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RESEARCH PAPER

Revisiting the Economic Costs of Arsenicosis: A PSM Approach

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Abstract: The present paper uses the propensity score matching (PSM) method to calculate the economic loss of arsenicosis-affected households. In contrast to prior studies, whose estimates of income loss were limited to labour-market sources, the PSM method controls for labour market and other sources of income, as well as demographic and educational factors, to identify losses from social discrimination. It first establishes that arsenicosis-affected households are subject to social discrimination, and then shows that this leads to a significant loss of expenditure. Second, it proves that overlooking social discrimination leads to an underestimation of income loss. The results have important implications, both for understanding the plight of arsenicosis-affected households and for cost–benefit calculations in the adoption of policies for fighting arsenic contamination.

Keywords: Arsenicosis, Economic Cost, Propensity Score Matching, Social Discrimination

1. INTRODUCTION

Arsenic is a metalloid that is found throughout the Earth's crust and in soil, sediments, water, air, and living organisms. The estimated global prevalence of arsenic in soil is 5 μg/kg (microgram per kilogram), but concentrations may vary considerably in different geological regions; the variations range from 0.1 to 4,000 μg/kg. Across different countries, arsenic is used as a drug as well as a poison.

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Arsenic can enter the human body directly through the consumption of contaminated drinking water and indirectly through the food chain, if arsenic-contaminated groundwater is used in agricultural production. Arsenic consumption leads to health hazards such as skin, lung, liver, bladder, and kidney cancer. It can harm the central and peripheral nervous systems as well as the heart and blood vessels. It may also cause birth defects and problems in the reproductive system. Arsenic-related health hazards may be classified into two types: (i) acute: including gastrointestinal discomfort, vomiting, diarrhoea, convulsions, coma, and ultimately death; (ii) chronic: including skin lesions (arsenicosis or arsenical dermatitis) that are characterized by hyper-pigmentation, hyperkeratosis, and hypo-pigmentation. Acute toxicity, however, is infrequent. Arsenic's effects on the victim are not immediately perceptible. Gradual arsenic poisoning from drinking tainted water can take years to ravage the body, producing pigment patches and scaly skin; swollen limbs and joints; and tumorous growths on limbs and feet. By the time even early symptoms are visible, the person is often riddled with cancer. Thus, arsenic has a cumulative toxic effect that destroys the human body, leading to inevitable death. Since rural areas, especially in developing countries, are seldomly supplied with treated surface water, people living there face a much higher threat of developing arsenicosis.

While arsenic contamination has been reported in 38 countries in the world (Chakraborti *et al.* 2009), Asian countries have been affected more than others. Globally, the countries most affected by arsenic contamination are all from Asia: India, Bangladesh, China, and Taiwan, with India having the highest and Taiwan having the lowest incidence. The Ganga–Meghna–Brahmaputra (GMB) plain of India and Bangladesh is the worst affected area in the world, giving cause for alarm. More than 500 million people living in the GMB plain may potentially be at risk from groundwater arsenic contamination (Nahar, Hossain, and Hossain 2008; BGS and DPHE 2001).

Arsenicosis affects the health and well-being of both the affected individuals and their families (Hanchett 2004; Roy 2008). The people affected by arsenic poisoning suffer from symptoms like gradual loss of energy, physical weakness, loss of appetite, lethargy, sleeplessness, diminishing ability to work, gastrointestinal distress, burning sensations, and gradually progressive debilitation, which lead to an inability to work, and loss in income. It also leads to strained relations within the family and social stress. When the symptoms of arsenicosis become more evident, various agonizing social issues often arise, such as affected persons being fired from their jobs, children being debarred from their schools, girls being denied marriage, and married women facing marital problems and even divorce.

The affected people are often socially boycotted and ostracized from social functions as they are mistakenly considered to be contagious. These social barriers create economic challenges for the affected people and their families (Becker 1971).[1]

Although arsenicosis cannot be cured, it can be adapted to and mitigated. The medical expenditures borne by affected households to treat arsenicosis are an example of adaptation. There are mitigation approaches that the affected persons can take as well: (i) using arsenic-safe water sources such as dugwells and deep tubewells that are regularly monitored for arsenic, piped water projects, etc., and (ii) improving one's nutritional status by adopting a healthy diet with plenty of vitamins such as A, C, and E (Quamruzzaman *et al.* 2003; Milton 2003).[2] The government may undertake policies to promote and complement these mitigation efforts. For example, it may spread awareness about arsenic-safe sources of drinking water and nutritional foods to combat arsenicosis. It may also undertake piped water projects and mark arsenic-safe tubewells.[3] The economic impact of arsenicosis on a household, therefore, depends on the adaptation and mitigation efforts of the household as well as various social and policy parameters.

While several studies have investigated arsenic contamination, most of them have explored its geological aspects, the related health problems, and technologies for its removal. Studies like Mandal *et al.* (1996), Chowdhury *et al.* (1999), Chowdhury *et al.* (2000), Chakraborti *et al.* (2002, 2003, 2009), and Ahmed *et al.* (2006) have mapped the spatial spread of arsenic risk zones in West Bengal, India, and in Bangladesh. These studies have also evaluated the scale of the problem in terms of the at-risk population. The geological aspects of groundwater arsenic contamination have been studied by Harvey *et al.* (2002, 2005), Akai *et al.* (2004), Acharyya and Shah (2007), Biswas *et al.* (2012), and Planer-Friedrich *et al.* (2012). Studies on epidemiological issues and adverse health effects related to chronic arsenic toxicity include Datta (1976), Milton (2003), Chakraborti *et al.* (2004), Kapaj (2006), Ghosh (2008), Vahter (2009), and Rahman *et al.* (2009). Substantial literature is also available on mitigation strategies and technologies for arsenic removal (Misbahuddin and Fariduddin 2002; Hossain *et al.* 2006). As mentioned before, besides its chronic effects, groundwater arsenic

[1] A publication by the World Health Organization points out that the social problems arising from groundwater arsenic contamination increase the pressure on the economies of the affected areas (Curry *et al.* 2000).

[2] Malnutrition slows down the elimination of toxic arsenic from the body and aggravates arsenicosis.

[3] Arsenic-safe tubewells are coloured green and unsafe tubewells are coloured red.

contamination creates widespread social and psychological problems for the affected people and their families. Over the last decade, a number of studies, mostly in Bangladesh, have highlighted the social, socio-cultural, socio-economic, psychosocial, and mental health effects of arsenic poisoning (Curry *et al.* 2000; Barkat 2004; Hadi and Parveen 2004; Hanchett 2004; Hassan *et al.* 2005; Ahmad *et al.* 2007; Nahar, Hossain, and Hossain 2008; Brinkel *et al.* 2009; Sarker 2010; Mahmood and Halder 2011; Sultana *et al.* 2012; Syed *et al.* 2012). However, there is a dearth of such valuable studies that examine the social dimension of arsenic contamination in the Indian context.

Studies evaluating the economic cost of arsenic contamination are limited, but designing any arsenic mitigation programme would require cost estimates. This study attempts to derive such an estimate of the costs involved. Studies like Khan (2007), Roy (2008), Mahanta *et al.* (2016), and Thakur *et al.* (2019) have measured the arsenic-affected households' willingness to pay for mitigation projects by estimating their losses from labour market participation and remedial medical expenditures. Additionally, affected households also experience losses due to the social discrimination they face. The methodologies adopted by Khan (2007), Roy (2008), Mahanta *et al.* (2016), and Thakur *et al.* (2019) overlook this dimension of income loss. The present paper attempts to fill this gap.

This paper accounts for the income loss of arsenic-affected households from reduced labour market participation as well as social discrimination. First, it shows that calculating the economic cost based on the labour market alone would lead to underestimation, as such calculations will not account for losses caused by social discrimination. Then, it estimates the labour supply behaviour and spending behaviour of the households facing social discrimination. It shows that in the presence of sufficiently strong social discrimination, households may work more, and when the labour market effects are controlled, such households spend less than other households.

This theory is supported by survey data collected in 2005–06 from arsenic-affected and unaffected households in Kolsur village in North 24 Parganas district, West Bengal, India. Our estimation of the economic cost compares the incomes of arsenic-affected households and observationally similar households which differ only in terms of the presence of arsenicosis. The observational match has been found using the propensity score matching

(PSM) method pioneered by Rosenbaum and Rubin (1985).[4] With PSM, we control for the labour market and other sources of earning like working on their own land or on land owned by others, the household's per capita working days per month in different seasons (summer, winter, and monsoon), adaptive expenditure to avoid labour market loss, and a host of other demographic and educational factors. We show that social discrimination exists and estimate the income loss that it creates. The results show that the measure of income loss per capita derived by Roy (2008) based on labour market outcomes alone, in a similar geographical region and during a similar time period, is an underestimation.[5]

The paper contributes to the literature by providing a broader measure of the economic costs of arsenicosis by including the costs of the social discrimination faced by arsenic-affected households. It argues that the economic costs are greater than any estimate generated based on labour market outcomes alone. The results of the paper are important from a policy point of view, as the suggested method of economic cost calculation may make viable several arsenic removal programmes that are stalled due to unfavourable cost–benefit calculations. The paper also highlights the importance of policies in eliminating the social discrimination against arsenic-affected households, as it leads to significant economic losses for them.

The paper is organized as follows: Section 2 presents a theoretical model to illustrate the way arsenicosis affects a household's labour supply, income, and expenditure. It also shows that considering only labour market effects underestimates the welfare loss of arsenic-affected households and why a technique like PSM is required for this purpose. Sections 3 and 4 describe the methodology and data collection, respectively. Section 5 analyses the data and discusses the results. Section 6 presents the conclusions.

2. THEORETICAL FOUNDATIONS

Consider a representative arsenic-affected household that derives its utility from the consumption of commodities and leisure. The expenditure on commodities is represented by x. The time endowment of the household is represented by $T(A)$ hours, out of which L hours is consumed as leisure.

[4] See Caliendo and Kopeinig (2008), Imbens and Wooldridge (2009), Heinrich *et al.* (2010), and Kassie *et al.* (2010) for recent reviews of the literature.

[5] Our result is not directly comparable to those of either Mahanta *et al.* (2016) or Thakur *et al.* (2019) due to geographic and temporal dissimilarities.

The utility function of the household is: $U = U(x, L)$, which is maximized by the choice of $\{x, L\}$ subject to the budget constraint:

$$x = w(T(A) - L) + M(A) \quad (1)$$

In Equation (1), w stands for the market wage rate and $M(A)$ stands for the non-labour income of the household. In our model, $A > 0$ is an index of the severity of arsenicosis in the household. A high value of A implies a high severity of arsenicosis. We assume that $T'(A) < 0$ that is, the more severely a household is affected with arsenicosis, the less time it has both for work and leisure. We also assume that $M'(A) < 0$, that is, the greater the severity of arsenicosis in a household, the lower the non-labour income of the household. We treat $M(A)$ as an indicator of the social capital enjoyed by the household. We assume that the lower non-labour income of an affected household reflects the social discrimination it faces.

Assuming the existence of an interior solution $\{x^* > 0, T(A) > L^* > 0\}$ to the household's utility maximization problem, the equilibrium amount of labour supply and the equilibrium expenditure of the household are written as:

$$L^* = T(A) - L^*[w, T(A), M(A)] \quad (2)$$

and

$$x^* = wL^* + M(A) \quad (3)$$

respectively. Since leisure is a normal good, by income effect it follows that $\frac{\partial L^*}{\partial T} > 0$, $\frac{\partial L^*}{\partial M} > 0$ and $\frac{\partial L^*}{\partial A} = \frac{\partial L^*}{\partial T} T'(A) < 0$.

Substituting $\{x^* > 0, T(A) > L^* > 0\}$ in the utility function above, the indirect utility function of the household is defined as:

$$v(A) = U[x^*(A), L^*(A)] \quad (4)$$

Proposition 1: The welfare loss of households due to arsenicosis calculated based only on labour market outcomes leads to underestimation.

Proof: Applying the first-order conditions of the household's utility maximization problem from Equations (3) and (4), we derive:

$$\frac{\partial v}{\partial A} = \frac{\partial U}{\partial x}[wT'(A) + M'(A)] \quad (5)$$

The first term of the RHS of Equation (5) captures the loss in welfare due to the labour market effect, and the second term captures the loss due to lack of social capital, which is due to social discrimination.

From the assumptions of the model, we know $\frac{\partial U}{\partial x} > 0$, $w > 0$, $T'(A) < 0$ and $M'(A) < 0$. Therefore, the RHS of Equation (5) is negative. Hence, the statement of the proposition follows.

Proposition 1 justifies the use of the PSM method for estimating the welfare loss of a representative arsenic-affected household. The method also captures the loss of income that arises due to the erosion of the social capital of such households, which previous studies have failed to capture.

Proposition 2: (a) $\frac{\partial L^*}{\partial A} \geq$ or $<$ 0 *if and only if* $T'(A) \geq$ or $<$ $[T'(A)\frac{\partial L^*}{\partial T} + M'(A)\frac{\partial L^*}{\partial M}]$;

(b) (i) *if* $T'(A) \geq [T'(A)\frac{\partial L^*}{\partial T} + M'(A)\frac{\partial L^*}{\partial M}]$, $\frac{\partial x^*}{\partial A} < 0$

(ii) *if* $T'(A) < [T'(A)\frac{\partial L^*}{\partial T} + M'(A)\frac{\partial L^*}{\partial M}]$, $\frac{\partial x^*}{\partial A} \geq$ or $<$ 0

if and only if $w\frac{\partial L^*}{\partial A} \geq$ or $<$ $-[M'(A)]$.

Proof: From (2) we obtain:

$$\frac{\partial L^*}{\partial A} = T'(A) - T'(A)[\frac{\partial L^*}{\partial T} + M'(A)\frac{\partial L^*}{\partial M}];$$

and from (3) we obtain:

$$\frac{\partial x^*}{\partial A} = w\frac{\partial L^*}{\partial A} + M'(A)$$

The statement of the proposition follows.

As the incidence of arsenicosis escalates in a household, the endowment of time and social capital shrinks. In terms of labour supply, this evokes two kinds of reactions from the household. First, a direct effect of the reduction of time endowment $T'(A)$ through which its supply of labour falls. Second, an indirect effect $[T'(A)\frac{\partial L^*}{\partial T} + M^*(A)\frac{\partial L^*}{\partial M}]$ through which the change in income causes a decline in consumption and leisure but an increase in labour supply. The household's supply of labour falls if the direct effect dominates the indirect effect. For such households, consumption expenditure falls as well. However, if the indirect effect dominates, the labour supply rises, i.e., the household works more. If social discrimination is strong, i.e., $M'(A)$ has a large magnitude, the indirect effect would also be strong. If it is strong enough, as Proposition 2 suggests, it is perfectly possible that an arsenic-affected household works more than an arsenic-unaffected household, and its consumption expenditure is more than that of an arsenic-unaffected household. However, if the labour supply remains unchanged or rises, social discrimination would imply a fall in the consumption expenditure of arsenic-affected households.

Earlier studies like Khan (2007), Roy (2008), Mahanta *et al.* (2016), and Thakur *et al.* (2019), which do not consider the theoretical possibility of social discrimination and do not apply the PSM method as their empirical methodology, found that the labour supply and, consequently, the welfare of affected households, declined due to arsenicosis. The data and the methodology applied in this paper yielded a different result, which we explain at the end of Section 4.

3. EMPIRICS: METHODOLOGY

Impact evaluations (causal inferences) are fundamentally based on randomized experiments. In the case of successful randomization, the treated or affected group and the untreated or control group are identical with respect to all observed and unobserved characteristics except the treatment status. The two groups are thus totally interchangeable. Although a perfectly randomized experiment is considered a theoretically ideal, in practice, randomization is mostly infeasible, specifically in social science experiments or social behavioural research studies. Under such circumstances, non-experimental methods are used. But the non-random observational studies or non-experimental methods usually suffer from a selection bias (a bias in the sample selection). Techniques like multivariate regression analysis, instrumental variable method, quasi-experimental method, and PSM are used to minimize the selection bias. In this paper, we use the PSM method.

The propensity score $\{P(X)\}$ is defined as the probability of participating in a programme given the observed set of variables X. Unlike with randomization, in PSM, the two groups are identical only in their observed characteristics. Dealing with multiple covariates, confounding background covariates, and observed background characteristics is too troublesome due to both computational and data problems. So, Rosenbaum and Rubin (1985) suggested the use of a propensity score, which acts as a balancing score. When the set of variables to match is large, the applied matching procedure based on this unidimensional balancing score is known as PSM. In other words, PSM refers to the pairing of the treatment and control or comparison units with similar values on the propensity score, possibly discarding all unmatched units (Rubin 2001).

3.1. Evaluation framework and matching basics

Inferences about the impact of the treatment on the outcome of an individual involves speculation about how this individual would have performed without the treatment. The standard framework to discuss this problem is the potential outcome approach or Roy-Rubin model (or Rubin causal model). In the case of a dichotomous/binary treatment, the treatment indicator $D_i = 1$ if an individual i receives the treatment or is affected and zero otherwise. The framework assumes that there are two potential outcomes Y_1 and Y_0 corresponding with ($D_i = 1$) and ($D_i = 0$). Importantly, a unit i can only be in one state (either $D_i = 1$ or $D_i = 0$) at one point of time, so only one of the two outcomes (Y_1 or Y_0) is observed. If, say, Y_1 is observed, the unobserved outcome Y_0 is taken as the "missing link". The unobservable outcome of this framework is termed as "counterfactual" since it is counter to fact (Winship and Morgan 1999), i.e., what the outcome would be without the programme at the same point of time. Hence, we need a comparison group that will allow us to attribute any change in the treatment group to the programme to gauge causality properly. The PSM method matches the treatment and the comparison/control group based on their observed characteristics and investigates the impact of the treatment.

In the present study, we consider the incidence of arsenicosis as the treatment. The outcome variables are per capita monthly household income and per capita monthly household expenditure. The use of the PSM method ensures that any selection bias is minimized with regard to observable characteristics.

In applying PSM, we adopt the three-step analytic process described by Guo and Fraser (2010). The steps are as follows:

Step 1: Selection of background covariates

The first is to search for and select the best background covariates that could be causing an imbalance between the treated and control groups. The treatment group (arsenic-affected group) and the control group (arsenic-unaffected group) are compulsorily made to share a similar set of background covariates.

Step 2: Calculation of propensity scores

The propensity scores are calculated for each household using binary logistic regression or a binary discrete choice model (Gujarati and Sangeetha 2007). Denoting the binary treatment condition as D_i, we define $D_i = 1$ if a household is in the treatment condition (arsenic-affected) and $D_i = 0$ if a household is in the control condition (arsenic-unaffected).

The vector of the conditioning variables is denoted as X_i and the vector of the regression parameters is denoted as β_i. The binary logistic regression depicts the conditional probability of receiving the treatment as follows:

$$P(D_i \mid X_i) = E(D_i) = \frac{e^{X_i\beta_i}}{1+e^{X_i\beta_i}} = \frac{1}{1+e^{-X_i\beta_i}} \qquad (6)$$

Note that this is a nonlinear model, as D_i is not a linear function of the vector of conditioning variables X_i. But the transformed equation through the logit function (i.e., the natural logarithm of odds or $\log[\frac{P(Di)}{1-P(D_i)}]$ becomes a linear function of X_i. The logit model being estimated is specified as:[6]

$$L_i = \log_e(\frac{p}{1-p}) = X_i\beta_i \qquad (7)$$

where P denotes $P(D_i)$. The propensity score is the estimated value of $P_i = P(D_i)$. As PSM is applied for the comparison of the outcomes of the two groups, the two assumptions mentioned below need to be satisfied.

Assumption 1: D_i s are independent over all i.

The non-randomized data of this study ensure that Assumption 1 holds.

[6] Alternatively, a probit model or a discriminating analysis can be used for the same purpose.

Assumption 2: Conditional independence assumption (CIA): $Y(0), Y(1) \cup D \mid X$.

Assumption 2 implies that given a set of observable covariates X, which are not affected by the treatment, potential outcomes are independent of the treatment status. That is, it is assumed that the outcomes $Y(0), Y(1)$ are independent of the treatment status conditional on X. In this study, we assume that the CIA holds.

As we have considered several background covariates, there is a problem of multidimensionality. To reduce this multidimensionality, the propensity scores are estimated. The background covariates are described in Section 4. The questionnaire based on which the data on the selected background or confounding covariates was collected is given in Appendix 1. After the propensity scores are calculated, we use them to match the two groups.

Step 3: Matching

After the propensity score estimation, the PSM is implemented. We construct matched pairs between the two types of households, i.e., the arsenic-affected households (treatment group) and the arsenic-unaffected households (control group) based on the maximum closeness of their propensity scores. Before matching, we must satisfy the following assumption.

Assumption 3: Common support or overlap condition: $0 < P(D = 1 \mid X) < 1$.

To identify the common support region, we adopt the "minima and maxima criterion" approach, which eliminates all observations whose propensity scores are smaller than the minimum and larger than the maximum in the opposite group. Observations that lie outside the described region are discarded from the analysis.

In the present study, we applied the most straightforward, traditional pair-wise matching method (Rubin 1973), nearest neighbour (NN) matching, where households from the comparison group are chosen as a matching partner for the treated household that is closest in terms of the propensity score. NN matching is of two types: "with replacement" and "without replacement". In the former case, an untreated/control household can be used more than once as a match, whereas in the latter case, it is considered only once (i.e., once a treated case is matched to a non-treated case, both cases are removed from the pool). In the present study, the sample size of the control group is large, so we use NN matching without replacement.

Formally, if P_i and P_j represent the respective propensity scores of the treated and control participants, and if I_1 and I_0 represent the respective sets of treated and control participants, a neighbourhood $C(P_i)$ contains a control participant j (i.e., $j \in I_0$) as a match for the treated participant i (i.e., $i \in I_1$) if the absolute difference in propensity scores is the smallest among all possible pairs of propensity scores between i and j, as:

$$C(P_i) = \min || P_i - P_j ||, j \in I_0$$

Once j matches to i, j is removed from I_0 without replacement. If for each i there is only a single j found to fall into $C(P_i)$, then the NN matching is 1-to-1 matching. If for each i there are n participants found to fall into $C(P_i)$, then the NN matching is 1-to-n matching. Note that here we are not imposing any kind of restriction on the distance between P_i and P_j as long as j is the NN to i in terms of the estimated propensity score. Even if $||P_i - P_j||$ is large (i.e., j's propensity score is vastly different from i's), j would still be considered a match to i. To overcome this problem, the following condition is derived, where the absolute distance between the propensity scores of the two participants will be less than the pre-specified tolerance for matching or a calliper (ε) satisfying:

$$|| P_i - P_j || < \varepsilon, j \in I_0 \tag{8}$$

Rosenbaum and Rubin (1985) suggest that the size of the calliper be 0.25 of the standard deviation of the sample estimated propensity scores (σ_p)(i.e., $\varepsilon \leq 0.25\sigma_p$). This variety of NN matching, which has been adopted in the present study, is known as calliper matching. Here, we are using NN matching without replacement within a calliper. By adopting this method, we get a subsample of the control participants and treated participants whose propensity scores have been matched.

Step 4: Post-matching analysis

After the matched treatment and control groups are formed, we compare the average of the outcome variables for the two groups and check if they are significantly different or not. The questionnaire about the outcome variables is presented in Appendix 1.

4. DATA

The data used in the empirical analysis are drawn from a household database created by School of Environmental Studies, Jadavpur University (SOES, JU), using a primary survey during 2005–2006 in the arsenic-affected village of Kolsur located in Deganga block, North 24 Parganas district (West Bengal, India). The database was a complete enumeration of 1,000 households in the village. Of these, 374 households were arsenicosis affected, and the rest (i.e., 626 households) were unaffected. In our study, we included all the 374 affected households in the treatment group. The control group was constituted by unaffected households living within a radius of 6–9m from each of the affected households. Selected in this way, there were 392 households in the control group. Both the treatment and control households were deliberately chosen from the same geographical area so that they did not differ much in terms of socio-economic and demographic characteristics, and the unobserved heterogeneity of the households was not too vast. All the households in both the groups had the same source of drinking water, which was arsenic-affected. We have collected household data on two outcome variables: per capita monthly income and per capita monthly expenditure (both in Indian National Rupee [INR]).[7] The descriptive statistics and the comparison of the outcome variables are presented in the Table 1.

Table 1: Descriptive statistics and comparison of the outcome variables of arsenic-affected households and arsenic-unaffected households

Outcome variables	Arsenic-affected (no. of observations = 374)			Arsenic-unaffected (no. of observations = 392)			Mean difference
	Mean	Min	Max	Mean	Min	Max	
Per capita monthly household income (INR)	1,475.52 (495.15)	500	4,000	2,187.11 (832.20)	833	6,000	-711.59*
Per capita monthly household expenditure (INR)	1,300.81 (277.97)	677	3,725	1,730.33 (555.28)	677	5,033	-429.52*

Note: Standard deviations are in parentheses and *, **, *** denote a 1%, 5%, and 10% level of significance, respectively.

[7] INR 1 = $0.02 on 4 May 2005. See Pound Sterling Live (2005). Roy (2008) also uses the same exchange rate.

In both the outcome variables, on average, the control group performs better than the treatment group (Table 1). They earn more and spend more. They differ significantly in terms of their per capita monthly income and per capita monthly expenditure. On average, the arsenic-affected households and the arsenic-unaffected households earn ₹1,475.52 and ₹2,187.11 per month per capita, respectively, and spend ₹1,300.81 and ₹1,730.33 per month per capita, respectively (see Table 1). The standard deviations of both the income and expenditure variables are high, with income showing more variation than expenditure.

We consider three different sets of background covariates for our study. The first set relates to the demographic characteristics of the households and contains variables like religion, percentage of male and female members, and percentage of people of working age (15–64 years old) in the household. The second set relates to the income as well as medical expenditure of the households. This includes whether the household earns farm or non-farm income. Under farm income, whether the income is earned by working on one's own land or on land owned by others is considered. Other variables included are the household's per capita working days per month in different seasons (summer, winter, and monsoon) and the household's per capita monthly medical expenditure (INR), which we use to approximate the adaptive measures taken by the household to avoid possible labour market loss. The third set includes variables that capture the level of educational attainment in the households. This includes the percentage of household members having attained middle-school education (passed class 8), higher-secondary education (passed class 12), and graduate education, and the percentage of household members who are literate. Land being the major asset in rural areas, we also include the per capita land ownership of households in terms of *katha*[8] to record the wealth of the households.[9] We describe the data on the background covariates in Table 2.

There are more female members in arsenic-unaffected households compared to arsenic-affected households (significant at 5% level). Among the income as well as medical expenditure–related variables, the treatment group and the control group are significantly different on three counts.

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[8] 1 katha = 0.017 acre.

[9] We have not included the source of drinking water as a background covariate since in our sample, as arsenic-contaminated ground water is consumed both by the treatment (arsenic-affected) households and the control (arsenic-unaffected) households. Therefore, it is not a source of variation in explaining the observed incidence of arsenicosis. We thank one of the referees for bringing up this issue.

Table 2: Descriptive statistics and comparison of the background covariates of arsenic-affected households and arsenic-unaffected households

Background variables	Arsenic-affected (no. of observations = 374)			Arsenic-unaffected (no. of observations = 392)			Mean difference
	Mean	Min	Max	Mean	Min	Max	
Religion dummy (Hindu = 1, Muslim = 0)	0.40 (0.49)	0	1	0.48 (0.50)	0	1	-0.08
% of males in the household	36.07 (14.13)	0	75	37.61 (12.83)	0	66.67	-1.54
% of females in the household	33.70 (12.86)	0	75	36.87 (12.97)	0	66.67	-3.17**
% of household members of working age (15–64 years)	74.75 (20.55)	33.33	100	75.73 (22.37)	0	100	-0.98
Working on own land *	0.47 (0.50)	0	1	0.48 (0.50)	0	1	-0.01*
Working on others' land *	0.23 (0.42)	0	1	0.19 (0.39)	0	1	0.04***
Other source of income (non-farm)	0.60 (0.49)	0	1	0.53 (0.50)	0	1	0.07
Per capita working days p.m. in summer	9.70 (3.42)	3.33	30	9.76 (3.20)	4.33	15	-0.06
Per capita working days p.m. in winter	9.71 (3.44)	3.33	30	9.76 (3.20)	4.33	15	-0.05
Per capita working days p.m. in monsoon	9.53 (3.51)	0	30	9.66 (3.21)	3.75	15	-0.13
Per capita monthly household medical expenditure (INR)	24.02 (21.16)	10	225	13.56 (6.54)	4	50	10.46*
Middle school (up to class 8) (%)	75.64 (24.39)	0	100	77.44 (24.42)	0	100	-1.8
Higher secondary (%)	1.85 (7.34)	0	50	1.90 (7.80)	0	50	-0.05
Graduate (%)	1.01 (5.32)	0	50	0.76 (4.70)	0	50	0.25
Literate persons (%)	72.96 (23.55)	0	100	75.24 (24.19)	0	100	-2.28
Per capita land ownership (in katha)	6.87 (7.36)	0.5	55.5	5.78 (5.73)	0.67	40	1.09*

Note 1: Standard deviations are in parentheses and *, **, *** denote a 1%, 5% and 10% level of significance, respectively).

Note 2: * implies Yes = 1, No = 0.

Note 3: p.m. = per month.

There are more households in the control group who work on their own land compared to the treatment group (at a 1% level of significance). But there are more households in the treatment group who work on others' land compared to the control group (significant at a 10% level). Again, the per capita monthly medical expenditure of the arsenic-affected households is more compared to that of the arsenic-unaffected households (significant at a 1% level), which confirms our apprehension that the per capita monthly medical expenditure essentially reflects the adaptive expenditure of the arsenic-affected households from possible labour market loss. The two groups are not significantly different in any other aspect except that the treatment group has more per capita ownership of land than the control group (significant at a 1% level). The similarity in the number of per capita working days across the groups shows (Proposition 1) that the direct and indirect effects of arsenicosis almost balance each other out, which indicates the social discrimination of the arsenic-affected group.

5. ANALYSIS AND RESULTS

We performed the PSM analysis using the Stata 12 software. Through PSM, we first paired the households in the treatment group with the households in the control group who observationally possess similar characteristics. To do this, we identified the common support region between the treatment and control groups in terms of their propensity scores. PSM can be performed only on the observations in the common support region between the two groups. From the propensity score calculations, we found 329 households of the treatment group (i.e., arsenic-affected group) and 392 households of the control group (i.e., arsenic-unaffected group) in the common support region. The rest (45 households) of the treatment group were out of the common support region. The 329 households (on support) of the treatment group were matched with exactly 329 households (on support) of the control group. According to the methodology described above, we used the standard deviation of the propensity scores (estimated as 0.26) to calculate the value of the calliper as 0.0656.

The differences in the mean outcomes of the matched pairs were interpreted as the impact of the treatment, i.e., the economic loss suffered due to arsenicosis. Table 3 describes the results of the comparison of the outcome variables of the two groups. From Table 3, it can be observed that the mean of the monthly household per capita income of the 329 households of the treatment group is obtained as ₹1,485.98 per month per capita, while for the 329 households of the control group it is ₹2,174.17 per month per capita. The former is lower than the latter by ₹688.20 (equivalent to $13.76) per month per capita, which turns out to be significant at a 1% level. We can take this figure as a measure of welfare loss per capita due to arsenicosis on account of social discrimination.[10] Note that this figure is more than the income loss figure calculated by Roy (2008), which stands at ₹350 (equivalent to $7).The difference arises because while Roy (2008)[11] calculates the income loss which arises only due to adverse labour market outcomes, our figure captures the income loss from non-labour sources like social discrimination as well. Therefore, the empirical findings of the paper confirm that the figures provided by Roy (2008) underestimate the economic loss due to arsenicosis as claimed in Proposition 1 stated in Section 2.

Table 3: Comparison of the outcome variables of matched households (no. of observations = 329)

Outcome variables	Arsenic-affected			Arsenic-unaffected			Mean difference	S.E.	T-stat
	Mean	Min	Max	Mean	Min	Max			
Per capita monthly household income (INR)	1,485.98 (515.64)	640	4,000	2,174.17 (888.33)	1,000	6,000	-688.20*	70.38	-9.78
Per capita monthly household expenditure (INR)	1,309.06 (309.42)	677	3,725	1,751.85 (596.65)	765	5,033	-442.78*	46.05	-9.61

Note: Standard deviations are in parentheses and *, **, *** denote a 1%, 5% and 10% level of significance, respectively).

We have also compared the per capita average monthly household expenditure for both the treatment and control groups. While the mean of the per capita monthly household expenditure of the treatment (arsenic-affected) group was ₹1,309.06, the same for the control (arsenic-unaffected) group was ₹1,751.85; this is a difference of ₹442.78 (equivalent to $8.86) per month per capita, which is significant at a 1% level. Since we have controlled for the labour market effects (and other kinds of wealth effects

[10] The treatment and control groups of our study are matched in terms of their hours of labour supply in different seasons of the year and their adaptive medical expenditure. This controls for labour market effects on the household income.

[11] More recently, Mahanta *et al.* (2016) and Thakur *et al.* (2019) as well.

like land holding) in our empirical study, according to Proposition 2 derived in Section 2, this can happen only if social discrimination against arsenic-affected households exists.[12]

6. CONCLUSIONS

The present paper proves two points. First, social discrimination exists against arsenicosis-affected households and, consequently, these households suffer from significant economic losses, both in terms of per capita income and per capita consumption. Second, the existence of social discrimination leads to an underestimation of income loss when calculated only based on labour market sources. The results have important implications for cost–benefit calculations in the adoption of policies tackling the problem of arsenicosis.

While prior studies that estimate economic loss due to arsenicosis concentrate only on loss of labour income due to illness, the present paper constructs a theoretical model to argue that such a method underestimates the true economic loss of these households as they also face social discrimination. We argue that the PSM method, when applied properly, offers a way to estimate the loss from non-labour market sources like social discrimination. In this study, we apply the method on a dataset collected from a household survey in an arsenic-affected village in West Bengal, India, to estimate the income and consumption loss due to social discrimination. We then compare the estimates with a previous study by Roy (2008) during a similar time period to show the extent of possible underestimation. On a policy front, the paper highlights two aspects. First, since the paper shows that social discrimination against arsenic-affected households exists and causes them significant losses in income and expenditure, there should be policies to build awareness against the social discrimination faced by such households. Second, the cost–benefit analysis conducted for projects aimed at solving the arsenic problem should take into account the losses from social discrimination, which are significantly high, as we show in this paper. Projects that were previous considered

[12] This argument follows from the fact that the differences in labour supply between the treatment and control households across all seasons were not significantly different (statistically) from zero (Table 2), and that there is no evidence in our survey that there exists more than one wage rate in the market (the labour supply on one's own land also fetches the market wage rate [in the sense of opportunity cost]). Moreover, our PSM study with per capita working days per month in the three seasons as an outcome variable showed that the treatment households supplied significantly more labour compared to their matched control households in the sample. We report the results in Appendix 2 of the paper.

unviable because of an unfavourable cost–benefit analysis may become viable in this new method.

The study suffers from an important limitation. Social discrimination is an unobserved factor in this study, which causes significant per capita income and expenditure differences between the treatment and control group households. A direct measure of social discrimination would have made the results robust. The present study faces data limitations on this count. This work can be updated with a more recent and comprehensive database. The impact of various policy interventions on the arsenic-affected households can also be studied. These remain as future research agenda.

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APPENDIX 1

Table A.1: The questionnaire

<table>
<tr><td colspan="8">Name of the head of the family</td></tr>
<tr><td rowspan="2">Family size</td><td>Male</td><td>Female</td><td>Total</td><td rowspan="2"></td><td colspan="3">Religion dummy</td></tr>
<tr><td></td><td></td><td></td><td>Hindu (1)</td><td colspan="2">Muslim (0)</td></tr>
<tr><td colspan="4">No. of literate persons</td><td></td><td colspan="3">Percentage of literate persons</td></tr>
<tr><td colspan="4">Percentage of males in the household</td><td colspan="4">Percentage of females in the household</td></tr>
<tr><td colspan="2">Working in own land</td><td colspan="2">Working on others land</td><td colspan="4">Other source of income (non-farm)</td></tr>
<tr><td>Yes (1)</td><td>No (0)</td><td>Yes (1)</td><td>No (0)</td><td colspan="2">Yes (1)</td><td colspan="2">No (0)</td></tr>
</table>

<table>
<tr><td rowspan="2">House-hold members</td><td colspan="3">Education level</td><td colspan="3">Education level (in %)</td><td>Age (years)</td><td>Percentage of household of working age range</td></tr>
<tr><td>Middle school (up to class 8) (1)</td><td>Higher secondary (2)</td><td>Graduate (3)</td><td>(1)</td><td>(2)</td><td>(3)</td><td></td><td></td></tr>
<tr><td>1.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Total land ownership of the household (katha)	
Per capita land ownership of the household (katha)	
Total monthly household income (₹)	
Per capita monthly household income (₹)	

Household working days per month in different seasons

Summer		Winter		Monsoon	

Household per capita working days per month in different seasons

Summer		Winter		Monsoon	

Total monthly household expenditure (₹)	
Per capita monthly household expenditure (₹)	
Total monthly household medical expenditure (₹)	
Per capita monthly household medical expenditure (₹)	

APPENDIX 2

Table A.2: Comparison of labour supply of matched households (no. of observations = 329)

Outcome variables	Arsenic-affected			Arsenic-unaffected			Mean difference	S.E.	T-stat
	Mean	Min	Max	Mean	Min	Max			
Per capita working days per month in summer	9.76 (3.49)	3.33	30	9.21 (2.95)	4.33	15	0.55**	0.25	2.19
Per capita working days per month in winter	9.77 (3.50)	3.33	30	9.21 (2.94)	4.33	15	0.57**	0.25	2.24
Per capita working days per month in monsoon	9.59 (3.58)	0	30	9.10 (2.94)	3.75	15	0.49	0.26	1.94

Note: Standard deviations are in parentheses and *, **, *** denote a 1%, 5% and 10% level of significance, respectively.