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Awareness as an Adaptation Strategy for Reducing Mortality from Heat Waves: Evidence from a Disaster Risk Management Program in India*

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Abstract

Heat waves, defined as an interval of abnormally hot and humid weather, have been a prominent killer in recent years. With heat waves worsening with climate change, adaptation is essential; one strategy has been to issue heat wave warnings and undertake awareness campaigns to bring about behavioral changes to reduce heat stroke. Since 2002, the Indian state of Odisha has been undertaking a grassroots awareness campaign on "dos and don'ts" during heat wave conditions through the Disaster Risk Management (DRM) program. Selection criteria for DRM districts were earthquake, flood, and cyclone incidence; but subsequently heat wave awareness also received intensive attention in these districts. We present quasi-experimental evidence on the impact of the program, taking DRM districts and periods as treatment units and the rest as controls, analyzing the impact on the death toll from heat stroke for the 1998 to 2010 period, using difference-in-difference (DID) regressions with a district level panel data set and a set of control variables. We find indications of program effectiveness with initial DID specifications, but results are not strongly robust. We then take into account a statewide heat wave advertising program, to which the poor have limited exposure but which may also provide spillover benefits, using a triple differencing approach; results suggest the heat wave awareness programs may have complementary impacts. We examine research strategies for much-needed improvement in the precision of impact evaluation results for innovative programs of this type.

JEL classifications: Q54, 013, I18

Keywords: Adaptation to climate change, Awareness campaigns, Heat waves, Disaster Risk Management Program, India, Odisha, Difference-in-difference

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1. Introduction

The global surface temperature has increased by $0.3^{\circ}C$ to $0.6^{\circ}C$ during the last century, with NOAA data showing the 2000s being the hottest decade and the 1990s the second hottest. The world is facing more frequent hot days, hot nights and heat waves which apparently is already leading to adverse effects on human health including mortality due to hyperthermia (IPCC, 2007a; Mohanty, 2006).

A 'Heat Wave' is a period of abnormally and uncomfortably hot and humid weather; there is no universally accepted definition of the term and it is usually defined relative to the normal weather in an area (Meehl and Tebaldi, 2004). Temperatures that people from a hotter climate consider normal may be termed a heat wave in a cooler area if outside the normal climate pattern for that area (Robinson, 2001). The temperature threshold above which a heat wave is defined varies widely across the world; the threshold being $28^{0}C$ in Denmark, $32^{0}C$ in northwestern United States, $40^{0}C$ in Australia and $45^{0}C$ in India. There may be further variation in these thresholds depending on the humidity in the atmosphere or coastal or interior areas.

Heat waves have an absolute health component in addition to a relative climate component. During heat waves, the evaporation of perspiration that cools the human body slows down, and the body has to work harder to maintain normal core body temperature. Generally humans maintain a core body temperature of approximately $37^{0}C$ irrespective of the local climate whereas skin temperature is strongly regulated at $35^{0}C$ or below under normal conditions (Sherwood and Huber, 2009). Skin temperature has to be lower than core body temperature for metabolic heat to be transmitted to the skin. Sustained skin temperature above $35^{0}C$ due to heat waves slows dissipation of metabolic heat and elevates the core body temperature, and it may attain lethal values (42–43°C causing hyperthermia) for skin temperatures of 37–38°C even for acclimated and fit individuals (Mehnert et al., 2000; Bynum et al., 1978). Thus, high temperature can pose serious threats to all individuals, irrespective of their age and health status (Sherwood and Huber, 2009).

In recent years, severe heat waves have caused high mortality and morbidity in many parts of the world (e.g. Chicago in 1995 and 1999, most parts of Europe in 2003, and the states of Odisha and Andhra Pradesh in India in 1998 and 2003). Between 1992 and 2001, deaths from excessive heat in the United States numbered 2190, compared with 880 deaths from floods and 150 from tropical cyclones (hurricanes), making heat waves the most lethal weather phenomenon (Basu and Jonathan, 2002). The death toll from European heat waves of 2003 was approximately 35,000, of which 14,800 occurred in France alone (IPCC, 2007b). Heat waves in the Indian states of Odisha in 1998 and Andhra Pradesh in 2003 killed 2042 and 3000 people respectively. This scenario is likely to become aggravated in coming years (IPCC 2007a, 2007b, Kunkel et al. 2008); and the WMO predicts heat related fatalities will double in less than 20 years. Under these circumstances, adaptation is a key response strategy to minimize potential deaths and other adverse health effects of heat waves (Menne and Ebi 2006). Mendelsohn (this issue) raises the basic question: "What should be the public health response to potential deaths caused by climate change?" This paper examines one such public health response, a public awareness campaign on "dos and don'ts" during heat waves.

There are broadly two relevant categories of studies on heat waves, the first in the public health literature and the second in the impact evaluation literature. The first set of studies examines the link between mortality and temperature anomalies by studying either the daily fluctuations in mortality or the aggregate annual death counts. Studies generally find a positive association between excess mortality and temperature, especially when temperature exceeds a specified threshold.[1]

Studies analyzing specific heat wave calamities, generally in the U.S., have found various death risk increasing factors such as race, living in impoverished neighborhoods, having only a high school education or less (O'Neil et al. 2003), not having access to air-conditioning (Smoger 1998a), living alone and leaving home regularly, and other socio-economic factors (e.g. Gouveia and Armstrong 2003; Naughton et al., 2002; Semenza et al., 1996). These factors amplify the effect of temperature on mortality. Older people and those with health related problems are also reported to be more vulnerable to heat attacks (O'Neil et al. 2005, 2009). Davis et al (2003) suggests a decline in heat related mortality over the years due to physiological adaptation along with the use of air-conditioning.

Using a case crossover approach and pooled data, Bell et al (2008) examined heat related deaths in Mexico City, Sao Paulo and Santiago between 1998 and 2002 and found same and previous day temperature, and high age significantly related to deaths. The significance of factors such as education and gender were found not to be robust, in that the impacts differ across communities and vary between cities. Both these categories of studies clearly indicate the existence of socio-economic gradients for heat related deaths along with factors such as age, health history and weather.

There is some previous evidence that health education through mass media or public awareness campaigns on environmental quality brings substantial behavioral changes in people, though it seems to depend on the structure, timing, and soundness of campaign content (Cutter and Neidell 2009; Randolph and Viswanath 2004; Hornik 2001). Das and Vincent (2009) concluded that warning has been effective in saving lives during storms and is complimentary to other death reducing factors; and there is some limited evidence from

[1] See e.g. Deschenes and Moretti, 2009; Deschenes and Greenstone, 2007; Medina-Ramon and Schwartz, 2007; Medina-Ramon et al., 2006; and O'Neill et al., 2003.

impact evaluation studies of state intervention, particularly heat wave warnings and other information to reduce mortality, that heat early warnings do reduce deaths (Alberini et al 2008; Ebi et al 2004). But although educating people about appropriate behavior during hot weather is widely thought to be an effective adaptation strategy by many governments (Menne and Ebi 2006; WHO 1990), there remains a dearth of research on the impacts of public education about heat waves or heat wave warnings.[2]

In this paper we focus on the impact of the grassroots Odisha Disaster Risk Management (DRM) in reducing heat stroke deaths, while taking into account broader media efforts. There are anecdotal field reports of the program's effectiveness in changing behavior in accordance with DRM's public messages,[3] but systematic evidence has not been available. Our identification strategy is first to exploit the plausible exogeneity of program site selection with respect to heat wave vulnerability. The criteria for designating districts for DRM participation were earthquake, flood and cyclone incidence; but helping people adapt to heat waves through awareness subsequently also received intensive attention in these districts. We thus take these districts as treatment units and the rest as controls. Given other engogeneity concerns, we analyze the impact on the death toll from heat stroke for 1998 to 2010 using difference-in-difference and triple-difference regressions with a district level panel data set. Results show districts with an active program have witnessed some reduction in the heat wave death toll compared to non-programmed districts after controlling for heat wave conditions, supporting the hypothesis that programs for generating awareness help people

[2] Alberini et al. (2008) analyzed daily death counts for all non-trauma and other specific causes covering 86 US counties using a regression discontinuity design (RDD) and found heat stress to have resulted in appreciable increase in mortality of cardiovascular and respiratory patients and elderly. They found the heat alerts issued by National Weather Services (NWS) to have reduced the impact of heat stress appreciably, but the effects were different across regions. It seemed to reduce excess mortality among elderly by 25% in Midwest, Northeast and Mid-Atlantic states, but neither heat nor heat warning seemed to have any effect on mortality in the south, possibly due to acclimatization and behavior. Ebi et al. (2004) assessed the impact of the advanced Kalkstein heat/health warning system in early years of its introduction in Philadelphia and estimated that it saved 117 lives between 1995 and 1998.

3 Personal communications to the authors from scholars based in the area (Dr. Mamata Swain), regional NGO leaders (Bratindi Jena of Action Aid), and scientists (Akalabya Das and Prasanna Kumar of Odisha Remote Sensing and Application Center).

change their behavior and reduce mortality due to heat stress. At the same time, results are not highly robust with respect to specification changes. We examine data requirements and experimental and quasi-experimental strategies for the next phases of research on this topic.

2. The State of Odisha and the Disaster Risk Management Program

The State of Odisha in eastern India is disaster prone with a history of frequent cyclones, droughts and floods. By comparison, casualties from regular heat waves were not viewed as a serious problem. But in 1998, the state witnessed unprecedented heat waves, taking the administration and general public unaware. Compared to heat stroke casualties of just 1 to 22 in previous years, the death toll in 1998 rose dramatically to 2042 (see table 3).

The Grassroots DRM Program. In 1999, the state was devastated by a super cyclone with 256 km per hour landfall wind velocity and 7 meters of storm surge that killed nearly 10,000 people and caused colossal loss of property. After these calamities, in 2000 the state government formed the Odisha State Disaster Mitigation Authority (OSDMA). In 2002, the Disaster Risk Management (DRM) Project of the Government of India and United Nations Development Program was initiated with the aim of sustainably reducing disaster risk in some of the most hazard-prone districts in India.[4] The disasters prodding the DRM initiative were the 1999 super cyclone in Odisha, the massive 2001 Bhuj Earthquake in Gujurat, and the devastating 2001 flood in Bihar. The DRM program was implemented in two phases, Phase I from 2002 to 2004 and Phase II from 2003 to 2008. In phase I, only 28 districts of Odisha, Gujurat and Bihar were covered under the program and later in Phase II, another 97 districts were brought under it. The state of Odisha has 30 districts of which 12 were covered under DRM in Phase I and an additional 4 in Phase II.[5] The OSDMA (in liaison

[4] See http://www.ndmindia.nic.in/EQProjects/goiundp2.0.pdf.
[5] Of these 16, three of the districts were only partially covered: Ganjam (13 of the 22 blocks which are cyclone prone), Keonjhar (3 of the 13 blocks which are flood prone), and Mayurbhanj (11 of the 26 blocks which are flood prone). Ganjam was brought under DRM in phase I and the other two in phase II.

with the UNDP) was the nodal agency to implement the program. Selection of districts under the DRM program was based on the Vulnerability Atlas of India, which was prepared on the basis of a housing risk table.[6] Cyclones, earthquakes and floods being the disasters that spurred the DRM program, only these natural calamities were taken into account in calculating the risk index and selection of the vulnerable districts in the country to be covered under DRM. We exploit this plausibly exogenous feature of the heat wave program implementation as part of the paper's identification strategy, as explained below.

Awareness generation was an important strategy of disaster management under the DRM project; and in keeping with this objective, the disaster preparedness of the state under OSDMA undertook a paradigm shift by changing the focus from "relief, restoration and rehabilitation" (3Rs), to "planning, preparedness and prevention" (3Ps) – thus, making people 'aware of a disaster,' and telling them 'what to do' became a core activity of OSDMA in preparing the public. Review of IEC (information, educational and communication) materials prepared for different disasters show the strategy of awareness focused on simply providing knowledge on 'dos and don'ts' when a disaster strikes. Although occurrences of heat waves was not among the criteria for the selection of vulnerable districts under the DRM (in fact almost all districts of the state suffer from heat waves casualties), heat wave preparedness received a boost in DRM districts as overall vulnerability reduction was the aim of the DRM project, and heat waves had now become recognized as a major, regular killer. Only in the targeted DRM districts, a major grassroots campaign was then carried out, as local people or volunteers in each ward and village are trained under the project to help disseminate information; and there are project officers in every district to continuously monitor and provide feedback during crises.

[6]The of Government of India (GOI) Ministry of Urban Development along with the Indian Meteorological Department, Central Water Commission, Geological Survey of India, and the University of Rourkee Department of Earth Engineering, prepared the vulnerability map. First, housing risk tables were prepared, taking in to account the frequency and intensity of cyclones, floods, and earthquakes (as these hazards damage houses) and housing quality. Then, districts were ranked on the basis of risk indexes.

The Awareness Media Program. Monitoring heat waves and preparing people to face them became an important and regular activity of OSDMA. In keeping with DRM approaches, one of the main strategies to counter heat attack has been to undertake awareness campaigns on dos and don’ts during heat wave periods along with the broadcast of heat wave warnings. The awareness campaign has been in the form of giving precautionary instructions such as what to do to avoid heat stroke, symptoms of heat attack and the subsequent first aids to avoid serious consequences (see Table 2 for details). Multiple media including electronic and print media, posters, and pamphlets are being used.[7] Along with this campaign, other activities undertaken include giving directions to various government departments to reduce exposure of workers during peak hot hours, changing school and bus timings, and ensuring smooth supply of water and electricity. These other activities, however, were also being undertaken since 1999 (after 1998 calamity) by the calamity mitigation committee of the Government of Odisha prior to the creation of OSDMA and have been done routinely since then.

People’s exposure to this information will likely depend on their level of literacy (whether they read newspapers or not) and affluence (whether or not they own a television or radio or indeed have access to electricity).

Thus we expect the Awareness Media Index (if effective in reducing adverse health impacts or changing behavior) to have a negative effect on heat wave deaths for the whole state (as we cover years before and after the campaign). For reasons detailed below, there are reasons to anticipate that the programs may be complementary and reinforce the heat wave

[7] The number of media used to disseminate information seems to be directly linked to the severity of heat waves as the number of hot days seems to have gone up in more recent years. The coefficient of correlation between the media used in a year or awareness media index (AMI), and the different measures of heat waves are the following: number of days with more than 40^0 C temperature (r=0.54, P=0.00), number of heat wave days (r=0.48, P=0.00), number of severe heat wave days (r= -0.02, P = 0.56) and dummy variable for excessive hot year (r=0.08, P=0.09). However, the latter two heat wave measures show the highest impact on death (as seen from Tables 5 and 7) are they have little or no correlation with the AMI.

awareness measures; but evidence for complementarity and of awareness media impact is mixed.

Overall, the main focus of the paper is on the DRM (grassroots) program, for two sets of reasons. First, research on the grassroots program is likely to be more beneficial for understanding problems and solutions of low-income adaptation. People living below or near the poverty line have limited if any access to modern media. They may be functionally if not completely illiterate; and too poor to own a television or radio, indeed in many cases lacking electricity. Moreover, the poor initially tend to be more vulnerable to heat stress; so the media campaign might have less mortality-reducing impact on the non-poor, who are already less likely to die of heat stroke. Further, the statewide media campaign tends to become more active during high heat wave periods, and thus is likely to some degree to be intrinsically correlated with heat stroke deaths. Although we control for heat wave incidence, we lack some of the data that would be useful, such as consecutive hours or days of exposure; our AMI is also subject to measurement error. Note that as a result, we have an ambiguous prediction of the sign of the coefficient on the (uninteracted) AMI; and thus we examine the heat wave awareness campaign both without and with using AMI as a direct program input measure.

Study Area. The study area for this paper is the coastal state of Odisha in eastern India, the Bay of Bengal forming its eastern boundary. Odisha is among the poorest states in India. Agriculture and related activities constitute the main occupation, engaging more than 76% of the population. More than 85% of the people live in rural areas, the percentage of urban population varying between as high as 42.93 for Khurda district to 4.29 for Nayagarh as per the Census of India 2001 estimates. The average density of population is 236 per square kilometer for the state and it varies between 666 for Khurdha district to 81 for Kandhamal district. Thus the coping capacity of people to extreme weather events is limited.

The state has 30 districts of which 16 have been covered under the DRM project of Government of India and UNDP (the highlighted districts in figure 1), 12 in phase I (2002 to 2004) and 4 in phase II (2003 to 2008). Cyclone and flood occurrences being the main criteria of selection of districts under DRM, all coastal and adjoining districts have been covered under the program. Other interior districts covered are either flood prone or are in high seismic zone. As the map in Figure 1 indicates, this program selection process resulted in a geographic concentration of districts. Thus, the district selections were not random; and although the selections are plausibly exogenous *with respect to heat wave impacts* as defined in this study, for improved identification we use double difference and triple difference specifications, including appropriate controls as explained below.

FIGURE 1 ABOUT HERE

The state has 19 weather stations, and has been divided into 10 agro-climatic zones. Using the heat wave definition given by the Indian Meteorological Department (IMD) of the Government of India (GOI), heat wave days are calculated for the state as a whole and for districts separately. Next, the heat wave days are compared with heat wave deaths in DRM and non-DRM districts (see Table 3, Figure 2 and 3).

The IMD formally defines heat waves as in Table 1 as follows:

TABLE 1 ABOUT HERE

Thus, the heat wave definition given by IMD differs from that used in some other regions, as it does not take into account the number of consecutive days (three or five or more) when the temperature exceeds the thresholds. As per the IMD definition, there can be a heat wave or severe heat wave even for one day depending on the maximum temperature of the day (as seen in Table 3).

3. Empirical Methods.

This research addresses the implicit policy assumption that heat wave awareness campaigns can lead to behavioral changes, which can in turn reduce heat stroke deaths. While we cannot test the intermediate behavioral effects directly, we address it implicitly by testing the hypothesis that behavioral awareness program reduces deaths. The study evaluates the awareness campaign in terms of its effect on reduced mortality. The logic chart in Table 2, based on written materials prepared and used by the DRM program, clarifies the projected corresponding linkages.

TABLE 2 ABOUT HERE

Interventions take the form of telling people what to do or not to do to avoid heat stroke during heat wave period. This is expected to create awareness in people on heat stroke problems, thus leading them to change their behavior, and ultimately reduce mortality or required hospitalization and loss of work time. The ultimate effect of these inputs on impacts, however, will depend on other intervening factors such as heat wave conditions, education, wellbeing, and natural conditions present. In this study, mortality reduction is used to evaluate the impact of this campaign, as it was difficult to get reliable data on hospitalization cases, work-time loss, and other indicators.

Table 3, and Figures 2 and 3, show heat related deaths have declined in Odisha since the 1998 heat wave disaster, despite the fact that the number of heat wave days has remained at historically elevated levels. However, if 1998 is ignored as an outlier, the decline in deaths no longer looks striking (Figure 2). There is a decline in deaths both in DRM and non-DRM districts (Figure 3); this may be due in part to physiological adaptation (Davis et al., 2003), and probably income growth and other factors.

FIGURES 2 AND 3 ABOUT HERE

TABLE 3 ABOUT HERE

4. Methodology

The paper begins with a Difference-in-Difference (DID) identification strategy to measure the impact of the grassroots awareness campaign on reductions in heat stroke deaths in DRM districts in comparison to control districts. We utilize DID to measure the counterfactual outcome, that is, the outcomes that would occur in the absence of the policy being implemented.[8] In our analysis, we utilize a Poisson specification with data from 13 time periods. For exposition, the simplest setup of DID is one in which outcomes are observed for the treatment and control groups for two time periods. One group (B) is exposed to a treatment in the second period but not in the first, while the other group (A) has no exposure to the treatment. With a repeated cross section, the linear model may be written as

$$\mathbf{Y}_{it} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1} * d_B + \boldsymbol{\beta_2}\, \mathbf{d}_T + \boldsymbol{\beta}_3(d_B * \mathbf{d_T}) + \boldsymbol{\varepsilon} it \qquad \textbf{(1)}$$

where y is the outcome of interest (in our case heat wave deaths, for district i in time t); d_B is a dummy variable that takes the value of 1 for a treatment (DRM) district, intended to capture possible differences between the treatment and control districts prior to the intervention, and d_T is a time period dummy variable. In equation (1), β_0 measures the base line average, β_1 measures the differences between the two districts in year 1; and β_2 represents the time trend in the outcome, the effect of factors that would cause a change in y even in absence of the program. $\boldsymbol{\beta}_3$ is the parameter of interest, representing the difference in the differences over time; that is, it isolates the treatment effect on outcome **Y** under the maintained assumptions. In other words the policy impact is captured by the coefficient of the interaction term $d_T * d_B$,

[8] See e.g. Angrist and Pischke (2008); Wooldridge (2002); and Card and Krueger (1994). For presentational clarity, the exposition in this section focuses on a basic linear case, which in the paper represents a specification for robustness checks.

which is a dummy variable equal to one for those observations in the treatment group and in the second (treatment) period (and zero otherwise). Thus the DID estimate is equivalent to:

$$\hat{\beta}_3 = (\overline{Y}_{B,2} - \overline{Y}_{B,1}) - (\overline{Y}_{A,2} - \overline{Y}_{A,1}) \qquad (2)$$

This simple set up can be extended to account for various subsets of treatment and control groups (in which case we include further interaction terms), and to measure appropriate Difference-in-Difference-in-Difference (DDD) specifications. In our application, we compare the effect of the DRM program (DRM districts in the DRM period) with a given media campaign, against non-DRM districts with similar campaigns during the same period. Let M_t be the media awareness index for period t. Now equation 1 is expanded as

$$\mathbf{Y}_{it} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 * d_B + \boldsymbol{\beta}_2 * \mathbf{d}T + \boldsymbol{\beta}_3(d_B * \mathbf{d}_T) + \boldsymbol{\beta}_4 M_t + \boldsymbol{\beta}_5 d_B * M_t + \boldsymbol{\beta}_6 d_T * M_t + \boldsymbol{\beta}_7 d_B * d_T * M_t + \boldsymbol{\varepsilon} it \qquad \mathbf{(3)}$$

where $\boldsymbol{\beta}_7$**,** the coefficient of the triple interaction term – of the treatment districts in the treatment period for a given media exposure – now represents the total program effect. As in this paper, one can also add covariates to control for compositional changes or observed heterogeneity in the groups, and use data on multiple time periods and groups.

With panel data, as we use, the model can be written as

$$Y_{it} = X_{it}{}'\beta + Z_{it}{}'\gamma + c_i + u_{it} = X_{it}{}'\beta + Z_{it}{}'\gamma + \varepsilon_{it} \qquad (4)$$

where i are the units (= 1, …., M), t is time (= 1, …, T), and X_{it} is the binary indicator that equals unity if district i participates in the program at time t. Z_{it} are the district specific other covariates; and the error ε_{it} is defined to have a time invariant component (c_i) and a time varying component (u_{it}) such that $\varepsilon_{it} = c_i + u_{it}$. The coefficient β is the treatment effect.

We note that specification choice for functional form is particularly important in this context. Following the study design, for the initial estimations, we present results from the Poisson specification, because the dependent variable, number of deaths in the i^{th} district in the year t, is a non-negative count variable.[9] Alternative linear specifications, paralleling the exposition above, are then presented for robustness checks.

In contrast to a linear specification, with the Poisson model the equation estimated is the mean or expected value function of Y_{it}, i.e $E(Y_{it} \mid X_{it}) = \mu_{it}$, The specification for μ_{it} with panel data depends on the estimation method. With pooled Poisson estimates, $\mu_{it} = \exp(X_{it}'\beta) = \exp(Y_{it})$ in the present case; the coefficients have the same interpretation as in case of cross section data[10] and marginal effects can be measured. However, these estimates ignore group (district) heterogeneity, which can be addressed through the panel properties of the data. Both fixed and random effect estimates take into account the group heterogeneity explicitly. If these estimators are used, then the group effect enters into the mean function and it is written as $\mu_{it} = E(Y_{it} \mid c_i , X_{it}) = c_i \exp\{X_{it}'\beta)\} = \exp\{(\ln c_i + X_{it}'\beta)\} = \exp\{(\ln c_i + Y_{it})\}$, where Y_{it} is as in equation (4) above in general and takes the specific form of (5) below; and c_i is the group effect.[11] Thus the coefficients have same basic interpretation as in the case of pooled Poisson estimates. The program effects are captured by the coefficients of the interaction variable, but the marginal effects of the variables cannot be measured as the group effects or the c_i terms are not determined.

The difference-in-difference estimation assumption is that the treatment and comparison districts would follow the same trend in the absence of the program. If this assumption is not satisfied, then the estimate of the treatment effect will be biased in general.

[9] The models were estimated in Stata with xtpoisson commands. On a priori grounds, Poisson regressions were the first ones estimated for this project, and are also presented first for this reason; test statistics support this choice as described in Section 6.

[10] That is, they reflect the percentage change in the mean value due to the j^{th} variable, i.e., $\beta_j = \frac{\partial[\ln \mu_{it}]}{\partial X_{it,j}}$.

[11] These are of course treated differently with random and fixed effect.

Thus, we augment these basic specifications by controlling for a set of observables that could be important for selection of districts into the program, specifically those that might affect the original decision to include the district in the program, and the outcome variables such as reduced mortality. Including these control variables addresses possible selection on observables, making it more plausible that the counterfactual trend for the DRM districts is well represented by the actual trend in the comparison districts. Using panel data, a DID approach with controls and estimates the following equation (5).

$$\begin{aligned} Y_{it} &= \beta_0 + \beta_1 drm\_period + \beta_2 drm\_district + \beta_3 drm\_periodXdrm\_district + \beta_4 T + \\ &\beta_5 population_{it} + \beta_6 DNDP_{it} + \beta_7 PCI_{it} + \beta_8 Coastal\_dummy + \beta_9 Forest\_cover_{it} + \\ &\beta_{10} share\_agri\_labor_{it} + \beta_{11} share\_other\_worker_{it} + \beta_{12} share\_marginal\_worker_{it} + \\ &+ \beta_{13} HWD_{it} + \beta_{14} SHWD_{it} + \beta_{15} Severity\_dummy_{it} + \\ &\beta_{16} 40degree\_more_{it} + \varepsilon_{it} \end{aligned} \tag{5}$$

The variables are defined as follows:

Y: Number of human deaths for the ith district (1, .. , 30) in the t[th] y ear (1998, 1999, … , 2010),

Drm_period: the treatment period dummy (=1 for 2003 and onwards for the 12 districts where DRM program started in 2002 and =1 for 2004 and onwards for 4 districts where program started in 2003)[12],

Drm_district: the treatment group dummy (=1 for a DRM district if the entire district was covered by the program; equaling the ratio of number of blocks covered by the program to the total number of blocks of the district if only a subset of blocks have been covered by the program, and = 0 for rest of the districts in which no blocks are covered)

T: time trend (to account for the physiological adaptation of human body to high temperature and other time variant changes),

Population: ith district population in the year t,

*DNDP:*ith district net domestic product in the year t (account for growth as well as level of urbanization),

PCI: Per capita income of the ith district in year t

Coastal_dummy: Dummy variable for the district adjoining the seacoast (controlling for the level of humidity and other factors); the state has 7 such districts.

Forest_cover: Area (sq km) of the district under forest cover (presence of vegetation is likely to reduce the heat impact)

Share_agri_labour: Percentage of population working as agricultural labor (poorer and likely to be more exposed)

Share_other_worker: Percentage of population working in occupations other than agriculture and household industries (including teachers, barbers, washer men, priests, other

[12] A one-year lag was used between the signing of the documents and actual implementation of the policy at the level of the public as per the suggestion of OSDMA officials. Moreover, information on the campaign media was available only from 2003.

industrial workers (likely to be better-off, but jobs requiring going out of the house, leading to exposure)

Share_marginal_workers: Percentage of population not having any regular job (poorer people; chance to get a job depends on availability and may not be obtained during peak heat period)

Awareness_mediums: Number of media used in the year t to generate awareness (varies from 1 to 10 in different years),

HWD: Number of heat wave days as defined by IMD,

SHWD: Number of severe heat wave days as defined by IMD,

Excessive_hot_year: Dummy variable for the year t when the temperature deviation has been more than 10^{o} C (exceptionally hot years) in the ith district as per the temperature recorded by the nearest weather station or by the one falling in its agro-climatic zone,

40degree_more: Total number of days in the year t when the temperature has crossed 40^{o}C in the ith district (too many days with marginally more than 40^{o}C temperature may not be captured by heat wave days, but may cause heat stress due to continuous high temperature),

ε: The error term.

When media exposure is taken into account, equation (5) is augmented with four additional variables: the AMI and its interaction with DRM grassroots program period, grassroots district, and their product; that is, *awareness_media, awareness_mediaXdrm_period, awareness_mediaXdrm_district, and awareness_mediaXdrm_periodXdrm_district.*

As mentioned earlier, the DRM program was introduced in response to cyclone, earthquake and flooding events; heat wave risks were not a factor. One potential source of endogenous selection into treatment could be problematic if there is significant correlation between occurrences of heat waves, and of the disasters that were taken into account to prepare the housing risk table and the selection of DRM districts. If there is significant correlation, then there could be different underlying trends between treatment (DRM) and control districts, which could threaten the DID strategy. To pursue this, the coefficients of correlation between the four measures of heat waves and, separately, occurrences of flood, heavy rains, and cyclones[13] were calculated for DRM, non-DRM and all districts separately.

[13] There was no report of any loss due to earthquakes in the state in between 1998 to 2010 or in the recent past. We examine correlations with heavy rains (which do not qualify as a disaster) as an additional strategy to check for the presence of humidity that aggravates heat wave impacts and also might be associated with cyclones.

These were found insignificant except for SHWD. However, SHWD was significantly correlated only with occurrences of flood, (r = -0.15 for all the districts and = -0.29 for the DRM districts). In sum, we conclude that heat wave occurrences are not correlated with flood and cyclone occurrences to a degree that would raise systematic concerns about selection bias from this source.[14]

We note that income, wealth, and occupation may directly affect the ability of households to adapt. Moreover, if there were any nonrandom placement of the program with respect to heat wave incidence (not otherwise captured with the differencing strategies), this also might be correlated with income. We control for per capita income primarily for these reasons; note, however, that a priori it is not possible to say whether there could be negative selection via government intention to assist the more vulnerable, or positive selection via greater political influence of the affluent - or indeed if their opposite effects might essentially cancel each other out. We further control for district level net domestic product and population primarily to mop up its potential association with selection such as greater political influence of districts with larger economies and populations (which may also be correlated with other factors affecting capabilities to adapt). We also control for the percentage of three different types of workers who are likely to be more exposed to extreme heat as described above.[15] The added covariates should also improve precision of the DID (and DDD) results. Taken together, these approaches help to address remaining concerns

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[14] We do not claim this as entirely definitive evidence. In particular, we cannot rule out that the weather or other data are insufficiently precise for these tests to be definitive. As a result, we have a small remaining concern that DRM districts may not be strictly exogenous with respect to heat waves in that high humidity worsens heat wave conditions and also may be associated with storm conditions; however the correlation between floods and severe heat waves is actually negative. We also explored the use of the difference-in-difference matching (DIDM) estimator that combines a DID approach with the matching technique to eliminate time invariant unobserved heterogeneity (Heckman et. al., 1998, Todd, 2007); but this estimation approach could not be implemented as the sample size is small and number of observations in each bin for the propensity score was small and with a highly uneven distribution of treatment and control units. The use of DIDM and other matching estimators will be valuable to consider in future research. With the available data, we are unable to rule out that estimated treatment effects may be contaminated by selection on unobservables that vary over time.

[15] Indeed, the program explicitly notes on its web site that poorer and more exposed workers in Odisha are more vulnerable to heat waves and less able to expend resources to reduce their risks (OSDMA 2010).

regarding biased estimates due to endogenous selection of districts into the DRM program, so that the impact coefficients more plausibly provide the Average Treatment Effect (ATE) of being assigned to the group of interest.

5. Data Sources and Descriptive Statistics

Data from multiple sources have been used to estimate the models. Data on human casualties was collected from OSDMA and, prior to the formation of OSDMA, from the Senior Relief Commissioner's office. Deaths refer to those verified and certified by a medical officer that the cause of death was heat stroke. These figures are also certified by the magistrate of the district where the death occurred as government pays compensation for such deaths.[16] Daily maximum temperature data for the months of March, April, May and June (summer months for the state of Odisha) for the period 1998 to 2010 have been used in different measures of the heat wave index from the Indian Meteorology Department, Bhubaneswar. As mentioned above, criteria suggested by the IMD have been used to calculate heat wave and severe heat wave days at the district level. The state has 30 districts, but only 18 weather stations (see figure 1); and thus, the agro climatic division of the state was used to identify the weather station that can best capture the temperature of the district. For those districts having weather stations within their borders, temperature variables are simply taken from those recorded in the respective weather stations. Data for districts not having any weather station within its boundary were taken from the temperature recorded in the nearest weather station situated within its agro-climatic zone.

[16] The state has the provision to pay INR10, 000 as compensation for every heat wave casualty. Thus, every death, if reported to have been due to heat wave is examined and certified by a government appointed doctor. The paper analyses only such deaths as are certified by doctors to have been due to heat stress. A caveat is that we have no data to address whether this procedure may bias the reported statistics in either direction.

Information on other district-level disasters (in particular cyclones, floods, and earthquakes) was collected from IMD publications (Climatology of Odisha, yearly Natural Disaster Reports) and OSDMA publications.

Information on the media used for general improvement in heat wave awareness in different years was collected from the OSDMA office. Various media such as radio stations, television channels, print media and posters have been used and for different duration in different years; due to data constraints, an "awareness media index" of these awareness efforts has been simply taken as the sum of the media used in a year.[17] The same value of the awareness media index is used for both DRM and non-DRM districts as the channels and the newspapers used are viewed and read statewide depending on affordability. The DRM local awareness campaign is a separate, grass-roots activity targeted for those unlikely to receive significant exposure to these modern media.

Population figures for non-census years were interpolated from the 1991, 2001 and 2011 census data using district decadal growth rates. However, shares of worker categories are based on 1991 and 2001 census values (as the figures pertaining to 2011 census are yet to be published). District level net domestic product data were collected from Planning Commission of India publications. These figures were available only for the years 1992-93 to 2004-05; for years beyond 2004-05, extrapolated values have been used. Forest cover was collected from Forest Survey of India reports; these figures are available for alternating years and the simple arithmetic average of the preceding and following years was used for the missing values.

The panel data provides 13 years of observations on 30 districts, of which 16 districts are part of the DRM program and the remaining 14 are non-DRM. Of the 13 years, five are

[17] No special weighting has been given to the duration or type of media; although impacts plausibly differ in magnitude some of the details are not available in the data, and the choice of weights would have been conjectural.

pre-DRM and eight are post DRM years. Summary statistics of the variables are reported in Table 4.

TABLE 4 ABOUT HERE

The summary statistics show the average death per year per district to be little different between the DRM and non-DRM districts (7.97 and 7.50 respectively), but the non-DRM districts to have been suffering from more severe heat attacks, the average value of all the measures of heat wave being higher for these districts. Non-DRM districts are less populous and the average district net domestic product is nearly half of that of DRM districts, but incomes do not seem to vary much between the two groups of districts. There is narrow difference between the average per capita incomes of DRM districts compared to non-DRM ones. Comparison of different categories of workers also shows these districts not to be very different so far as occupational structure is concerned. Average forest cover in non-DRM districts is marginally higher than that of DRM districts. The striking difference regards the coastal districts; not a single coastal district is non-DRM, as cyclone occurrences were the main criteria for the selection of DRM districts.[18]

6. Results

In this section, we present econometric results. Different specifications of the basic form of equation 5 are estimated. In section 6.1 we examine baseline results. In section 6.2 we consider an approach to capture impacts of the statewide media campaign and its possible interactions with the grassroots campaign. We describe the strengths and weakness of these specifications. In each case, we begin by presenting baseline Poisson results on program impact, followed by robustness checks.

[18] We also control for potentially confounding variables. Of course, we still cannot rule out that the differencing strategies and controls may not completely compensate for some of the divergent characteristics of the districts, particularly unobserved time-variant heterogeneity.

6.1. Double Difference Poisson Results for the DRM Program Impacts.

Equation 5 has been estimated with both random effects and district fixed effects, as well as in a pooled regression specification. As mentioned before, Poisson estimates are used for the baseline estimates.[19]

In the specification in Table 5, the program impact is measured from the interaction of DRM_period and DRM_district; results suggest the DRM program had a statistically significant impact on reducing heat related deaths in Odisha. Both random effect and fixed effect estimates (as well as pooled regressions) give similar results on DRM program impacts, and indicate a positive and significant effect on reducing mortality from heat stroke.

TABLE 5 ABOUT HERE

The other coefficients are of only secondary interest; as described above the corresponding variables primarily serve as controls to make the DID estimates more credible. However, their signs may be given relatively straightforward interpretations. The heat wave measures have positive and significant coefficients, excepting the number of heat wave days, which is positive and insignificant. The time trend has a negative and significant coefficient, consistent with the hypothesis that people acclimate with greater experience with living with higher temperatures.[20] The more the forest-cover in a district, the fewer the heat stroke deaths. The district net domestic product has a positive and significant coefficient, suggesting that other things equal districts with higher domestic product are more vulnerable to heat

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[19] The dependent variable is the number of deaths in the i^{th} district in the year t; this is a non-negative count variable. Heat stroke death cases are low probability events and with the non-negative count nature of the dependent variable use of a Poisson specification is indicated (Green 2000). A Box-Cox fitting of the variables produced a theta value of -0.06, which is close to zero, supporting a log linear model for the data. To avoid the problems of zero death cases, we added 0.1 to the dependent variable before running Box-Cox. Despite this, it may still be a concern that results are not robust with respect to using a linear per capita deaths specification. This may be seen as an additional motivation for focusing on the triple difference specification (see below). The models were estimated in Stata with xtpoisson commands. We also ran pooled Poisson regressions.

[20] This variable could also be capturing some of the effects of the introduction of other activities such as changing school and bus timing, opening *Jalchhatra* (free distribution of water) by the state government, or newspaper reporting on heat wave deaths leading to precautionary behavior. It may also capture part of the impact of change in wealth over time.

stress. This could reflect increased urbanization leading to congestion and other risk-heightening conditions; supporting evidence for this interpretation is found in the positive and significant coefficient for the population percentage working as other workers in different districts. More travel time to work (as well as working in a more exposed environment) suggests greater exposure to heat stress.[21]

We used the pooled Poisson DID coefficients to approximate the program effect in terms of lives saved (as marginal effects cannot be calculated using fixed effect Poisson estimates).[22] The pooled coefficients provide an estimate of a cumulative total of 155 lives saved (summed over DRM districts over the life of the program through 2010), associated with the awareness program in DRM districts. We stress, however, that we do not have the precision to take this numerical estimate in a literal way.[23] Indeed, impact results do not generalize from Poisson to linear specifications (results are summarized in Table 6); so at this stage caution is called for regarding program impact, and more research is needed.

TABLE 6 ABOUT HERE

6.2. Investigation of the Complementary Role of Awareness Media

We now examine results from incorporating the awareness media index (AMI) into the regression analysis. The AMI is introduced directly and also interacted with DRM_period and with DRM_district, and - for the coefficient of interest - with the product (interaction) of these latter two variables. The fixed effects estimation is also the preferred specification for the regression results presented in Table 7; we also present results from

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[21] This category of workers constitutes occupations other than agriculture and household industries (mostly services and other industrial activities)

[22] $ME_j = \partial E[Y_{it}]/\partial X_{it,j} = \alpha_i \exp(X'_{it}\beta)\beta_j$, while α_I is unknown (Trivedi, 2010); ME_j is the marginal effect of the jth variable.

[23] We further note that a limitation of the estimates is that under robust options and the DID specification, the program effects become insignificant for pooled Poisson and other fixed effect estimates.

random effects.[24] As with Table 5, a Poisson fixed effect specification is used for the baseline estimates because of the non-negative count nature of the dependent variable and supporting test statistics. With the negative and statistically significant coefficient on the triple interaction variable the results suggest that the effects of the grassroots and media programs are complementary.[25] Results are also consistent with the proposition that the grassroots awareness program can lead to reduced casualties.

TABLE 7 ABOUT HERE

Table 8 presents results from robustness checks with respect to alternative linear specifications. All six specifications have a negative sign on the triple interaction variable, consistent with a complementary program impact in reducing mortality; but we emphasize that in each of these latter cases the impact coefficient result is statistically insignificant.

TABLE 8 ABOUT HERE

For our final specification test for the results in Table 7, we consider that the awareness programs may be expected to have significant impact on reducing heat stroke mortality primarily during periods experiencing substantial heat waves. For some districts and periods there were essentially no heat wave conditions. Accordingly, we examine three restricted samples corresponding to our three applicable heat wave incidence measures:

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[24] In general, the fixed effect results will be the preferred estimates as the sample is not a random draw of districts (even though heat waves was not a factor in selection), and these estimates help control for the unobserved heterogeneity across the districts. Secondly, the number of panels in the data is larger than the number of years (in our case 30 > 13) (Wooldridge 2002). The data set also displays the within variation to be much higher than the between variation for most of the variables, which calls for a fixed effect model.

[25] A causal interpretation relies on the assumptions spelled out above. One potential limitation is that the index captures some aggregative impact, whereas the more appropriate method will probably be to develop an awareness media index for each day and capture its impact by analyzing the daily occurrences of deaths. In future work it will also be useful to take account of the cumulative knowledge generated by the ongoing campaign. The main activity to control heat stroke has been the awareness campaign; and it needs to be defined carefully to capture the full impact of the intensive DRM interventions on heat waves.

districts and years with five or more days of temperatures exceeding 40 degrees Centigrade; districts and years with at least one heat wave day; and districts and years with at least one severe heat wave day. We may think of the exercise as a restriction of the treatment effect study only to cases in which treatment may be needed. Alternatively, we may view these tests as an exploration of possible impact at a future point in time in which heat waves (in an absolute sense) become more pervasive. Finally, for regressions using the first two heat wave definitions above, we may think of the exercise as eliminating outliers (with a reduction of sample size from 390 respectively to 326 and 330).

Table 9 presents the resulting fixed effect Poisson estimates (results were similar for random effects) for the triple interaction coefficient of interest, for the samples restricted by the corresponding heat wave indicator levels (results for other variables are not shown, but are available from the authors). Coefficients are -1.260, -0.906, and -1.004 respectively with corresponding significance levels of 5%, 15%, and 10%. These coefficients are very similar in magnitude but somewhat greater in significance level compared to the full sample estimate given in Table 8 (with -0.904, significant at the 15% level).

TABLE 9 ABOUT HERE

Again, the fixed effect Poisson results in Tables 7 and 9 highlight the potential interaction between two distinct programs – the main grassroots awareness campaigns implemented only in the DRM districts on the one hand, and the general media efforts statewide on the other hand. The result is the product between DRM districts, DRM periods, and number of media used in the statewide information campaigns, that is, DRM_periodXDRM_districtXAwareness_Mediums. Thus, speaking loosely, we interact the grassroots program impact with the concurrent media program impact. Information may first be received via the newspaper (conveyed verbally in the case when household members are illiterate), or seen on television at a village center, and then may be reinforced by visits of grassroots program officers. Similarly, people may be reminded of the in-depth information they received from the village visits when hearing a brief message on the radio. Thus, the two programs may be mutually reinforcing. For some individuals or communities, mass media may carry more credibility and the grassroots campaign serves as a reminder; in other communities the reverse may be true. We find a significant negative coefficient, indicating that the two approaches may be complementary as awareness strategies in helping to avert mortality. But again, we stress that the results are no longer significant in the linear specifications (although they are of the same sign), and more research is needed.

More generally, results involving the awareness media measure should be interpreted with caution at this stage. Lacking more detailed data, the AMI has been defined as the sum of the different forms of awareness media used throughout the year. This weights all media equally, and does not allow for variation in intensity in any one medium. In addition, our heat wave measures do not capture all of the heat wave effects that may threaten heat stroke. For example, ideally we might like to have a measure capturing the number of consecutive hours in which temperature exceeds a high threshold, but such data are not available. The program may respond to periods in which this type of occurrence is more frequent by using more media channels to publicize heat wave precautions. As such, it is possible that the AMI could capture some of the heat wave impact itself in addition to the impact of the program itself. This interpretation is consistent with the positive sign on AMI in Table 7. Still, the possibility of interaction effects across programs is highlighted by these results, and this warrants the further research that will be needed before unambiguous policy implications can be drawn in this case.

7. Concluding Remarks

The results in this paper are consistent with the view that heat wave awareness campaigns can significantly reduce heat stroke deaths during heat waves in a developing country context. Further research will be highly valuable. More work is needed on the effectiveness of different awareness media in changing peoples' behavior per se. Research is also needed to address whether there are specific limits to compliance with the campaign's dos and don'ts, for example due to financial, social or cultural barriers.

In this paper we have addressed the hypothesis that awareness programs alter behavior indirectly, by measuring their impact on heat stroke deaths. Behavioral change has essentially been treated as a black box. In future research, it will be valuable to directly measure the impact of awareness programs on the amount of specific kinds of awareness of factual knowledge, and on the specific behavioral responses to this awareness, to complete our understanding of linkages. Special-purpose household level data will need to be collected for future research (possibly as additions to other planned surveys), including awareness and behavioral questions. Such household level data can also provide information on other heat wave costs such as loss of work-time or school absences, and potentially reductions of these costs as an impact of the program. Moreover, in future research it will be valuable to complement data on mortality with reliable information on hospitalization cases and other relevant public health data. Another important data consideration is that improved heat wave awareness may have increased the accuracy of family reporting of heat stroke as a cause of death. This could lead to the underestimation of program impact, or even misleading regression coefficients suggesting that the program "causes" heat stroke. There may be an analogy with the otherwise paradoxical finding in some of the developing country literature that a health training program sometimes leads to higher reported cases of disease, even when the actual incidence of the disease is reduced.

This paper demonstrates the importance and potentially substantial impact of awareness programs as a way of facilitating household adaptation to adverse climate change. We would thus conclude with a plea for more comprehensive research, under exacting experimental conditions. In particular, for the study of grassroots initiatives such as the DRM program, we recommend use of a district or sub-district level randomized control trial (RCT). (If the program proves effective, then other districts can be added to the program in a future year). If an RCT does not prove feasible, development of a sample size allowing the use of DIDM or other matching estimators, or instrumental variables techniques, will be valuable to consider in future research. Generally, whether or not an RCT study is feasible, in future research significant strides can be made with improved data availability.

Thus for future research we recommend: collecting data at the household level, including not just deaths but other impacts such as hospitalizations and days lost from work; recording characteristics of those who learned from the awareness media campaigns and from the DRM campaigns; generating measures of actual learned knowledge (such as a series of questions on a household survey), allowing for accumulated knowledge from repeated exposure to health messages over time; measuring the degree to which households complied with what they learned, and reasons for noncompliance (such as cost); designing data collection to make it possible to distinguish impacts of which media were noticed and facilitated learning; ensuring careful and accurate reporting on deaths; using daily data; using additional data emphasizing the extent of exposure such as number of consecutive hours over specified high temperatures such as 44C; and collecting details on program costs.

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Table 1: IMD Temperature Ranges for Heat Wave Designations.

(i)	The normal temperature is **< 40° C**. Any increase from the above normal temperature is called a heat wave.
	+ (5 or 6) ° C – Moderate heat wave or simply Heat Wave Days (HWD)
	+**7° C** or more – Severe Heat Wave Day (SHWD)
(ii)	The normal temperature is **≥ 40° C**. Any increase from the above normal temperature is called heat wave.
	+ (3 or 4) ° C – Moderate Heat Wave (or HWD)
	+**5° C** or more – Severe Heat Wave Day (SHWD)
(iii)	If the maximum temperature of any place continues to be **45° C** consecutively for two days (**40° C** for coastal areas)**,** it is also called a heat wave condition or HWD

Table 2: Logic Model for Awareness Campaign

Program Input	Program Output	Program Outcome	Program Impacts
A: Precautions to avoid heat stroke: • Eat enough food and drink enough water before going out. • Consume different types of liquids like water rice, *belapana*, *sarbat* (locally available sweet drinks), curd water, ORT solution, watermelon, cucumber etc. • Carry required amount of water if going out. • Wear light colored cotton cloths • Either avoiding travel during noon or use umbrella, cap, turban, wet towel, shoes and if possible, goggles when walking under sun. • If too hot, reschedule your work so as to work more during morning and afternoon and less during noon. • Remain alert for children, elderly, fat people, pregnant women and persons with high blood pressure, diabetes or epilepsy. • Do not give water if the person faints due to heat attack. • Do not take alcoholic drinks. • Please consult doctor if feeling uncomfortable due to heat. B: Symptoms of heat stroke • Feeling of tiredness. • Headache, body ache and vomiting. • Dry throat. • Blink vision. • Abnormal increase in body temperature. • Increased palpitation • Being unconscious Media used: Television, Newspapers, Radio, Pamphlets, Panchayat Meetings and Volunteers	• Awareness on heat waves • Being able to recognize symptoms • Awareness of consequences if do not follow the precautions	• Change in dietary habits • Change in clothing • Carry umbrellas or cover head with wet cloths, caps etc if traveling during noon. • Less exposure during noon or change in work plans. • Able to recognize if the person is suffering from heat attack • Remain alert and consult doctor if needed.	• Less mortality • Less hospitalization • Less loss of work-time.
Other Factors impacting output and outcome: • Climatic factors like temperature, humidity etc. • Economic well being • Relative alertness • Other defensive measures (use of air conditioner, water coolers, presence of medical facilities etc.) • Natural adaptation (vegetation cover, water bodies or wetland area)			

Table 3: Yearly estimates of number of heat wave days,[26] number of human casualties in DRM and non-DRM districts, and the state as a whole

Year	Heat Wave Days	Deaths in DRM districts	Deaths in non-DRM districts	Deaths in the state
1983	1	NA	NA	3
1987	2	NA	NA	1
1988	1	NA	NA	22
1989	1	NA	NA	1
1995	1	NA	NA	9
1996	2	NA	NA	3
1998	28	1124	918	2042
1999	25	57	34	91
2000	18	8	21	29
2001	12	21	4	25
2002	21	29	12	41
2003	28	48	20	67
2004	8	35	10	41
2005	29	161	75	234
2006	4	17	4	21
2007	8	28	19	47
2008	12	41	27	69
2009	29	63	22	85
2010	38	25	35	61

Source: Indian Meteorological Department, Bhubaneswar; and Odisha State Disaster Mitigation Authority (OSDMA, 2006)

[26] Defined as days with temperature deviation more than 5^0C above the normal.

Table 4: Summary Statistics

	DRM districts (n= 208)		**Non_DRM districts (n= 182)**	
Variables	Mean (std error)	Min (Max)	Mean (std error)	Min (Max)
Heatstroke_death	7.971 (26.788)	0 (254)	7.505 (32.795)	0 (367)
40deg_more	15.822 (15.829)	0 (77)	27.604 (20.189)	0 (77)
HWD	5.678 (6.568)	0 (38)	8.709 (7.768)	0 (38)
SHWD	3.072 (4.453)	0 (19)	4.540 (5.584)	0 (25)
Severity_dummy	0.149 (0.357)	0 (1)	0.143 (0.356)	0 (1)
Population	1568078 (660186)	500374 (3375738)	892892 (462323)	254169 (1979572)
DNDP	242658 (174255)	39193 (955390)	129040 (94361)	24588 (585983)
Per capita Income	18266 (11368)	6412.57 (78333)	14851 (8581)	4283 (58257)
Coastal dummy	0.438 (0.497)	0 (1)	0 (0)	0 (0)
Forest_cover	1427 (1361)	13 (4132)	1817 (1368)	276 (5484)
Awareness_media	5.385 (7.937)	0 (23)	5.385 (7.930)	0 (23)
Share_agri_labour	0.113 (0.042)	0.048 (0.198)	0.150 (0.041)	0.081 (0.228)
Share_other_worker	0.113 (0.033)	0.074 (0.218)	0.088 (0.029)	0.059 (0.161)
Share_marginal_worker	0.107 (0.044)	0.048 (0.182)	0.143 (0.033)	0.082 (0.208)

Table 5: Disaster Risk Management Project impact on heat stroke death
Random and Fixed Effect Poisson Estimates
(Dependent variable: number of deaths in a district in a year due to heat stroke)

Explanatory Variables	District fixed effect Poisson estimates	Random effect Poisson estimates
DRM_period	1.842*** (0.178)	2.015*** (0.165)
DRM_district	----------	-1.091 (1.248)
DRM_periodXDRM_district	-0.536 ***(0.128)	-0.683*** (0.117)
Time_Trend	-0.524*** (0.029)	-0.590 *** (0.027)
Population	-0.111 (0.079)	0.104 ** (0.055)
District Net Domestic Product	0.225 *** (0.083)	0.152 ** (0.074)
Per Capita Income	0.012 (0.011)	0.017* (0.009)
Dummy_ Coastal Districts	----------	-0.702 (1.513)
Forest_cover	-0.004*** (0.001)	-0.002*** (0.001)
Population_share_agri_labor	41.299 (118.053)	-36.473 (33.469)
Population_share_other_worker	61.911 *** (21.886)	51.408*** (14.669)
Population_share_marginal_worker	-46.441 (125.713)	60.152 (40.542)
Number_HeatWaveDays	0.001 (0.006)	0.003 (0.007)
Number_SevereHeatWaveDays	0.067 *** (0.007)	0.057*** (0.007)
Dummy_Excessive_Hot_Year	0.716*** (0.065)	0.712*** (0.065)
Days with more than 40C degrees temperature	0.044*** (0.003)	0.048*** (0.003)
Constant	-----------	-2.668 (2.193)
/lnalpha	------------	1.034 (0.321)
alpha	-----------	2.814 (0.904)
Wald Chi2	Wald Chi2 (14)=5373.24, Pro>Chi2=0.00	Wald Chi2 (16)=5387.89, Pro>Chi2=0.00
Log likelihood	-1066.723	-1263.827
Log likelihood-ratio test of alpha=0	---------	Chibar2 (01)=1288.89, Pro>= chibar2=0.00
Number of observations	390 (groups=30, Observations per group=13)	390 (groups=30, Observations per group=13)

Note: Figures in parenthesis are standard errors. ***, **, and * implies level of significance being 1%, 5% and 10% respectively.

Table 6: Sign and significance of program effect with alternate DID specifications

Estimates used	Dep. variable = Total deaths		Dep. Variable = Per capita deaths	
	Coefficient value of *drm_pdXdrm_dist*		Coefficient value of *drm_pdXdrm_dist*	
	Fixed effect	Random effect	Fixed effect	Random effect
Poisson panel	-0.536** (0.128)	-0.683 ** (0.117)	--------	-------
Linear panel	6.554 (6.250)	6.404 (5.880)	0.000011*(0.000006)	0.000015**(0.000006)
Pooled Poisson	-0.362*** (0.101)		------------	
Pooled linear	6.404 (5.880)		0.000015**(0.000006)	

Note: Figures in parenthesis are standard errors. ***, **, and * implies level of significance being 1%, 5% and 10% respectively.

Table 7: Difference-in-Difference-in-Difference with Awareness_media. Fixed and random effect Poisson estimates.

Explanatory Variables	District fixed effect Poisson estimates	Random effect Poisson estimates
DRM_period	2.265*** (0.199)	2.522*** (0.179)
DRM_district	------------	-0.790 (0.909)
DRM_periodXDRM_district	-0.362** (0.154)	-0.553*** (0.137)
Awareness_Media	1.304** (0.517)	1.661*** (0.519)
Awareness_mediaXDRM_pd	-1.238*** (0.517)	-1.593*** (0.519)
Awareness_mediaXDRM_dist	0.889 (0.601)	0.546 (0.614)
DRM_periodXDRM_districtXAwareness _Media	-0.904+ (0.601)	-0.548 (0.614)
Time_Trend	-0.661*** (0.034)	-0.733*** (0.029)
Population	-0.007 (0.083)	0.144*** (0.047)
District_Net Domestic Product	0.151* (0.085)	0.136* (0.075)
Per Capita Income	0.012 (0.011)	0.013 (0.010)
Dummy_ Coastal Districts	------------	-1.207 (1.197)
Forest_cover	-0.004*** (0.001)	-0.001*** (0.0004)
Population_share_agri_labor	-74.647 (119.577)	-27.485 (24.199)
Population_share_other_worker	52.983*** (23.448)	34.246** (13.897)
Population_share_marginal_worker	75.501 (126.779)	32.992 (31.780)
Number_HeatWaveDays	0.002 (0.007)	0.0042 (0.007)
Number_SevereHeatWaveDays	0.073*** (0.008)	0.059*** (0.008)
Dummy_Excessive_Hot_Year	0.610*** (0.069)	0.595*** (0.068)
Number_Days with more than 40degree temperature	0.038*** (0.003)	0.043*** (0.003)
Constant	----------	-0.127 (2.048)
/lnalpha	------------	0.652 (0.367)
alpha	-------------	1.920 (0.705)
Wald Chi2	Waldchi2 (18) =5458.05, Pro>Chi2=0.00	Waldchi2 (20)= 5538.66, Pro>Chi2=0.00
Log likelihood	-1031.492	-1222.166
Log likelihood-ratio test of alpha=0	------------	Chibar2(01)=1132.29, Pro>Chibar2=0.00
Number of observations	390 (groups=30, Observations per group=13)	390 (groups=30, Observations per group=13)

Note: Figures in parenthesis are standard errors. ***, **, *, and + implies level of significance being 1%, 5%, 10%, and 15% respectively.

Table 8. Sign and significance of Alternate Specifications for Awareness Media and DRM interaction program effect.

Estimates used	Dep. variable = Total deaths		Dep. Variable = Per capita deaths	
	Coefficient value of triple interaction term i.e. awareness_mediaX*drm_pdXdrm_dist*		Coefficient value of triple interaction term i.e. awareness_mediaX*drm_pdXdrm_dist*	
	Fixed effect	Random effect	Fixed effect	Random effect
Poisson panel	-0.904[+] (0.601)	-0.548 (0.614)	------------	-----------
Linear panel	-7.908 (27.218)	-7.464 (26.097)	-0.0000083 (0.000026)	-0.000014 (0.000026)
Pooled Poisson	-1.134** (0.597)		--------------	
Pooled linear	-7.464 (26.097)		-0.000014 (0.000026)	

Note: Figures in parenthesis are standard errors. **, and + imply levels of significance of 5% and 15% respectively

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Table 9: Difference-in-Difference-in-Difference with Grassroots and Awareness Media Programs. Poisson Fixed Effect Estimates for Heat Wave Affected Periods

Explanatory Variables	Districts and years with 5 or more days of temperatures exceeding 40 degrees (N=326)	Districts and years with at least one heat wave day (HWD>1) (N=330)	Districts and years with at least one severe heat wave day (SHWD>1) (N= 226)
DRM_periodXDRM_districtXAwareness_Media	-1.26 (0.603)**	-0.906 (0.594)+	-1.004 (0.587)*

Note: Figures in parenthesis are standard errors. **, *, and + imply levels of significance of 5%, 10%, and 15% respectively.

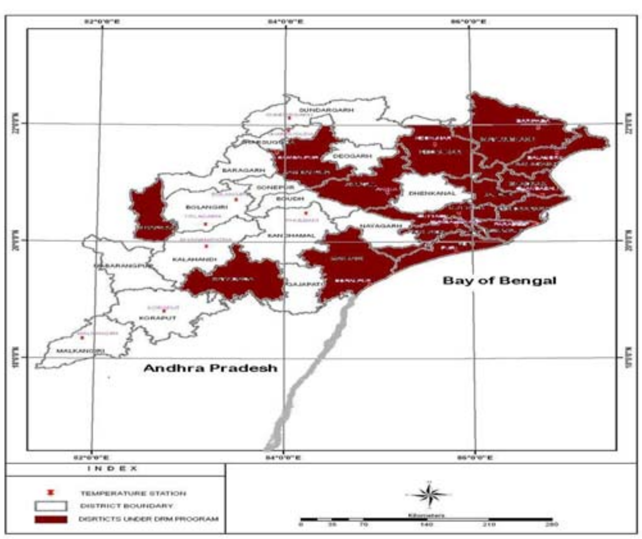

Figure 1: Location of districts covered under the Disaster Risk Management program in Odisha.

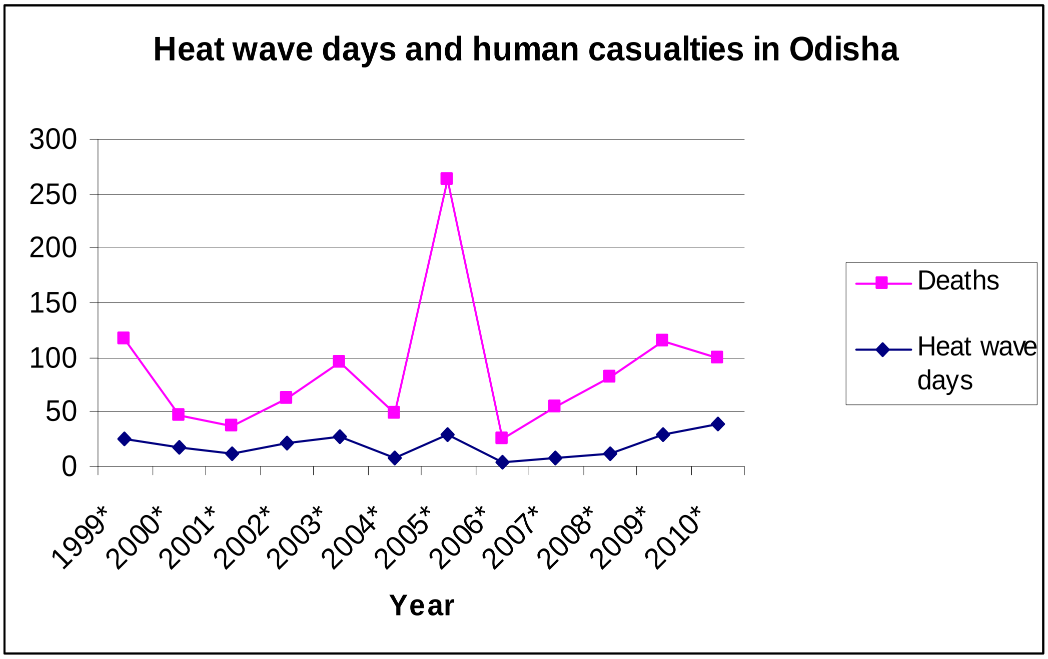

Figure 2: Number of Heat Wave Days and Human Casualties in Odisha

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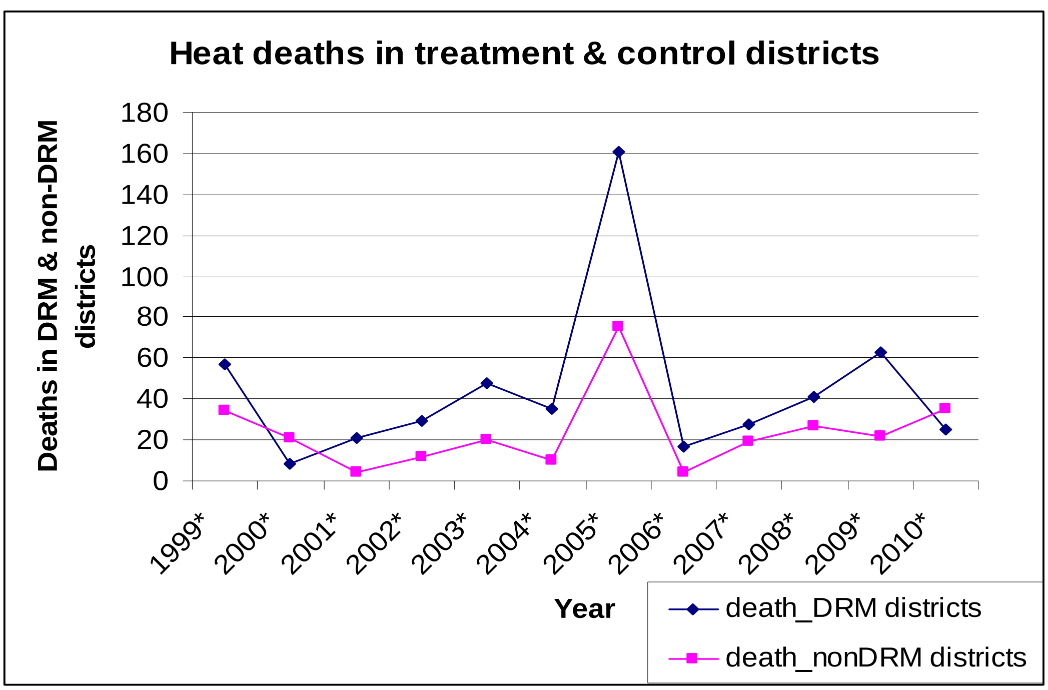

Figure 3: Heat Wave Related Deaths in DRM program districts and non-DRM Districts