The economic impact of climatic change on labour productivity Applying on Egypt Institutions

Dr. Hanan Alaa Elden Abdel Sadek Gaffar
Lecturer – College of Management & Technology (Cairo)
Arab Academy for Science, Technology & Maritime Transport

Abstract:

The research investigates the implication of climate change on labor productivity and its wider economic consequence on Egypt. Climate change is expected to continue increasing extreme weather events and rising temperatures, which greatly affects the productivity of workers, especially in labor-intensive sectors like institutions. The study identifies heat stress and extreme weather conditions as key contributors to reduced worker output, increased absenteeism, and economic losses in vulnerable industries. It then goes on to discuss institutional responses to these challenges, with a particular focus on the differential capacity for adaptation. While some institutions have initiated climate-resilient measures, the study finds that efforts toward adaptation remain uneven across sectors, with certain sectors facing more significant barriers than others. The findings underline that proactive policies, investment in climate-resilient infrastructure, and a deep understanding of sector-specific vulnerabilities are required to mitigate the economic risks of climate change. The study concludes with directions for future

research: longitudinal analyses of labor productivity, sector-specific adaptation strategies, and the broader social and health impacts of climate change on Egypt's workforce.

Keywords : Climate change, Labor productivity, Economic impact, Institutional adaptation, Egypt

الملخص:

تبحث الدراسة في تأثير تغير المناخ على إنتاجية العمل وتأثيره الاقتصادي الأوسع على مصر. من المتوقع أن يستمر تغير المناخ في زيادة الأحداث الجوية القاسية وارتفاع درجات الحرارة، مما يؤثر بشكل كبير على إنتاجية العمال، خاصة في القطاعات الكثيفة العمالة مثل المؤسسات. تحدد الدراسة الإجهاد الحراري والظروف الجوية القاسية كعوامل رئيسية تساهم في تقليل إنتاجية العمال، وزيادة معدلات التغيب، والخسائر الاقتصادية في الصناعات الأكثر ضعفًا. وتتناول الدراسة أيضًا استجابات المؤسسات لهذه التحديات، مع التركيز على التفاوت في القدرة على التكيف. ورغم أن بعض المؤسسات قد بدأت في تنفيذ تدابير مقاومة للمناخ، إلا أن الدراسة تجد أن جهود التكيف لا تزال غير متساوية عبر القطاعات، حيث تواجه بعض القطاعات عقبات أكبر من غيرها. وتؤكد النتائج على أن السياسات الاستباقية، والاستثمار في البنية التحتية المقاومة للمناخ، وفهم عميق لنقاط الضعف الخاصة بكل قطاع، ضرورية للتخفيف من المخاطر الاقتصادية الناجمة عن تغير المناخ. وتختتم الدراسة بتوجيهات للبحث المستقبلي تشمل: تحليلات طويلة الأمد لإنتاجية العمل، استراتيجيات تكيف موجهة للقطاعات، والتأثيرات الاجتماعية والصحية الأوسع لتغير المناخ على القوى العاملة في مصر.

الكلمات المفتاحية: تغير المناخ، إنتاجية العمل، التأثير الاقتصادي، التكيف المؤسسي، مصر.

1. Introduction

Climate change refers to the long-term alteration in the average temperature, precipitation patterns, and other conditions of the atmosphere as a result of human activities like the burning of fossil fuels, deforestation, and industrial emissions. It has big consequences for the environment, social aspects, and the economy. From changes in sea levels to increasing frequencies of extreme weather events, climate change impacts ecosystems, biodiversity, and people's ways of living around the globe (Bolan et al., 2024).

Climate change is a real economic challenge. It disrupts many sectors, especially agriculture, energy, infrastructure, and health, due to reduced productivity and increased costs. The economic impact is especially dire in regions highly dependent on climate-sensitive industries, such as agriculture and tourism. For example, changes in the pattern of temperature and precipitation may affect crop yields; similarly, heat waves and natural disasters can have devastating effects on infrastructure and reduce the efficiency of workers in labor-intensive industries (Scholze et al., 2023).

The impacts of climate change on labor productivity are among the important economic issues. As temperatures increase—especially in hot climates—physical labor becomes more stressful, causing much fatigue, heat stress, and increased vulnerability to health risks among workers. It then results in reduced hours on the job and lower efficiency, along with

increased absenteeism. Sectors like agriculture, construction, and manufacturing are particularly vulnerable to this sort of influence because physical labor in such sectors is fundamental. Climate change will also provoke changes in labor markets where businesses and workers try to adapt to new conditions arising from the environment and likely lead to the loss of jobs in certain industries and more employment in others (Ebi et al., 2021).

In Egypt, a country already facing high temperatures and water scarcity, climate change threatens to exacerbate existing economic vulnerabilities. Key sectors, such as agriculture, tourism, and manufacturing, will also be put at risk due to changing weather patterns, potentially decreasing productivity and GDP but increasing unemployment. Moreover, Egypt's strong dependence on the Nile for agriculture renders it very vulnerable to water scarcity due to climatic changes, hence affecting food security and livelihoods in rural areas. With such a critical issue at hand, the economic impact of climate change on labor productivity in Egyptian institutions truly needs to bring attention from policymakers, businesses, and researchers toward possible risk mitigation and adaptation to new environmental realities.

1.1 Significance of the Study

While climate change is becoming an issue in many parts of the world, some countries are more directly affected due to their specific geography, economic structure, and dependence on climate-sensitive sectors (Abbass et al., 2022). This study is

therefore quite relevant to understand how climate change would affect labour productivity in Egyptian firms, hence adding knowledge of economic consequences of such changes.

Given the fact that Egypt depends on labor-intensive industries such as agriculture, construction, and manufacturing, the nexus between rising temperature, changing weather patterns, and workforce productivity becomes very essential (Samari, 2024). In particular, this study has shed light on how climate-induced factors such as heat stress, reduction in working hours, and increased health risks could compromise work efficiency and consequently the profitability of institutions. By researching this link, the study reveals certain vulnerabilities in various economic sectors and points out those industries most vulnerable.

This can also be very important to policymakers and business leaders in Egypt, providing them with evidence-based recommendations on how to reduce the adverse impacts of climate change on labor productivity.

That will focus on adaptive strategies, including climate-resilient technologies, improving working conditions, and developing policies that can protect employees and institutions from disruptions caused by climate change. Knowledge of such impacts is very important for the sustainability of productivity and competitiveness in the face of a globally changing climate while Egypt tries to achieve economic growth and development under the framework of Egypt Vision 2030. This adds to the

greater literature on economics and climate change with this case study of a developing nation that suffers from unique environmental and economic challenges. It provides practical insights not only for Egypt but also for other countries with similar threats posed by the climate to labor productivity. The results of this study will therefore take an interest in academicians, international organizations, and governments interested in addressing the economic implications of climate change on labor markets in vulnerable regions.

1.2 Objectives and Research Questions

The main objective is to determine the economic consequences of climate change on labor productivity in Egyptian firms. This study will, therefore, seek to:

- Determine the relationship between the aspects of climate change such as increased temperature and changes in weather conditions with labor productivity in key sectors of the Egyptian economy, such as agriculture, construction, and manufacturing industries.
- Identify the most climate-change-vulnerable industries in Egypt in terms of impacts on labor productivity and quantify the level of these impacts on business performance and economic outcomes.
- Assess potential adaptation strategies to reduce the negative impacts of climate change on labor productivity via technology, workplace changes, and policy measures.

- Recommend ways in which policymakers and business leaders can help build resilience to climate-driven productivity losses while achieving sustainable economic growth in Egypt's most vital sectors.

This paper, in addressing the above objectives, attempts to answer the following research questions:

- To what extent do rising temperatures and other climatic factors influence labor productivity in Egyptian firms across different sectors, especially those sectors with high manual labor?
- Which industries in the Egyptian economy are most vulnerable to losses in productivity driven by climate-related factors, and how do impacts differ across these industries?
- How are firms and workers currently adapting to climate-driven shocks to productivity, and what adaptation measures, if any, are firms undertaking to alleviate these impacts?
- What strategies can be developed to reduce the adverse effect of climate change on labor productivity, and how can government policy and business practices support them?
- On which aspects does the finding of the current study align or differ from the global trend on the economic impact of climate change on labor productivity, and what lessons could be drawn for other developing countries facing similar challenges?

2. Literature Review

Several studies examined the diverse economic impacts of climate change using varied methodologies while taking different global regions and sectors into consideration. Mikayelyan and Vardanyan (2023) explore the disruptions in the global economy attendant on climate change, pointing out the role of carbon pricing mechanisms, including taxes and cap-and-trade, in driving sustainability and employment growth. The mixed-method study-involving statistical analysis, case studies, and policy evaluation-is an argument for systemic shifts toward low-carbon economies. Tol (2018) reviews and synthesizes 22 studies on the economic effects of climate change with the conclusion that the small, short run impacts are outweighed in the longer run by huge negative effects, especially for poorer, hotter, and low-lying countries. Review stresses the uncertainties in valuing the social cost of carbon and setting optimal carbon. The big three-groups of the poor countries have suffered from the greatest challenges from climate change undoubtedly contend are presently facing negative inflation while rising sea levels and uncertain climate policies pose threats to most economies (Adediran et al., 2022). Ultimately, while stock markets act in hedging against natural climate risk, they still show a strong susceptibility to the prospects of environmental policy changes. Momchilov (2021) highlights the moral paradox in its synthesis of literature that underdeveloped nations, especially in Sub-Saharan Africa and South Asia, collectively face the largest economic strain

from climate change, with negligible emissions of greenhouse gases. Lafakis et al. (2019) show that the human-induced climate change is thought to have widespread negative impacts on the agricultural sector, worker productivity, infrastructure, and coastal areas of the world. The current study explores the simultaneous disruptions by extreme weather events and they found out that rising sea levels constrain all vulnerabilities worldwide. All of these combine to provide a strong argument for the serious economic challenges that climate change brings and how mitigation and adaptation strategy formulation should go down the route based on regional-and sectoral-specific tasks.

Moreover, studies assess the possibility of climate change influencing labor productivity and certain occupational health variables, including difficulties, location differences, and adaptation strategies. Although the research does not provide numeric results, Marchetti et al. (2016) have outlined the adverse effects of climate change on worker health and productivity, especially among outdoor workers. According to Day et al. (2018), technical, regulatory, and behavioral options for mitigating productivity losses due to heat must come into play, citing the context-dependent effectiveness of passive cooling and flexible work hours as cost-effective solutions. Feriga et al. (2024) further consider unequal national climate change effects on labor demand across sectors, diminishing labor supply through absenteeism and productivity loss, while redirecting migration flows.

Parsons et al. (2021) found that climate-change-induced humid heat was contributing to a presumption of 650 billion hours of annual labor lost, which counts at least 400 billion hours more than previous estimates; this results in losses for some countries matching over 10% of GDP. Establishing a causal chain linking high temperature to productivity fall, Park (2017) identified a key adaptation mechanism on air conditioning, ameliorating productivity losses especially in heat-exposed industries such as construction and transportation. Szewczyk et al. (2021) project that the impacts of heat stress may lead to a decline of labor productivity by up to 5.4% in Europe by the 2080s, southern and eastern Europe being mutually affected. Hence, they found that adaptation measures such as air conditioning and wearable robotics are capable of tempering these losses, in amounts of up to 40%.

Kjellstrom (2016) emphasized the severe productivity and economic impact of climate change in tropical and subtropical regions, where current levels of heat alone generate huge losses to work capacity. It is projected that in these areas, it is expected that in the year 2050, over 40% of all annual work hours in occupations exposed to elevated heat stress conditions could be lost. Together, such studies underscore widespread and regionally differentiated economic and health threats stemming from climate change and call upon interventions targeted to improve adaptation planning.

Some other studies have examined the economic and agricultural impacts of climate change in Egypt, giving critical insights into crop productivity and the economy as a whole. Hosam Eldin Ali (2023) used the Autoregressive Distributed Lagged (ARDL) methodology to study the long-term relationship between climate change and wheat productivity in Egypt. The findings of the authors provide evidence of an inverse relationship between wheat productivity and the climate, supporting the economic theory in question. Smith et al. (2014) also presented an analysis of the economic vulnerability of Egypt to climate change in various sectors: supply of water, agriculture, and tourism. They generated their quantitative estimates of the range of total economic losses between 200 and 350 billion Egyptian pounds (equivalent to 2-6% of future GDP). The study noted that these impacts were severe: lowered agricultural yield, increased unemployment, and heightened food prices, all exacerbated by the impending threat of sea-level rise to the agricultural land in the Nile Delta.

Versatile and promising is this analysis. With a multi-market model, Ahmed and others (2020) have estimated the economic costs of climate change on Egyptian agriculture. Under a worst-case scenario, they found farm production might fall off between 10 and 18 percent with significant job losses in agriculture and prices of agricultural commodities rising between 7 and 24 percent for consumers and 12 and 22 percent for producers. In

yet another study, Taha et al. (2020) engaged in ARDL modeling to ascertain how rising maximum temperatures affect the productivity of major cereal crops. The results confirmed those of others by showing a consistent inverse relationship between climate change and cereal productivity.

Abd El Fatah (2023) performed an econometric analysis of the impact of climate change on clover and sugarcane in northern Egypt, by highlighting the distinctions between new and old agricultural lands. Climatic changes have negatively affected clover productivity on old lands, with a reduction rate of 0.77 tons per feddan, but strangely, productivity increased on new lands by 3.62 tons per feddan. Abdelaal and Elsherbini (2021) evaluated wheat production on Egypt's northern west coast through FMOLS regression analysis. It was found that rainfall has a positive effect on wheat productivity, with a 1% increase yielding 3.3% more bouza. Temperature, on the other hand, has a negative contingent productivity, where an increase of 1% is exceedingly productive in reducing yields by 5.7%. The most intense impact of these changes occurred in remote western districts, such as El-Negaila and Sidi Barrani, in which changes in rainfall had a tremendously larger effect.

Matsumoto et al. (2021) examined the worldwide economic consequences of diminishing labor productivity for heat-induced climate stress. This work used a coupled computable general equilibrium (CGE) model in conjunction with an Earth system

model to confirm the socioeconomic consequences of how wet bulb globe temperature (WBGT) impinged on labor productivity and how that productive impact is expressed in terms of GDP netted off CO2 emissions, all under various climate scenarios. Labor productivity was seen to decline with climatological advancement; hence the global GDP edges downward. Regional GDP changes were not equal; few areas enjoyed slight added productivity through comparative advantages in labor. The resulting lesser economic activity led to lessening of CO2 emissions, concentrations and temperatures, but only marginally.

This literature examines the effects of increasing temperatures on economic productivity and labor supply in South Africa. The use of micro-survey panel data and an overlapping generations model showed how temperature affects labor supply and welfare. In their econometric analysis of identifying conditions that bring about maximum labor supply, it was revealed that these conditions vary by sector. Rising temperatures now render a diminished supply of low-skilled labor, narrowing the wage gap between levels of skills while resulting overall in an economic output reduction by 20% per adult as compared to a no-change scenario on climate change.

van Maanen et al. (2020) conducted a comprehensive intercomparison of labor productivity models, applying multi-bias climate-adjusted data and empirical exposure-response functions from global surveys. Their results produced robust,

spatially explicit projections of changes in labor productivity, showing significant regional and working environment variation. The innovative model from this work made sub-national projections possible, allowing for hierarchy uncertainties in existing models while streamlining a procedural path for the calculation of labor productivity changes due to climate.

Kahn et al. (2019) deal with the integration of labor productivity into climate factors through a multi-country stochastic growth model and the HPJ-FE estimator analysis. The evidence supporting the finding tends to come from the literature: deviations of any kind from historical temperature levels tend to negatively affect economic growth in a worldwide spreading manner irrespective of whatever level one considers development to be. The report emphasized that observing the Paris Agreement to produce a global temperature increase would help mitigate economic losses. Furthermore, they portray detrimental effects across multiple U.S. sectors, pointing toward the pressing need for climate policies.

Flouris et al. (2022), in their research on climate change and agricultural labor productivity, computed the global implications with the help of time-and-motion studies and labor loss functions obtained from temperature data. The findings suggested that there exists an inverted U-shaped relationship between temperature and productivity at a temperature optimum of 15°C. Climate change was expected to decrease significantly

agricultural productivity compared to all other sectors, ultimately resulting in human labor mobility and wealth redistribution. Economies near the equator will sustain a huge projected loss on the order of 1.2%, whereas colder regions are expected to gain up to 6.3%, widening global inequity even further.

Masuda et al. (2024) used a new empirical model to measure the world impact of humid heat on labor productivity. They estimated the hours travailly lost annually to be over 650 billion, equal to 148 million full-time jobs with losses amounting to $2.1 trillion in economic terms (2017 PPP). That number was some 400 billion hours higher than other estimates, demonstrating how even small temperature shifts (<0.5°C) hold some potential to greatly impact labor and economic output. This study reveals yet another urgency for adaptation strategies to counter these broad productivity losses.

Egypt, as a developing economy, offers quite a unique opportunity-its economic structure, dependence on climate-sensitive sectors, and vulnerability to temperature rise and scarcity of resources substantiate a justification for a close investigation of this phenomenon. It sheds light to reuse in developing mitigation and adaptation studies in regional settings.

3. Theoretical Framework

The theoretical framework connecting climate change and labor productivity finds its basis in human capital theory and occupational health theories.

Human Capital Theory posits education, skill, and health as determinants of productivity. Climate change, being a health hazard to workers, reduces labor efficiency (heat stress, increased absenteeism), resulting in devaluation of human capital and productivity (Almendarez, 2011). Additionally, the Environmental Kuznets Curve (EKC) provides a conceptual framework following the premise that the economic effects of climate upon societies are contingent upon the level of economic development, with developing economies like Egypt facing the greatest burden (Shaker, 2022).

In order to investigate the economic effects of climate change on labor productivity, this study relies on economic models and theories such as; Solow-Swan Growth Model, Ricardian Climate Model, General Equilibrium Models (CGE), and Social Cost of Carbon (SCC) Framework.

Solow-Swan Growth Model explains how factors of production such as labor, capital, and technology help in realizing economic growth. Climate change has adverse effects on labor inputs owing to health impacts and productivity declines and follows a growth trajectory of economic development (Fankhauser & Tol, 2005).

On the other hand, the Ricardian climate model recommends assessing how various climate factors, such as temperature and rainfall, affect productivity and land use. It draws attention to the

sensitivity that agriculture, one of the core sectors in the Egyptian economy, has upon climate change (Bouteska et al., 2024).

Based on theoretical linkages and literature, the following hypotheses are drawn:

H1: Climate change has a negative effect on labor productivity in Egypt.

H2: Adaptation strategies can reduce the adverse effect of climate change on labor productivity.

H3: Climate change impacts on labor productivity and economic outcomes are moderated by regional factors such as resource availability and infrastructure quality.

4. Methodology

This study uses a quantitative research design. Using a structured questionnaire, it will investigate the impacts of climate change factors on labor productivity in educational institutions throughout Egypt. The approach is descriptive and correlational, looking at the relationships between the independent variables (climate change factors) and dependent variables (labor productivity). Data collection will be done through a questionnaire, a primary research instrument based on literature and contextualized for Egyptian schools and universities. It has five sections: demographic information, climate-related factors, productivity indicators, institutional and personal control variables, and open-ended feedback for qualitative insights.

Data collection will target teachers, teaching staff, and administrative staff from urban and rural schools and universities. The questionnaire will be administered using Google Forms and distributed manually for institutions with limited internet access. The collecting phase of the data will last for four weeks to allow for maximum participation and representation. Stratified random sampling is used to ensure proper representation of the different types of institutions and kinds of the professionals' field. Educational institutions are stratified by location (urban/rural) and type(school/university). The target sample size is 90, which offers sufficient size for meaningful and statistically valid insights into sectoral climate impacts.

Analysis of the data will include quantitative methods. Descriptive statistics will summarize demographic data and response distributions. Reliability testing using Cronbach's Alpha will partially confirm whether the questionnaire scales are consistent. The relationship between climate change factors-such as temperature, humidity, and air quality-and labour productivity indicators-such as productivity levels, absenteeism, and work efficiency-will then be evaluated using multiple linear regression analysis. Hierarchical regression will also be utilized to investigate the moderating effects of control variables such as institutional resources and infrastructure.

4.1 Study instrument

The main research instrument used in this study is a structured questionnaire, which is aimed at comprehensively investigating the relationship between climate change factors and labor productivity in educational institutions in Egypt. The survey questionnaire has been segmented into four sections to elicit responses on demographic information, independent variables related to aspects of climate change, dependent variables related to labor productivity, and control variables that address both institutional and personal factors.

Section 1: Demographic Information

This section collects the respondents' background information: position (teacher, lecturer, or administrative staff), type of institution (school or university), age, gender, and years of experience in education. These are contextual variables that allow subgroup variations to be analyzed.

Section 2: Independent Variables (Climate Change Factors)

The second section pertains to the independent variables, assessing respondents' perceptions of various climate change factors. These include temperature-related impacts, humidity levels, heatwaves, air quality, and seasonal changes. In the survey, respondents answer by showing the level of their agreement with certain statements using a five-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree." For

instance, some items measure the impacts of high temperature on task efficiency, the impacts of humidity on physical comfort, how often heatwaves occur and their impacts, the influence of poor air quality on work performance, and any disruptions brought about by changes in seasonal patterns.

Section 3: Dependent Variable (Labor Productivity)

This section assesses labor productivity through specific dimensions: productivity metrics, absenteeism, employee health, and work efficiency. Items have been set with the goal of knowing how extreme climate conditions-high temperatures, heatwaves, and poor air quality-influence daily productivity, absenteeism rates, health concerns, and overall work quality. All items were rated on a five-point Likert rating scale.

Section 4: Control Variables-Institutional and Personal Factors

The last section is dedicated to control variables that can affect how climate change factors influence labor productivity. It includes questions on institutional factors such as the sufficiency of a cooling system, infrastructure quality, and the availability of resources, in addition to policies to mitigate extreme weather conditions. Furthermore, personal adaptability and sensitivity to environmental conditions are assessed by statements about individual responses to the variation in temperature and environmental stressors.

In order to test the reliability of the questionnaire, Cronbach's Alpha was used, a statistical measure of internal consistency that indicates how well the items within a scale are correlated and measure the same underlying construct. The calculated Cronbach's Alpha for the instrument was 93%, which is considered excellent according to standard benchmarks. A reliability so high indicates that the questionnaire items are highly consistent and dependable in capturing the intended variable. It therefore ensures the validity of the instrument on valid measurement for impacts brought by climate change factors on labour productivity.

5. Analysis and Results

5.1 Descriptive analysis

Demographic data

The participants were categorized into Administrative Staff, Lecturers, and Teachers. From these categories, the Administrative Staff added to about 31; therefore, roughly 34.4%. For Lecturers, a record of about 42 made them the most prevalent and prominent in the questionnaire and survey, which gives an approximately 46.7%. The teachers, who were the smallest group, had 17 respondents, 18.9% of the total sample. This breakdown ensures a good mix in the representation of roles for the participants, with a majority being lecturers, followed by administrative staff, and then teachers. Such variation in professional positions will ensure the capturing of diverse

opinions, hence a better understanding of the study's objectives. The data illustrates the distribution of respondents based on the type of institution they are affiliated with.

These, the majority being 57 (63.3%), relate to the universities. That then denotes that a reasonable sample is related to this very higher education spectrum; and because such type has possibly captured the wider representations or simply have developed more interest in the content. Another 27 (30%) belongs to other types of institutions; examples here would be a private organisation, research centers, and generally an alternative educational location from school. This group adds variety to the sample by incorporating points of view from outside the traditional school or university setting. Meanwhile, the smallest group comes from schools, with only 6 respondents (6.7%). This indicates that the sample is predominantly composed of university-based respondents, followed by other institutions, while school environments play a minimal role in this particular study. This variation may affect the results, and the institutional context should be considered when interpreting the findings. The largest age group is those aged 30–40, comprising 41 participants (45.6%).

This group is close to half of the sample, indicating that middle-aged respondents were the largest single contributor in the study. This could represent a period of professional maturity with considerable experience that their opinions become highly relevant. The next biggest category falls to 41–50 years old,

totaling 31 respondents or 34.4% of the participants. This age group also signifies a considerable percentage of the sample and reflects the involvement of experienced practitioners who are likely to hold long-term views on the topics under investigation. Together, these two age groups comprise the majority of respondents, suggesting a workforce that is mainly in mid-career stages. In contrast, the youngest age bracket, those below 30 years of age, consists of only 8 participants (8.9%), which makes them the smallest group in the sample. This limited representation may point to fewer early-career professionals being engaged in the context of this study. On the other hand, the over-50 age group contains 10 respondents, which forms 11.1%, reflecting modest participation of people nearing their retirement or with extensive career experience. In this research study, the majority of respondents were females, totaling 54 or 60%, while 36 were males, accounting for 40%. The majority in the category of years of experience were between 11 and 20, with 37 respondents.

This means that most of the respondents are experienced, with a great deal of expertise that adds depth and reliability to the findings of the study. The second most represented group is those with 21 to 30 years of experience, with 19 people. This shows that a number of highly experienced professionals were included in this study, bringing a lot of experience and long-term perspectives. Similarly, the 16 respondents who fall between 5 to 10 years of experience represent a mid-career cohort, bridging

the gap between early-career and highly seasoned professionals. At the early career stage, 10 participants have less than 5 years of experience, providing insights from those relatively new to the profession. Their perspectives offer valuable information about the challenges and opportunities faced by newer entrants in the education sector. Meanwhile, those with over 30 years of experience total 8 participants, adding a veteran perspective and showing the viewpoints of those who have been engaged in education for decades.

Independent Variables (Climate Change Factors)

- **Temperature effect**

The data shows the perceived effects of temperature on work performance and comfort. It looks at the impact of heat on focused attention and concentration and at how high temperatures add to general discomfort in the workplace. For the mean score on how heat affects focus and concentration, the rating is 3.9, which still falls into the category that the respondents generally agree with the statement that heat affects them negatively in their focusing. This perception is further supported by a median and mode of 4, which shows that most responses were in the "agree" range. The standard deviation for this factor is 1.07, reflecting moderate variability in participants' experiences, with scores ranging from 1 to 5. Similarly, the perception of discomfort caused by high temperatures in classrooms or offices has a slightly higher mean of 4.02, suggesting a stronger agreement

among participants. Like the previous factor, the median and mode were 4, indicating that there was consensus on this issue. The standard deviation of 1.04 indicates slightly less variability, reflecting that participants' responses were more in agreement about this topic. For both factors, minimum and maximum scores span from 1 to 5, ranging from strongly disagree to strongly agree, reflecting the diversity of experiences among the participants. The sample variances are 1.15 for the first factor and 1.07 for the second, further depicting the level of variation in responses. The standard error values, 0.11 and 0.10 respectively, indicate that the mean scores are reliable estimates of the views of the wider population.

Climate Change Factors	*Heat affects focus and concentration.*	*Working become uncomfortable due to high temperatures*
Mean	3. 9	4.02
Standard Error	0.11	0.1
Median	4	4
Mode	4	4
Standard Deviation	1.07	1.04
Sample Variance	1.15	1.07
Minimum	1	1
Maximum	5	5

- **Humidity effect**

The data shows the effects of high levels of humidity on perceived focus and physical comfort at work. The first factor, addressing the impact of high humidity on the ability to focus and maintain concentration, has a mean score of 4.01, indicating general agreement among participants that humidity indeed makes it hard to focus. The median and mode at 4 reinforce this observation, indicating that the greatest number of respondents shared an identical opinion about the negative influence of humidity on focus. With a standard deviation of 0.99, there is moderate variability in the responses, though most participants agree on the issue. The sample variance of 0.99 further supports this, showing a slight spread in the data, while the minimum and maximum values ranging from 1 to 5 indicate a wide range of responses. The second factor, which evaluates how humidity affects physical comfort for completing tasks, has a slightly lower mean of 3.87, indicating a somewhat less strong, but still significant, agreement that humidity affects comfort. Again, the median and mode are both 4, showing that most participants agree on this issue. The standard deviation of 1.05 indicates that there is a little more variation in the responses when compared to the first factor, as some of the respondents have shown less agreement. The sample variance is relatively higher at 1.11, further indicating that there is a bit more diversity in how participants perceive humidity's effects on comfort. In both

factors, the minimum score is 1, and the maximum score is 5, showing a broad spectrum of responses across participants. The standard errors are 0.105 and 0.11, which shows that the means for both factors are fairly reliable. The data reflects two factors related to heatwaves: the perceived increase in frequency of heatwaves at work and the impact of heatwaves on productivity.

Climate Change Factors	*Humidity Levels High humidity levels in my work environment make it difficult to stay focused.*	*Humidity affects the physical comfort necessary for effective tasks.*
Mean	*4.01*	*3.87*
Standard Error	*0.105*	*0.11*
Median	*4*	*4*
Mode	*4*	*4*
Standard Deviation	*0.99*	*1.05*
Sample Variance	*0.99*	*1.11*
Minimum	*1*	*1*
Maximum	*5*	*5*

- **Heatwaves effect**

The data explores the impact of heatwaves on the work environment, focusing on two factors: the perceived increase in the frequency of heatwaves and the effect of heatwaves on productivity. The first factor, which assesses whether the frequency of heatwaves has increased in the work environment, has a mean score of 3.98, indicating that participants generally

agree that heatwaves have become more frequent in recent years. The median and mode of 4 suggest that most respondents strongly agree with this statement. With a standard deviation of 0.99, the responses show moderate variability, indicating that while most respondents agree, there are some differences in opinion. The sample variance of 0.99 further confirms this variability, and the minimum and maximum scores, ranging from 1 to 5, show a wide range of responses. The second factor, which investigates the consequences of heatwaves on sustaining output, has a mean that is slightly lower, at 3.88, to indicate that, while there is general agreement among the respondents that heatwaves make it harder to maintain usual productivity levels, the strength of the agreements is not as high as for the frequency of heatwaves. The median and mode of 4 in this question show that most respondents feel this way. The standard deviation is 0.91, a little lower than that of the first factor, showing lesser variation in responses. The sample variance of 0.84 also indicates less scatter, meaning more consistent agreement by the participants. The minimum and maximum values for both, like in the first factor, range from 1 to 5, indicating a wide spectrum of opinions. The data investigates the influence of climatic conditions, such as extreme heat and poor air quality, on absenteeism in the workplace.

Climate Change Factors	*Heatwaves* *The frequency of heatwaves has increased over recent years in my work environment.*	*During heatwaves, I find it harder to maintain my usual productivity levels.*
Mean	*3.98*	*3.88*
Standard Error	*0.1*	*0.09*
Median	*4*	*4*
Mode	*4*	*4*
Standard Deviation	*0.99*	*0.91*
Sample Variance	*0.99*	*0.84*
Minimum	*1*	*1*
Maximum	*5*	*5*

- **Air quality**

The data examines the impact of climate conditions, specifically extreme heat and poor air quality, on absenteeism in the work environment. The first factor explores whether climatic conditions, such as extreme heat or poor air quality, result in more frequent absences. The mean score for this factor is 3.8, indicating a general agreement among participants that climate conditions contribute to increased absenteeism. The median and mode values stand at 4, hence indicating that most respondents strongly agree with this statement. Standard deviation is 1.02, indicating moderate variability around the mean, which describes that there is some difference over how strongly the individuals feel about this issue. The sample variance of 1.06 corroborates this, suggesting that while there is an overall feeling of agreement, responses actually vary to some extent. The minimum and maximum range from 1 to 5, showing a wide range of

opinions. The second factor relates to the perceived rise in the rate of absenteeism among colleagues due to health concerns arising from heat. The mean is 3.6, indicating that most responses show a moderate degree of agreement with the assertion that the absenteeism of colleagues is often due to health problems related to heat. The median and mode are 4; hence, most of the respondents agree to this assertion. The standard deviation for this factor is 1.02, showing similar variability in responses as the first factor. The sample variance of 1.05 also shows that while there is general agreement, individual perceptions of absenteeism due to heat-related health concerns vary. Similar to the first factor, minimum and maximum values range from 1 to 5, reflecting a wide range of perspectives. The data provided probes into the impact of seasonal changes on physical comfort at work and on the general learning or working environment.

Climate Change Factors	*Climate conditions (e.g., extreme heat or poor air quality) lead to more frequent absences.*	*I feel that air quality has worsened over time, impacting my health and productivity.*
Mean	3.8	*4.11*
Standard Error	0.1	*0.106*
Median	4	*4*
Mode	4	*4*
Standard Deviation	1.02	*1.01*
Sample Variance	1.06	*1.02*
Minimum	1	*1*
Maximum	5	*5*

- **Seasonal Changes**

The data provided explores the effect of seasonal changes on both physical comfort at work and the overall learning or working environment. The first factor probes the impact of shifting seasonal patterns on respondents' physical comfort at work. The mean score of 3.9 indicates a moderate to high level of agreement, with respondents generally feeling that seasonal changes do influence their comfort. The median and mode are 4, indicating that most participants strongly agree with this statement. A standard deviation of 1.17 indicates small variability in the intensity with which subjects view the impact of seasonal changes on their physical comfort. The sample variance is 1.37, reiterating that there is more variability. Minimum and maximum values range from 1 to 5, indicating a wide spectrum of responses and a difference in the opinion about the level at which seasonal changes affect comfort. The second factor refers to the disruption of the overall learning or working environment caused by seasonal changes. This factor also reflects a moderate level of agreement, with a mean score of 3.7. The median and mode values of 4 suggest that a majority of respondents believe seasonal changes do cause some disruption. This factor has a standard deviation of 0.9, relatively lower than that of the first factor, indicating lesser dispersion in the responses. The sample variance of 0.81 confirms this observation. Like the first factor, the minimum and maximum values fall within 1 to 5, reflecting diverse opinions about how seasonal chan

Climate Change Factors	*Shifts in seasonal patterns affect my physical comfort at work.*	*I believe that seasonal changes disrupt the overall learning or working environment*
Mean	*3.9*	*3.7*
Standard Error	*0.123464*	*0.09*
Median	*4*	*4*
Mode	*4*	*4*
Standard Deviation	*1.171286*	*0.9*
Sample Variance	*1.37191*	*0.81*
Minimum	*1*	*1*
Maximum	*5*	*5*

Dependent Variables (Labor Productivity)

- **Productivity Metrics**

The data show the perceived influence of the factors of climate change on the level of productivity. The first factor investigates the effect of high temperatures on daily productivity. The respondents generally agree, with a mean score of 3.62, that high temperatures reduce their productivity, though not strongly. The median and mode stand at 4, signifying that most participants tend to be in agreement with the statement, further indicating that a majority are affected by high temperatures to reduce their productivity. The standard deviation is 0.95, showing moderate variability in responses, while the sample variance of 0.91 indicates the variation in how individuals perceive high temperatures affecting their productivity. The

minimum and maximum scores, from 1 to 5, indicate a far-reaching perception by respondents, including those who feel no effect to those whose productivity is badly reduced. The second level of discussion involves the sustaining of productivity during cooler seasons. The mean score of 3.9 reflects a stronger agreement than the first factor that generally, respondents find it easier to maintain their productivity during cooler seasons. Similar to the first factor, the median and mode values are both 4, showing a consistent response from most participants. A standard deviation of 0.99 and a sample variance of 0.99 indicate a moderate dispersion in the responses, though a little higher than the first factor, indicating that perceived variations in productivity due to cooler seasons are more diverse. Minimum and maximum scores also range from 1 to 5, showing that there are those who experience minimal or extreme changes in productivity based on seasonal temperature changes.

Climate Change Factors	*High temperatures reduce my daily productivity levels.*	*I can sustain my productivity levels better during cooler seasons*
Mean	3.62	3.9
Standard Error	0.1	0.1
Median	4	4
Mode	4	4
Standard Deviation	0.95	0.99
Sample Variance	0.91	0.99
Minimum	1	1
Maximum	5	5

- **Absenteeism**

The data explores the relationship between absenteeism and climate change factors, focusing on extreme heat, poor air quality, and heat-related health concerns among colleagues. Two dimensions are evaluated: the general impact of climate conditions on absenteeism and the specific influence of heat-related health issues. The mean for the first dimension, "Climate conditions (e.g., extreme heat or poor air quality) lead to more frequent absences," is 3.8, indicating a general agreement among respondents. This suggests that climate conditions are perceived to moderately affect absenteeism. The median and mode values are both 4, signifying that the most common responses align with agreement. The standard deviation is 1.03, reflecting some variability in perceptions, which implies that while many agree on the impact, others may perceive it as less significant or more severe. The sample variance of 1.06 further supports the moderate spread of responses. The response range is from 1 to 5, showing that opinions span the spectrum from no impact to significant impact, though the majority lean toward agreement. For the second dimension, "I notice an increase in absenteeism due to heat-related health concerns among colleagues," the mean is slightly lower at 3.6. This shows a slight decrease in agreement compared to the first dimension, indicating that while respondents acknowledge the issue, it is not as strongly emphasized. Nevertheless, the median and mode remain at 4,

demonstrating consistency in responses toward agreement. The standard deviation of 1.02 indicates a similar variability as observed in the first dimension. The sample variance is 1.05, again underscoring the range of perceptions among respondents. The minimum and maximum responses for this statement also extend from 1 to 5, indicating diverse viewpoints on the role of heat-related health issues in absenteeism.

Climate Change Factors	*Climate conditions (e.g., extreme heat or poor air quality) lead to more frequent absences.*	*I notice an increase in absenteeism due to heat-related health concerns among colleagues*
Mean	3.8	3.6
Standard Error	0.108	0.1
Median	4	4
Mode	4	4
Standard Deviation	1.02	1.02
Sample Variance	1.06	1.05
Minimum	0.34	1
Maximum	-0.84	5

- **Employee Health**

The data analyzes the effect of climate change factors on the health of employees, specifically how extreme weather and environmental conditions affect physical health and contribute to stress or fatigue in the workplace. Two important dimensions are considered: the impact of extreme weather on physical health and its subsequent impact on work efficiency, and the experience of stress or fatigue due to workplace environmental conditions. The

first dimension, "Extreme weather affects my physical health, influencing my work efficiency," has an average response of 3.4. This suggests that there is a moderate degree of agreement in the perception that extreme weather diminishes work efficiency because of its effects on health, though not overwhelming. The median and mode are 4, which indicates that agreement is the most common response. However, the standard deviation of 0.97 suggests that there is a variety regarding perceptions, so even though some have strongly agreed to this question, for others, it might be less significant. A variance of 0.94 in the sample substantiates moderate dispersion in the response opinion. The fact that responses fall between 1 and 5 shows the variance of experiences, ranging from experiencing no impact at all to very severe impacts. The second level of dimension, "Experience stress or fatigue due to environmental conditions at work," has a higher mean of 3.83, which indicates that there is stronger agreement on the part of respondents in regard to this issue. That means stress and fatigue linked with environmental factors are more universally recognized as workplace challenges. The median and mode are 4, which stresses again that the predominant answer is agreement. With a standard deviation of 0.87, there is slightly less dispersion than the first dimension, and, thus, greater uniformity within participants in the acknowledgment of this issue. The sample variance of 0.76 supports this claim of lesser dispersion. Responses also range

from 1 to 5; however, the higher mean and the lower variability support that more respondents actually face and understand the problems of stress or fatigue due to environmental conditions.

Climate Change Factors	*Extreme weather affects my physical health, impacting my work efficiency.*	*Experience stress or fatigue due to environmental conditions at work.*
Mean	3.4	3.83
Standard Error	0.1	0.09
Median	4	4
Mode	4	4
Standard Deviation	0.97	0.87
Sample Variance	0.94	0.76
Minimum	1	1
Maximum	5	5

- **Work Efficiency**

The data explores the influence of climate change factors on work efficiency, focusing on two critical dimensions: the relationship between comfort levels in the working environment and efficiency, and the impact of environmental conditions such as heatwaves and poor air quality on work output quality. In the first dimension, "My work efficiency is directly influenced by the comfort level of my working environment," the mean score is 3.7. This shows a moderate to strong agreement among respondents, reflecting significant recognition that workplace comfort substantially affects efficiency. The median and mode both fall at 4, showing that most respondents agree with the statement. However, the standard deviation of 0.93 shows that there is some variability in the responses, meaning while

many see comfort as a critical factor, there are differing degrees of agreement. This is further confirmed by the sample variance of 0.88. The range from 1 to 5 illustrates diversity in experiences, with some not feeling the effect much or hardly at all, and others felt it to a great extent. The mean in the second dimension is higher at 4, showing stronger consensus among respondents for this aspect, "Environmental conditions such as heatwaves or poor air quality lower the quality of my work output". The median and mode were the same, at 4, reinforcing the view that agreement is the leading response. A standard deviation of 0.76 is lower, therefore indicating less variability in responses than the first dimension, and points to more uniform acknowledgment of the issue. The sample variance is 0.59, which again confirms reduced dispersion. As in the case of the first dimension, responses vary from 1 to 5; however, the higher mean and lower dispersion indicate that more respondents feel the challenging environmental conditions significantly influence work output.

Climate Change Factors	*My work efficiency is directly influenced by the comfort level of my working environment*	*Environmental conditions such as heatwaves or poor air quality lower the quality of my work output.*
Mean	3.7	4
Standard Error	0.09	0.08
Median	4	4
Mode	4	4
Standard Deviation	0.93	0.76
Sample Variance	0.88	0.59
Minimum	1	1
Maximum	5	5

Control Variables (Institutional and Personal Factors)

- **Institution Type**

The data evaluates the role of institution type in addressing climate change factors, focusing on the adequacy of cooling systems and the effectiveness of institutional infrastructure in mitigating the impact of extreme weather on productivity. In the first category, "My institution has adequate cooling systems to deal with high temperatures," the mean score is 3.74. This reflects a moderately positive perception among respondents about the presence and adequacy of cooling systems in their institutions. The median and mode both stand at 4, indicating that the majority agree with this assessment. The standard deviation of 0.86 suggests some variation in responses, pointing to differing experiences across institutions. With a sample variance of 0.75 and a response range from 1 to 5, it is evident that while many respondents feel their institutions provide sufficient cooling, some perceive significant gaps. In the second category, "The infrastructure of my school/university (institution) helps mitigate the effects of extreme weather on productivity," the mean score is slightly higher at 3.91, suggesting a stronger agreement regarding the role of infrastructure in countering extreme weather effects. The median and mode are again at 4, showing that agreement is the prevailing sentiment. However, the standard deviation of 0.95 and sample variance of 0.91 reveal a slightly greater variability compared to the cooling systems category. The response range

remains from 1 to 5, indicating that while most respondents acknowledge the positive impact of institutional infrastructure, others identify significant room for improvement.

Climate Change Factors	*My institution has adequate cooling systems to deal with high temperatures.*	*The infrastructure of my school/university (institution)helps mitigate the effects of extreme weather on productivity.*
Mean	3.74	3.91
Standard Error	0.09	0.1
Median	4	4
Mode	4	4
Standard Deviation	0.86	0.95
Sample Variance	0.75	0.91
Minimum	1	1
Maximum	5	5

- **Work Environment Adaptations**

Meanwhile, the data covers the adaptations of climate change in work environments by describing resources to cope with heat and policies that are flexible during very extreme weather conditions. For the first aspect, "My institution offers resources (e.g., water, shade, air-conditioning) to cope with heat," the mean score is 3.6, reflecting a moderate level of satisfaction among respondents regarding the availability of resources to mitigate heat-related challenges. The median and mode both stand at 4, indicating that the majority of respondents agree that such resources are provided. However, the SD of 1.036 and sample variance of 1.074 indicate considerable variation in responses.

This would tend to suggest that while many institutions provide adequate resources, there are others where respondents perceive significant inadequacies. Minimum and maximum values range from 1 to 5, showing large variation across institutions in experience with resource availability. The second category, "There are policies in place to allow flexibility in working hours during extreme weather," recorded a higher mean at 3.89, showing on the one hand more favorable assessments of institutional policies for addressing weather extremes. The median and mode maintained consistency at 4; thus, this issue would show overall broad agreement by respondents. A standard deviation of 1.01 and a sample variance of 1.021 indicate that there is variability in the experiences, but it is relatively less dramatic than in the provision of resources. The response range is from 1 to 5, meaning some institutions have gone a long way in implementing flexible policies, while others lag behind.

Climate Change Factors	*. My institution offers resources (e.g., water, shade, air-conditioning) to cope with heat.*	*There are policies in place to allow flexibility in working hours during extreme weather.*
Mean	3.6	3.8
Standard Error	0.11	0.1
Median	4	4
Mode	4	4
Standard Deviation	1.03	1.01
Sample Variance	1.07	1.02
Minimum	1	1
Maximum	5	5

- **Employee Characteristics**

The data looks into the characteristics of employees in regard to climate change factors, such as their adaptability to temperature changes and sensitivity to environmental conditions in terms of health and productivity. For the first aspect, "I personally find it easy to adapt to temperature changes in my work environment," the mean score is 3.11, indicating a slightly above-average level of self-reported adaptability among employees. The median is 3, indicating that for most respondents, adaptability is generally at a medium level, whereas the mode of 4 suggests that many find it relatively easy to adjust. A standard deviation of 1.27 and sample variance of 1.60 indicate large variations in individual differences in their level of adaptability, further emphasized by the range in scores from 1 (low) to 5 (high). The dispersion, again, reflects the variety of workers' abilities to stand the temperature variations, probably linked to personal resilience, job type, or institutional support. "My health and productivity are sensitive to changes in environmental conditions"-in the second category, the average goes up to 3.34, which means a moderate sensitivity to environmental changes. The mode and median are 4, indicating a significant number of respondents felt that environmental factors affect their health and productivity. The standard deviation of 1.07 and a sample variance of 1.15 indicate variation, but slight and less compared to the adaptability category. Responses range

across the full spectrum from 1 to 5, indicating that some report little sensitivity, while others find their health and productivity seriously affected by environmental variation.

Climate Change Factors	*I personally find it easy to adapt to temperature changes in my work environment.*	*My health and productivity are sensitive to changes in environmental conditions.*
Mean	3.11	3.34
Standard Error	0.13	0.11
Median	3	4
Mode	4	4
Standard Deviation	1.2	1.07
Sample Variance	1.6	1.14
Minimum	1	1
Maximum	5	5

5.2 Inferential Statistics

Relationship between the climate change factors and productivity

The regression analysis on the relationship between climate change factors and productivity reveals several important insights. The Multiple R value of 0.856 suggests a strong positive correlation between the climate change factors and productivity, indicating that the climatic conditions in the study have a significant influence on productivity. The R Square value of 0.733 indicates that approximately 73.3% of the variation in productivity can be explained by the climate change factors included in the model. The Adjusted R Square value of 0.717 provides a slightly adjusted measure of the goodness of fit,

accounting for the number of predictors, and reinforces the strength of the model.

The Standard Error of 0.371524 indicates the average distance between the observed values and the predicted values, which shows a relatively moderate prediction error.

When examining the individual climate factors, the Temperature variable shows a strong and statistically significant positive relationship with productivity, with a coefficient of 0.451289. The t-statistic of 6.719365 and a p-value of 2.05^{-09} indicate that the temperature factor is highly significant in predicting productivity, meaning higher temperatures contribute positively to productivity. This may seem counterintuitive, but it could imply that moderate temperatures lead to better working conditions, enhancing productivity.

The Humidity factor, however, has a negative coefficient of -0.04759, suggesting a slight reduction in productivity as humidity increases, but the relationship is not statistically significant. With a t-statistic of -0.63542 and a p-value of 0.526879, humidity does not significantly impact productivity based on the data in this model.

The Heatwaves variable, with a positive coefficient of 0.258687, suggests that heatwaves are associated with increased productivity. However, this relationship is statistically significant, as evidenced by the t-statistic of 3.290092 and a p-value of 0.001465. This could be due to more intense, focused

work periods during heatwaves, although it is important to consider the broader context of heatwave impacts.

Air quality, with a negative coefficient of -0.01114, indicates a very slight negative relationship with productivity. However, the relationship is not statistically significant, as indicated by the t-statistic of -0.16158 and the high p-value of 0.872027. This suggests that air quality does not have a substantial impact on productivity in the dataset analyzed.

Finally, Seasonal changes have a positive coefficient of 0.146921, indicating that seasonal changes tend to enhance productivity slightly, with a t-statistic of 2.384766 and a p-value of 0.019341, which makes this variable statistically significant. Seasonal variations likely affect productivity due to changes in environmental comfort and work adaptability.

Thus, the regression model shows that temperature, heatwaves, and seasonal changes significantly influence productivity, while humidity and air quality seem to have less of an impact.

Regression Statistics	
Multiple R	0.856288
R Square	0.73323
Adjusted R Square	0.717351
Standard Error	0.371524
Observations	90

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Temperature	0.451289	0.067162	6.719365	2.05E-09
Humidity	-0.04759	0.074899	-0.63542	0.526879
Heatwaves	0.258687	0.078626	3.290092	0.001465
Air quality	-0.01114	0.06892	-0.16158	0.872027
Seaonal changes	0.146921	0.061608	2.384766	0.019341

Discussion

Results from this study also show that the impact of climate change is highly pervasive and touches on labor productivity, absenteeism, health, and workplace efficiency. These findings corroborate broader research evidence into the economic and work-related challenges posed by environmental changes. High temperatures, humidity, and heatwaves were observed to be a critical factor that influences comfort and productivity, as corroborated by various studies like Mikayelyan and Vardanyan (2023) and Tol (2018). These studies signal the disproportionate economic strains imposed by disrupted climates, particularly for those areas characterized by high temperatures and vulnerability.

The participants' consensus on the impact of temperature on focus and discomfort, with mean scores of 3.9 and 4.02, respectively, is in line with Lafakis et al. (2019), which quantifies productivity losses due to rising temperatures. Similarly, heatwaves showed significant disturbances in the frequency and productivity impact, with mean scores of 3.98 and 3.88, respectively, thus

supporting Adediran et al. (2022) in arguing that extreme weather amplifies vulnerabilities in fragile economies.

It can be seen that the seasons and environment have also presented an impacting feature: mean score physical comfort is 3.9 and work environment has shown the score of 3.7, thus proving Parsons and Day et al. (2018). From SD 0.9-1.17, variability is due to individualized impact arising from localized climatic incidents. It states here, Marchetti et al. (2016), this evidence has therefore arisen with climate change incidents.

Absenteeism due to heat and air quality, with mean scores of 3.8 and 3.6, respectively, aligns with Feriga et al. (2024), emphasizing climate-driven absenteeism and cascading labor impacts. These findings collectively underpin the importance of adaptive strategies, such as passive cooling and flexible work hours, as proposed by Day et al. (2018), in mitigating adverse climate impacts on workforce productivity.

The findings on climate change factors and their impacts on labor productivity carry significant implications for Egypt's economy and institutional structures. Egypt is highly vulnerable to rising temperatures and extreme weather events, with challenges ranging from reduced agricultural productivity to economic vulnerabilities and the strain on labor markets.

The findings on institutional strategies for climate adaptation were mixed, with a mean score of 3.74 for cooling systems and 3.91 for weather-mitigating infrastructure. These scores indicate

that targeted interventions are urgently needed to enhance institutional capacities in response to extreme weather challenges. These negative impacts can be mitigated by building energy-efficient cooling systems, enhancing air quality controls, and implementing region-specific policies that assure workplace comfort and productivity.

Policies that allow flexible working hours during very bad weather mean score of 3.89 are essential in ensuring sustained productivity. According to Day et al. (2018), adaptive strategies such as flexible work hours and telecommuting will enable the institution to cope with productivity loss.

The dispersion in the responses is reflected in the standard deviations of 0.86 to 1.01 for institutional performance, indicating large differences in adaptation measures across institutions. Such gaps are better addressed through coordinated national strategies that ensure fair distribution of resources and implementation of best practices across sectors.

The findings underscore the need for proactive climate adaptation planning by Egyptian institutions. Integrating climate resilience into development plans, enhancing public awareness, and adopting innovative technologies like wearable cooling devices (Szewczyk et al., 2021) could help sustain productivity and economic stability amid changing environmental conditions.

Conclusion

The present study focuses on the relations of climate change to labor productivity and their implications for the economy and institutions of Egypt. Its main findings provide important information on the challenges posed by climate change in the country. First, this study shows that increased temperatures, extremes, and season shifting have an intense effect on labor productivity. Outdoor labor-intensive sectors such as agriculture, construction, and tourism are particularly vulnerable to such climatic disruptions. For instance, heat stress means reduced worker output and increased absenteeism, which undermines productivity across these critical sectors. The study also shows the differential impacts of climate change, with some sectors being more resilient than others to the challenges.

The study also explores institutional responses to climate change, and indeed, it presents a mixed picture in terms of adaptation. While some institutions have adopted measures such as cooling systems, flexible work policies, and climate-resilient infrastructure, the capacity for adaptation remains highly variable. Such variation in institutional performance would hint that some sectors are well placed to deal with climate-related disruptions, while others face significant challenges in implementing effective adaptation strategies. Apart from that, there are the economic vulnerabilities regarding labor productivity loss due to climate change. Lower yields in agriculture, mainly from disturbances due

to climate change, may incur massive economic losses, therefore heightening the burden that has been facing Egypt's economy. Growing healthcare costs resulting from climate-induced diseases amid increase in commodity prices are aggravating the economic burden faced by the country.

There are several limitations of this study that need to be acknowledged. The main limitations are the reliance on secondary data sources and available literature, which may not capture regional variations in climate impacts or the long-term trends in labor productivity losses across different sectors in Egypt. The focus of the study on labor productivity as a key variable also excludes other important factors, such as climate-induced migration, mental health impacts, and broader societal consequences, which could provide a more comprehensive understanding of the issue. Additionally, the analysis of institutional responses was limited, with insufficient detail on the effectiveness of specific policies and adaptation measures. Further research into the successes or challenges of different institutional frameworks would be enormously instructive for future work in this area.

The study opens several pathways that could be explored in future research. Longitudinal studies that track the long-term impact of climate change on labor productivity within Egypt would give a better understanding of evolving trends in the effectiveness of adaptation strategies. The investigation into

sector-specific vulnerabilities, particularly agriculture, construction, and tourism, might go into greater detail in highlighting specific challenges of each industry and possible solutions toward its resilience. Moreover, further studies might take into account the health consequences of climate change on labor more generally, such as the consequences of heat-related diseases and psychiatric disorders, in the design of policies that can provide protection. In-depth reviews of the effectiveness of existing policies on climate adaptation and institutional responses will be necessary to identify best practices and elaboration of more robust and sector-specific frameworks for managing climate change impacts.

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