Heat Waves Decrease Labour Supply: Evidence on low-income urban workers in weather-exposed occupations

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ABSTRACT

In recent years, frequent heat waves in developing economies have seriously impacted workers in exposed occupations, especially in urban areas where the work pattern has little seasonal variation. The paper identifies the coping strategies and labour reallocation of very poor urban workers on a heat wave day compared to a normal summer day by surveying workers who work in the open. Findings show workers to work one or two hours less, spend less time at home, and rest one-and-a-half or two hours longer on a heat wave day than on a normal summer day. They resort to other measures like eating food with high water content, covering the roof of their living space with paddy straw, and using fans for longer hours to adapt to frequent heat waves. In the heat wave month, their routine expenditure increases by Rs 600 (approximately US$10) on average. This extra expenditure constitutes some 7–35 per cent of the monthly income of the workers as most of them earn between Rs 20,000 and Rs 100, 000 annually. Nearly 80 per cent of workers surveyed reported to have suffered some form of heat attack as these adaptations are inadequate and they cannot afford more. Seemingly Unrelated Regression Estimates show only natives (not migrants) and those who have changed occupation are not suffering work time loss or are adapting better to heat waves.

Keywords: Adaptation, adaptation cost, climate change, heat waves, labour supply, urban workers

JEL classification: J22, J28, Q54, Q58

1 INTRODUCTION

A heat wave is generally defined as an extended period of hot and humid weather, although there is no universal definition of the term, and is measured relative to the normal weather in the area (Meehl and Tebaldi 2004). Temperatures that people from a hot climate consider normal could be a heat wave in a cooler area if these are outside the normal climate pattern for that area (Robinson 2001). With climate change, the frequency and duration of heat waves have gone up, and the world is facing hot days, hot nights, and heat waves more frequently (IPCC 2007a).

The normal core temperature of the human body should be around 37^0 C, irrespective of the local climate. Heat waves are a health hazard as these slow the evaporation of perspiration, which cools the human body which, in turn, has to work harder to maintain the normal core body temperature. The human skin temperature is strongly regulated to remain at 35^0 C or below, under normal conditions (Sherwood and Huber 2009). The skin temperature has to be lower than the core body for metabolic heat to be transmitted to the skin. Sustained skin temperature above 35^0 C due to heat waves elevates the core body temperature, causes tiredness, nausea, body ache, etc., and thus, drastically reduces the person's work efficiency. If the heat wave is prolonged, and the core body temperature attains lethal values like 42–43° C, it can cause hyperthermia (death due to heat stress). This can happen with skin temperatures of 37–38° C even for acclimated and fit individuals if the heat wave is prolonged (Mehnert et al. 2000; Bynum et al. 1978). Thus, high temperatures can pose serious threats to all individuals, not necessarily only the old and unwell, and every possible effort should be made to maintain one's skin temperature at around 35^0 C.

1.1 Heat Waves and Labour Market

Based on experiences in different parts of the world, the Intergovernmental Panel on Climate Change (IPCC) predicts that the increase in the frequency or intensity of heat waves will increase the risk of mortality and morbidity for people in older age groups and among the urban poor (IPCC 2007b). There is seasonality in the rural work pattern, which may help rural workers by reducing their exposure to extreme heat during heat waves. But urban workers in secondary or tertiary sector activities—which are little influenced by weather, continue yearlong, and occur in poor and exposed environments—are more vulnerable to weather-related hazards like heat waves that continue for a few days. Other than the health implications on the working poor, such climatic changes may impact labour supply and productivity, particularly in labour-intensive activities.

There is much discussion in the labour economics literature on the labour–leisure model of unemployment. Using micro-data, the inter-temporal labour–leisure elasticity of substitution is estimated to be 0.2 (McCurdy 1981). Labour substitutes labour for leisure usually under external stress, like the presence of consumption commitments (for example, expenditure associated with children such as food and schooling). Short-run wage declines also motivate workers to increase short-run market hours to maintain cash flow (Dau Schmidt 1984). Now, the question arises: how is this income induced labour-leisure substitution affected by exogenous stress from heat waves, which may impose multiple constraints on the worker (like low-income due to less availability of work, low productivity due to heat effect on health, and high expenditure to adapt to extreme heat), etc.?

During the peak hot hours of a summer month (or on heat wave days), workers may withdraw from the market, or there may be fewer customers than usual; therefore, workers may earn less. To offset this loss, workers may like to work longer. But they may not be able to do this if the type of work provides little scope for such substitution,[1] or the thermal stress is strong enough to force him/her to rest more. Poor health has been found to reduce the capacity to work and has significant effects on wages (Currie and Madrian 1999). In this light, one may presume that heat-affected workers may not be able to work longer, and therefore might earn less. If income recovery is not possible, then the person is forced to remain at a lower level of well being. The loss of income and the additional expenditure, if any, to cope with the extreme heat can be a measure of private adaptation cost, especially for self-employed people or informal sector workers.

In some developing economies that have been experiencing heat waves and problems due to these, the organised sector has started taking adaptive measures, like changing work hours, working at night, providing shade or air-conditioned restrooms at the workplace, etc. The producer class bears these costs. Beyond these, workers make private arrangements for adaptation, which they pay for; this paper sheds some light on these.

South Asia is poised for faster growth, which involves large-scale construction and other exposure-based activities. If the present trends in temperature continue, this may involve large increases in private and public expenditure on adaptation, more provision of electricity, change in technology and work environment, etc. There is little research on these issues, though the research findings are likely to have strong policy implications.

1.2 Focus of the Study

In this paper, an attempt is made to find out the burden in terms of working hour loss, loss in family work time, and monetary cost incurred by low-income urban informal workers because of severe heat waves in two cities of Odisha—Bhubaneswar and Sambalpur. These two cities, along with most of the rest of the state, have been witnessing severe heat waves since 1998, and both the people and the government have been adopting various behavior to

[1] Certain activities are constrained to work within a certain time frame; for example, after the market shuts in the evening, petty traders cannot operate.

cope.[2] The heat wave management efforts of the government have had some success in terms of reducing mortality (Das and Smith 2012; Das 2014).

Most workers in this study who are exposed to heat are in a sense own-account enterprises in trade and services activities and who, unlike the service class, make their own independent labour allocation decision to maximise utility. Gronau (1987) provides an excellent review of studies on home production. Work at home is said to be a close substitute to work in the market in terms of the direct utility these activities generate. However, to understand these issues at the household level, time budget data are required, which this study attempts to collect through a questionnaire survey.

A primary survey based on purposive random sampling was pursued in these areas, where heat waves are regular, to get responses to the questionnaire. An attempt was made to find out if people suffered from any type of heat attack, changed their occupation because of heat, know of the government's heat wave awareness campaign, or their expenditure to cope with extreme hot temperature, etc. This is an exploratory study to find out the prevalence of the problem and its effect, if any, on labour supply. Therefore, most questions on labour allocation were phrased to be indirect, such as 'What do you do during 7 am to 9 am now (i.e. yesterday)?' and 'What do you do during 7 am to 9 am during a heat wave day?' The interview was conducted during peak summer (not heat wave), and the area had experienced a heat wave two weeks before, so incorrect reporting for heat wave days are supposedly low.

The sections below describe the survey, the descriptive statistics of the sample, and some theoretical literature on heat stress and labour supply issues. Subsequently, the model estimation is reported, and the results, which focus on the main findings. The last section concludes. The findings of the study may have wide policy implications given the global nature of the problem. This may as well help estimate the adaptation cost of some urban sectors to climate change.

2 SAMPLING

A purposive random sampling was conducted in Bhubaneswar and Sambalpur—two cities in Odisha affected repeatedly by heat waves—to collect information on adaptation to heat stress by poor urban workers. Ten types of urban workers from the low economic strata who work mostly in the open environment were chosen: vegetable/fruit sellers, cobbler, construction workers, coolies, rickshaw/trolley driver, auto rickshaw driver, taxi driver, mobile marketing and sales executive/ representative, vendors (mobile sellers of household items in trolleys), and owners of and workers in open-air retail enterprises (temporary stall owners).

[2] See, for example, the web page of the Odisha State Disaster Management Authority on heat waves at bit.ly/hwosdma and on their awareness campaign strategy at bit.ly/acsosdma, both accessed on 21 May 2014.

Secondly, the sample was taken from comparatively crowded and backward market areas of the cities, like areas close to railway station, bus stop etc., as workers in these areas are poorer. The sample was drawn randomly by picking 15 workers from each of these 10 categories. The questionnaire-based survey was conducted simultaneously in both cities in 2013 between 25 April and 20 May, when the temperature was around 42–43^0 C in Sambalpur and 40^0 C in Bhubaneswar, but it was not a heat wave period. It is considered a heat wave when the temperature is around 45^0 C in Sambalpur and 42^0 C in Bhubaneswar, which occurs many times during the summer and occurred around 15 April 2013 also. As reported before, answers to most of the questions on time allocation to different activities for a heat wave day were elicited through recall. The temperature was already high, and people were asked what they did in each two-hour period (7–9 am, 9–11 am, etc. going up to 9–11 pm) the previous day and what they do on a heat wave day (using the local name for heat waves); therefore, it is hoped that people's answers were mostly accurate.

2.1 Sample Features

The sample comprised of mainly middle-aged people and was dominated by men. In the study area, occupations chosen are usually undertaken by males, so the sample had just 6 per cent female respondents. The average age was 37 years, with 63 per cent of workers in the 20–40 year age group (Appendix Table A1). There was a mix of different education levels in the sample; most respondents were educated up to Class 10 (Figure 1). Appendix Table A2 details the educational distribution by occupation. Most of the illiterates are either cobblers, rickshaw drivers, or retail sellers whereas mobile marketing and sales executives are either graduates or postgraduates. Not a single worker from other occupations has a graduate or postgraduate degree. Only 4 per cent of the sample had some technical education like motor garage work, driving, electrical training, etc.

Most respondents were Hindus (94 per cent); 18 per cent belong to the general class, 43 per cent were backward classes, 30 per cent belonged to the scheduled caste, and 9 per cent to scheduled tribes. The family size was 5.17 members on average, although some families had as many as 18 members. On average, most families had 3.5 dependents. Fifty six respondents had no children, 143 had one child each, 76 had two children each, 16 had three children each, and nine had more than three children each. Most respondents were migrants; only 29.3 per cent were born in these cities. Around 75 per cent of the respondents were household heads.

Table 1 shows the distribution of different occupation class in the sample based on annual income. The modal annual income of respondents was between Rs 50,000 and Rs 100,000, which includes the incomes of 52 per cent of respondents. Some were very poor (1 per cent), with an annual income of less than Rs 10,000, and some were relatively well-off (1 per cent), with an annual income of more than Rs 300,000. Cobblers are the poorest—45 per cent make less than Rs 20,000 annually—followed by coolies or manual labourers in transport and other sectors. Mobile marketing and sales executives make Rs 50,000–100,000 annually at the least and are the richest in the sample; 80 per cent of them make Rs 100,000–300,000 annually.

Figure 1 Distribution of education class in the sample (%)

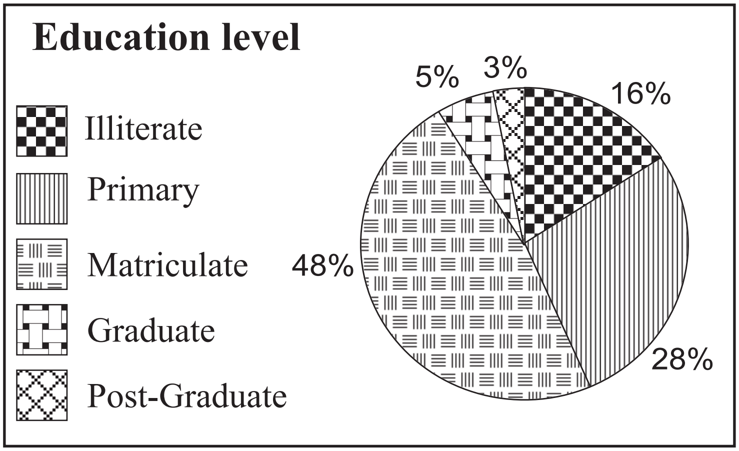

Table 1 Distribution of the sample by Occupation & Income Class(%)

Occupation	Annual Income Class (in INR)					
	Less than 10000	10000-20000	20000-50000	50000-100000	100000-30000	Above-30000
Vegetable/Fruitseller	0.03	0	0.43	0.47	0.07	0
Cobbler	0.10	0.35	0.13	0.29	0.13	0
Construction worker	0	0.03	0.63	0.33	0	0
Coolie (manual labour in transport or other sectors)	0	0	0.38	0.62	0	0
Rickshaw/trolley drivers	0	0	0.53	0.43	0.03	0
Auto driver	0	0	0.13	0.55	0.32	0
Taxi driver	0	0	0.13	0.73	0.13	0
Mobile marketing and sales executive	0	0	0	0.13	0.80	0.07
Vendors (mobile sellers of household items in trolleys)	0	0	0.04	0.93	0.04	0
Owners & workers in open retails enterprises	0	0.06	0	0.74	0.19	0
Total	0.01	0.05	0.24	0.52	0.17	0.01

2.2 Health Problems from Heat Waves

To know the public perception of heat waves in these two cities, those born there were asked if it had always been very hot in summer. Though most said it had, some 10 per cent answered that recent years, especially after 2005-06, had been hotter than before. Some workers reported heat waves caused them many health problems. Examples of such problems are fever (15 per cent), tiredness (12 per cent), respiratory problems (8 per cent), getting unconscious (5 per cent), blurred vision (8 per cent), feeling of nausea (10.3 per cent), and body ache (4 per cent), etc., though only 37 per cent of the respondents had some prior history of health problems. Of the respondents who reported previous health problems, most were cobblers, coolies, rickshaw pullers, or auto drivers; there were few marketing and sales executives. Hospitalisation was reported by 15 per cent of workers because of health problems from heat attack, of which 18 per cent were coolies, 16 per cent rickshaw pullers, 13 per cent cobblers, and the rest from other categories. This clearly indicates that the major victims of heat attack are in the lowest income categories from among low-income workers. Only 2.3 per cent of the respondents reported changing their occupation because of heat. Thus, the sample seemed to be a mixture of people who had experienced and suffered heat waves and also of people who had taken precautions to avoid health problems from heat waves.

2.3 Effect of Awareness Programmes on People

Since 2003, the Government of Odisha has been conducting an awareness programme on things to do during heat waves and things to avoid. When workers were asked if they knew of the programme, find it useful, and if they have taken the advice, around 99 per cent said they knew of the programme. The source of information was radio (63 per cent), newspaper (64 per cent), television (73 per cent), pamphlets (31 per cent), volunteers (18 per cent), neighbours (14 per cent), and NGOs (12 per cent), etc. Most had received the information from multiple sources; 83 per cent from maximum three sources[3] (either radio, or television, or newspaper or pamphlets) 13 per cent from two sources and only 4 per cent from only one source.

Around 93 per cent of the respondents found the government campaign very helpful and 99 per cent reported to have changed their habits during heat waves because of the campaign.[4] On average, it was found that during heat waves, 73 per cent of respondents drink water and 65 per cent eat cucumber and onion before leaving home; 63 per cent carry a water bottle; 64 per cent carry an umbrella, 26 per cent wear light-coloured cotton clothes; 21 per cent do not walk barefoot; and 33 per cent do not work during noon hours. Though the

[3] Nobody reported receiving information from more than three sources.

[4] See Appendix Table A1 for the behavioural advice in heat wave awareness campaigns.

behavioural changes because of the campaign seem high, one does find a lower response rate for the ones involving extra expenditure. It may be that poor economic condition restricts people from buying cotton clothes, umbrellas, and walking slippers. However, responses to precautions like 'be more responsive to old people, pregnant women, patients etc during heat waves', 'do not consume alcohol', 'consult doctor if feeling unwell', 'do not sprinkle water if somebody loses consciousness', etc. elicited very low response rates. This may be because respondents did not come across such a situation.

The changed behavioural pattern discussed above clearly indicates that people have been adapting to heat waves by changing their behaviour, habits, etc. With this background of the sample, it should be interesting to analyse the impact of heat waves on labour supply for this informed and adapted working class. The impacts of heat waves on labour supply for this group will be net of adaptation and can be useful for policymaking.

3 HEAT STRESS AND LABOUR SUPPLY

The effect of climate change on labour supply has been discussed in terms of labour availability constraints in vulnerable regions because of the migration of labour from vulnerable areas to less vulnerable areas.[5] Regular heat waves may have no effect on total labour availability in a region, as such phenomena do not induce migration, but are likely to constrain labour productivity by restricting the individual's ability to work efficiently due to unbearable weather. Heat stress may alter the marginal productivity of labour or the marginal cost of supplying labour to activities where the individual is exposed to heat. Thus, under a heat wave scenario, one expects change in workers' decision regarding the allocation of time from labour to rest, especially in exposed sectors, such as agriculture, construction, manufacturing, etc. (Zivin and Neidell 2010). Studies show marginal productivity of labour gets impacted by lower endurance, fatigue (Gonzalez-Alonso et al. 1999; Galloway and Maughan 1997; Nielsen et al. 1993), and cognitive performance (Epstein et al. 1980; Ramsey 1995; Hancock et al. 2007; Pilcher et al. 2002), etc., and heat stress can cause all such health effects. Studies under ergonomics have also established the strong association between productivity loss and rise in temperature (Niemelä et al. 2002; Lan et al. 2010; Mahamed and Srinavin 2005).[6] Simultaneously, the marginal utility from leisure activities may go up during peak heat (Ma et al. 2006; Pivarnik et al. 2003; US Department of Health and Human Services 1996; Eisenberg and Okeke 2008) triggering the leisure-work substitution. This may have serious welfare implication for people, especially for low-income workers for whom every hour of work matters. The link between external shock from heat waves and the wellbeing of

[5] For details, see the web site of the International Organization for Migration at http://www.iom.int/cms/envmig. Also see papers on migration and climate change, by the Asian Development Bank at bit.ly/rwimcc, and by UNESCO at bit.ly/migratun (both accessed on 21 May 2014).

[6] Other comprehensive studies and meta-analyses examine the ergonomics and physiology of thermal stress in humans (Pilcher et al. 2002; Hancock and Vasmatzidis 2003; Hancock et al. 2007).

poor labour class is yet to be explored in detail, though there are plenty of studies on the effect of heat waves on human health, especially in epidemiology (Kovats and Hajat 2008). Based on an aggregative analysis on temperature and labour supply at the level of counties, Zivin and Neidell (2010) showed large reductions in labour supply in climate-exposed industries in the US as the temperature rose over 85° F. Secondly, at higher temperatures, unemployed people reduced outdoor leisure activity; this shows their preference to stay indoors during heat waves. Effective labour supply—defined as a composite of labour hours, task performance, and effort—is decreasing for temperature deviations from the biological optimum, according to a study that uses country-level panel data on population-weighted average temperature and income (1950–2005) to illustrate the potential magnitude of this effect (Heal and Park 2014).

Beyond labour–leisure substitution, another setback could be a longer absence from home on heat wave days. This could take one of the three forms: (1) leave home earlier than usual; (2) return home late to avoid travelling in the scorching sun; or (3) work overtime in the evening or at night to recoup the loss in income during the usual working hours. All this means being unable to help in housework. Such absence may be very high, especially for those who live far from work, and their family members may suffer more compared to others because of heat waves. The effect of heat waves on family work is less talked about, as it is usually considered a part of leisure activities in labour allocation studies. This study accounts for the time explicitly allocated to house, and analyses the heat wave effect on time allocation of very poor self-employed workers whose family do all household related works manually, because of low income, and family members help each other. If a member is away from home for long, other members of the household are likely to be over-burdened, but the worker is forced to be away either to rest more or to work during odd hours to compensate the loss in income due to loss in work time during the day because of high temperature. While losing time for housework may not reduce income, it may have utility implications, as the utility from housework is different from the utility from rest.

The labour class reallocates time between labour and leisure to maximise welfare because of the income effect. During heat waves, a reversal of such allocation may occur because either leisure provides more utility, or because the likely health effect of working long hours under heat wave conditions will be too adverse, and require a lot of medical expenditure, which may have serious economic implications. Therefore, during heat waves, workers allocate time to different activities to minimise the negative impacts of heat stress on health. Thus, the choice of activity and location, i.e. whether to work at home or at work (place) or spend time under a shady tree (rest), as happens in underdeveloped countries, is undertaken rationally to minimise the negative impact of temperature by reducing the exposure to hot weather. I take the hypothesis that workers reallocate time between work, rest, and time spent at home to minimise the negative impact of heat waves on health. Any marginal change in time required for rest will impact time allocated to work in the house or outside, and will depend on the seriousness of the heat wave. The income effect of outside work being very strong for poor people, the individual will first reallocate time from housework to rest, but ultimately may reduce work time, as the scope of reducing housework may not be great. As, usually, housework takes a few hours every day, and some of it (like cooking or help in cooking, buying groceries, or taking bath, etc.) is important and cannot be ignored, the individual will be forced to allocate more time from economic work to rest if heat stress requires more rest.

3.1 Theoretical Model

How individuals allocate time to different activities has been studied extensively, assuming they maximise utility subject to constraints of budget and time, starting with Becker's household production model (Becker 1965). Using some of the assumptions of Becker's model, the present paper tries to find out the change in the time allocation of manual workers in an open environment due to heat waves that severely restrain their work capacity. The worker categories considered in this paper constitute a significant portion of the urban informal workforce in developing countries. These people perform manual, weather-dependent jobs using limited market inputs and are affected by extreme weather. Therefore, any substantial temperature anomaly is assumed to influence workers' productivity and time allocation decision. On a heat wave day, the primary objective of the worker is to minimise the negative health effect of the heat wave; therefore, rest assumes utmost importance, and work at home and outdoors is adjusted to ensure enough rest. The temperature anomaly determines the hours of rest needed and, thus, enters the rest function.

The individual is assumed to allocate time among three activities: rest (Z_1), which promotes his/her health; work at home (Z_2), which may be in the form of doing some household chores, helping the family to produce something that can be sold in the market, or used by the family, or used as raw material to work outside; and outside activity (Z_3), the main source of income for the family. Following Wolff and Makino (2012), Palmquist et al. (2010), Jacobsen and Kooreman (2005), etc., where Becker's home production function model has been extended to include utility maximisation over time blocks, a simple model is described below where the individual is assumed to maximise utility from two similar activities, rest and housework, under environmental stress.

The work done at home is assumed to follow constant returns to scale in labour time (Wolff and Makino 2012; Becker 1965), whereas rest is assumed to produce an increasing marginal return over some range of time—the relevant range of time being different from that of normal outside work that brings in income. Of the total time (L) available, l_1, l_2, l_3 are allocated for rest, housework, and outside work respectively such that it satisfies the time constraint.

$$l_1 = h(Z_1)c^{(T-T^*)} \quad \text{... (1)}$$

$$l_2 = \beta Z_2 \quad \text{... (2)}$$

with $h'(Z_1) > 0$ *and* $h''(Z_1) < 0$ in the relevant range of time allocation for rest.

$$L \equiv l_1 + l_2 + l_3 \quad \text{... (3)}$$

In equations 1 and 2,

Both Z_1 and Z_2 are defined in terms of time allocated to these (Eq.1 and 2).

l_1, and l_2 are time spent on activity Z_1, and Z_2 respectively,

T^* is the normal maximum bearable atmospheric temperature for the area,

T is actual temperature of the area and 'c' is a positive number reflecting the intensity of heat wave effect on the individual that, in turn, determines the amount of rest needed to cope with the heat stress.

The value of 'c' is influenced by the individual's socioeconomic background and by other adaptations undertaken (say, change of job, habits, etc.) to cope with heat waves. An increase in temperature (T) will not negatively impact an individual's productivity or health as long as $T \leq T^*$, T^* being the acclimatised bearable maximum temperature of the area. Therefore, the impact of temperature on an individual's time allocation can be visualised under three different scenarios.

1. $/T < T^*/$, so $l_1 = \dfrac{h(Z_1)}{c^{/T-T^*/}}$ it will be considered pleasant weather; therefore, an individual will require less rest than normally required in summer. Therefore, time spent on Z_2 and Z_3 may increase.

2. $T = T^*$, $l_1 = h(Z_1)$ so this case will represent a normal summer day and there will be no adverse weather effect on the individual as T^* is the maximum temperature that the individual can tolerate, and time allocated to activities will be the same as the person is physically capable of.

3. $T > T^*$, $l_1 = h(Z_1)\, c^{T-T^*}$ so this case will represent extreme weather like a heat wave, when temperature will stress an individual's health and reduce his work capacity. It will also increase the marginal utility from rest by improving health like, say, minimising the negative effect of heat stress on health. Thus, he/she will allocate $c^{(T-T^*)}$ times more time to rest

compared to the day when $T = T^*$ and reduce the time available for work in the house or outdoors. Initially, because of the income effect, outdoors work may be less affected than housework[7], but it will be affected more when heat waves worsen or difference between T and T^* widens and workers require more rest.

Thus, high temperature can alter the time allocation of individuals in labour-intensive occupations.. This can be shown from the utility maximisation conditions. Let the individual maximise utility from rest (Z_1) and house work (Z_2) and allocate l_3 amount of labour time to earn income from outside work (Z_3).

$$U=(Z_1,Z_2) \qquad \text{... (4)}$$

Both these activities require some marketable inputs, X, which is explained by linear technology[8]:

$$X_i=\alpha_i Z_i, \{i=1,2\} \qquad \text{... (5)}$$

Let the budget constraint of the individual corresponding with this maximisation problem be given by:

$$wl_3 + I_0 = w(L-l_1-l_2) + l_0 = w[L-\beta Z_2- h(Z_1)c^{T-T^*}] + l_0 \qquad \text{... (6)}$$

$$= p_1\alpha_1 Z_1+p_2\alpha_2 Z_2+A$$

where w is wage rate,

I_0 is non-wage income,

$p_i s$ are the input prices, and

A is other consumption.

Solving the first order condition of utility maximisation, it can be shown that

$$\frac{\partial U}{\partial Z_1} \Big/ \frac{\partial U}{\partial Z_2} = \frac{wh'(Z_1)c^{(T-T^*)} + p_1\alpha_1}{w\beta + p_2\alpha_2} = \frac{\pi_1(rest)}{\pi_2(house\,work)} = \lambda \qquad \text{... (7)}$$

Equation 7 shows the ratio of marginal utilities or the relative price of rest ($\pi_{1\ (rest)}$) vs. housework ($\pi_{2\ (housework)}$) to the individual. These prices are found to be the sum of input cost ($p_i\alpha_i$) and the shadow value of the time (in terms of wage rate) devoted to these activities. The

[7] Outside work is the source of income and, initially, the individual may not sacrifice it to rest more to adapt to the heat waves if only a little more rest is required.

[8] Cases of 'α' taking value zero for activity like 'rest' are not ruled out, as there can be a situation like the person taking rest under a tree during peak heat. The input requirement will be zero in such cases.

shadow value of time used for rest is influenced by temperature anomalies, i.e. for low temperature ($T<T^*$) the value is $\frac{wh'(Z_1)}{c^{T-T^*}}$ and for high temperature ($T>T^*$), it is $wh'(Z_1)c^{T-T^*}$ which is higher than the value at low temperature and this changes the equilibrium allocation of time to these activities Other things ($p_i\alpha_i$, c, and w) remaining constant, let $(\pi_1/\pi_1)=\lambda=\lambda_1$ for $T^* = T$ and $\lambda = \lambda_2$ for $T>T^*$. Then, $\lambda_2 > \lambda_1$, implying that with increase in temperature above the maximum bearable limit, the marginal utility of rest will go up compared to housework, and the individual will prefer to rest more than when $T = T^*$. With a time constraint, if time allocated to rest goes up, the time allocated to other activities will go down.

Similarly, if the weather is pleasant ($T<T^*$) λ will have a value lower than λ_1 and the marginal utility of rest will be low compared to housework in comparison to the situation when $T=T^*$. Thus, the individual will allocate more labour time to housework and less to rest. As housework is less flexible in terms of time requirement—though it contributes little to family income—any substantial change in time needed for rest will ultimately affect time allocated to outside work. To generalise, if on a normal day with temperature T^t, the individual allocates l_1^t, l_2^t, and l_3^t towards activities Z_1, Z_2, and Z_3, then on a heat wave day with temperature $T^\oplus$ and $T^\oplus > T^t$, he/she will allocate $l_1^\oplus$, $l_2^\oplus$, $l_3^\oplus$ to these activities and $l_1^\oplus > l_1^t$, $l_2^t < l_2^\oplus$, and $l_3^\oplus \leqslant l_3^t$, as $l_1^t + l_2^\tau + l_3^\tau = l_1^\oplus + l_2^\oplus + l_3^\oplus$ [9] The impact of heat waves on labour supply can, thus, be measured from a worker's relative time allocation on a heat wave day compared to a normal day to each such activity, after one controls for wage rate, input prices and factors (income, other socioeconomic factors, family background, work place environment, etc.) affecting the value of 'c'. The present study follows this approach.

The paper examines the differences in time allocation and the relative time allocation, e.g. $l_1^\oplus - l_1^t$, $l_2^\oplus - l_2^t$, and $l_3^\oplus - l_3^t$ and $\frac{l_1^\oplus}{l_1^\tau}, \frac{l_2^\oplus}{l_2^\tau}, and \frac{l_3^\oplus}{l_3^\tau}$ to each of the three activities on a heat wave day compared to a normal summer day to see whether heat waves have increased or decreased the time allocation to these activities. Next, Seemingly Unrelated Regression Equation (SURE) estimates (Zellner 1962) have been calculated taking some family, income, workplace, and health-related variables to determine the factors (other than temperature) influencing workers' decision to allocate time, i.e. to find out the determinants of 'c'. SURE estimates assume the error of each equation depends on the other equation.

3.2 Estimating Equation

The paper estimates the following equations to find out the determinants of 'c'.

$$\frac{l_1^\oplus}{l_1^\tau} = \alpha + \beta W + \gamma H + \eta X + \varepsilon \quad \dots (8)$$

$$l_{1\oplus} - l_{i\tau} = \alpha + \beta W + \gamma H + \eta X + \mu \quad \dots (9)$$

[9] Depending on the difference between $l_1^\oplus$ and l_1^τ, $l_3^\oplus$ could be strictly less than l_3^τ.

where i is activity 1, 2, and 3;

W, H and X are vectors of work place, health and family (income, house members) related variables; and ε and μ are error terms.

Because of the time constraint (Equation 3), I estimate these equations for activities 1 (rest) and 3 (outside work).

The time allocation data collected through the survey have been used to estimate the models. The survey listed workers' activities during each two-hour period between 7 am and 11 pm on the day before the interview date (a normal summer day) and also on the heat wave day two weeks before, and then grouped the activities into 'rest', 'house work', and 'outside work'. Next, the hours spent on each of these three groups of activity were counted to measure the time allocation on a normal summer day and on a heat wave day.

4. RESULTS

4.1 Summary Statistics on Time Allocation

Workers allocate time differently on a heat wave day than on a normal summer day, and spend more during heat wave months than in normal summer months; because of heat stress, they both lose time and spend more (Table 2). It shows that workers have rested longer and spent less time on both outdoors work and housework which, perhaps, is the first finding from the real life experience of poor workers in a very poor and deprived part of the world.

On average, 1.19 hours of work time and 0.46 hours of family time were lost per heat wave day, as workers reallocated these hours to rest because of heat stress. This has very serious implications for poor workers who live from hand to mouth. Rickshaw drivers lost the most work time (1.65 hours), followed by coolies (1.62 hours), construction workers (1.54 hours), taxi drivers (1.52 hours), etc., but the time lost is less for temporary stall owners (0.53 hours), vegetable sellers (0.73 hours), and sales executives (0.74 hours). This could be because temporary stall owners and vegetable sellers work either in the morning or late in the afternoon, and sales executives, who are comparatively well off, probably take better precautions so that they do not lose more work time. As expected, time loss from housework is low, as these activities require some minimum amount of time and such time required can not be changed much, as explained before.

Table 2 also shows that workers spend more on regular items in months with heat wave days, the average extra expenditure being Rs 600, varying between minus (-) Rs 300 to Rs 3,000 for different workers. On average, every category of workers spends more to adapt to this weather stress. Around 76 per cent of workers earn between Rs 20,000 to Rs 100,000

Table 2 Economic burden in terms of extra averted expenditure & work time.

Occupation	**change in average daily time allocation on a heat wave day compared to a normal summer day (In Hours)**			**change in monthly routine expenditure during heat wave days compared to normal summer (in INR)**		
	Regular outside	house work	Rest	average increase	Minimum increase	Maximum increase
Vegetable/fruit seller	-0.73	-0.22	0.95	810	0	3000
cobbler	-1.23	-0.47	1.70	597	-100	2000
Construction worker	-1.54	-0.38	1.93	450	0	1000
Coolie (manual labour in transport or other sectors	-1.62	-1.02	2.64	597	-100	2000
Rickshaw/trolley drivers	-1.65	-0.52	2.17	557	0	2000
Auto driver	-1.06	-0.21	1.28	694	0	2000
Taxi driver	-1.52	-0.68	2.2	612	0	2750
Mobile marketing and sales executive	-0.74	-0.37	1.1	693	200	1200
Vendors (mobile sellers of household items in trolleys	-1.26	-0.18	1.44	339	-100	800
Owners and workers in open retail enterprises (temporary stall)	-0.53	-0.58	1.11	639	0	2000
Average change	**-1.19**	**-0.46**	**1.65**	**600.83**	**-300**	**3000**

annually, or Rs 1,700 to Rs 8,333 per month, and the extra expenditure from heat waves constitutes some 7–35 per cent of their monthly income—a very high loss for the low-income working class.

4.2 Regression Results

Next, SURE estimates of Equations 8 and 9 are derived to find out the factors, other than temperature, that significantly influence the time reallocation to activities like rest and outside work on a heat wave day compared to a normal summer day. As mentioned before, these variables are the determinants of 'c' in Equation 1. The variables used are explained in Table 3 and the regression results are presented in Tables 4 and 5. The two dependent variables of Equation 8 are the following:

$$\frac{l_1^{heat\_wave\_day}}{l_1^{normal\_summer\_day}} \quad \text{and} \quad \frac{l_3^{heat\_wave\_day}}{l_3^{normal\_summer\_day}}$$

where

l_1 and l_3 are time allocated to rest and outside work respectively.

Similarly, the two dependant variables for Equation 9 are:

$l_1^{heat\_wave\_day} - l_1^{normal\_summer\_day}$, and $l_3^{heat\_wave\_day} - l_3^{normal\_summer\_day}$

To increase the degrees of freedom, the ten different occupations and income classes were put into four and three categories respectively, and are explained in Table 3. The reference category for occupation was 'occu_other', which included marketing executives and shop owners, and for income was 'income_low', i.e. workers who made less than Rs 20,000 annually.

Table 3 Variables used in estimation and description

Explanatory Variables	Meaning	Mean (std. dev)
Bhubaneswar	City dummy	0.50 (0.50)
Occu_vendor	Dummy for working as vendors (includes vegetable sellers and mobile marketing)	0.20 (0.40)
Occu_manual Work	Dummy for doing manual job in the open (includes ricshaw pullers, cobblers and porters)	0.40 (0.49)
Occu_driver	Dummy for working as drivers (includes auto and taxi drivers)	0.20 (0.40)
Distance Workplace	Distance to workplace from home (km)	4.29 (4.23)
Workplace Congested	Dummy if workplace is congested	0.28 (0.45)
Workplace Tree	Dummy if work place has good tree cover	0.71 (0.45)
Profession Change Heat	Dummy if the person has changed job because of heat	0.02 (0.15)
Dependant Ratio	Share of dependants in total family members	0.65 (0.17)
Born in the City	Dummy if born in the city	0.29 (0.46)
Illiterate	Dummy if illiterate	0.16 (0.36)
Hospitalized Heat attack	Dummy if the person was hospitalised because of heat attack	0.15 (0.36)
Health Problem	Dummy if the person suffers from some health problem	0.37 (0.48)
Income Medium	Dummy if annual income is in the range of Rs30000 to Rs100000	0.76 (0.43)
Income High	Dummy if annual income is more than Rs100000	0.18 (0.38)

Table 4 shows the results for Equation 8 using the two dependent variables described above (the ratios of hours allocated to work and rest on a heat wave day relative to hours allocated to these activities on a normal summer day). First, one finds workers in Bhubaneswar working longer during heat waves than workers in Sambalpur. This could be because the cost of living in Bhubaneswar is high or because it cools early in the afternoon, being close to the sea, and people find it easy to compensate the work time loss during noon. As expected, people doing manual jobs in the open lose much more work time due to heat

Table 4 : SURE estimates of relative time reallocation to rest and outside work (Eq.8) during heat wave

Estimated Coefficients (absolute t-values)				
Explanatory Variables	Dependent variable: Ratio of time allocated to work on a heat wave day compared to a normal summer day		Dependent variable: Ratio of time allocated to rest on a heat wave day compared to a normal summer day	
Bhubaneswar	0.129***	(5.97)	– 0.006	(0.08)
Occu_vendor	0.028	(1.03)	– 0.027	(0.28)
Occu_manual Work	– 0.074***	(3.14)	0.213***	(2.61)
Occu_Driver	– 0.028	(1.05)	0.177*	(1.94)
Distance Workplace	– 0.004**	(1.98)	– 0.001	(0.09)
Workplace Congested	– 0.022	(1.09)	0.009	(0.13)
Workplace Tree	– 0.025	(1.15)	0.166**	(2.22)
Profession change Heat	0.089*	(1.62)	– 0.324*	(1.70)
Dependant Ratio	0.001	(0.01)	– 0.092	(0.51)
Born in the City	0.028	(1.33)	– 0.007	(0.10)
Illiterate	0.014	(0.58)	– 0.022	(0.26)
Hospitalized heat attack	– 0.015	(0.62)	0.121 +	(1.46)
Health Problem	– 0.033*	(1.80)	– 0.079	(1.22)
Income Medium	– 0.083**	(2.20)	0.187 +	(1.43)
Income High	– 0.095**	(2.13)	0.096	(0.62)
Cons	0.971***	(15.64)	1.069***	(4.97)
RMSE	0.14		0.48	
R^2	0.27		0.10	
Chi.sq (P value)	111.62	(0.00)	34.04	(0.003)

Level of significance : ***1 per cent, **5 per cent, *10 per cent and +15 per cent

waves than others, as do people who live far from work or who have health problems or are well off. The results with regard to being well off or belonging to a little higher income category shows people with medium to high income to work much less on heat wave days compared to people with low income in the region. This could be reflecting the typical risk-averse behaviour/attitude of well-off people in underdeveloped regions—being a little better off, they do not take the risk of working under heat, and prefer to rest more. The other line of argument could be that the heat stress is so severe that allocating same amount of time to outside work as one does on a normal summer day is too risky for health, so workers who are somewhat well off and can afford to avoid the risk, do it by working less. This way, they reduce exposure to sun and avoid heat stroke. But people at lower economic strata cannot afford to rest more and are forced to risk their health by working under the scorching sun. The study area reports 100–200 people dying from heat stroke almost every summer, and the Odisha State Disaster Management Authority (OSDMA) reports that most of them are labourers; this second line of argument explains the results on income categories more appropriately for the study area. The Government of Odisha has banned manual work during peak hot hours in the state to avert mortalities from heat waves, but only the organised sector follows this rule; unorganised informal sectors workers risk working under the scorching sun due to economic hardship, and some succumb to heat stroke. Such findings call for the

	Estimated Coefficients (absolute t - values)			
Explanatory Variables	**Dependant variable: Difference between time wave day compared to a normal summer day**		**Dependant variable: Difference between time allocated to rest compared to a normal summer day**	
Bhubaneswar	1.046***	(4.97)	-1.355***	(6.58)
occu_vendor	0.328	(1.22)	-0.317	(1.21)
occu_manual_work	-0.656***	(2.86)	0.816***	(3.64)
occu_driver	-0.221	(0.86)	0.280	(1.12)
distance_workplace	-0.31+	(1.50)	0.003	(0.14)
workplace_congested	-0.208	(1.07)	-0.018	(0.10)
workplace_tree	-0.267	(1.27)	0.081	(0.40)
profession_change_heat	0.999*	(1.86)	-1.007*	(1.92)
dependant_ratio	-0.244	(0.48)	0.286	(0.57)
born_in_the-city	0.206	(1.01)	-0.116	(0.58)
illiterate	0.151	(0.64)	-0.179	(0.78)
hospitalized_heat_attack	-0.151	(0.64)	-0.179	(0.78)
health_problem	0.214	(1.18)	-0.029	(0.16)
income_medium	-0.738**	(2.00)	0.901**	(2.50)
income_high	-0.923**	(2.12)	0.876**	(2.06)
_cons	-0.194	(0.32)	0.917+	(1.55)
RMSe	1.35		1.32	
R2	0.23		0.31	
Chi.sq (P value)	87.15	(0.00)	135.83	(0.00)

Level of significance: *** 1 per cent, ** 5 per cent, * 10 per cent, and + 15 per cent

APPENDIX

Table A1 Occupation and age class

Occupation	Age Group					
	Less than 20	**20-40**	**40-60**	**60-80**	**Eighty or More**	**Total**
Vegetable/Fruit Seller	0	14	16	0	0	30
Cobbler	0	14	13	3	1	31
Construction Worker	2	22	5	1	0	30
Coolie (Manual Labour in Transport or Other Sectors	0	22	6	1	0	29
Rickshaw/Trolley Drivers	0	17	13	0	0	30
Auto Driver	0	22	9	0	0	31
Taxi Driver	0	21	9	0	0	30
Mobile Marketing and Sales executive	0	25	5	0	0	30
Vendors (Mobile sellers of Household items in trolleys)	0	13	14	1	0	28
owners & workers in open retail enterprises (temp stall)	2	20	9	0	0	31
Total	4	190	99	6	1	300

Table A2 Education level of respondents

Occupation	Education Class					
	Illiterate	Class 5 or Below but not Illiterate	Class 12 or Below but above	Graduate	Po.-Graduate (Management	Total
Vegetable/Fruit Seller	6	3	21	0	0	30
Cobbler	14	10	7	0	0	31
Construction Worker	5	19	6	0	0	30
Coolie (Manual Labour) in Transport or Other Sectors	4	19	6	0	0	29
Rickshaw/Trolley Drivers	8	14	8	0	0	30
Auto Driver	0	3	28	0	0	31
Taxi Driver	0	4	26	0	0	30
Mobile Marketing and Sales executive	0	0	3	17	9	29
Vendors (Mobile sellers of Household items in trolleys)	3	8	17	0	0	28
Owners & workers in open retail enterprises (temporary stall)	7	3	21	0	0	31
Total	47	83	143	17	9	299

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