Economic Implications of Extreme Event Impacts in Odisha, India

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Abstract:

As per existing studies, frequency and intensity of extreme events are increasing and likely to be increased in the forthcoming decades. A large number of studies are therefore given more attention to explore the cause behind currently rising destructive potential of extreme events. These studies have mostly focused on developed nations (e.g. the USA), and derived three conclusions: (i) scientific and one normalization studies have claimed climate change is the major cause for rising impact, (ii) after normalizing the societal factors, some studies have found no significant increasing trend and (iii) other normalization studies found both the climate change and the societal factors are responsible for rising impact. Since mixed conclusions are persisting, it requires to validate such findings with taking case study from developing nations where climate change impact is high due to high frequency and low adaptive capacity. Thus, this study has taken a case study as Odisha state which is highly prone to a wide range of extreme events, and normalized economic impact during 1972-2008 with asking research question as whether the societal factors are important to drive total damage cost. In doing so, it has followed four normalization methodologies available in the literature: (i) income, wealth per capita and population, (ii) income, wealth per capita and household, (iii) proportional to nominal GDP and (iv) actual potential loss ratio. After normalization, it arrived at two conclusions. First, the total normalized damage cost trend is showing positive growth, which infers that climate change has an influence on rising impact. Second, it finds lower significant growth rate in the case of normalization and also shows an evidence of bigger damages during the 1980s and 1990s than the current decade. It henceforth infers that the incurrence of higher damages in the current decade are partly due to the societal factors, and the damage cost will manifold in the decade to come if such factors are not considered in the ongoing disaster mitigation policy.

Key words: extreme events, normalization, climate change, societal factors, Odisha.
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1. Introduction:

The Fourth Assessment Report (AR4) of the Inter-governmental Panel on Climate Change (IPCC) has reported that frequency and intensity of extreme events (e.g. floods, storms and droughts etc) is likely to increase in the decades to come (Solomon *et al.*, 2007). The climatic impact cost assessment studies, however, have either omitted the impact cost in their analysis or included it in a crude manner (Bouwer, 2011; see Nordhaus, 1993; Fankhauser, 1994; Stern, 2006; and Tol, 2008). In particular, the recent assessment on 'past disaster losses' (e.g. Munich Re, 2010) has highlighted that direct economic loss due to weather related hazards has increased (Bouwer, 2011). For instance, the global economic loss (inflation adjusted) has increased from an annual average of US$ 8.9 billion (1977-86) to US$ 45.1 billion (1997-2006) - with the decadal growth rate being approximately 125 percent (Bouwer *et al.*, 2007: 753). Such positive growth of damage cost has attracted more scholars to investigate which is the cause of increasing economic impact in recent decades, namely, climate change[2] or societal factor or both[3].

The magnitude of the extreme events depends on a) frequency and intensity of weather parameters such as, wind speed, storm height and precipitation, b) location specific growth of economy and population and c) government as well as individual level disaster mitigation policies (Pielke and Downton, 2000; Nordhaus, 2010; and Neumayer and Barthel, 2011). In the USA context, Pielke and Landsea (2002), Emanuel (2005) and Elsner *et al.* (2008) reported increasing trend of destructive tropical cyclones. Similarly, Mohanty *et al.* (2008) stated that cyclonic storms that have occurred during the late 20th century[4] in Odisha, India were severe in intensity and caused unprecedented loss of life and property due to both wind speed and associated storm surges[5]. These studies concluded that climate change is the major cause for presently rising destructive potential. However, Pielke and Landsea (1998) results showed no upward trend in the damage cost of USA hurricane when the data is normalized to remove the

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[2] In this context, there is still difficult to distinguish between climate variability and human-induced climate change.

[3] As per IPCC (2001), the upward trend in disaster losses over the past 50 years is linked to both climate and societal factors (*c.f.* Neumayer and Barthel, 2011: 13).

[4] Srivastava *et al.* (2000) have found no significant trend of increasing cyclone frequency in the Bay of Bengal during the 20th century (p. 114).

[5] For example, 90 percent damage was due to inundation caused by the combined effects of tides and surges, and the 10 percent of damage was from the very strong winds associated with cyclones (Mohanty *et al.*, 2008: 16).

effects of societal change. This study argued that increasing income, wealth and population in the susceptible region would result in more people and wealth being exposed to such events. After normalizing the economic impact to correct for income growth, Nordhaus (2010), in contrast, found unprecedented damage associated with the wind speed in the case of USA hurricane. Bouwer and Botzen (2011) critically analyzed the same data which was used by Nordhaus and found no significant trend of increasing the damage cost. This study criticized Nordhaus's assessment for not having taken into account the other societal factors like population and stock of wealth for normalization. Pielke and Downton (2000), on the other hand, have indicated that both climate and societal factors are responsible for growth of total damage of the USA flood in the recent decade. Since the results are mixed, we need to validate these results by empirically analyzing economic impact in developing nations where the climate change impact is high due to high frequency and low adaptive capacity (see Stern, 2006; Mendelsohn *et al.*, 2006; Parry *et al.*, 2007).

In the context of India, Raghavan and Rajesh (2003) have analyzed the economic impact of cyclonic storm in Andhra Pradesh state and found no significant trend. In order to validate the conclusions existed in the literature, this study has made an attempt to normalize Odisha's economic impact associated with extreme events as it is highly prone to such events (see Chittibabu *et al.*, 2004; World Bank, 2008; Mohanty *et al.*, 2008; and Kumar *et al.*, 2010). The advantage of this study is that it has used all four normalization methodologies available in the literature: (i) income, wealth per capita and population (Pielke and Landsea, 1998); (ii) income, wealth per capita and household (Collin and Lowe, 2001); (iii) proportional to nominal GDP (Nordhaus, 2010) and (iv) actual potential loss ratio–APLR (Neumayer and Barthel, 2011), and the research question being pursued is whether the societal factors play a significant role in deriving the total damage cost. Since there is lack of data on the long-term impact for each extreme event separately, this study has assessed the causes of the total damage cost taking into account three extreme events, namely, flood, cyclone and drought.

This paper is structured as follows: the first part describes the theoretical underpinnings and empirical review of normalization studies; the second part outlines the methods and the data sources used in the estimation of normalized economic impact of the extreme events; the third part shows the empirical result of normalization and the final part concludes with some policy implications of the results.

2. Normalization – Theoretical Underpinnings and Review of Empirical Studies:

In the case of actual damage estimation, the trend in extreme event's economic impact is increasing (or decreasing) over a period of time, and hence, one would conclude that the intensity of these extreme events is rising (or falling) due to increase (or decrease) in frequency and duration of such events. However, such assessment under-estimates the influence of the societal factors and government's as well as individual's adaptive behaviour. For example, the damage cost might have increased in the recent decade as more people and properties might have been exposed in the susceptible region. Further, the trend in damage cost with adaptation may be lower than that of without adaptation. The original damage cost therefore should be normalized to remove the importance of both societal factors and adaptive behaviour (see Neumayer and Barthel, 2011), and then should be compared with both normalized and actual damage costs to determine the role of societal factors in causing the damage. As there is lack of information on adaptive behaviour (e.g. building cyclone or flood resistant house, and early warning system etc) in the context of the developing nation like India, this study focuses mainly on the role of societal factors.

The Figures 1 and 2 show the trend lines with equal and different physical intensity of extreme events. In Figure 1, the positive linear trend line A_0A_0 represents the actual impact cost, which indicates an increasing trend over a period of time. Suppose the physical intensity is same across the years Y_1 and Y_2. If we normalize the impact cost of the year Y_2 under Y_1 societal condition, the impact cost in both the years is equal (i.e. $E_1Y_1= E_2Y_2$). Contrary to expectation, the original impact cost in Y_2 (i.e. E_3Y_2) is higher than the Y_1 (i.e. E_1Y_1). The gap (i.e. E_2E_3) is therefore is attributed to the societal factors.

In the context of developing nations, the physical intensity of such event in general is missing in the historical data (Landsea *et al.*, 2006). In this case, we can also normalize the original impact data to see to what extent the societal factors are responsible for the total damage cost (see Figure 2). In Figure 2, N_0N_0 shows the normalized impact cost, where the original impact was normalized under Y_1 societal condition. Here, the difference between actual and normalized impact cost (i.e. E_3E_4) is derived due to the societal factors. On the other hand, the difference between normalized impact cost and the cost of the normalized year Y_1 (i.e. E_2E_4) is derived due to the climate change. Instead of N_0N_0, suppose we find the normalized impact cost is N_0N_1, which shows a declining trend after normalizing for the year Y_1. Here, the difference between actual and normalized impact cost (i.e. E_3E_5) is attributed to the societal factors.

Figure 1: Trend Line with Equal Intensity

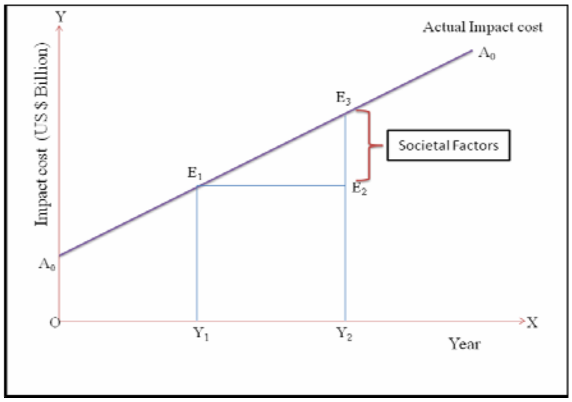
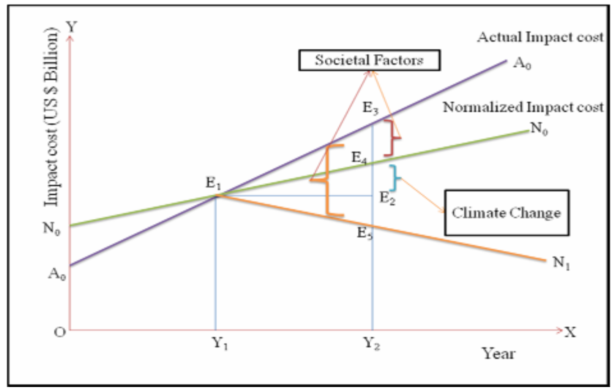


Figure 2: Trend Line with Different Intensity



In the context of empirical studies, the recent review article by Bouwer (2011) has reviewed 22 normalization studies, and hence, concluded no upward trend in disaster losses, after normalizing the change in population and capital risk. The present study has also cited a few of them (see Table 1). These studies have normalized either direct economic loss (i.e. immediate loss after the event) or insured loss (i.e. compensation given by insurance companies). The former is normalized for inflation, changes in exposure and vulnerability that are related to growth in population and wealth. The latter, on the other hand, is corrected for changes in insurance portfolio (number of policy holders) and changes in insurance conditions (cover and deductibles).

The Table 2 shows compound annual growth rate (CAGR) of NSDPFC (Net State Domestic Product at Factor Cost) at current price, NSDPFC at constant price, GSDP (Gross State Domestic Product) at current price, population and households in Odisha during the study period (1972-2008). In sum, these five societal indicators have grown positive trend. Such inference indicates that the societal factors might be part of the reason for the currently increasing destructive potential of the extreme events

Table 1: Normalized Impact Cost Studies

Sl No.	Extreme Events	Location	Period	Normalization	Normalized Loss	Reference
1	Hurricane	USA	1900-1995	Income, wealth and Population	No trend since 1900	Pielke and Landsea (1998)
2	Flood	USA	1932-1997	No Adjustment Population Wealth	Increasing Trend Increasing Trend No Trend	Pielke and Downton (2000)
3	Hurricane	USA	1900-1999	Income, wealth and housing unit	No trend since 1900	Collin and Lowe (2001)
4	Tropical storm	Andhra Pradesh, India	1977-1998	Income and population	No trend	Raghavan and Rajesh (2003)
5	Tropical storm	Latin America	1944-1999	Wealth and population	No trend	Pielke *et al.* (2003)
6	Tropical Storm	USA	1900-2005	Wealth and population	No trend since 1900	Pielke *et al.* (2008)
7	Weather (flood, thunderstorms, hail and bushfires)	Australia	1967-2006	Dwellings and dwelling values	No trend	Crompton and McAneney (2008)
8	Flood	Europe	1970-2006	Wealth and population	No trend	Barredo (2009)
9	Windstorm	Europe	1970-2008	Wealth and population	No trend	Barredo (2010)
10	Hurricane	USA	1900-2008	GDP	Increase Trend since 1900, and ninth power law of damage	Nordhaus (2010)
11	Natural Disaster	World	1980-2009	same as Pielke and Landsea (1998); and GDP	No trend	Neumayer and Barthel (2011)
12	Hurricane	USA	1900-2005	Pielke and Landsea (1998); Collin and Lowe (2001); and Nordhaus (2010)	No Trend, but elasticity is probably in the rage of a 6.5 up to 8 power	Bouwer and Botzen (2011)

Table 2: Rate of change of Societal Indicators of Odisha (1972-2008)

Sl No.	Societal Variables	CAGR (%)
1	Per Capita Net State Domestic Product Factor Cost (NSDPFC) at Current Price	10.77
2	Per Capita Net State Domestic Product Factor Cost (NSDPFC) at Constant Price (1993-94)	2.00
3	Gross State Domestic Product (GSDP) at Current Price	12.93
4	Population	1.69
5	Households	2.92

Note: CAGR → Compound Annual Growth Rate
Source: Analysis of data collected from Census (1971, 1981, 1991 and 2001); GoO (2005 and 2008); and State of the Environment Report- Orissa (2007)

3. Data and Methods:

There are three types of impacts of the extreme events such as, direct (i.e. immediate loss after the event), secondary (i.e. increasing diseases like skin itching, fever and diarrhea etc after the event) and tertiary (long-term impact on the state economy, i.e. the cost of rebuilding infrastructure and capital). Since the data is available only on the direct impact, this study also looks at this dimension just as existing normalization studies have done so far. Data has been collected regarding the extreme event damage from different sources, e.g. journal articles, white papers on the super cyclone of 1999, Odisha Human Development Report 2004, and various 'Annual Reports on Natural Calamities' published by Special Relief Commissioner, Revenue and Disaster Management Department, Govt. of Odisha, Bhubaneswar (2001-08). The data on macro-economic indicators like NSDPFC at both current and constant price (1993-94), and GSDP at current price have been collected from 'state domestic product of Odisha: from 1950-51 to 2002-03' (GoO, 2005), which is published by Directorate of Economics and Statistics, Govt. of Odisha. Since the NSDPFC at constant price is available up to 2005, this study has extrapolated for 2006-08 based on the assumed annual growth rate between 2002-05 (Raghavan and Rajesh, 2003). Further, the demographic data for the year 1971, 1981, 1991 and 2001 has been obtained from the 'State Environment Report 2007'[6]. After calculating the annual growth rate from the decadal variation, this study has extrapolated the demographic statistics for each year. As we don't have data for the year 2011 at present, it has extrapolated the demographic statistics of 2001-08 assuming annual growth rate of 1991-2001. In addition, the census household data has been collected from 'Census of India' reports. Like demographic statistics, this study has also extrapolated household data for each year till 2008. Further, the damage statistics for the year 2000 is missing (either not reported or no extreme event in that year), and therefore this study has followed linear interpolation methodology[7] to fill-up data for the year 2000.

In order to normalize the societal factors, this study as already mentioned has followed four methods, e.g. (i) income, wealth per capita and population: PL method (Pielke and Landsea, 1998); (ii) income, wealth per capita and household: CL method (Collin and Lowe, 2001); (iii) proportional to nominal GDP: N method (Nordhaus, 2010) and (iv) actual potential loss ratio–APLR: NB method (Neumayer and Barthel, 2011). In the case of 'wealth per capita', the estimation is based on current cost of net stock of fixed assets and consumer durable goods produced each year (Pielke *et al.*, 2008) or the value of dwellings (Crompton and McAneney, 2008). As we do not have such data in the Odisha context, this study has used a proxy variable for wealth as NSDPFC at constant price (Raghavan and Rajesh, 2003). The CL method has taken household instead of population, because the PL method could under-estimate the magnitude of the impact as the amount of property at risk is higher than the population growth (Pielke *et al.*, 2008). The household in Odisha, for example, has grown at a rate of 2.92% yr^{-1}, which is hgher than the population growth rate, i.e. 1.69% yr^{-1} (see Table 2). Importantly, it assumes that the societal indicators in the extreme event prone areas have grown at the same rate. Following both PL and CL methods, this study has normalized each year's total damage

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[6] http://www.cesorissa.org/soe/soer.html; last accessed on 22nd February 2010.

[7] $t_2 = \left(t_1 + \left((t_3 - t_1) / 2 \right) \right)$

under 2008 societal condition, i.e. what will be the impact if such events had occurred in the year 2008.

On the other hand, Nordhaus (2010) has estimated nromalized damage as the actual damage proportion to nominal GDP, which is an approriate method to correct economic growth, assuming no adaptation and neutral changes in technology and the location and structure of economic activity. Neumayer and Barthel (2011), in contrast, have criticized the conventional methodology (e.g. PL and CL methods), and calculated relative damage, i.e. relative loss of total wealth. As per their methodology, dividing damage by wealth in the same year, they did not require to control population and inflation (see Neumayer and Barthel, 2011: 15). The main advantage of this methodology is that it corrects spatial variation in addition to temporal variation. Since this study has estimated normalized damage for Odisha state only, there is no scope to utlize advantage of correcting spatial variation. For wealth, this study has taken a proxy variable as GSDP (Gross State Domestic Product)[8] (Neumayer and Barthel, 2011).

This study, however, has five methodological limitations: inconsistency in data (i.e. impact data is missing for some years, and importantly, small disasters may be not reported in the early period relative to later period); not considering non-market direct loss (i.e. loss of eco-system, and historical and cultural assets), and indirect loss (i.e. secondary and tertiary impact) (see Hallegatte and Przyluski, 2010); scale of assessment (i.e. the local scale variation of anthropogenic climate change, population and wealth is not perfectly captured, i.e. spatial variation) (see Neumayer and Barthel, 2011); assuming no adaptation in the context of individual and government (see Crompton and McAneney, 2008; and Neumayer and Barthel, 2011); and geo-physical change (i.e. some region may be geographically highly susceptible than others).

As per PL method (Pielke and Landsea, 1998),

$$PLD_{2008} = D_Y \times I_Y \times IN_Y \times P_M \quad (1)$$

[8] The advantage is that GSDP particularly captures potential economic loss associated with the natural disaster, however it is relatively poor proxy for capturing stock of wealth that was destroyed by natural disaster as the GSDP is the flow of economic activity. In particular, GSDP can only be considered as a proxy for wealth (Neumayer and Barthel, 2001: 16).

As per CL method (Collins and Lowe, 2001),

$$CLD_{2008} = D_Y \times I_Y \times IN_Y \times HH_M \quad (2)$$

As per N Method (Nordhaus, 2010),

$$\mathrm{ND_t} = \left(\mathrm{Damage_t} / \mathrm{GDP_t} \right) \times 100 \quad (3)$$

As per NB method (Neumayer and Barthel, 2011),

$$\mathrm{NBD_t} = \frac{\mathrm{Damage_t}}{\mathrm{Wealth_t}} \quad (4)$$

Normalized Population Affected in reference to year 2008 (Pielke *et al.*, 2008),

$$P_{2008} = P_Y \times P_M \quad (5)$$

Normalized Houses Affected in reference to year 2008 (Pielke *et al.*, 2008)

$$HH_{2008} = HH_Y \times HH_M \quad (6)$$

Where,

PLD_{2008} → PL method Normalized Damages in 2008 Price; CLD_{2008} → CL method Normalized Damages in 2008 Price; D_Y → Reported Damages in Current Year Price; I_Y → Inflation multiplier; IN_Y → Income multiplier; P_Y → Population for the reported damage year; P_M → Population multiplier; HH_Y → Household for the reported damage year; HH_M → Household multiplier; and ND_t → Nordhaus method normalized damage in year ‘t’; $Damage_t$ → Actaul damage in the year ‘t’; GDP_t → Gross domestic Product in the year ‘t’; NBD_t → NB method normalized damage in the year ‘t’; and $Wealth_t$ → wealth in the year ‘t’.

The inflation and income have been adjusted using NSDPFC at both Current (CU) and Constant (CO) price (Raghavan and Rajesh, 2003). In addition, the population and household are controlled through multiplier of both the variables (Pielke *et al.*, 2008).

$$I_Y = \left(\frac{NSDPFCCU_{2008}}{NSDPFCCO_{2008}}\right) \Big/ \left(\frac{NSDPFCCU_Y}{NSDPFCCO_Y}\right) \quad (7)$$

$$IN_Y = \frac{NSDPFCCO_{2008}}{NSDPFCCO_Y} \quad (8)$$

$$P_M = \frac{P_{2008}}{P_Y} \quad (9)$$

$$HH_M = \frac{HH_{2008}}{HH_Y} \quad (10)$$

Where,

NSDPFCCUY → NSDP FC at Current price for the reported damage year; NSDPFCCU2008 → NSDP FC at Current Price for the normalizaed year 2008; NSDPFCCOY → NSDP FC at Constant price for the reported damage year; NSDPFCCO2008 → NSDP FC at Constant price for the normalized year 2008; P2008 → Population for the normalized year 2008; and HH2008 → Household for the normalized year 2008.

Further to test for existence of a trend, both actual and normalized damage from each year is regressed on a linear year variable and an intercept (see Neumayer and Barthel, 2011).

$$(\text{Actual Population Affected})_t = \alpha_0 + \beta_1 \text{Year}_t + \varepsilon_t \quad (11)$$

$$(\text{Normalized Population Affected})_t^{2008} = \alpha_0 + \beta_1 \text{Year}_t + \varepsilon_t \quad (12)$$

$$\left[\text{Ln}(\text{Actual Economic Impact})\right]_t = \alpha_0 + \beta_1 \text{Year}_t + \varepsilon_t \quad (13)$$

$$\left[\text{Ln}\left(\text{Normalized Impact\_PL Method}\right)\right]_t^{2008} = \alpha_0 + \beta_1 \text{Year}_t + \varepsilon_t \quad (14)$$

$$\left[\text{Ln}\left(\text{Normalized Impact\_CL Method}\right)\right]_t^{2008} = \alpha_0 + \beta_1 \text{Year}_t + \varepsilon_t \quad (15)$$

$$\left(\text{Normalized Impact\_N Method}\right)_t = \alpha_0 + \beta_1 \text{Year}_t + \varepsilon_t \quad (16)$$

$$\left(\text{Normalized Impact\_NB Method}\right)_t = \alpha_0 + \beta_1 \text{Year}_t + \varepsilon_t \quad (17)$$

4. Economic Impact of Extreme Events in Odisha:

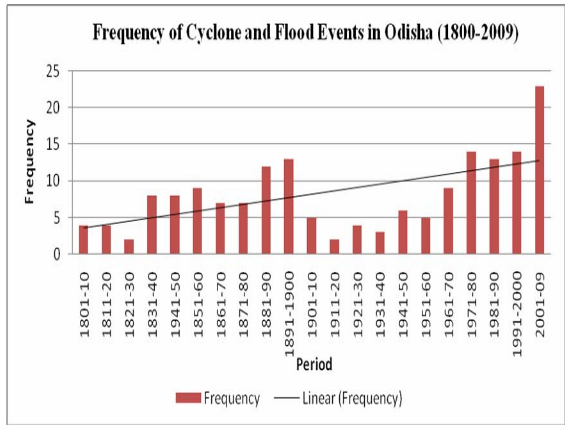
4.1. Background of Odisha:

The state of Odisha is geographically situated at the eastern coast of India (see Figure 3), particularly at the head of the Bay of Bengal that consists of coastal stretch of around 480 km. In addition, a large number of perennial rivers (e.g. *Mahanadi, Brahmani, Baitarani, Rushikulya, Birupa*, *Budhabalanga* and *Subarnarekha* etc), and its tributaries pass through Odisha. It appears that changes in the behaviour of the sea (i.e. cyclonic storm, high and low tide, and sea level rise) and rainfall patterns (i.e. high erratic rainfall) have negative economic imapct on Odisha, particualrly poor people living in the fragile environment. As per Odisha Human Development Report 2004, Odisha has experienced a wide range of extreme events, e.g. floods for 17 years, droughts for 19 years, and cyclones for 7 years during 1965-2000 (GoO, 2004: 162-3). In particular, Odisha has come across 172 times both floods and cyclones since the 18th century, with most of them occurring during the second half of the last century and the current decade (see Figure 4)[9]. In the spatial scale context, GoO (2009: 10) outlines that more than half of the districts of Odisha are always affected by the extreme events (e.g. flood, cyclone and drought) during 1995-2009. In the damage cost context, the value of property loss was around INR 1050 million during the 1970s, which is increased to nearly seven times in the 1980s and more than 10 times in the 1990s (GoO, 2004: 163).

[9] This data is being compiled by author based on journal articles and government reports, for example Bhatta (1997), Chittibabu *et al.* (2004), GoO (1999a and b), GoO (2004) and GoO (2008).

Figure 3: Geographical Map of Odisha

Figure 4: Frequency of Cyclones and Floods



4.2. Normalized Economic Impact of Extreme Event:

This section has normalized the original impact of the extreme events in Odisha during the period of 1972-2008 by using available four normalization methdologies described above, and expolored the influence of the societal factors to derive the total damage cost. In this context, Table 3 illustrates the actual and normalized impact of the extreme events in Odisha. The figures 5, 6, 7, 8, 9, 10 and 11 show the actual and normalized population and economic impact respectively. These figures show postive linear trend, even though the slopes vary. This suggests that the economic impact of the extreme event is increasing even in the case of normalization and hence, the climate change has an influence on the current potential damage cost. Further, table 4 illustrates Mann-Whitney test for actual and normalized population and economic impact. It, in particular, outlines significant different in the context of actual and normalized impact (both PL and CL method), but not in the case of population. It infers that there is a significant difference between actual and normalized economic impact.

Table 3: Actual and Normalized Extreme Event's Impact in Odisha (in Millions)

Year	Actual Population Affected	Normalized Population Affected	Actual Damage	Normalized Damage			
				PL Method	CL Method	N Method	NB Method
1972	0.48	0.87	128.9	9358.58	14434.93	0.84	0.008
1973	0.44	0.78	29.1	1721.28	2655.41	0.15	0.002
1974	1.07	1.89	128.9	7242.79	11175.28	0.64	0.006
1975	0.43	0.75	34.4	1864.12	2876.73	0.16	0.002
1976	2.86	4.86	179.1	9890.64	15266	0.87	0.009
1977	1.2	1.99	92.2	4158.17	6419.14	0.37	0.004
1978	1.53	2.51	95.9	4079.95	6299.46	0.36	0.004
1979	6.32	10.17	325.7	13128.5	20273.93	1.15	0.011
1980	2.44	3.86	305.4	9313.28	14384.66	0.82	0.008
1981	0.62	0.96	125.6	3423.84	5289.14	0.3	0.003
1982	18.18	27.69	1071.1	27554.56	42550.11	2.41	0.024
1983	2.1	3.15	493.9	9841.28	15191.3	0.87	0.009
1984	7.53	11.05	1188.9	23971.54	36989.28	2.09	0.021
1985	2.78	4.01	1388.8	23335.54	35994.34	2.04	0.02
1986	7.35	10.4	938.1	14543.3	22424.15	1.26	0.013
1987	6.93	9.63	664.6	10145.96	15638.04	0.87	0.009
1988	2.79	3.8	270.1	3255.44	5015.74	0.28	0.003
1989	6.37	8.53	371	3915.62	6030.63	0.34	0.003
1990	15.5	20.39	1994.9	21624.31	33292.06	1.83	0.018
1991	7.61	9.83	2292.5	19196.64	29543.36	1.64	0.016
1992	10.82	13.76	15497	121160.46	184536.84	10.24	0.102
1993	6.08	7.62	7790.8	52868.2	79690.05	4.2	0.042
1994	10.78	13.3	1532.6	8655.45	12911.8	0.69	0.007
1995	3.94	4.79	1099.5	5074.62	7491.83	0.41	0.004
1996	6.33	7.59	1432.3	6946.41	10149.22	0.54	0.005
1997	3.49	4.12	685.5	2689.56	3889.03	0.21	0.002
1998	9.82	11.42	20321.9	71436.3	102227.03	5.71	0.057
1999	12.57	14.39	18159.35	52163.32	73875.33	4.7	0.047
2000	10.50	11.84	14112.27	40371.46	56584.32	3.24	0.032
2001	8.43	9.36	10065.18	26767.96	37129.95	2.14	0.021
2002	29.8	32.62	18770	46197.88	49169.68	3.74	0.037
2003	7.62	8.22	3497.159	7012.91	7386.88	0.57	0.006
2004	0.31	0.33	746.156	1288.25	1342.92	0.1	0.001
2005	2.06	2.15	2433.541	3832.29	3953.63	0.31	0.003
2006	6.74	6.95	23824.26	31281.78	31938.65	2.55	0.026
2007	7.91	8.03	14002.26	16100.03	16268.19	1.32	0.013
2008	6.02	6.02	26874.3	26874.3	26874.3	2.2	0.022
Mean	6.43	8.10	5215.22	20061.80	28301.71	1.68	0.017

Source: Analysis of data from GoO (1999a, and b); GoO (2004: 164); and GoO (2008)

Figure 5: Actual Population Affected

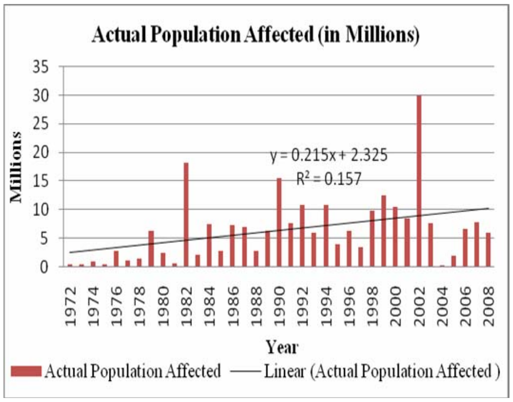


Figure 6: Normalized Population Affected

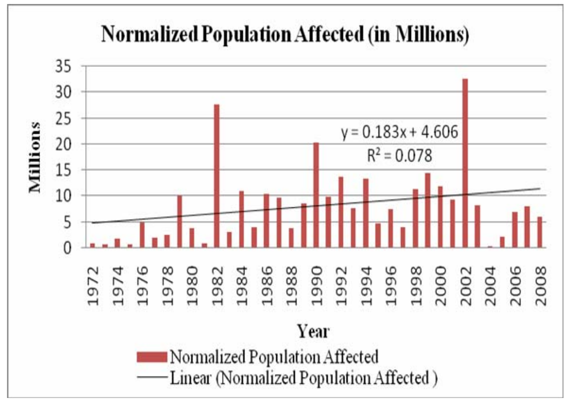


Figure 7: Actual Economic Impact

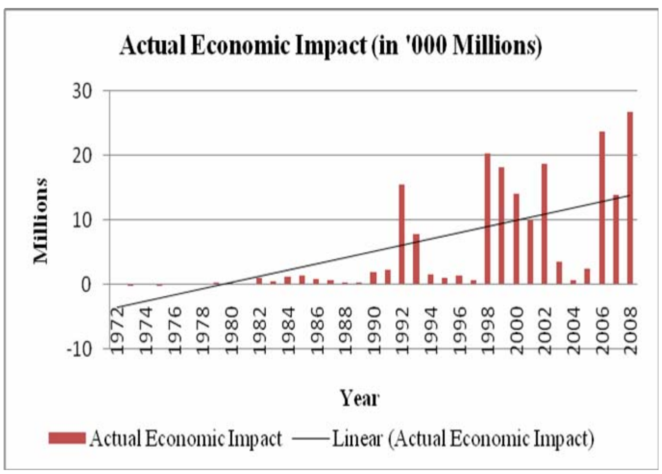


Figure 8: Normalized Impact (PL Method)

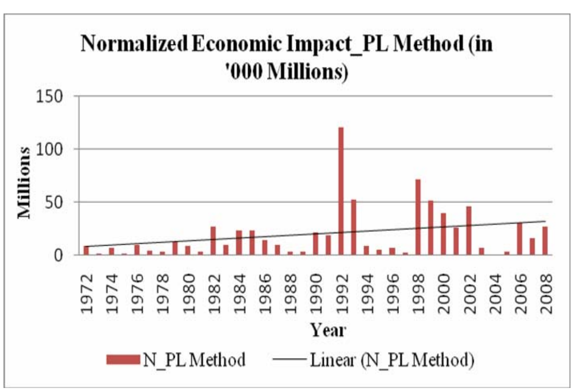


Figure 9: Normalized Impact (CL Method)

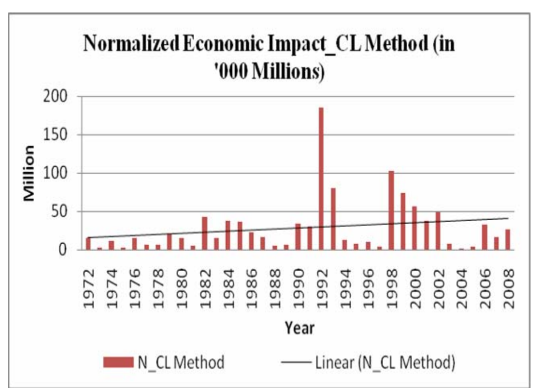


Figure 10: Normalized Impact (N Method)

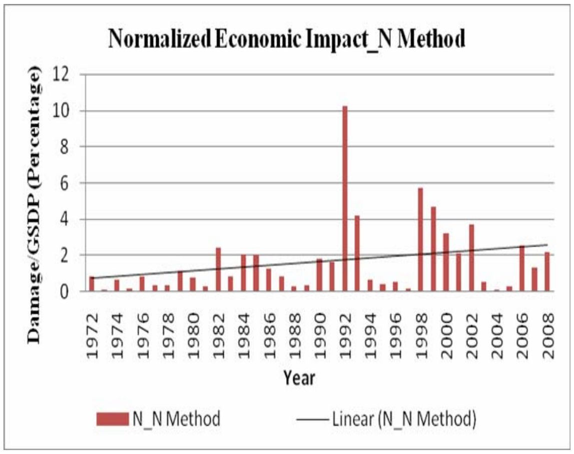


Figure 11: Normalized Impact (NB Method)

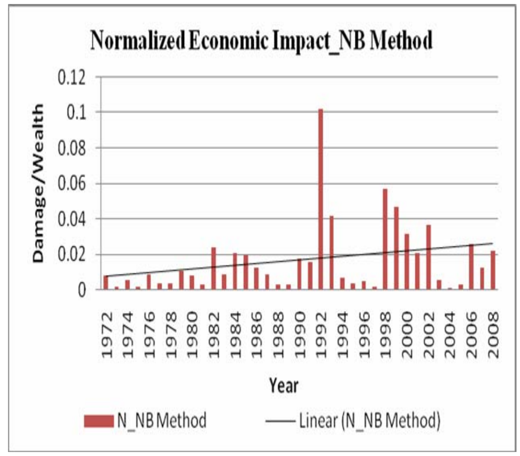


Table 4: Mann-Whitney Test for Actual and Normalized Variables

Sl No.	Variables	N	Mean Rank	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)	Exact Sig. (2 tailed)
1	Actual Population Affected	37	34.38	569.00	-1.249	.212	.214
	Normalized Population Affected	37	40.62				
2	Actual Damage	37	25.47	239.50	-4.811	.000	.000
	Normalized Damage (PL method)	37	49.53				
3	Actual Damage	37	24.20	192.50	-5.319	.000	.000
	Normalized Damage (CL method)	37	50.80				
4	Normalized Damage (PL method)	37	34.28	565.00	-1.286	.198	.200
	Normalized Damage (CL method)	37	40.72				

Source: Same as Table 3

In order to identify the importance of the societal factors, we estimated coefficient of time trend by regressing the actual and normalized damage from each year with linear year (see Table 5). In table 5, we observe a significant coefficient for all the variables except normalized impact with CL method. The coeeficient for actual population affetced is positive at 5 percent significant level. The time trend coefficient for normalized population affected is less than actual population affected. From the actual economic impact coefficient figure, one can outline that the damage cost increases at 15.2 percent per year with 1 percent significant level (see Table 5). However, such figure is very low in the case of normalized impact. It is 3.3 percent in the PL method (10 percent significant level), 5.1 percent in the N method (10 percent significant level) and 0.1 percent in the NB method (10 percent significant level) (see Table 5). In the case of CL method, it has not found any significant trend. Such findings infer that there is lower potential impact in the normalization context, and hence, we conclude that the societal factors play a major role to derive the total damage cost.

Table 5: Estimates of Damage Intensity Function with Time Trend

Sl. No		Coefficient on Year			Observations
		Coeffieicnt (β)	Std. Error	t-statistics	
1	Actual Population Affected	.215**	.084	2.56	37
2	Normalized Population Affected	.183***	.106	1.72	37
3	Actual Economic Impact	.152*	.016	9.40	37
4	Normalized Impact_PL Method	.033***	.017	2.03	37
5	Normalized Impact_CL Method	.022	.017	1.30	37
6	Normalized Impact_N Method	.051***	.030	1.72	37
7	Normalized Impact_NB Method	.001***	.0002	1.71	37

Note: *,** and *** → 1%, 5% and 10% level of significance respectively
Source: Same as Table 3

Further, in order to understand the importance of the societal factors exclusively, it needs to compare the damage figures for different year and time period during the study period 1972-2008.

Table 6 ilustrates period-wise population affected in terms of total and average for both actual and normalization respectively. In the actual impact context, it is found that higher number of people are affected in the current decade, e.g. 1997-2001 and 2002-2008. For instance, the average number of people affected during these periods are 8.96

million and 8.64 million respectively (see Table 6), which is higher than the other study periods and the total mean (i.e. 6.43 million). Such result infers a higher destructive potential in the current decade. The normalization result, in contrast, outlines that a greater number of people are affected during the 1980s (i.e. 1982-86 and 1987-91) as compared to the period 2002-08 (see Table 6). In particular, the mean population affected during the periods 1982-86 and 1987-91 were 11.26 million and 10.44 million respectively, which is higher than that of recent period 2002-08 (i.e. 9.19 million). Table 7, which shows frequency of population affected, reports that there are three times more than 20 million people affected in the normalization context, whereas it is only one time in the case of actual impact. This imply that a higher number of people affected in the current decade could be partly attributed to the population growth.

Table 6 : Period-wise Actual and Normalized Population Affected

Period	Actual People Affected		Normalized People Affected	
	Total People Affected (in Millions)	Average People Affected (in Millions)	Total People Affected (in Millions)	Average People Affected (in Millions)
1972-1976	5.28	1.06	9.15	1.83
1977-1981	12.11	2.42	19.49	3.90
1982-1986	37.94	7.59	56.3	11.26
1987-1991	39.2	7.84	52.18	10.44
1992-1996	37.95	7.59	47.06	9.41
1997-2001	44.81	8.96	51.13	10.23
2002-2008	60.46	8.64	64.32	9.19
Total	237.75	6.43	299.63	8.10

Source: Same as Table 3

Table 7: Frequency of Population Affected

People Affected	Frequency	
	Actual	Normalized
Count> 20 Million	1	3
10 – 20 Million	6	8
5 – 10 Million	14	10
1 – 5 Million	11	11
Count< 1 Million	5	5
Total	37	37

Source: Same as Table 3

In addition, Table 8 shows period wise actual and normalized damage cost in terms of total and average respectively. In the actual damage cost context, this study asserts that the total damage cost has increased in the current decade. The damage cost, for instance, is Rs. 90147.68 million (with a mean of Rs. 12878.24 million) during 2002-08, which became higher during the study period. In the case of the total damage cost, this study provides different results in the normalization context. For example, the damage cost is high during the 1990s (i.e. 1992-96 and 1997-2001) in comparison to the current period (i.e. 2002-08). During the 1992-96, the damage cost is Rs. 194705.14 million (with a mean damage of Rs. 38941.03 million) and Rs. 294779.74 million (with a mean damage of Rs. 58955.95 million) in both PL and CL methods respectively. These figures are higher than the damage cost in the current decade, i.e. 2002-08. The damage cost during 2002-08, for instance, is Rs. 132587.44 million (with a mean damage cost of Rs. 18941.06 millions) and Rs. 136934.25 million (with a mean damage cost of Rs. 19562.04 million). Here, this study also finds higher damage cost in the current decade in the case of actual economic impact, whereas the normalized damage cost is high during the 1990s (see Table 8). It seems that currently rising damage cost is partly due to the location specific growth of economic activity and population, in addition to the climate change.

Table 8: Period wise Actual and Normalized Damage Cost

Period	Actual		PL Method		CL Method	
	Damage (in Millions)	Average Damage (in Millions)	Damage (in Millions)	Average Damage (in Millions)	Damage (in Millions)	Average Damage (in Millions)
1972-1976	500.40	100.08	30077.41	6015.48	46408.35	9281.67
1977-1981	944.80	188.96	34103.74	6820.75	52666.33	10533.27
1982-1986	5080.80	1016.16	99246.22	19849.24	153149.18	30629.84
1987-1991	5593.10	1118.62	58137.97	11627.59	89519.83	17903.97
1992-1996	27352.20	5470.44	194705.14	38941.03	294779.74	58955.95
1997-2001	63344.20	12668.84	193428.60	38685.72	273705.66	54741.13
2002-2008	90147.68	12878.24	132587.44	18941.06	136934.25	19562.04
1972-2008	192963.18	5215.22	742286.52	20061.80	1047163.34	28301.71

Source: Same as Table 3

5. Conclusions

In order to understand the importance of the societal factors to derive the total damage cost, this study has normalized the actual impact data of the extreme events of Odisha state during the period 1972-2008. After normalization, this study arrived at two conclusions. First, the total normalized damage cost trend is showing positive growth, even though the growth rate is different in between actual and normalized damage cost. It infers that the climate change has an influence on the rising destructive potential in the current decade.

Second, this study finds lower significant growth rate in the case of normalization except CL method, and also comes across bigger damages during the 1980s and 1990s as compared to the current decade while the actual impact data is normalized to remove the importance of the societal factors. Thus, the occurrence of higher damages in the current decade is partly due to the societal factors, in addition to the climate change. It is the cautionary warning to the disaster mitigation policy makers. Since we are becoming wealthier and more populated in comparison to the earlier period, we therefore found that the damages associated with the extreme events are increasing over a time period. If these factors are not considered in the ongoing disaster mitigation policy, there will be a manifold increase in damages in the decades to come. Since there are five methodological limitations, it is very hard to say exactly to what extent both the climate change and the societal factors are played a major role to derive the total damage cost.

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