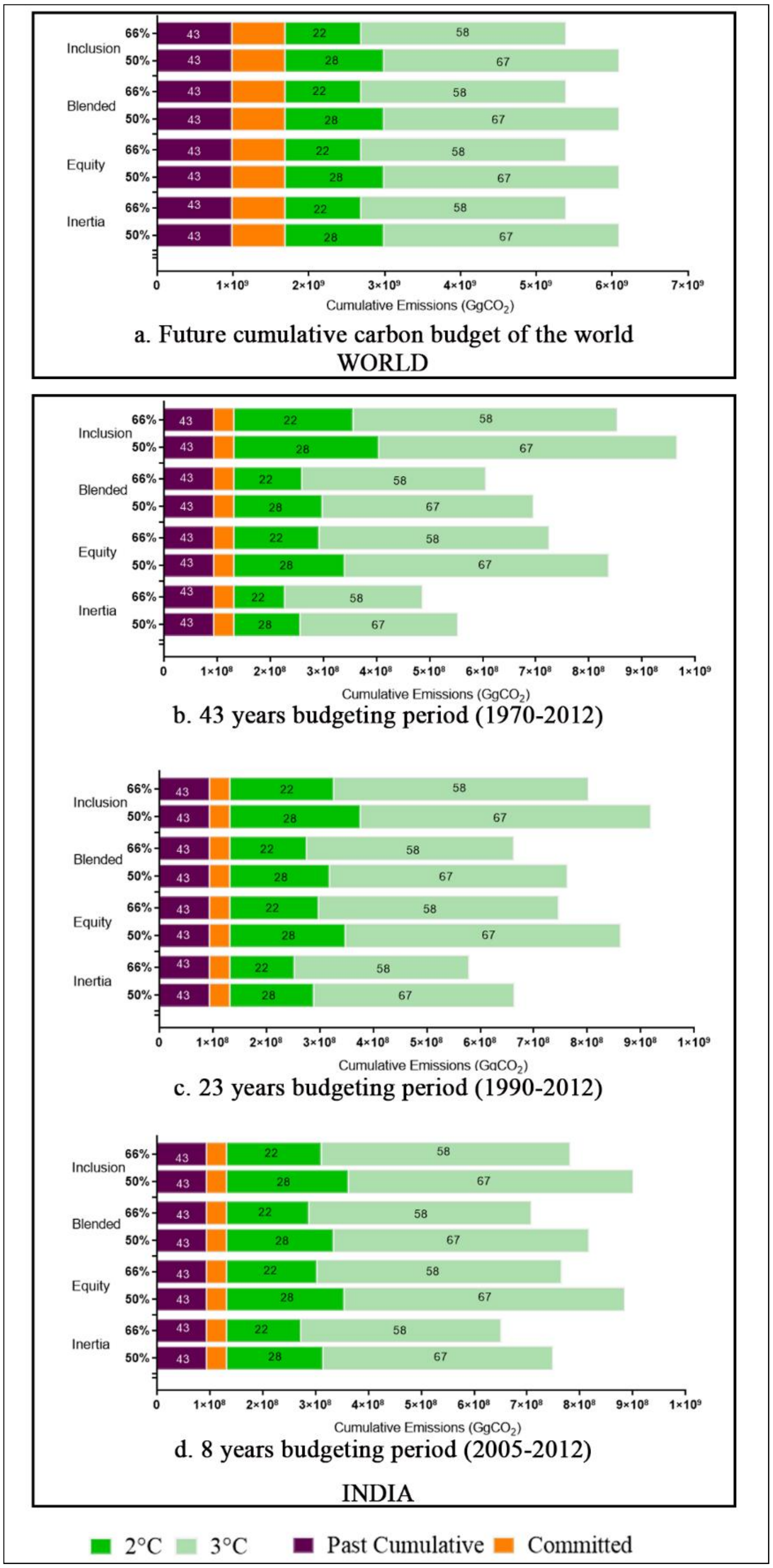


**Fig. 1. Future cumulative carbon budget for 2°C and 3°C**

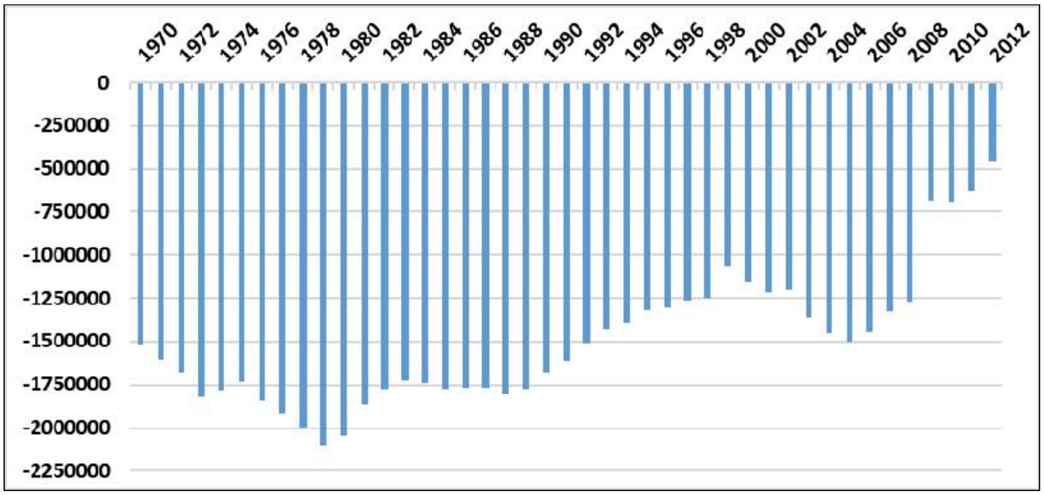

**Fig. 2. India's negative historical debt (credit) from 1970 to 2012**

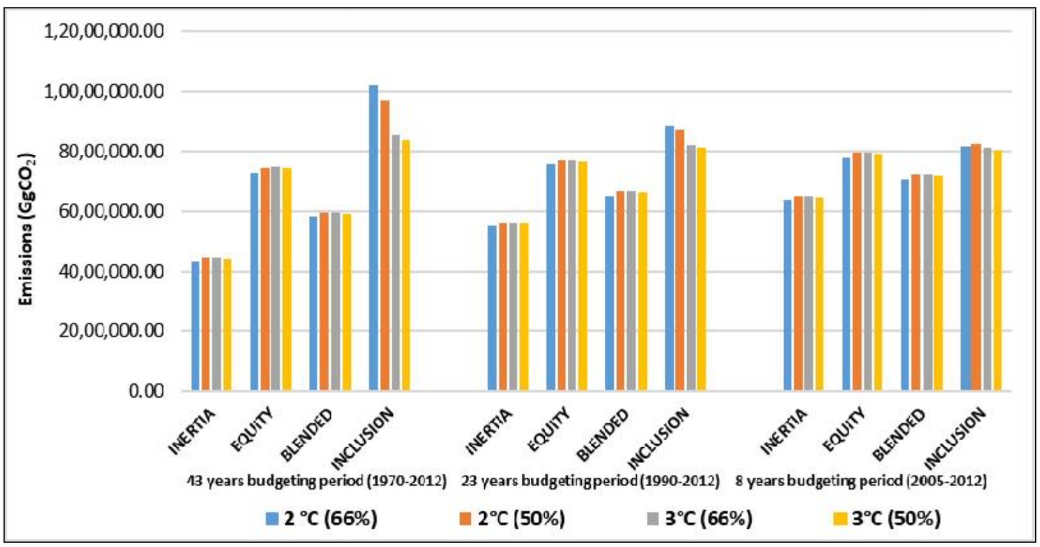


**Fig. 3. Yearly emissions corresponding to future cumulative emission budget**

Finally, from the above results we can say that inertia sharing principle is in India's good interest only if less number of years and more recent years are considered for the budgeting period. This is because the recent emissions of India have been high. Same holds true for the equity sharing principle, it stands in India's good interest if less number of years and more recent years are accounted as budgeting period because of the high population count. The blended principle being a balance between the two is all good for India in the same conditions as above. But, the inclusion sharing principle is in the *best interest* of India if more years are accounted for, also the more number of former years are included; the better will be the results using the inclusion sharing. Historical accounting factor is the obvious reason for the same.

## 4. DISCUSSION AND CONCLUSION

In this paper authors have explored India's share in the world's carbon budget for different budgeting periods using different sharing principles, and find out which sharing principle is in the best interest of the country. Using the four different sharing principles (equity, inertia, blended and inclusion) proposed in previous studies, India's share in carbon budget has been calculated. Calculations are done for three budgeting periods (1970-2012; 1990-2012; 2005-2012) in order to find a concrete result. Observations are made to find the different conditions in which various budgets may allocate a high carbon budget to India. It has been found that the higher number of historical emissions years are taken into calculations, higher is the budget allocation to India. Thus, for a developing country like India, historical accountability is an important factor for budget sharing decisions and inclusion sharing principle has been claimed to be in the best interest of the country.

A general assumption is that the populated countries of the world will be most benefitted in terms of carbon budgets if equity sharing principle is adopted. Currently, India has the second highest population count in the world. But the assumption does not stands correct for it. Our results show that India is most benefitted if inclusion sharing principle is followed. Hence, we strongly advocate the inclusion of factor of historical accountability in the carbon budget sharing decisions. From our results, it is clear that for the developing economies whose populations are also as big as India's, it is most advantageous to prefer the sharing principle which accounts for historical responsibility. The emissions of India are increasing and historical accountability is simultaneously decreasing (Fig. 2). If the trend follows, within a decade, a total turn of results can be expected which might result in a low share of world emissions to the country if former years of emissions are not accounted for in the distribution decisions. With the high population share and a fragile economic state of the country, it is imperative to secure the country's emission share. The newly found '*sharing disparity trend'* also supports the statement that it is preferential for India to ensure its emission rights supporting the inclusion of historical accountability under strict climate targets. This theory is also supported by other studies [35,38] where the stress is laid on the importance of historical accountability for justified emission sharing and a study has also found that India is the country which will be most benefitted if historical accountability is accounted for in the emission reduction burden sharing [35]. Table 2 shows that inertia, equity and blended principles show an increasing trend with the advancing of total budgeting years. But, inertia and equity sharing principles, being on the opposite ends of the justice spectrum, have been more criticized than accepted by academicians and political theorists [55,56,57]. And blended principle, drawing a balance between the two but still not addressing the factor of historical responsibility cannot be accepted in the present form for the same reasons. These principles stand good for India only when the most recent years are being accounted in the emission sharing calculations.

Furthermore, researchers have also proposed other principles for justified emission sharing that present a blend of these two and (or) are inclusive of other factors [27,28,58]. Of the many principles, Contraction and Convergence' (C&C) proposed by Meyer [59] is most talked about. According to this principle, India (with all the other countries), has to bring its per capita emissions at an equal level to all the other parties (countries/regions) until a convergence year after which, each party's share of world emissions will be proportional to its population, i.e. each party is allocated the same per capita emission count. In the Indian context, the principle is beneficial as India is the second most populated country and hence its emissions share will be high. But, we argue that since this principle does not hold the parties accountable for their past emissions (which we have proved is beneficial for developing countries like India), and allots same per capita emissions to all the parties in future irrespective of their current development statuses, the principle is not fully justified for the developing and least developed countries. Efforts are being taken to dissolve the gaps in the C&C methodology too. There are studies that have explored the concept of historical accountability in C&C [38] and others that have proposed the idea of common but differentiated convergence where countries with different economical statuses are to take actions for controlling their emissions at distinct times in the process [60]. These concepts are of course directed towards the right targets, but concrete frameworks are yet to be developed. Alcaraz used equity based emission sharing with historical accountability for estimating emissions for all the countries [35]. Calculations are done based on per capita emissions and historical accountability is determined using per capita emissions of the country and the world. Calculations are done for emissions allowed from 2013 to 2100. 1992 has been chosen as the start year and hence the budgeting period is 21 years. We argue that the use of per capita emissions for future cumulative emissions budget may not be the best solution. For instance, the current emissions of China are much higher than USA. But if emission accountability is calculated using per capita emissions for the current year, China will rank far low compared to USA. Similar will be the case with other highly populated countries which are also the top emitters of the world like India and Indonesia. Hence, to account for a 'fair' distribution, we strongly support the use of cumulative emissions in the carbon budget calculations along with historical accountability factor for emission sharing calculations.

Through the goal of 'common but differentiated responsibilities', article 3 of the UNFCCC brings forth the significance of fair responsibilities [61]. In this purview, the current study argues that for India, inclusive sharing is the best principle and including the factor of historical accountability is the fairest methodology. The time-scale considered in the analysis is definitely an important factor that has the potential to alter the results in huge magnitudes, but as the study proves, the factor of historical accountability holds high importance for the developing countries of the world.

The study justifies the emission rights of India which can be directly translated into shaping the future of the country. Other than contributing to the research literature, the study can be significant for climate scientists and researchers in determining how rational the different sharing principles are and how the changing time-scales can bring huge differences in the results. Understanding this fact is crucial for the budget sharing decision-making process and determining how these decisions may affect the development of a region.

## CONSENT

The authors give their full consent for the publication of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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