Worker Productivity Impacts of Climate Change Induced Salinization [*]

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Abstract

Climate change-induced salinization (CCIS) has exacerbated the global crisis of safe drinking water, particularly in vulnerable coastal regions of low-income countries. However, the economic repercussions of increased salt intake resulting from CCIS remain under-researched. In this study, using 12 rounds of high-frequency longitudinal data collected from 615 Jute factory workers in Bangladesh, we examine the effects of high salt exposure on worker productivity along both intensive (worker efficiency conditional on showing up for work) and extensive (worker absenteeism due to sickness) margins. Leveraging within-worker variation in temporal water consumption with exogenous seasonal variation in groundwater salinity, we find that high salt intake is associated with a 1.69 percentage-point (pp) reduction in worker efficiency (3%) and a 0.5-day increase (96%) in sickness-related absenteeism among workers older than the median age. Exploiting a natural experiment framework provided by the hotter summer months, this impact intensifies to a 2.59 pp reduction in efficiency (4.3%) and a 0.8-day increase in absenteeism (150%). We document significant heterogeneity by gender and task type: efficiency losses and absenteeism are larger for male workers and those engaged in physically intensive tasks. We identify hypertension as the likely mechanism: above median-age workers exposed to high salt intake are 53% more likely to be hypertensive. Our simple cost estimates indicate that the Jute industry alone in Bangladesh could face a monthly revenue loss of USD 10.4 million due to CCIS, with an associated annual increase of 3.4 million hypertension cases, 123,000 Disability-Adjusted Life Years (DALYs), and approximately 5,300 deaths for the representative population. Nevertheless, consistent with medical literature, we observe that blood pressure responses to salt intake are immediate, suggesting that targeted public policy efforts could help mitigate the adverse effects of CCIS.

Keywords: Salinization, worker productivity, hypertension, coastal Bangladesh

JEL Classification: I15, J24, O10

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1 Introduction

Access to safe drinking water is crucial for safeguarding public health, ensuring quality of life, and maintaining food safety — all of which align with the United Nations Sustainable Development Goals (United Nations, 2024). However, more than 844 million individuals globally are deprived of adequate drinking water, a crisis intensified by climate change-induced salinization (CCIS) in low-elevation coastal zones (Collins et al., 2018). As of January 2023, approximately 898 million people inhabit these vulnerable areas, with over 420 million in low-income countries, facing significant risks from dwindling freshwater supplies (Barbier, 2015; Reimann et al., 2023). The consumption of saline water is closely linked to severe health risks such as preterm delivery due to pre-eclampsia, acute respiratory infections, skin diseases, and malnutrition (Khan et al., 2011; Rahaman et al., 2020). Moreover, the escalation in water salinity can potentially trigger an epidemic of hypertension and other chronic conditions in these regions (Caminade et al., 2019; Vineis et al., 2011). This looming health crisis could also have adverse economic consequences, as worker health is intricately associated to productivity and economic growth (Dupas and Miguel, 2017; Schultz, 2005; Strauss, 1985). In this study, we aim to understand the economic impacts of CCIS by investigating the effects of saline water consumption on worker productivity among low-income coastal populations — an important but underexplored research that requires more academic and policy attention.

The context of our study is Bangladesh, a country apt for the study of CCIS due to its vulnerability to the effects of climate change given its geographic proximity to the ocean and low-lying topography. Over several decades, there has been a significant increase in river salinity in Bangladesh owing to CCIS. This increased salinity has affected the primary drinking water sources in the coastal areas including rivers, ponds (for surface water), and tube wells (for groundwater) (Haque, 2006). Within coastal Bangladesh, we focus on the Jute industry in Khulna — a coastal division that contains two-thirds of the country's total jute factories. Bangladesh accounts for 33% of global jute production and employs an estimated 50,000 workers in this sector (Somoy News, 2023).

A key strength of this study is the rigorous high-frequency longitudinal data collection from 615 workers at a Jute factory in Khulna. We conducted 12 rounds of in-person surveys, beginning with a baseline from October to December 2022, followed by 11 monthly follow-ups throughout 2023. We examine the relationship between high salt exposure and worker productivity after accounting for individual, month, work shift, and day-of-the-week specific effects. We incorporate time-invariant individual fixed effects to account for factors that remain constant over time but vary across individuals. These fixed effects are crucial as they capture inherent personal characteristics such as genetic predispositions, early childhood exposures, and persistent habits (such as smoking). Our rich dataset also enabled us to account for seasonality and examine the lagged impacts of salt exposure—analyses that would not be possible with data collected at a lower frequency. We also utilize the exogenous seasonal variation in groundwater salinity and a natural experiment framework provided by the hotter summer months to identify the causal effect of high salt intake. We collected data on workers' salt intake through their drinking water consumption, calculated by multiplying the quantity of water consumed from each source (i.e., home and factory) by the respective groundwater salinity levels measured directly at factories and workers' homes using dip-based salinity testers. For productivity, we study two key margins: the intensive margin (worker efficiency conditional on showing up for work) and the extensive margin of whether they show up for work (i.e. worker absenteeism due to sickness). Our study especially focuses on older workers (above the median age of 34 years), given the vast medical literature documenting that increased age is associated with a significant increase in the prevalence of hypertension with salt intake (Anderson, 1999; Bray et al., 2004; Frisoli et al., 2012; Lionakis et al., 2012; Lloyd-Jones et al., 2005).

We document four key results. First, on the intensive margin of productivity, high salt intake is associated with a 1.69 percentage-point (3% of mean efficiency) decrease in efficiency for workers with above-median age ($p < 0.05$). These magnitudes are larger than the estimated impacts of large particulate matter (PM) pollution shocks on worker productivity among garment sector workers in India (Adhvaryu et al., 2022). Second, on the extensive margin of worker absenteeism, high salt intake for above median-age workers is associated with a 0.48-day (93%) increase in the number of days absent due to sickness ($p < 0.1$). Third, exploiting a natural experiment framework provided by the hotter summer months, this impact intensifies to a 2.59 pp reduction in efficiency ($p < 0.1$) and a 0.78-day increase in absenteeism ($p < 0.05$). Fourth, examining heterogeneous effects, we document significantly larger impacts of high salt intake for male workers and workers engaged in manual work — a decrease of 7 to 8% in mean efficiency ($p < 0.05$) and more than doubled the sick absence rate ($p < 0.05$).

We identify hypertension (high blood pressure) as the potential mechanism for these adverse effects of high salt intake on worker productivity. Our data shows a strong association between high salt intake and hypertension: above median-age workers exposed to high salt intake were six percentage points (53%) more likely to be hypertensive ($p < 0.01$). Furthermore, male workers of above median age and exposed to a high salt intake were 11 percentage points (98%) more likely to be hypertensive ($p < 0.01$). These findings are consistent with the heterogeneous effects of gender on efficiency, thereby further supporting our hypothesis that hypertension acts as a potential mechanism for the relationship between CCIS and worker productivity.

To assess the robustness of our findings, we examine the lagged effects of high salt exposure from previous months. Our data suggests that the negative impact of high salt intake on worker efficiency is an acute response rather than a cumulative effect. We find no evidence of delayed effects from high salt exposure in the previous months — conditional on contemporaneous high salt intake in the current month, high salt intake (via water consumption) in the last 1, 2, 3, or 11 months does not display a statistically significant relationship with worker efficiency. This finding aligns with medical literature, which indicates that the health effects of sodium intake are more immediate and acute rather than delayed (Gupta et al., 2023).

The productivity losses that we document are significant for both factories and workers. We estimate a significant loss of USD 10.4 million in monthly revenues for the jute industry alone in Bangladesh. Furthermore, our findings suggest that high salt intake for above median-age workers could cause 144 Taka (approximately USD 1.18) wage losses monthly. In addition to the economic losses, our findings underscore significant public health costs arising from disease burden and mortality risks. When scaled to Khulna's 15-64-year-old population, our estimates suggest 3.4 million additional cases of hypertension, leading to an estimated 123,000 Disability-Adjusted Life Years (DALYs) and 5,300 hypertension-related deaths annually. These estimates underscore the urgent need for targeted public health interventions and policy measures, especially given that CCIS-related hypertension remains undetected,[1] and untreated among these vulnerable coastal communities, and the impact is more acute than permanent.

Our study contributes to the literature in several important ways. While there is growing evidence that climate change brings persistent negative impacts in the developing world, most studies focus on climate-induced temperature, precipitation, and pollution extremes (Adhvaryu et al., 2022; Banerjee and Maharaj, 2020; Burgess, 2017; Deschenes, 2014; Shah and Steinberg, 2017). To the best of our knowledge, this is the first study to examine the worker productivity impacts of climate change-induced salinization (CCIS). In assessing the potential role of hypertension, we contribute to two further strands of the literature. One strand examines the adverse impact of CCIS on health. Existing studies have documented a strong link between salinity exposure and hypertension, cardiovascular and renal diseases, and infectious disease (i.e., skin diseases, fever, dysentery, and diarrhea) outbreaks in coastal areas globally (Abedin et al., 2012; Gheorghe et al., 2018; Khanam et al., 2015; Rahaman et al., 2020; Scheelbeek et al., 2017). In the context of Bangladesh, studies show that exposure to excessive salinity induces the prevalence of severe health problems in pregnant mothers (i.e., gestational hypertension, (pre)eclampsia, and miscarriages) (Khan et al., 2014,1; Talukder et al., 2016) (Guimbeau et al., 2024) and chronic and acute nutritional deficiency among children (Das et al., 2019).

A separate strand of the literature studies the link between hypertension and worker productivity in developed country settings (Asakura et al., 2021; Hird et al., 2019; MacLeod et al., 2022). Here, the causes of hypertension are primarily due to lifestyle choices including a high-sodium diet. However, there is limited evidence on the relationship between hypertension and worker productivity in developing country contexts, where individuals are exposed to high salt intake due to CCIS and rising groundwater salinity. Moreover, these are also settings where individuals are less likely to have access to medication for hypertension,

[1] At the baseline 13.33% of our sample was aware of any blood-pressure related issue, whereas we detected the rate of hypertension among upper median sample is 25%.

owing to poor public health capacity and financial constraints. Our results that explore the role played by hypertension in the link between CCIS and worker productivity contribute to this gap in the literature. Our study also speaks to the literature that deals with the adverse impact of external factors on firm productivity, which includes political unrest (Ksoll et al., 2023), electricity outage (Allcott et al., 2016; Fisher-Vanden et al., 2015) and air-pollution (Adhvaryu et al., 2022). We contribute to this literature by demonstrating CCIS lead health impact on firm productivity.

The remainder of the paper is organized as follows: Section 2 describes the background and setting, Section 3 discusses the data and key variables, and Section 4 discusses the empirical specification. The impacts of CCIS on worker productivity are discussed in Section 5, and we explore hypertension and mental health as potential mechanisms in Section 6. Section 7 describes our robustness checks and Section 8 concludes.

2 Background and Setting

Our study area is Bangladesh, a country vulnerable to the effects of climate change due to its geographic proximity to the ocean and low-lying topography. Coastal Bangladesh is part of the flat Ganges Delta that streams water from the Himalayas into the Bay of Bengal, and it accounts for 32 percent of the land area and 25.7 percent of the population of Bangladesh (Dasgupta, 2015). River salinity in the coastal area depends on the volume of freshwater discharges from the upstream river systems, the salinity of the Bay of Bengal near the coast, and the circulation pattern of the coastal waters induced by the ocean and strong tidal currents. Since 1948, there has been a significant increase (around 45%) in river salinity due to reduced freshwater inflows from the transboundary Ganges River, elevated sea levels, siltation of Ganga tributaries, and other rivers. Such changes in salinity in coastal Bangladesh can thus be considered exogenous owing to the nature of the factors outlined above. This increased salinity affects the primary drinking water sources in coastal areas, including rivers, ponds (for surface water), and tube wells (for groundwater) (Haque, 2006). There is a heavy dependency on rainwater, and people face severe drinking water scarcity during the dry seasons due to recurrent droughts (Abedin and Shaw, 2018; Atiq Rahman and Ravenscroft, 2003).

Within coastal Bangladesh, we focus on the Khulna region due to its position as a coastal division threatened by climate change, rising sea levels, and drinking water salinity. The mean sodium concentration in potable water sources in Khulna ranges from 700 to 1500 mg/L, which can easily exceed the WHO recommended level of 2000 mg/L of sodium intake just by drinking 2 to 3 liters of water (Scheelbeek et al., 2017; Shammi et al., 2019).[2] Khulna is also one of the key industrial regions of Bangladesh, hosting a diverse array of industries, including Jute mills, Shrimp processing, and Shipbuilding. These sectors are significant contributors to

[2] A recommended minimum daily quantity of water for drinking is 5.3 liters (L)/person in Bangladesh (World Health Organization, 2021).

the regional and national economy and employ thousands of workers. Specifically, Khulna is home to two-thirds of the total number of Jute factories in Bangladesh, and private Jute factories in Khulna have seen a significant rise in exports and global market interest in recent years (Desk, 2023). Given this background, we took the Jute industry as a representative industrial sector of the region.

For the purpose of this study, we collaborated with a Jute factory in Khulna to collect high-frequency data on workers. The factory operates in two production units: yarn (henceforth, Production Unit 1) and jute bags (henceforth, Production Unit 2). Both units have different sections that use various types of machinery. There are eight sections in Production Unit 1 - Batching, Carding, Drawing, Spinning, Roll Winding, Precision Winding, Twisting, and Roping; whereas Production Unit 2 has seven sections – Damping, Calendering, Lapping and Cutting, Bangla Loom, S4A Loom (China Loom), Herakle & Hemming, and Hand Sewing. Appendix Table A1 summarizes the activities performed in each section.

There are three different working shift schedules. In Unit 1, three shifts run continuously for 24 hours: morning (6:00 AM to 2:00 PM), evening (2:00 PM to 10:00 PM), and night (10:00 PM to 6:00 AM). The workers in Unit 1 rotate shifts every 15 days, moving from morning to evening, from evening to night, and night to morning. In contrast, Unit 2 has a more stable schedule: Morning and evening shifts are fixed, while the night shift runs occasionally based on production demand. Approximately 80% of the workforce is employed in Production Unit 1. This unit requires relatively less manual work than production unit 2 because spinning, roll winding, and precision winding involve higher levels of mechanization than looming and Herakle & Hemming, where manual intervention and workmanship are needed.

Workers in our study factory receive a flat wage of 270 Taka (about USD 2.22) per shift, which does not depend on performance or productivity (which is also not recorded at the individual level). Our detailed discussion with factory management confirmed that shift and line managers (and supervisors) can only observe shift-level, unit-level, and line-level outputs. Factory management informed that skilled Jute workers in Khulna are in high demand; as such, workers usually do not lose jobs if they display higher rates of absenteeism. Most of the workers come to the factory either commuting from their natal villages (the factory provides transportation facilities for this purpose) or staying in the residential hostel provided by the factory.

3 Data and Key Variables

For this study, we selected the production sections of the factory based on two criteria: (a) the section needs to have at least 25 workers, and (b) production output can be measured at the individual level. Six of the 15 production sections satisfied these criteria: Roll winding, Precision winding, and spinning from production unit 1 and Bangla loom, S4A loom (China loom), and Herakle & Hemming from production unit 2.

We implemented a rigorous high-frequency data collection protocol, conducting baseline assessments (first round of data collection) of 615 factory workers from October to December 2022, followed by 11 rounds of follow-up data collection throughout 2023. A majority of the wokers (68%) said that they were born in the area of their current residence. When asked about their reasons for living in their current residence, no one mentioned salinity as a factor. Thus, migration or endogenous relocation away from high-salinity areas is unlikely a concern in our setting. In terms of the distribution of the workers across sections in the factory, we document the following: Roll Winding (45.86%), Precision winding (18.74%), Bangla loom (13.98%), S4A loom (17.21%), and Herakle & Hemming (5.01%).

Data on workers' demographic characteristics, health habits, work experience, and earnings information was collected during the first round of the survey. We also collected the height, weight, and arm circumference of the participants to compute the body mass index (BMI) and MUAC using a measuring tape (cm) and a weighing scale (kg), respectively. During each of the subsequent 11 follow-up survey rounds, data on water consumption by source, groundwater salinity, physical and psychological health, blood pressure measurement, and production of each worker was collected once every month, along with the baseline.[3] Data on worker absence rates and underlying reasons were collected from follow-up rounds 6 to 11.

Worker Output and Productivity We collected a standardized measure of the productivity (efficiency) of the workers across a range of tasks in the Jute factory. First, we recorded the actual production (i.e., product weight, number of pieces of cloth) of each worker along with specific production-related data for each section, which includes information on the number of machines operated, working time (break times and time wasted due to machine-related issues subtracted from the total shift hours), input, product, and machine specifications. Next, we calculate a production benchmark or the maximum possible output for each section utilizing the production-related data and industry-standard production formulas. Productivity is then measured by comparing the actual production to the calculated production benchmark, and efficiency is expressed as a percentage. The appendix section B.1 discusses the data collection process and the efficiency calculation formulae for each section of the factory in detail.[4] We also report an alternative measure of productivity rescaled to the maximum productivity achieved in each section, and report the results in Appendix Table A2.

We took several steps to address potential concerns relating to experimenter demand effects throughout our study. For example, the research and field management team held

[3]With the exception of helpers in the spinning section. The spinning section has two types of workers - machine operators and helpers. A helper's primary job is to help arrange the yarn and move the product from the spinning section to the storage room of the next production process. We did not include helpers in this study due to the inability to clearly define and measure their individual-level output.

[4]Our measures of productivity are independent across sections, i.e., productivity declines in one section do not spillover to our measures of productivity for other sections. This is because any waiting time (such as waiting for processed yarn from another section) is included in the break time for workers.

meetings with the factory supervisors to explain the study objectives and data collection procedures. We clarified that our goal was to calculate worker productivity for research purposes, and not to evaluate individual performance for the factory. The supervisors understood that this process would not impact workers' job security or their benefits. The supervisors helped ensure that the workers remained unaware of the monitoring of their activities and outputs. Each week, we randomly selected workers to monitor and record their activity and production. Since the enumerators moved around the factory continuously to observe and record data, workers were unaware of exactly which individuals were being monitored. Product weights were also measured and recorded in locations not visible to the workers to maintain anonymity. More details about our data collection procedures are available in Appendix B.1.

Absence Due to Sickness Since follow-up six, workers were asked to recall the total number of days they did not come to the factory last month and the reasons behind it. The total number of days in a month a worker was absent due to sickness is used to define the 'Sickness Absence' for that particular month.

Blood Pressure Individual-level blood pressure measures were collected monthly using digital blood pressure monitoring devices. The monitor uses the oscillometric method, a non-invasive way to measure blood pressure using an automated cuff. Field enumerators who collected health information and blood pressure measurements were trained and supervised by a medical health professional who occasionally visited the data collection site.[5] We focus on four standard measures of blood pressure: (1) systolic blood pressure, the pressure in the arteries when the heart contracts (2) diastolic blood pressure, the pressure in the arteries when the heart is relaxed, (3) hypertension, when systolic blood pressure is greater than or equal to 140 mmHg or diastolic blood pressure is greater than or equal to 90 mmHg (Chakraborty et al., 2019; Nahian et al., 2018)[6], and (4) pulse pressure, the difference between the systolic and diastolic blood pressure, representing the force that the heart generates each time it contracts. High pulse pressure is defined as an indicator equal to 1 if the individual's pulse pressure exceeded 60 mmHg, and 0 otherwise. This can be indicative of increased arterial stiffness or other cardiovascular conditions.

Ground Water Salinity Digital water salinity testing machines were used to measure the salinity of drinking water at respondents' homes and the factory. We collected information on the amount of water workers usually drink from each source. Workers were given uniquely identified 250 ml bottles the day before an interview to collect the drinking water they typically drink at home. Enumerators collected the bottles from workers during the health data collection. For factory water, samples were collected from four designated sources

[5]If the blood pressure is much higher than the normal level (i.e., systolic pressure 200 or more and diastolic pressure below 60 or 65 then the respondent were advised to go to the factory medical center immediately.

[6]Respondents who were taking medication for hypertension at the time of the survey are considered hypertensive.

(two water sources from each production unit) on each survey day. After collecting the samples, water salinity was measured by CON30 TDS (mg/l)/Conductivity (µS/cm)/Salinity (mg/l) testers. A worker's total salt intake via drinking water consumption is calculated by multiplying the amount of water from each source (i.e., home, factory) by the groundwater salinity of the respective source and measured in milligrams. The WHO recommends a maximum concentration of 200 mg/L for sodium (Na) and 250 mg/L for chloride (Cl) in drinking water (approximately, 442 mg/L salinity), which has been standardized based on taste threshold, not on health considerations. The standard value of sodium chloride intake adopted by Bangladesh is 150-600 mg/L (approximately, 265-1060 mg/L salinity) (Akter et al., 2016; Benneyworth et al., 2016). However, in case of lack of non-availability of alternative sources, a significantly higher level of chloride intake of 1000 mg/L (approximately, 1650 mg/L of sodium chloride or salt) is considered acceptable for the coastal regions in Bangladesh (Ahmed, 2000; Nahian et al., 2018).

3.1 Summary Statistics

Table 1 provides an overview of the demographic characteristics, health conditions, water consumption and salt intake patterns of the study sample in the baseline. Panel A shows that the average age of the sample workers is 33.48 years, with a standard deviation of 12.47 years, indicating a relatively young population with a wide age range. 62.1% of the sample workers are male, and 60.5% of the sample is married. In terms of educational attainment, 12.5% of the participants reported having no formal schooling. Panel B shows the overall nutritional status of the workers. 60.7% of the participants fall within the healthy BMI range of 18.5 to 25. On the other hand, 16.4% are identified as malnourished, based on the Mid-Upper Arm Circumference (MUAC).

Panel C reports the blood and pulse pressure measures of the sample. The mean systolic blood pressure is 117.31 mmHg, while the mean diastolic blood pressure is 73.74 mmHg. Hypertension — a systolic blood pressure of 180 mmHg or higher or a diastolic blood pressure of 90 mmHg or higher — is prevalent among 13.3% of the workers. We also calculate pulse pressure, which is the difference between systolic and diastolic blood pressure readings. About 8.1% of our sample workers have a pulse pressure exceeding 60 mmHg (high pulse pressure).

Panel D shows the amount of water consumed from home and the factory, along with the salinity levels in the respective water sources. Participants consume, on average, 4.75 liters of water per day — 3.51 liters from home and around 1.24 liters from the factory daily. The salinity of home water is notably high, with a mean concentration of 910.97 mg/L, while factory water has a mean salinity of 792.71 mg/L. This high groundwater salinity results in an average daily salt intake of 3,968.31 mg solely from water consumption, with some individuals exceeding 8,700 mg per day. Moreover, 25% of the respondents consume more than the WHO-recommended maximum daily salt intake of 5,000 mg (or 2,000 mg/day of sodium) (WHO, 2024) only via water consumption.

Appendix Figure A1 shows the variation in average groundwater salinity (mg/L), water consumption (liters), and salt intake from water (mg/day) by month. Our data shows that despite a decrease in groundwater salinity, the total salt intake of factory workers is higher during the summer (May to August).[7] A significant increase in water intake in the hot and humid months (on average, our sample workers drink 0.54 liters more water in summer months compared to non-summer months) compensates for the relatively lower salinity, leading to an overall increase in salt intake compared to the cooler, drier months.

One implication of the high salinity in drinking water sources is its potential effect on the perception of water taste among the population. At baseline, we asked the respondents about the water taste, and we noticed that the majority were unaware of the water salinity and accustomed to the elevated sodium concentration in their drinking water. Only 12.5% of participants believe that the taste of their water has changed over the years (Panel E). Among those who have observed a change, 47.1% report that their water now tastes more salty. This lack of awareness among the coastal population underscores the urgent need for targeted policy interventions and public health measures to address the CCIS issue.

Appendix Figure A2 presents the distribution of worker production efficiency as a density plot using the Epanechnikov kernel smoothing method. It shows the variation in worker productivity: worker's efficiency might be on average as little as 35% or as much as 85% efficiency in a given month, with the average efficiency falling around 60%.

4 Empirical Specification

While an ideal experiment to study high salt intake and productivity might randomly assign some workers to have a high salt intake, this is neither ethical nor feasible in practice. We run, as a starting point, the following equation for worker *i* in shift *s* on day *d* of the week at time (month) *t*:

$$Y_{isdt} = \beta_0 + \beta_1 HighSaltIntake_{it} + \alpha_i + \delta_s + \lambda_d + \gamma_t + \varepsilon_{isdt} \quad (1)$$

where Y_{isdt} is our outcome variable of interest (worker productivity, absenteeism, or a potential mechanism such as hypertension). $HighSaltIntake_{it}$ is defined as an indicator equal to 1 if the worker's salt intake (combined over the home and factory water consumption) was 0.25 SD above the sample mean. Since time-invariant factors such as genetics and gender could affect one's salt intake and productivity, we include individual fixed effects (α_i) that leverage our rich panel data. Since individuals do not change their production unit section, the individual fixed effects also capture production section fixed effects. Thus, average productivity differences across sections and differences in working conditions across

[7] We collected monthly average temperature data (°C) from 1991 to 2022 from the Bangladesh climate database. Based on the historical temperature data, we define three seasons: 1) Hot and Humid Summer including May to August with an average temperature of 28.65°C; 2) Autumn including September to November with an average temperature of 26.67°C; and 3) Winter including December to February-March with an average temperature of 23.55°.

sections (such as noise or the difficulty of operating machinery) are accounted for by these fixed effects. The timing of the shift (morning, evening, or night) may also affect salt intake and productivity (for example, productivity may be lower during the night shift due to fatigue or higher due to cooler temperatures at night) and so we include shift fixed effects (δ_s). Similarly, salt intake and productivity may vary by the day of the week and the month of the year, and so we include day of the week (λ_d) and month fixed effects (γ_t). The coefficient on $HighSaltIntake_{it}$, β_1, is our coefficient of interest. To account for the within-individual correlations over time, standard errors are clustered at the worker level.

A vast medical literature documents that increased age is associated with a significant increase in the prevalence of hypertension with salt intake (Anderson, 1999; Bray et al., 2004; Frisoli et al., 2012; Lionakis et al., 2012; Lloyd-Jones et al., 2005).[8] To study the impact of CCIS on worker productivity for older workers, we run, as our primary specification, the following equation for worker i in shift s on the day d of the week at time (month) t:

$$\begin{aligned} Y_{isdt} &= \beta_0 + \beta_1 HighSaltIntake_{it} + \beta_2 AboveMedianAge_i \\ &\quad + \beta_3 HighSaltIntake_{it} * AboveMedianAge_i + \alpha_i + \delta_s + \lambda_d + \gamma_t + \varepsilon_{isdt} \end{aligned} \tag{2}$$

where $AboveMedianAge_i$ is an indicator equal to 1 if the worker was above the median age of workers (34 years) in our sample. Here, the coefficient on the interaction term, β_3, is our coefficient of interest. Standard errors are clustered at the worker level. We also report results using age as a continuous variable in Appendix Table A5.

Despite our rich set of fixed effects, a potential concern with our empirical strategy might be that salt intake is endogenous and potentially correlated with unobservable time-varying factors that are also correlated with productivity. To address this concern, we use a natural experimental framework of summer months in Bangladesh (May to August), which is interacted with groundwater salinity as a triple difference estimator.

We define the variable "High groundwater salinity" based on the weighted average of salinity levels from the workers' home and factory water sources.[9] In this way, we distinguish between salinity and salt intake, to disentangle the endogenous response of workers drinking more water in the hotter summer months. Thus, we run the following alternative specification:

$$\begin{aligned} Y_{isdt} &= \beta_0 + \beta_1 HighGroundwaterSalinity_t + \beta_2 AboveMedianAge_i + \beta_3 Summer_t \\ &\quad + \beta_4 HighGroundwaterSalinity_t * Summer_t + \beta_5 AboveMedianAge_i * Summer_t \\ &\quad + \beta_6 HighGroundwaterSalinity_t * AboveMedianAge_i \\ &\quad + \beta_7 HighGroundwaterSalinity_t * AboveMedianAge_i * Summer_t + \alpha_i + \delta_s + \lambda_d + \gamma_t + \varepsilon_{isdt} \end{aligned} \tag{3}$$

[8]For example, Bray et al. (2004); Frisoli et al. (2012) note that sodium reduction to a level of 1500 mg/d lowers blood pressure more in older adults than younger adults. In a trial, systolic blood pressure decreased by 8.1 mmHg in those aged 55 to 76 years, compared with 4.8 mmHg for adults aged 23 to 41 years.

[9]These weights do not vary by worker and are determined as the ratio of average water consumed from a source to the total average water consumption for that season.

where $Summer_t$ is an indicator for the summer months in Bangladesh (May to August) and $HighGroundwaterSalinity_t$ is an indicator variable taking the value 1 when groundwater salinity is more than 0.25 SD above the average groundwater salinity.

To study how the heterogeneous impacts differ by worker and task characteristics, we augment equation 2 and use the following specification:

$$\begin{aligned} Y_{isdt} &= \beta_0 + \beta_1 HighSaltIntake_{it} + \beta_2 AboveMedianAge_i + \beta_3 X_i \\ &+ \beta_4 HighSaltIntake_{it} * X_i + \beta_5 AboveMedianAge_i * X_i + \beta_6 HighSaltIntake_{it} * AboveMedianAge_i \\ &+ \beta_7 HighSaltIntake_{it} * AboveMedianAge_i * X_i + \alpha_i + \delta_s + \lambda_d + \gamma_t + \varepsilon_{isdt} \end{aligned} \tag{4}$$

where X_i is a worker or task-specific characteristic of interest. We focus on two characteristics. First, in line with medical literature documenting the heterogeneous effects of blood pressure by gender (see, for example, Lloyd-Sherlock et al. (2014); Pimenta (2012); Safar and Smulyan (2004)), we study the differential impacts on gender. Second, we hypothesize that workers performing tasks that are more physically intensive in nature may be more affected by CCIS. This hypothesis is in line with that of Adhvaryu et al. (2022), who studies whether workers performing tasks that are more cognitively challenging may be more affected by pollution.

We construct the variable $JobIsManual_i$, an indicator equal to 1 if the worker was assigned to production unit 2. As detailed in Section 2, this unit performed manual tasks, including Damping, Calendering, Lapping and Cutting, Bangla Loom, S4A Loom (China Loom), Herakle & Hemming, and Hand Sewing. Here, the coefficient on the triple interaction term, β_7, is our coefficient of interest. Standard errors are clustered at the worker level.

5 The Impacts of CCIS on Worker Productivity

5.1 Main Results on Efficiency and Absenteeism

Table 2 presents our main results of the effect of CCIS on worker efficiency conditional on showing up for work (i.e. an intensive margin of productivity). While column (1) shows a negative but statistically insignificant relationship between salt intake and efficiency in the overall sample, column (2) highlights that high salt intake is associated with a 1.69 percentage-point decrease in efficiency for workers above median age ($p < 0.05$). On a base productivity of 60% across all workers, this represents about a 3% decrease in productivity. When using our alternative measure of productivity rescaled to the maximum productivity achieved in each section, we estimate that high salt intake is associated with a 1.87 percentage-point decrease in efficiency for workers above the median age (see Appendix Table A2). These magnitudes are larger than the estimated impacts of large particulate matter (PM) pollution shocks on worker productivity — for example, Adhvaryu et al. (2022) estimate that a 1 SD increase in pollution decreases efficiency by about 0.8 percentage points or 1.6% of the mean productivity among garments sector workers in India.

While efficiency is an important intensive margin measure of worker productivity, we also assess the effect of CCIS on the extensive margin of worker absenteeism. Columns (3) and (4) of Table 2 examine the relationship between high salt intake and absenteeism due to sickness. Column (3) highlights that high salt intake is associated with a 0.5-day increase in the number of days absent from the factory due to sickness in the past month ($p < 0.01$). On a base of an average of 0.51 days absent per month, this represents a large, 96% increase in absenteeism. Column (4) shows that for workers above median age, high salt intake is associated with a 0.48-day increase in the number of days absent due to sickness — i.e., a 92% increase ($p < 0.1$).

Our estimates are robust to alternative definitions using cutoffs that are smaller (0.15 SD above the mean) or larger (0.35 SD above the mean). These results are presented in Appendix Table A3. Our finding that the relationship between salt intake and efficiency is most salient for older workers is further highlighted in Table A5 and Figure A3. Columns 1 and 2 of Table A5 shows that the negative effect of high salt intake on productivity (both intensive and extensive margin) increases with workers' age. Figure A3 explores the heterogeneity in the relationship between high salt intake and efficiency by 10-year age bins. While we do not observe statistically significant relationships for workers aged 30 and below, every age bin greater than age 30 displays statistically significant differences at the 10% level.[10] This is consistent with the medical literature documenting that increased age is associated with a significant increase in the prevalence of hypertension (Anderson, 1999; Bray et al., 2004; Lionakis et al., 2012; Lloyd-Jones et al., 2005).

To examine potential non-linearities in the relationship between salt intake and our outcomes of interest, we also estimate a quadratic functional form (including the square of $HighSaltIntake_{it}$) in equation 1. These results are presented in Appendix Table A4. We do not find statistically significant non-linearities in the relationship between salt intake and our measures of efficiency and hypertension. This is consistent with the mixed evidence in the medical literature: while some studies have documented non-linear relationships between salt intake and health or performance outcomes (Graudal et al., 2014; Mente et al., 2016), others have not detected such non-linearities (He and MacGregor, 2010; O'Donnell et al., 2014).

Taken together, our results highlight large and statistically significant impacts of CCIS on the intensive and extensive margins of worker productivity.

5.2 Main Results Utilizing Variation over Summer Months

As noted in Section 4, a potential concern with our empirical strategy might be that salt intake is endogenous and potentially correlated with unobservable time-varying factors that are also correlated with productivity. To address this concern, we estimate specification 3 and present these results in Table 3 and Table A6. We find that workers exposed to high groundwater salinity in the summer months were 2.59 percentage points less efficient ($p < 0.1$) and had a 0.78-day increase ($p < 0.5$) in sickness absence. These workers were also 6.9 percentage points more likely to be hypertensive ($p < 0.05$) as shown in Table A6. This evidence using

[10]Except for the 51-60 year age bin which suffered from limited sample hence the estimate is noisy.

an alternative identification strategy adds credibility to our claim that high salt intake has a negative impact on worker productivity.

5.3 Heterogeneous Effects

In Table 4, we explore two important dimensions of heterogeneity that potentially impact the relationship between CCIS and worker productivity: gender and the manual nature of work. The triple interaction term in column (1) highlights that male workers of above median age exposed to high salt intake had 4.8 percentage points (or 8%) lower efficiency relative to female workers of below median age who were not exposed to high salt intake ($p < 0.01$). Furthermore, column (3) highlights that male workers of above median age exposed to high salt intake were associated with a 1.2-day increase in the number of days absent from the factory due to sickness in the past month ($p < 0.05$).

The triple interaction term in column (2) highlights that above-median-age workers engaged in more manual work and exposed to high salt intake had 4.12 percentage points (or 7%) lower efficiency relative to below-median-age workers not engaged in manual work who were not exposed to high salt ($p < 0.05$). In addition, column (4) shows that above-median-age workers engaged in more manual work and exposed to high salt intake were associated with a 1.1-day increase in the number of days absent from the factory due to sickness in the past month ($p < 0.05$). This heterogeneity aligns with findings by Adhvaryu et al. (2022), who find that workers performing tasks with complexity at least 1 SD above the average exhibit productivity losses roughly 3 times the size of those performing less complex tasks.

6 Potential Mechanisms

6.1 Blood Pressure

We focus on high blood pressure as a potential mechanism for our results for two reasons. First, a vast medical literature has documented the impacts of high salt intake on hypertension (Frisoli et al., 2012; He et al., 2005; Youssef, 2022). For example, Scheelbeek et al. (2017) document in a study in coastal Bangladesh that a 100 mg/L reduction in sodium in drinking water was associated with a reduction in systolic/diastolic blood pressure by 0.95/0.57 mmHg, and the odds of hypertension were lower by 14%. Second, a number of studies have established a relationship between hypertension and low productivity (see, for example, Asakura et al. (2021); Hird et al. (2019); MacLeod et al. (2022)). Taken together, blood pressure is a potential mechanism for the relationship between salt intake and productivity.

Table 5 highlights the relationship between high salt intake and blood pressure. As outlined in Section 3, we use four standard measures of blood pressure: systolic, diastolic blood pressure, hypertension, and high pulse pressure. Column (1) highlights that workers exposed to high salt intake were 3.1 percentage points more likely to be hypertensive ($p < 0.05$). Column (5) further highlights that above median-age workers exposed to high salt intake were 6 percentage points more likely to be hypertensive ($p < 0.1$). On a base of 11.3%, this represents a large, 53% association with hypertension for above median-age workers. Since hypertension is defined on the basis of systolic and diastolic blood pressure readings, columns (2) and (3) examine these separately. Columns (2) and (3) show that workers exposed to high salt intake had 1.23 mmHg higher systolic blood pressure readings ($p < 0.01$) and 0.51 mmHg higher diastolic blood pressure ($p < 0.1$). Similarly, columns (6) and (7) show that above median-age workers exposed to high salt intake had 2.25 mmHg higher systolic blood pressure readings ($p < 0.01$) and 1.39 mmHg higher diastolic blood pressure ($p < 0.05$). Lastly, columns (4) and (8) report impacts on high pulse pressure. Workers exposed to high salt intake were 2.6 percentage points more likely to have high pulse pressure ($p < 0.01$), while above median-age workers were 4.5 percentage points more likely to be have high pulse pressure ($p < 0.01$).

Our results on hypertension are also consistent with the heterogeneous effects explored in section 5.3. Table A7 shows that male workers of above median age and exposed to a high salt intake were 11 percentage points more likely to be hypertensive ($p < 0.05$). In contrast, no statistically significant relationship is seen for female workers of above median age exposed to high salt intake. These results are consistent with the findings shown in Table 4 for efficiency, thereby further supporting our hypothesis that hypertension acts as a potential mechanism for the relationship between CCIS and worker productivity.

6.2 Mental Health

We also study mental health as a potential mechanism underlying the relationship between high salt intake and productivity. In Appendix Table A8, we study two standard measures of mental health: depression and anxiety (assessed using the Patient Health Questionnaire (PHQ-9) and Generalized Anxiety Disorder (GAD-7) questionnaire). Overall, we do not find any statistically significant relationships between high salt intake and mental health.

Taken together, we find strong evidence of high blood pressure as a potential mechanism underlying the relationship between high salt intake and productivity, but do not find any evidence in favor of a mental health channel.

7 Robustness Check: Ruling out Lagged Effects

Since our results focus on the relationship between salt intake in the contemporaneous month and efficiency, a potential concern might be that lags of salt intake in previous months may also impact efficiency. Table A9 explores the relationship between lagged salt intake and worker efficiency. In columns (1) and (3), we study the impact of adding the previous month's salt intake (i.e. a one-month lag) to our main regression specification (2). We do not observe any statistically significant impact of high salt intake in the previous month on efficiency and absenteeism for above median-age workers. In columns (2) and (4), we add two additional lags (2 and 3-month lags, respectively). Here too, we do not observe any statistically significant impact of high salt intake in the previous 3 months on efficiency and absenteeism for above median age workers. These regressions suggest that lagged salt intake does not impact worker productivity.

These results are consistent with evidence in the medical literature concerning the short-term relationship between salt intake and high blood pressure. For example, Gupta et al. (2023) conducted a study in which participants were randomized to either a high-sodium diet with 2,200 mg of sodium added to their usual daily diet, or a low-sodium diet with a total of 500 mg sodium daily for one week. Participants then switched to the opposite diet for one week. The authors found that lowering blood pressure through dietary sodium reduction can be achieved safely and rapidly within one week. Our results on the lack of lagged effects are consistent with the medical literature documenting the short-lived effects of salt intake on blood pressure.

8 Discussion and Conclusion

Using 12 rounds of longitudinal data collected at a high frequency (monthly) from factory workers in Bangladesh, we document statistically significant relationships between climate change-induced salinization (CCIS) and worker productivity. On the intensive margin of productivity (i.e. conditional on showing up for work), we find that high salt intake is associated with a 3% decrease in efficiency for workers above median age ($p < 0.05$). On the extensive margin of worker absenteeism, high salt intake for above median-age workers is associated with a 94% increase in the number of days absent due to sickness ($p < 0.1$). Examining heterogeneous effects, we document significantly larger impacts of 7-8% decreases in efficiency for male workers and workers engaged in manual work ($p < 0.01$).

These losses are significant for both workers and factories. From the factory perspective, we perform a simple back-of-the-envelope calculation to understand revenue losses. On average, the factory had monthly revenues of 139 million Taka (USD 1.19 million) during our study period. Given our 3% efficiency impact, we estimate that high salt intake for above median-age workers could cost the factory USD 35,600 monthly. Across 291 jute mills in Bangladesh[11], this is a significant loss of USD 10.4 million in monthly revenues for the jute industry alone in Bangladesh. We also perform a simple back-of-the-envelope calculation to understand wage losses for workers. The workers are paid by shift and are paid, on average, 270 Taka per shift. Workers work, on average, 1.07 shifts per day. Given our absenteeism impact of 0.5 days per month, we estimate that high salt intake for above median-age workers could cause $270*1.07*0.52 = 144$ Taka (approximately USD 1.18) wage losses monthly.

In addition to the economic losses, our findings underscore significant public health costs arising from disease burden and mortality risks. Based on the hypertension-related age-standardized mortality risk in Bangladesh and disease burden calculations presented in (Islam et al., 2023), we estimate that approximately 27% of workers in our sample could

[11] https://www.juteyarn-bjsa.org/statistical-information/

develop hypertension due to high salt exposure, leading to an estimated 0.26 hypertension-related deaths and 6.12 Disability-Adjusted Life Years (DALYs).[12] When scaled to Khulna's 15-64-year-old population of approximately 12.3 million, this suggests annually 3.4 million additional cases of hypertension, leading to 123,000 Disability-Adjusted Life Years (DALYs) and an estimated 5,300 hypertension-related deaths. These estimates underscore the urgent need for targeted public health interventions and policy measures, especially given that hypertension mostly remains undetected and untreated among these vulnerable coastal communities.

Fortunately, our examination of hypertension as a potential mechanism offers hope for policy. We rule out lagged effects from high salt intake in previous months (conditional on contemporaneous high salt intake in the current month), consistent with medical literature that documents the short-lived response of blood pressure to salt intake, often within a week. This suggests that interventions aimed at reducing the salt intake among workers could reverse the negative effects on worker efficiency and absenteeism. We leave the exploration of adaptation and mitigation interventions to CCIS for future research.

[12]Our findings show that high salt exposure is associated with a 27.4% increase in hypertension (baseline hypertension is 11.3 percent and high salt exposure is associated with an increase in this rate by 3.1 percentage points). Therefore, approximately 169 additional workers out of the 615 (0.274*615) would be expected to have hypertension due to high salt exposure. Islam et al. (2023) note that the age-standardized death rate due to hypertension in Bangladesh was 155.74 per 100,000 in 2019. Taken together, the increase in hypertension-related deaths due to high salt exposure in our sample would be approximately 0.26 deaths (155.74/100000*169).

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Tables and Figures

Table 1: Socio Demographic Profile, Water and Salt Intake of Participants

	Mean	SD
Panel A: Demographic Information		
Age (in Years)	33.483	12.471
Male = 1	0.621	0.485
No schooling (1= Yes)	0.125	0.331
Married (1= Yes)	0.605	0.489
N	615	
Panel B: Body Mass Index and Malnourishment		
Healthy (bmi 18.5 to 25)	0.607	0.489
Malnourished (MUAC: Male<=23cm, Female<=22cm)	0.164	0.371
Panel C: Blood Pressure		
Hypertension (Systolic>=180 mmHg or Diastolic>=90 mmHg)	0.133	0.340
Systolic Blood Pressure (mmHg)	117.312	20.307
Diastolic Blood Pressure (mmHg)	73.758	12.347
High Pulse Pressure (Systolic - Diastolic BP > 60 mmHg)	0.081	0.274
Panel D: Drinking Water Source, Groundwater Salinity, Salt Intake via Water		
Water from Home (litre)	3.511	1.854
Water from Factory (litre)	1.238	1.213
Salinity in Home Water (mg/L)	910.966	484.560
Salinity in Factory Water (mg/L)	792.711	196.837
Salt Intake via Water Consumption (mg)	3,968.307	1,920.700
Panel E: Perception on Water Taste		
Water Taste Changed Over Years	0.125	0.331
Water Tastes More Saline | Water Taste Changed	0.471	0.503

Note: The mean values in Panel A report the average age of the workers and, the percentage of workers who are male, have no schooling, and are married. Panel B shows the workers' health status based on BMI and MUAC which we calculated from the recorded height, weight, and arm measurements. Panel C reports the average systolic and diastolic blood pressure and prevalence of hypertension among the study sample. Panel D reports workers' water consumption (in liter) by source, salinity level in the respective water, and workers' total salt intake (in milligrams) via drinking water consumption - the amount of water from each source (i.e., home, factory) multiplied by the groundwater salinity. In Panel E, we report workers' baseline perception of water taste.

Table 2: Effect of Salt Intake (via Water Consumption) on Worker Productivity

	(1) Efficiency	(2) Efficiency	(3) Sickness Absence	(4) Sickness Absence
High Salt Intake	-0.390	0.394	0.493***	0.277*
	(0.428)	(0.520)	(0.133)	(0.143)
Above Median Age * High Salt Intake		-1.689**		0.475*
		(0.856)		(0.270)
Individual FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Shift FE	Yes	Yes	Yes	Yes
Day of the Week FE	Yes	Yes	Yes	Yes
Mean Production capacity (%)-All Workers	60.038	60.038		
Mean Salt Intake from Water (mg/day)	3471.985	3471.985		
Average Monthly Absence due to Sickness (Day)			0.514	0.514
Salary Per Shift (BDT)			269.723	269.723
Average Monthly Earnings from this Job (BDT)			6934.182	6934.182
Observations	4344	4344	2186	2186
R-sqr	0.012	0.013	0.017	0.020

Note: This table reports the regression of workers' production efficiency and sickness absence on high salt intake. Columns 1 and 3 show the estimates of equation 1 and Columns 2 and 4 show the estimates of equation 2. 'Efficiency' is the ratio of actual output to the calculated production benchmark (output at machine capacity), expressed as a percentage. 'Sickness Absence' is measured as the total number of days a worker was absent last month due to sickness. 'High salt intake' is a binary variable that takes a value of 1 if the salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water. 'Above median age' is a binary variable that takes a value of 1 if the worker's age is above the median age (34 years) of sample workers. Both regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

Table 3: Effect of High Groundwater Salinity Exposure During Summer Months on Worker Productivity

	(1) Efficiency	(2) Sickness Absence
High Groundwater Salinity	0.197	0.106
	(0.675)	(0.183)
Above Median Age * High Groundwater Salinity	0.388	0.619*
	(1.175)	(0.322)
Above Median Age * High Groundwater Salinity * Summer	-2.587*	0.775**
	(1.530)	(0.356)
Individual FE	Yes	Yes
Month FE	Yes	Yes
Shift FE	Yes	Yes
Day of the Week FE	Yes	Yes
Mean Production capacity (%)-All Workers	60.038	60.038
Average Monthly Absence due to Sickness (Day)	0.514	0.514
Groundwater Salinity in Non-Summer Season (mg/day)	781.695	781.695
Groundwater Salinity in Summer (mg/day)	736.926	736.926
Observations	4402	4675
R-sqr	0.014	0.021

Note: This table shows the effect on workers' efficiency and sickness absence of high groundwater salinity by season. 'Efficiency' is the ratio of actual output to the calculated production benchmark (output at machine capacity), expressed as a percentage. 'Sickness Absence' is measured as the total number of days a worker was absent last month due to sickness. Groundwater salinity is measured as a weighted average of the salinity levels from workers' home and factory water sources, with the weights determined by the seasonal water consumption ratios (the ratio of average water consumed from a source to the total average water consumption for that season). The binary variable "High groundwater salinity" is assigned a value of 1 if the groundwater salinity is more than 0.25 standard deviations above the average groundwater salinity. 'Above median age' takes a value of 1 if the worker's age is above the sample median age. The variable 'Summer' takes a value of 1 if a month falls under the summer season (May to August). The table reports the estimates of equation 4 that includes the fixed effects of the month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

Table 4: Heterogeneous Effect of Salt Intake (via Water Consumption) on Worker Productivity

	(1)	(2)	(3)	(4)
	Efficiency	Efficiency	Sickness Absence	Sickness Absence
High Salt Intake	-0.614	0.144	0.486	0.289
	(0.644)	(0.565)	(0.368)	(0.195)
Above Median Age * High Salt Intake	0.967	-0.123	-0.215	-0.032
	(0.837)	(0.836)	(0.422)	(0.262)
Male * High Salt Intake	1.618*		-0.303	
	(0.967)		(0.387)	
Above Median Age * Male * High Salt Intake	-4.842***		1.190**	
	(1.634)		(0.583)	
Job is Manual * High Salt Intake		0.875		-0.041
		(1.233)		(0.245)
Above Median Age * Job is Manual * High Salt Intake		-4.116**		1.086**
		(1.959)		(0.517)
Individual FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Shift FE	Yes	Yes	Yes	Yes
Day of the Week FE	Yes	Yes	Yes	Yes
Mean Production capacity (%)-All Workers	60.038	60.038		
Mean Salt Intake from Water (mg/day)	3471.985	3471.985		
Average Monthly Absence due to Sickness (Day)			0.514	0.514
Salary Per Shift (BDT)			269.723	269.723
Average Monthly Earnings from this Job (BDT)			6934.182	6934.182
Observations	4344	4344	2186	2186
R-sqr	0.015	0.014	0.024	0.025

Note: This table shows the heterogeneous effect of high salt intake on workers' efficiency by gender and type of work. The table reports the estimates of equation 4, where Columns 1 and 3 show the heterogeneous effect by gender whereas Columns 2 and 4 show the heterogeneous effect by the type of work. 'Efficiency' is the ratio of actual output to the calculated production benchmark (output at machine capacity), expressed as a percentage. 'Sickness Absence' is measured as the total number of days a worker was absent last month due to sickness. 'High salt intake' is a binary variable that takes a value of 1 if salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water. 'Above median age' takes a value of 1 if the worker's age is above the sample median age of 34 years. Variable 'Male' indicates whether the worker is male, 0 otherwise. The variable 'Job is Manual' takes a value of 1 if the worker is in production unit 2, and 0 otherwise. Both regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 5: Effect of Salt Intake (via Water Consumption) on Blood Pressure

	(1) Hypertension	(2) Systolic Blood Pressure	(3) Diastolic Blood Pressure	(4) High Pulse Pressure	(5) Hypertension	(6) Systolic Blood Pressure	(7) Diastolic Blood Pressure	(8) High Pulse Pressure
High Salt Intake	0.031**	1.226***	0.511*	0.026***	-0.012	0.202	-0.122	0.006
	(0.013)	(0.407)	(0.281)	(0.008)	(0.010)	(0.484)	(0.383)	(0.010)
Above Median Age * High Salt Intake					0.060***	2.245***	1.387**	0.045***
					(0.017)	(0.815)	(0.555)	(0.015)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shift FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Section FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day of the Week FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hypertension (Systolic>=180 mmHg or Diastolic>=90 mmHg)	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
Mean Systolic Blood Pressure (mmHg)	112.209	112.209	112.209	112.209	112.209	112.209	112.209	112.209
Mean Diastolic Blood Pressure (mmHg)	70.924	70.924	70.924	70.924	70.924	70.924	70.924	70.924
(systolic pressure - diastolic pressure)> 60 mmHg	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
Observations	4959	4959	4959	4959	4959	4959	4959	4959
R-sqr	0.052	0.109	0.108	0.010	0.019	0.110	0.109	0.012

Note: This table shows the effect of high salt intake on hypertension. 'Hypertension' is an indicator variable that takes a value of 1 if the systolic blood pressure is greater than or equal to 140 mmHg or diastolic blood pressure is greater than or equal to 90 mmHg. Individuals currently taking medication for hypertension are also considered hypertensive. Systolic blood pressure is the pressure in the arteries when the heart contracts (systole). This is usually less than 140 millimeters of mercury (mmHg). Diastolic blood pressure is the pressure in the arteries when the heart is relaxed (diastole), and it is usually less than 90 mmHg in adults. 'High pulse pressure' is a binary variable that takes a value of 1 if the difference between systolic and diastolic blood pressure is greater than 60 mmHg. 'High salt intake' is a binary variable that takes a value of 1 if the salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water. 'Above median age' is a binary variable that takes a value of 1 if the worker's age is above the median age of sample workers. Columns 1, 2, and 3 report the estimates of equation 1 whereas Columns 3, 4, and 5 report the estimates of equation 2. All regressions include the fixed effects of the month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

A Appendix Figures and Tables

Figure A1: Groundwater Salinity, Water Consumption, and Salt Intake by Month

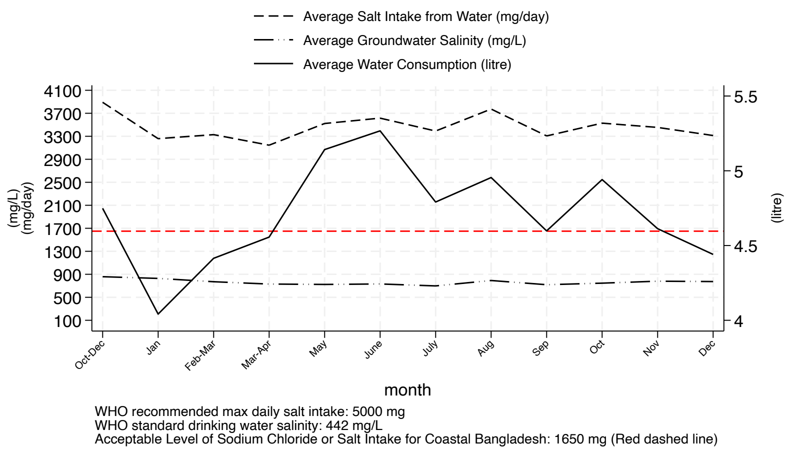


Figure A2: Distribution of Worker Efficiency

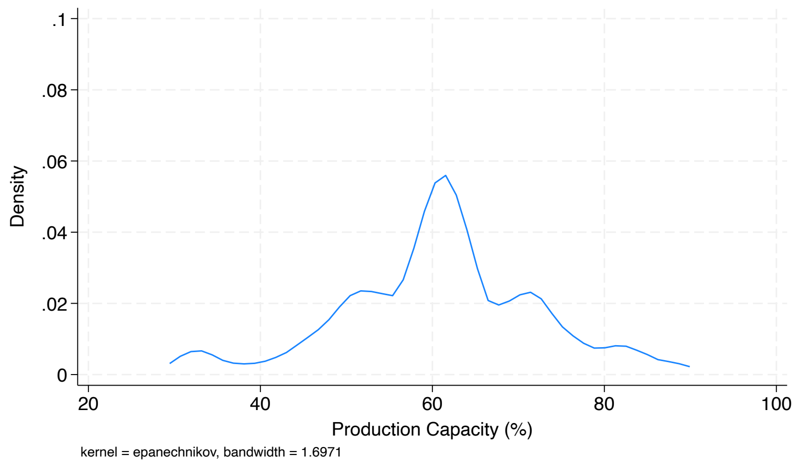
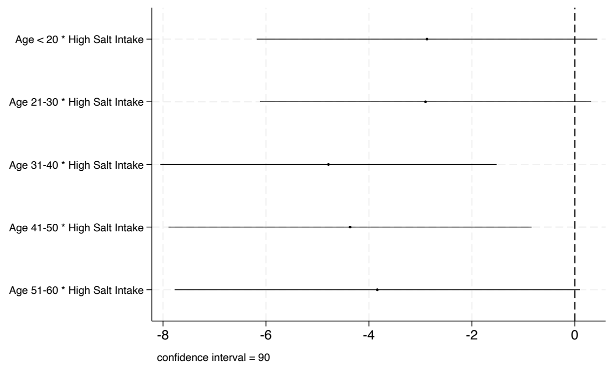
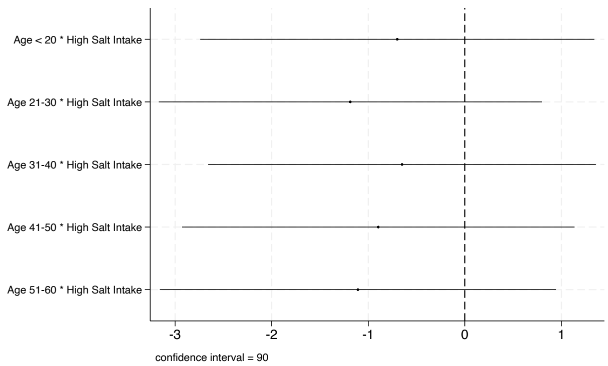


Figure A1 shows the variation in average groundwater salinity levels, water consumption, and salt intake by month. The data indicates that workers' water consumption increases significantly during the hot and humid months (May to August), leading to higher salt intake despite a slight decrease in groundwater salinity. In contrast, water consumption is relatively lower during the dry months (October to February), resulting in lower average salt intake. Figure A2 depicts the distribution of worker efficiency, showing that in a given month, worker's efficiency might be on average as little as 32% or as much as 83% efficiency, with the average efficiency falling around 59%

Figure A3: Effect of Salt Intake (via Water Consumption) on Productivity (by Age Groups)



(a) Efficiency



(b) Sickness Absence

Note: This figure shows the heterogeneous effect of high salt intake on workers' productivity by different age groups. We estimate a modified version of equation 2 (without the individual fixed effects), where indicators of six different age groups and interactions of high salt intake with the age groups are used instead of the 'above median age' indicator. Panel (a) shows the heterogeneous effect on efficiency and Panel (b) shows the effect on sickness absence by age groups. The figure displays the coefficients of the interaction terms of high salt intake and age groups with a 90% confidence interval. The regression includes fixed effects of the month, shift, section, and day of the week. Standard errors are clustered at the worker level.

Table A1: Factory Production Process

Unit 1		Unit 2	
Section	Activity	Section	Activity
Batching	In this section, jute is selected for a batch, piecing up, softening and lubricating, and conditioning or piling.	Damping	Rolled woven cloth is unrolled and water is sprinkled on it continuously to provide desired moisture.
Carding	Jute fibers are formed into ribbons called "sliver". Carding is a combining operation where jute reeds are split and extraneous matters are removed. It is the process by which long reeds of jute pass through high speed-pinned roller and are broken down into an entangled mass and delivered in the form of ribbon with uniform weight per unit length	Calendering	A process similar to the ironing of fabric.
Drawing	A process for reducing sliver width and thickness by simultaneously mixing 4 to 6 slivers together. There are three types of Drawing Frame machines. The first one makes blending, equalizing the sliver, and doubling two or more slivers, level and provide quality and color. The Second Drawing machine makes a more uniform sliver and reduces the jute to a suitable size for the third drawing. The Third Drawing machine is of high speed making the sliver more crimpled and suitable for spinning.	Bangla Loom	Traditional Carpet Weaving using the yarn from the Roll and Precision winding
Spinning	Producing yarn from silver obtained from the Third drawing - Capable of producing quality yarns at high efficiency with auto-doffing arrangements.	S4A Loom (China Loom)	Modern Carpet Weaving
Roll Winding	Provides yarn as spools and cops for beaming and weaving operations.	Lapping and cutting	Fabrics are folded into the required size on the lapping machine while the sacking cloth is cut to the required length for making bags for different sizes under the cutting process.
Precision Winding	wind materials with high accuracy and consistency.	Herakle & Hemming	Hemming stitches the raw edges while the Herakle machine stitches at the side.
Twisting	Used to fold and twist more than one yarn. Helps to produce quality yarns for premium fabrics.	Hand Sewing	Tie and Bundle
Roping	Turning the yarns and threads into plies		

Table A2: Effect of Salt Intake on Worker Productivity (Based on Highest Feasible Efficiency)

	(1) Efficiency	(2) Efficiency
High Salt Intake	-0.331	0.543
	(0.508)	(0.622)
Above Median Age * High Salt Intake		-1.873*
		(1.018)
Month FE	Yes	Yes
Shift FE	Yes	Yes
Section FE	Yes	Yes
Day of the Week FE	Yes	Yes
Mean Production capacity (%)- All Workers	68.282	68.282
Mean Salt Intake from Water (mg/day)	3471.985	3471.985
Observations	4146	4146
R-sqr	0.014	0.015

Note: This table reports the regression of workers' production efficiency on high salt intake. Columns 1 shows the estimates of equation 1 and Columns 2 shows the estimates of equation 2. 'Efficiency' is defined as the ratio of actual output to the section-wise production benchmark (the highest output achieved by workers in a section), expressed as a percentage. 'High salt intake' is a binary variable that takes a value of 1 if the salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water. 'Above median age' is a binary variable that takes a value of 1 if the worker's age is above the median age (34 years) of sample workers. Both regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

Table A3: Effect of Salt Intake on Worker Productivity (Variation in Cutoff Points)

	(1) Efficiency	(2) Efficiency	(3) Efficiency	(4) Sickness Absence	(5) Sickness Absence	(6) Sickness Absence
High Salt Intake (.15 cutoff)	0.161			0.253*		
	(0.522)			(0.139)		
Above Median Age * High Salt Intake (.15 cutoff)	-1.416*			0.396*		
	(0.826)			(0.239)		
High Salt Intake (.25 cutoff)		0.394			0.277*	
		(0.520)			(0.143)	
Above Median Age * High Salt Intake (.25 cutoff)		-1.689**			0.475*	
		(0.856)			(0.270)	
High Salt Intake (.35 cutoff)			0.545			0.334**
			(0.543)			(0.153)
Above Median Age * High Salt Intake (.35 cutoff)			-2.293**			0.486*
			(0.891)			(0.278)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Shift FE	Yes	Yes	Yes	Yes	Yes	Yes
Section FE	Yes	Yes	Yes	Yes	Yes	Yes
Day of the Week FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean Production capacity (%)-All Workers	60.038	60.038	60.038			
Mean Salt Intake from Water (mg/day)	3471.985	3471.985	3471.985			
Average Monthly Absence due to Sickness (Day)				0.514	0.514	0.514
Salary Per Shift (BDT)				269.723	269.723	269.723
Average Monthly Earnings from this Job (BDT)				6934.182	6934.182	6934.182
Observations	4344	4344	4344	2186	2186	2186
R-sqr	0.013	0.013	0.014	0.017	0.020	0.022

Note: This table reports the regressions of workers' production efficiency and sickness absence on high salt intake (estimates from equation 2) at different 'High salt intake' cutoff points. 'Efficiency' is the ratio of actual output to the calculated production benchmark (output at machine capacity), expressed as a percentage. 'Sickness Absence' is measured as the total number of days a worker was absent last month due to sickness. 'High salt intake' is a binary variable that takes a value of 1 if the salt intake via water consumption exceeds a certain number of standard deviations above the average salt intake via drinking water (0.15 in columns 1 and 4; 0.25 in columns 2 and 5; 0.35 in columns 3 and 6). 'Above median age' is a binary variable that takes a value of 1 if the worker's age is above the median age (34 years) of sample workers. Both regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

Table A4: Non-linear Effects of Salt Intake on Efficiency and Hypertension

	(1) Efficiency	(2) Hypertension
Salt Intake	-0.00045	-0.00001
	(0.00045)	(0.00002)
Salt Intake Square	0.00000	0.00000
	(0.00000)	(0.00000)
Month FE	Yes	Yes
Shift FE	Yes	Yes
Section FE	Yes	Yes
Day of the Week FE	Yes	Yes
Mean Production capacity (%)-All Workers	60.038	60.038
Mean Salt Intake from Water (mg/day)	3471.985	
Hypertension (Systolic>=180 mmHg or Diastolic>=90 mmHg)		0.113
Observations	4344	4959
R-sqr	0.211	0.189

Note: This table examines the non-linear effect of salt intake via water per day on workers' production efficiency and hypertension. It reports the estimates of a modified version of equation 1 (without the individual fixed effects) including the square of $HighSaltIntake_{it}$). 'Efficiency' is the ratio of actual output to the calculated production benchmark (output at machine capacity), expressed as a percentage. 'Hypertension' is an indicator variable that takes a value of 1 if the systolic blood pressure is greater than or equal to 140 mmHg or diastolic blood pressure is greater than or equal to 90 mmHg. Individuals currently taking medication for hypertension are also considered hypertensive. All regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

Table A5: Effect of Salt Intake (via Water Consumption) on Worker Productivity (Age as Continuous Variable)

	(1) Efficiency	(2) Sickness Absence
High Salt Intake	1.933	-0.722
	(1.177)	(0.448)
Age * High Salt Intake	-0.068*	0.029**
	(0.036)	(0.015)
Month FE	Yes	Yes
Shift FE	Yes	Yes
Section FE	Yes	Yes
Day of the Week FE	Yes	Yes
Mean Production capacity (%)-All Workers	60.038	
Mean Salt Intake from Water (mg/day)	3471.985	
Average Monthly Absence due to Sickness (Day)		0.514
Salary Per Shift (BDT)		269.723
Average Monthly Earnings from this Job (BDT)		6934.182
Observations	4344	4617
R-sqr	0.013	0.024

Note: This table reports the regression of workers' production efficiency and sickness absence on high salt intake. Columns 1 shows the estimates of equation 1 and Columns 2 shows the estimates of equation 2. 'Efficiency' is the ratio of actual output to the calculated production benchmark (output at machine capacity), expressed as a percentage. 'Sickness Absence' is measured as the total number of days a worker was absent last month due to sickness.'High salt intake' is a binary variable that takes a value of 1 if the salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water. 'Age' is a continuous variable that shows worker's age in years. Both regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

Table A6: Effect of High Groundwater Salinity Exposure During Summer Months on Hypertension

	(1) Hypertension
High Groundwater Salinity	-0.007
	(0.013)
Above Median Age * High Groundwater Salinity	0.020
	(0.022)
Above Median Age * High Groundwater Salinity * Summer	0.069**
	(0.034)
Month FE	Yes
Shift FE	Yes
Section FE	Yes
Day of the Week FE	Yes
Hypertension (Systolic>=180 mmHg or Diastolic>=90 mmHg)	0.113
Groundwater Salinity in Non-Summer Season (mg/day)	781.695
Groundwater Salinity in Summer (mg/day)	736.926
Observations	4961
R-sqr	0.019

Note: This table shows the effect of high groundwater salinity on hypertension. 'Hypertension' is an indicator variable that takes a value of 1 if the systolic blood pressure is greater than or equal to 140 mmHg or diastolic blood pressure is greater than or equal to 90 mmHg. Groundwater salinity is measured as a weighted average of the salinity levels from workers' home and factory water sources, with the weights determined by the seasonal water consumption ratios (the ratio of average water consumed from a source to the total average water consumption for that season). The binary variable "High groundwater salinity" is assigned a value of 1 if the groundwater salinity is more than 0.25 standard deviations above the average groundwater salinity. 'Above median age' takes a value of 1 if the worker's age is above the sample median age. The variable 'Summer' takes a value of 1 if a month falls under the summer season (May to August). The table reports the estimates of equation 4 that includes the fixed effects of the month, shift, section, and day of the week. Standard errors are clustered at the worker level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table A7: Heterogeneous Effect of Salt Intake on Blood Pressure (by Gender and Type of Work)

	(1) Hypertension	(2) Hypertension
High Salt Intake	-0.003	0.000
	(0.016)	(0.009)
Above Median Age * High Salt Intake	0.002	0.020
	(0.020)	(0.018)
Above Median Age * Male * High Salt Intake	0.111***	
	(0.034)	
Above Median Age * Job is Manual * High Salt Intake		0.112***
		(0.040)
Month FE	Yes	Yes
Shift FE	Yes	Yes
Section FE	Yes	Yes
Day of the Week FE	Yes	Yes
Hypertension (Systolic>=180 mmHg or Diastolic>=90 mmHg)	0.113	0.113
Observations	4959	4959
R-sqr	0.023	0.022

Note: This table shows the heterogeneous effect of high salt intake on blood pressure by gender and reports the estimates of equation 4. 'Hypertension' is an indicator variable that takes a value of 1 if the systolic blood pressure is greater than or equal to 140 mmHg or diastolic blood pressure is greater than or equal to 90 mmHg. Individuals currently taking medication for hypertension are also considered hypertensive. 'High salt intake' is a binary variable that takes a value of 1 if salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water. 'Above median age' takes a value of 1 if the worker's age is above the sample median age of 34 years. Variable 'Male' indicates whether the worker is male, 0 otherwise. The regression includes fixed effects of the month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

Table A8: Effect of Salt Intake on Mental Health

	(1) Depressed	(2) Depressed	(3) Generalized Anxiety Disorder	(4) Generalized Anxiety Disorder
High Salt Intake	-0.004	-0.005	0.004	0.004
	(0.012)	(0.016)	(0.011)	(0.014)
Above Median Age * High Salt Intake		0.003		-0.000
		(0.025)		(0.022)
Month FE	Yes	Yes	Yes	Yes
Shift FE	Yes	Yes	Yes	Yes
Section FE	Yes	Yes	Yes	Yes
Day of the Week FE	Yes	Yes	Yes	Yes
Suffering from Depression(%)	0.213	0.213		
Generalized Anxiety Disorder(%)			0.154	0.154
Observations	4959	4959	4959	4959
R-sqr	0.231	0.231	0.276	0.276

Note: This table reports the regression of workers' mental health indicators on high salt intake. Columns 1 and 3 show the estimates of equation 1 and Columns 2 and 4 show the estimates of equation 2. 'Depressed' is a binary variable based on the PHQ score. It takes a value of 1 if the PHQ score is greater than 0, indicating that the individual has some level of depression or mental health symptoms, and 0 otherwise. The 'Generalized Anxiety Disorder' is a binary variable based on the GAD score. It takes a value of 1 if the GAD score is greater than 0, indicating that the individual has some level of generalized anxiety symptoms, and 0 otherwise. 'High salt intake' is a binary variable that takes a value of 1 if the salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water. 'Above median age' is a binary variable that takes a value of 1 if the worker's age is above the median age (34 years) of sample workers. Both regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table A9: Lagged Effects of Salt Intake on Efficiency

	(1) Efficiency	(2) Efficiency	(3) Sickness Absence	(4) Sickness Absence
High Salt Intake (One Month Lag)	0.236	0.149	-0.021	0.014
	(0.504)	(0.687)	(0.122)	(0.113)
Above Median Age * High Salt Intake (One Month Lag)	0.229	-0.367	0.391	0.210
	(0.875)	(1.090)	(0.243)	(0.191)
Above Median Age * High Salt Intake		-2.623**		0.593**
		(1.081)		(0.256)
Above Median Age * High Salt Intake (Two Months Lag)		1.381		-0.080
		(1.087)		(0.200)
Above Median Age * High Salt Intake (Three Months Lag)		0.128		0.260
		(1.140)		(0.190)
Individual FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Shift FE	Yes	Yes	Yes	Yes
Day of the Week FE	Yes	Yes	Yes	Yes
Mean Production capacity (%)-All Workers	60.038	60.038		
Mean Salt Intake from Water (mg/day)	3471.985	3471.985		
Average Monthly Absence due to Sickness (Day)			0.514	0.514
Observations	4357	3183	4019	2864
R-sqr	0.014	0.016	0.016	0.020

Note: This table shows the lagged effect of high salt intake (high salt intake in previous months) on workers' production efficiency and reports the estimates of equation 2. 'Efficiency' is the ratio of actual output to the calculated production benchmark (output at machine capacity), expressed as a percentage. The lag salinity variables show workers' high salt intake (due to water consumption) from previous months. For example, 'High Salt Intake (One Month Lag)' takes a value of 1 if the salt intake via water consumption is greater than 0.25 standard deviations above the average salt intake via drinking water a month ago. Similarly, 'High Salt Intake (Two Months Lag)' and 'High Salt Intake (Three Months Lag)' take a value of 1 if the salt intake is greater than 0.25 standard deviations above the average salt intake via drinking water two and three months ago, respectively. 'High salt intake' takes a value of 1 if the salt intake in the current month is greater than 0.25 standard deviations above the average salt intake via drinking water, 0 otherwise. The variable 'High Salt Intake in Last 11 Months' is calculated by adding the number of months the worker had high salt intake (indicated by a value of 1) over the past 11 months. 'Above median age' is a binary variable that takes a value of 1 if the worker's age is above the median age (34 years) of sample workers. All regressions include fixed effects of month, shift, section, and day of the week. Standard errors are clustered at the worker level. * p<0.10, ** p<0.05, *** p<0.01

B Data Appendix

B.1 Production Data Collection Process

During the baseline phase, the research and field management team held meetings with the factory supervisors to explain the study's objectives and data collection procedures. We clarified that our goal was to calculate worker productivity for research purposes, not to evaluate individual performance. The supervisors understood that this process would not impact workers' job security or benefits. They cooperated by helping us locate the workers and ensuring that the workers remained unaware of the monitoring of their activities and outputs. This collaboration was crucial for maintaining the integrity of the data collection process.

Recording Worker Activity and Output: Each week, we randomly selected workers to monitor and record their activity and production. Factory supervisors assisted our enumerators in identifying the machines each worker was operating on specific days. Once located, the enumerators tracked the workers' movements, documenting their activities, breaks, output, and other relevant details on productivity sheets. The enumerators moved around the factory continuously to observe and record the movements. Therefore, workers were unaware of which individuals were being monitored.

Product weights were measured and recorded in locations not visible to the workers to maintain anonymity. In Production Unit 1, helpers removed bobbins and spools from the machines, loaded them onto trolleys, and set them aside or took them to the storeroom. Then our enumerators measured the weight of completed spools to ensure workers did not know whose production was being tracked. In Production Unit 2, at the end of their shifts, workers in the Bangla and China Loom sections cut, wrapped, and placed the carpets on the weighing scale before leaving. A tally clerk then measured the products after the workers had left, with the enumerator recording the weights. Workers in the Herakle & Hemming section bundled their products (i.e., jute bags) with labeled names and placed them in the storeroom. Enumerators counted the bags at the end of each shift after the workers had left.

Efficiency Calculation: We calculated a production benchmark or the maximum possible output for each section utilizing the production-related data and industry-standard production formulas. Productivity is then measured by comparing the actual production to the calculated production benchmark, and efficiency is expressed as a percentage. Formulas used for efficiency calculation for different sections are as follows:

Spinning

- **Production Formula (Kilograms)**

$$\frac{\text{RPM} \times \text{Count} \times 60 \times (\text{Working Hours-Break}) \times \text{No. of Spindles}}{\text{TPI} \times 36 \times 14400 \times 2.2046}$$

where, *Working Hours* = 7.5; Break = Prayer + Time lost due to mechanical issue

- **Machine Capacity: (Output at 100% efficiency)**

$$\text{Capacity Output} = \frac{3600 \times 13.75 \times 60 \times (7.5\text{-}0) \times 96}{3.8 \times 36 \times 14400 \times 2.2046} = \mathit{490.60\ KG}$$

- **Efficiency**

$$\text{Efficiency} = \frac{\text{Actual Output (per worker, in KG)} - \text{Trolley Weight (in KG)}}{\text{Capacity Output} \times \text{Number of Machines Operated}} + \frac{\text{No. of Spindles} \times (\text{No. of Doffing - No. of Empty Bobbin}) \times \text{Weight of single bobbin (in KG)}}{\text{Capacity Output} \times \text{Number of Machines Operated}}$$

Roll Winding

- **Surface Speed (S.S) of Winding Roller (Yards/Min)**

$$\text{R.P.M.} \times \frac{\text{Motor Pulley}}{\text{Machine Pulley}} \times \text{Roller Diameter} \times \frac{\pi}{36}$$

where,

$$\text{R. P. M} \times \frac{\text{Motor Pulley}}{\text{Machine Pulley}} = 1155;\ \mathit{Roller\ Diameter} = 3.10 \text{ inches};$$

$$\mathit{S.S\ of\ winding\ roller} = \left(\frac{1155 \times 3.10 \times 3.14}{36}\right) = 312.46 \text{ yards/min};$$

- **Production Formula (Kilograms)**

$$\frac{312.16 \times \text{Count} \times 60 \times (\text{Working Hours-Break}) \times \text{No. of Spindles}}{14400 \times 2.2046}$$

where, Break = Prayer + Time lost due to mechanical issue; *Working Hours* = 7.5;

- **Efficiency:**

$$\text{Efficiency} = \frac{\text{Actual Output (per worker, in kilograms)}}{\text{Capacity Output}}$$

Precision Winding

- **Surface Speed (S.S) of Precision Winder (Yards/Min)**

$$\text{R.P.M.} \times \frac{\text{Motor Pulley}}{\text{Machine Pulley}} \times \text{Spool Diameter} \times \frac{\pi}{36}$$

where,

$$\text{Motor R. P. M} \times \frac{\text{Motor Pulley}}{\text{Machine Pulley}} = 450;$$

- **Production Formula (Kilograms)**

$$\frac{450 \times \text{Count} \times 60 \times (\text{Working Hours-Break}) \times \text{Spool Diameter} \times \text{No. of Spool}}{14400 \times 2.2046} \times \frac{\pi}{36}$$

where, Break = Prayer + Time lost due to mechanical issue; *Working Hours* = 7.5; *Spool Diameter* = 10 inches

- **Efficiency:**

$$\text{Efficiency} = \frac{\text{Actual Output (per worker, in kilograms)}}{\text{Capacity Output}}$$

S4A Loom (China Loom)

- **Production Formula (Kilograms)**

$$\frac{\text{Picks per minute} \times 60 \times (\text{Working Hours-Break}) \times \text{Ounce/Yard}}{\text{Shorts} \times 36 \times 16 \times 2.2046}$$

where, *Picks per minute* = 234; *Working Hours* = 7.5 hours[13]; *Ounce/Yard* = 12.41; *Shorts* = 7; Break = Prayer + Time lost due to mechanical issue[14]

- **Machine Capacity (Output at 100% efficiency):**

$$\text{Capacity Output} = \frac{234 \times 60 \times (7.5\text{-}0) \times 12.41}{7 \times 36 \times 16 \times 2.2046} = \textit{147 KG}$$

- **Worker Efficiency:**

$$\text{Efficiency} = \frac{\text{Actual Output (per worker, in kilograms)}}{\text{Capacity Output} \times \text{Number of Machines Operated}}$$

Bangla Loom

- **Production Formula (Kilograms)**

$$\frac{\text{Picks per minute} \times 60 \times (\text{Working Hours-Break }) \times \text{Ounce/Yard}}{\text{Shorts} \times 36 \times 16 \times 2.2046}$$

where, *Picks per minute* = 150; *Working Hours* = 7.5; *Ounce/Yard* = 5.77; *Shorts* = 8; Break = Prayer + Time lost due to mechanical issue

- **Machine Capacity (Output at 100% efficiency):**

$$\text{Capacity Output} = \frac{150 \times 60 \times (7.5\text{-}0) \times 5.77}{8 \times 36 \times 16 \times 2.2046} = \textit{38.34 KG}$$

- **Efficiency:**

$$\text{Efficiency} = \frac{\text{Actual Output (per worker, in kilograms)}}{\text{Capacity Output} \times \text{Number of Machines Operated}}$$

[13] Eight hours shift minus half an hour break for lunch.

[14] If a mechanical problem occurs, workers in Unit 2 needs to wait for the mechanics to arrive and fix the issue. This waiting period affects workers' output as they cannot continue their tasks until the problem is resolved.

Herakle and Hemming

- **Production Formula (Number of Pieces)**

$$\text{(Working Hours-Break)} \times 60 \times \text{Standard production/minute}$$

where, *1 inch* = 2.5 stitches; *Possible stitches in 60 seconds* = 1076; *Standard production rate in Herakle* = 3 pieces/minute; *Standard production rate in Hemming* = 5 pieces/minute

- **Standard Capacity (Output at 100% efficiency):**

$$\text{Capacity Output (Herakle)} = (7.5\text{-}0) \times 60 \times 3 = 1350 \text{ pieces}$$
$$\text{Capacity Output (Hemming)} = (7.5\text{-}0) \times 60 \times 5 = 2250 \text{ pieces}$$

- **Efficiency:**

$$\text{Efficiency [Herakle]} = \frac{\text{Actual Output (per worker, in pieces)}}{1350}$$
$$\text{Efficiency [Hemming]} = \frac{\text{Actual Output (per worker, in pieces)}}{2250}$$