OLIVIER DESCHENES
University of California Santa Barbara, USA, and IZA, Germany

I Z A
World of Labor
Evidence-based policy making

Temperature, productivity, and income

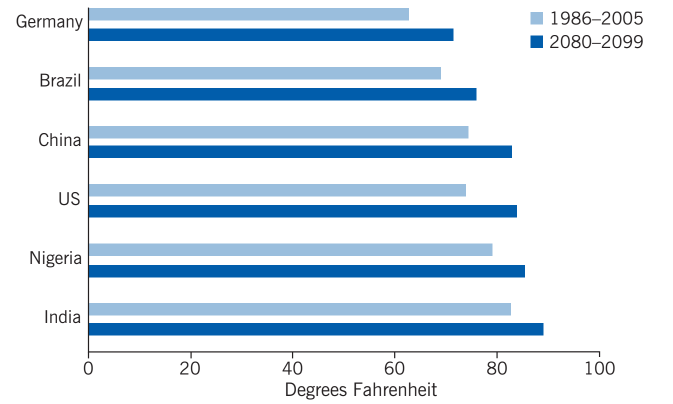
Rising temperatures due to climate change could dampen productivity growth for decades

Keywords: extreme temperature, climate change, productivity, gross domestic product

ELEVATOR PITCH

Climate change is rapidly deteriorating environmental conditions through droughts and floods, hurricanes, wildfires, rising temperatures, and more frequent and longer heatwaves. A growing literature has shown how higher temperatures reduce worker productivity and economic output. These effects are more pronounced in poorer countries and in climate-exposed economic sectors like agriculture, construction, and manufacturing. The development of new technologies that mitigate exposure to heat among workers, combined with better temperature control in the workplace, will be essential to reduce the economic burden of climate change.

Predicted average summer temperatures are on the rise



Source: Author's own calculations using data from Climate Impact Lab. Online at: https://impactlab.org/

I Z A World of Labor

KEY FINDINGS

Pros

- Rising temperatures due to climate change may increase income in some countries where current temperatures are sub-optimal for economic production.
- Investments in workplace infrastructure and adaptative measures to maintain ambient temperatures closer to productivity-maximizing levels may help mitigate some of the negative impacts of elevated temperatures on productivity and incomes.
- The marginal effect of temperature on GDP levels is more precisely estimated than the effect on GDP growth.

Cons

- Higher temperatures may reduce economic output through direct effects on worker productivity, by reducing cognitive or physical skills, labor supply or effort, or by reducing the productivity of other inputs that are complementary to labor.
- In the absence of future technological changes or productivity-increasing adaptations that can mitigate the negative impacts of high temperatures, average “business as usual” projections point to sizable reductions in average global incomes by 2100, relative to a world without climate change.
- There is a high degree of uncertainty about the predicted impacts of climate change on future levels of income and income growth rates.

AUTHOR’S MAIN MESSAGE

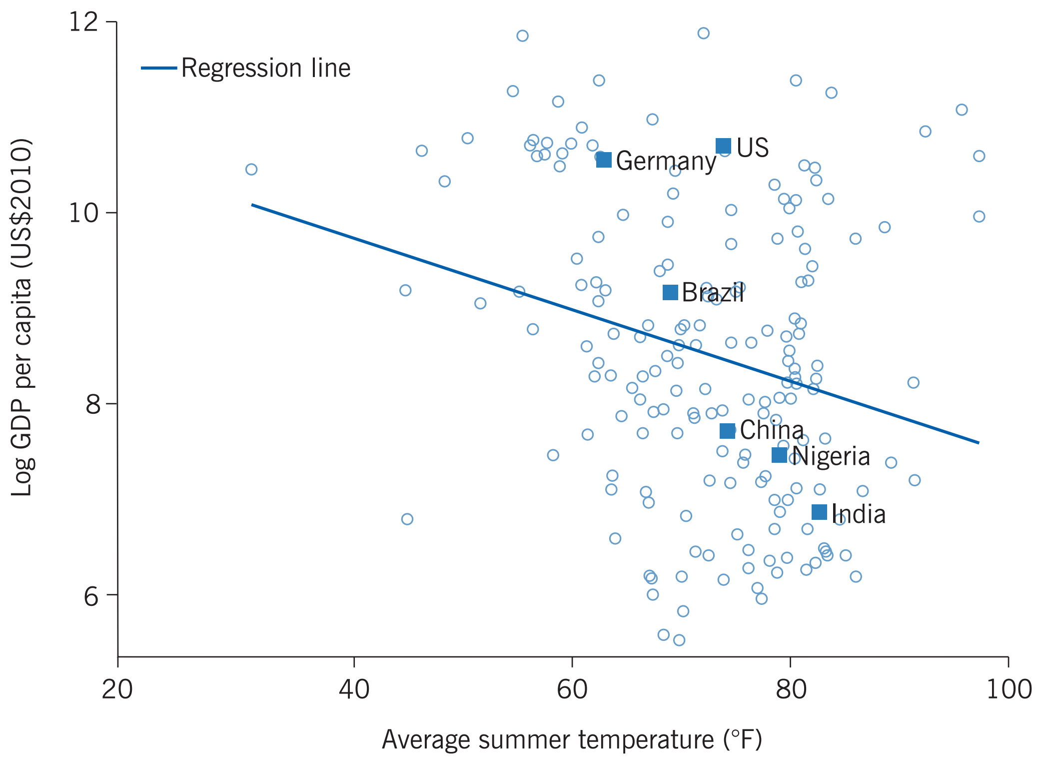
Recent empirical literature has documented how episodes of high temperatures reduce productivity and GDP levels across and within countries around the world. However, the evidence on the impact of high temperatures on GDP growth rates is less clear-cut and subject to more uncertainty. Unless new technologies are introduced or the utilization of current adaptation technologies that mitigate the negative impact of high temperatures on productivity is increased, rising temperatures due to climate change could lower incomes and dampen productivity growth for decades, even as efforts to mitigate greenhouse gas emissions are ramped up.

doi: 10.15185/izawol.505 | Olivier Deschenes © | February 2023 | wol.iza.org

MOTIVATION

Higher temperatures can affect a wide range of outcomes, from health and injury risk, to cognitive function and mental health, to labor supply, productivity, and national incomes (GDP). Figure 1 summarizes the cross-sectional relationship between summer temperatures and (the logarithm of) GDP per capita. The negative slope of the estimated regression line (–0.037) indicates that countries with higher average summer temperatures have lower levels of GDP per capita. For example, countries that differ in summer average temperatures by 3°F are predicted to have an 11% gap in GDP per capita.

Figure 1. Log GDP per capita and average summer temperature



Source: Author's own calculations using data from the World Development Indicators. Online at: https://databank.worldbank.org/source/world-development-indicators; and Climate Impact Lab. Online at: https://impactlab.org/

Further, growing evidence both at the global and local scales indicates that higher temperatures cause economically significant reductions in productivity and economic output. In the absence of new technologies or increased investments in temperature-control adaptations in the workplace that can decouple productivity from temperature extremes, these findings suggest that climate change could bring sizable reductions in productivity and incomes in the coming decades, even after considering the increased global focus on mitigating greenhouse gas emissions.

DISCUSSION OF PROS AND CONS

Why does ambient temperature affect productivity?

The human condition depends to a large extent on the surrounding environment. In particular, ambient temperature, humidity, and rainfall determine well-being through physiological, ecological, and economic channels. Deviations from normal environmental conditions can therefore affect physical and mental ability. The relationship between temperature stress and task productivity has long been studied in occupational medicine, industrial ecology, and ergonomic sciences. Meta-analyses of the extensive published literature indicate the overall detrimental effect of elevated temperatures on performance that varies across tasks. In particular, performance on psychomotor and perceptual tasks is more impacted by temperature, while cognitive performance is least affected [1]. Recent research from laboratory experiments with manipulated indoor temperatures also finds that the impact of temperature on cognitive tasks such as mathematics and verbal tasks varies by gender, with women performing better than men at higher temperatures, and men performing better than women at lower temperatures [2]. The evidence of a negative impact of indoor temperature on cognitive performance is also documented with outdoor temperatures, where a recent literature in economics shows that high ambient temperatures are linked to lower performance on high-stakes examinations [3].

In terms of aggregate output, higher temperatures may reduce production through direct effects on worker productivity, by reducing cognitive or physical skills, labor supply or effort, or by reducing the productivity of other inputs that are complements to labor. Therefore, investments in workplace infrastructure to maintain ambient temperatures closer to productivity-maximizing levels may help mitigate some of the negative impact of elevated temperatures on productivity.

Empirical methodology

Identifying the impact of temperature on productivity requires a comparison of productivity levels (measured for different workers, firms, or even geographical regions like countries or states) exposed to different levels of ambient temperature. There are several challenges to estimating such impacts, especially when the goal of the analysis is to use the estimated empirical relationship between productivity and temperature to derive projections of the impact of climate change.

First, there may be correlations between productivity and temperature through other channels than the physiological, behavioral, or cognitive channels described earlier. For example, workers and firms located in hotter countries or regions may have lower productivity levels because of lower access to infrastructure or complementary inputs (e.g. unreliable access to electricity), or because of productivity-reducing political or institutional features that are correlated with average temperature. In that case, simple regression comparisons will not be informative about the causal effect of temperature on productivity.

The recent literature, summarized in this article, has focused on natural experiments made possible due to natural variability in weather systems as a research design to identify and exploit exogenous sources of variations in ambient temperature. In the case of productivity, the basic idea is to contrast productivity outcomes for a given firm, worker, or geographical region across the levels of ambient temperature that occur in different time periods at a fixed location, while controlling for other predictors of productivity and for time trends. This approach is motivated by the fact that annual or monthly deviations in average temperature relative to a location's long-term average are plausibly exogenous (i.e. the weather is assumed to be a random draw from the climate distribution).

The standard approach to exploit this variation is through "two-way fixed effects" panel data regressions of productivity outcomes on measures of ambient temperature that include fixed effects for the cross-sectional units and for the time periods. The advantage of this method is that it can control for unobserved determinants of productivity of workers, firms, or regions, as well as controlling for common time trends that affect productivity. The challenge is to find the appropriate panel data tracking the same workers or firms over time, or repeated cross-sectional data on the same country or region. In addition, daily or monthly temperature data at the same or higher spatial frequency as the productivity data are also required in order to construct measures of temperature exposure that can capture potential nonlinear relationships.

While this approach can identify the causal impact of intertemporal variation in temperature (i.e. annual or monthly variation) on productivity, there are notable limitations when using the method to extrapolate from interannual deviations in temperature to project the impact of more permanent changes in average temperature as predicted by climate change models. In particular, adaptations and investments made by firms are likely to differ in response to a one-off increase in temperature versus repeated (and possibly) permanent increases in temperature. Such responses would be made to reduce the detrimental effects of higher temperatures on productivity. In that case, the estimated impact of higher temperature on productivity based on short-term variation in temperature would overstate the longer-term impact that includes adaptive responses and that is relevant to infer future climate change impacts.

Most studies in the literature acknowledge these limitations and some have attempted to capture differential degrees of adaptation by comparing productivity responses to temperature shocks across different climate zones (with the presumption that firms and workers located in hotter regions may be better adapted to face heat shocks than firms and workers located in colder regions).

Evidence

The following section summarizes recent empirical studies of the effect of temperature on various indicators of economic output, such as GDP growth rate, GDP per capita, total factor productivity (TFP), and output per worker. The goal is not to provide a complete review of all studies in the literature, but rather to focus on the leading articles that have brought methodological innovations or new data to the literature.

Aggregate studies

A pioneering analysis from 2012 links temperature fluctuations with economic growth, measured by the growth rate of output-per-capita [4]. The authors' inclusion of both the contemporaneous and lagged effect of temperature in the growth equation allows for the separate identification of the level effect and the growth effect of temperature shocks. This consideration is important as level effects refer to temperature shocks that have transitory impacts that eventually fade out, while growth effects have permanent impacts. For example, a temperature shock can have a long-lasting effect on economic growth by reducing investment or innovation in a given period.

The study uses panel data fixed effects regressions on a sample of more than 120 countries with more than 20 years of data [4]. The main finding is that higher temperatures substantially reduce economic growth, but only in poor countries (defined as countries with below-median purchasing power parity—adjusted per capita GDP). Specifically, a 1°C increase in annual average temperature in a given year reduces output-per-capita that year by 1.3 percentage points. No such result emerges for richer countries. Another important conclusion is that the impact of temperature on economic growth appears to be primarily driven by a growth effect as opposed to a level effect. This result has important implications for climate change policy and suggests the possibility of long-lasting and negative effects of temperature increases on economic growth in poor countries.

The empirical significance of growth effects in a cross-country panel regression of GDP growth on temperature has been debated and questioned in the follow-up literature. One key point is that uncertainty surrounding the empirical estimates of the growth effects is significantly larger than uncertainty about the estimates of the level effects of temperature, as recent research shows [5].

An influential follow-up cross-country study from 2015 examines the effect of temperature on GDP growth using data for 166 countries over 1960–2010 from the World Development Indicators and estimates the effect of temperature deviations on the growth rate of per capita income [6]. Two major differences from the 2012 study [4] involve the specification of a quadratic relationship between contemporaneous temperature and GDP growth rate instead of a linear lagged temperature structure as well as the analysis of a longer time series, with an endpoint of 2010 instead of 2003.

The main finding is that the GDP growth rate is nonlinearly related to annual average temperatures, with an increasing profile up to 13°C and decreasing afterwards [6]. To put this number in context, annual average temperatures in Germany, the US, and Nigeria are 8.8°C, 13.4°C, and 26.7°C, respectively. The implication of this finding is that the impact of temperature shocks on the GDP growth rate depends on where the shock occurs in the global temperature distribution. Inter-annual shocks to temperatures above the 13°C peak tend to reduce GDP growth while shocks below the peak tend to increase it. This suggests that climate change impacts on economic growth are likely to vary across countries, with the majority standing to lose, but some expected to win.

An important calculation in the 2015 study combines the estimated concave response function linking GDP growth rate and annual average temperature with data from global circulation models' prediction of future temperatures in order to quantify the potential impact of global warming on future economic growth and incomes [6]. This approach relies on the assumption that the empirical response function estimated over 1960–2010 can correctly be applied to future temperature scenarios. In other words, future technological or societal changes will not alter the estimated production function linking output and temperature. Overall, the conclusion is that under a "business as usual" assumption for future emissions of greenhouse gases, average global incomes will be reduced by 23% by 2100, relative to a world without climate change. Notably, there is a large degree of uncertainty in such projected long-term impacts of climate change [5].

There are noteworthy limitations of studies relying on cross-country panel regressions. First, there can be substantial variation in distributions of temperature and rainfall shocks within countries (which identify the econometric models), in particular, naturally for larger area countries. Averaging weather variation within a country to a single statistic reduces the variation exploited in the regression models. A second issue with country-year data settings is that it can mask large variations in economic output within countries. This greatly limits the ability of cross-country based models of climate change impacts on GDP growth and income to consider the distributional implications of climate change across the income distribution.

Regional analyses

Additional follow-up research has addressed the above-mentioned issues by assembling a new longitudinal sample of measures of economic output for more than 11,000 within-country regions (second-level administrative division of each country, known as districts) across 37 countries (including Brazil, China, India, Indonesia, the US, and EU countries) [7]. The main finding is that district-level GDP growth rates are negatively related to district-level annual average temperature exposure. The relationship between GDP growth rate and income is mainly driven by differences in average temperature between countries as opposed to differences within countries: the within-country relationships between income and temperature are weaker.

Climate change projections indicate that the continued increase in average temperature will exacerbate income inequality across countries [7]. An important concern related to this finding is that climate change impacts are inequitably distributed, where past emissions from richer countries impose a disproportionate burden on poorer countries that have contributed little to the global stock of carbon emissions. Further, economic development, which tends to mitigate the negative impact of temperature on GDP, is unlikely to be sufficient to eliminate climate change damages completely. Remarkably, the estimates suggest that the rise in average temperature since 2000 has already reduced output in the US and the EU by at least US$4 trillion.

Following the initial wave of cross-country studies, some empirical studies have now looked at within-country relationships between temperature and productivity, in particular in the context of the US. One such study reports a panel data study examining the relationship between GDP growth rate and temperature in the US at the state level [8]. A new consideration in the study is to model the impact of temperature on GDP growth separately by season. This reveals that summer and fall (autumn) average temperatures have opposite effects on GDP growth rates. Higher average summer temperatures tend to decrease GDP growth rates while higher average fall temperatures increase growth rates. Of the two, the summer temperature effect is the larger. Thus, other studies that only consider annual average temperatures may confound different impacts of temperature on income by season.

Further analysis identifies important and interesting variation that informs the mechanisms linking temperature and output. In particular the negative (positive) impact of average summer (fall) temperature on output is especially strong in the southern US. Moreover, higher temperatures also reduce the growth of labor productivity, so that the temperature–GDP growth relationship is attributable in part to a reduction in labor productivity [8]. Finally, the impact of summer temperature on GDP growth varies across industrial sectors. Sectors such as finance and real estate, services, and agriculture are negatively affected by high summer temperatures, while sectors such as mining and utilities benefit from it. Such diversity underscores that adaptation strategies to mitigate the economic impact of climate change must be complex and varied in order to be effective.

Short-term versus long-term temperature shocks

One limitation of the above-mentioned studies is that they mostly focus on the impact of annual (or seasonal) temperature deviations on economic growth. The economic impact of a one-off deviation in temperature may be very different from the impact of a long-lasting increase in annual temperature, that is, a change in climatic conditions. A recent study brings new evidence to this question by estimating both the impact of annual temperature deviations and the impact of long-term average temperature on GDP growth rates [9].

The study is based on a new global database of economic activity at the region level (i.e. state or province) for more than 1,500 regions in 77 countries, using a constructed regional measure of economic output similar to GDP, called gross regional product (GRP). The econometric model leverages within-country variation in annual temperature shocks and long-term average temperature in a multi-country setting. In addition to its global coverage, a key advantage of using regional data is that it permits identification of both panel and cross-sectional regressions for long-term average temperatures using panel data methods.

The key finding is that both annual temperature shocks and long-term average temperature are negatively related to GRP (in growth rates and levels, respectively). In particular, a 1°C deviation in long-term average temperature reduces GRP by 2–3%. The effect of annual temperature deviations on GRP growth rates depends on the baseline climate. Specifically, a 1°C temperature deviation reduces GRP by 0.8% in regions where the long-term average temperature is 10°C (i.e. Germany). However, the impact of the same temperature shock on GRP in a region with a long-term average temperature of 26°C (i.e. India) is a reduction of 4.6%. This finding has important implications for understanding the distribution of the economic costs of climate change both across and within countries, suggesting that the costs will be larger in hotter countries and regions.

Plant- and worker-level studies

The cross-country regressions of output and temperature reviewed so far are informed by aggregate production functions that cannot identify the precise mechanisms that connect temperature and economic activity. Knowledge of the mechanism is a key input in designing adaptation strategies. For example, if high temperatures reduce output due to constraints on factors of production (e.g. labor) reallocating across industries or regions, then adaptation investments should focus on lower factor mobility costs. On the other hand, if high temperatures reduce output due to direct productivity effects, then adaptation investments should focus on improving the temperature resiliency of production processes.

Firm- or plant-level data are necessary to learn about the mechanisms linking temperature and production. A study from 2018 reports the first comprehensive research of temperature shocks on TFP, factor inputs, and output using firm-level data for more than 500,000 Chinese manufacturing plants from 1987 to 2007 [10]. TFP, in principle, captures the ratio of output to inputs for a firm, and can be estimated using the residuals from a fitted Cobb-Douglas production function.

The empirical approach uses the standard panel data regression that exploits exogenous year-to-year variation in temperature distributions across counties in China to estimate the impact of temperature on firm-level outcomes [10]. The main finding is the existence of a nonlinear relationship between temperature and firm productivity, as measured by TFP. In particular, each individual day with average temperature above 32°C decreases TFP by 0.56%, relative to a day with average temperature between 10°C and 15°C. In contrast, labor and capital inputs at the firm level are not as related to daily temperature fluctuations over the course of a year. This implies that high temperatures affect output primarily through an effect on productivity (i.e. TFP) as opposed to an effect on inputs. An implication of this finding is that climate change will lead to output reduction unless investments can mitigate the negative impact of high temperatures on productivity.

Climate change impact projections under business-as-usual scenarios for CO_2 emissions in China (assuming the absence of additional adaptation in the manufacturing sector) indicate that annual Chinese manufacturing output will drop by 12% (or 4% of current Chinese GDP) by mid-century if the current temperature sensitivity of the sector remains the same [10].

Follow-up research also analyzes data on productivity and absenteeism at the worker level in India [11]. The data come from two industries where ambient temperature conditions may impact worker productivity (cloth weaving and garment sewing) due to an absence of temperature-control technologies inside the factories. Data are also available on productivity in a specific steel production sector (rail production for Indian Railways), where the production is mechanized and workers operating the machinery do so from temperature-controlled cabins. The main finding is that in industries without climate-controlled work environments, output falls in periods of excess heat, but it does not in industries with workplace climate control.

The authors hypothesize that the low-income status of the majority of Indian workers, combined with sustained heat exposure could induce fatigue, leading to workers not reporting for work [11]. This hypothesis is investigated with detailed worker-level data on their history of absenteeism. The authors find that prolonged increases in temperatures lasting around one week significantly increase the probability of worker absenteeism in the garment and steel production sectors. Interestingly, there is no statistical relationship between temperature and work absences in the cloth-weaving industry, where most workers are paid on piece rate. Combined, this evidence suggests that the detrimental impacts of high ambient temperatures on worker productivity can be mitigated by mechanization and controlling temperatures inside factories. Further, worker absenteeism is one of the mechanisms by which higher temperatures may reduce aggregate productivity.

LIMITATIONS AND GAPS

Evidence from the literature points to a clear negative effect of higher temperatures on measured productivity at the worker level, and on aggregated measures of GDP at the country or regional level. Estimates of the relationship between GDP and temperature are themselves key inputs necessary for assessing the impact of climate change. Taken together, this evidence helps inform the important but complex questions surrounding the design of optimal mitigation and adaptation policy.

At the same time, several scientific gaps remain. The evidence is shaped primarily by aggregate studies (e.g. country level), which can mask important heterogeneity and different mechanisms. More research is needed to understand the impact of temperature on worker-level productivity outcomes. Additionally, the precise mechanisms through which higher temperatures affect individual and aggregate productivity are not well established. A recent study suggests that work absences driven by heat exposure may be one such mechanism.

While temperature effects are relatively well-studied, much less is known about the effects of other climatic variables on economic output and productivity. For example, how will rising sea levels, droughts, wildfires, and other extreme events driven by climate change affect productivity and income? Toward this end, more research along the lines of a 2014 study which shows how cyclones reduce economic growth should be conducted [12]. Further, the literature includes insufficient examination of whether the damages associated with higher temperatures are made worse through interactions with other climatic shocks. For example, researchers do not know enough about the effect of concomitant droughts and heatwaves on income and productivity.

Finally, most of the literature relies on statistical models identified by short-term fluctuations in temperature, not long-term variations in temperature (i.e. climatic changes). In the long term, firms can respond to anticipated climatic shocks through capital investments or other forms of adjustment, and workers can reallocate their labor across economic sectors, or even regions. Thus, whether the relationship between productivity and temperature observed historically will persist into the future is an open question that can only be answered by additional research. In particular, other studies have shown that the impact of high temperature on mortality risks has declined substantially over time, consistent with adaptative responses [13]. The same phenomenon could alter the temperature–productivity relationship over time.

SUMMARY AND POLICY ADVICE

A large and growing literature has documented how temperatures affect productivity and income per capita using cross-country, regional-level, firm-level, and worker-level analysis. The damaging effects of higher temperatures are typically found to be larger in poorer countries and regions, as well as those more economically dependent on agriculture, in part due to higher exposure and vulnerability. Further, some studies conclude that temperature affects aggregate income through growth effects, which suggests that temperature shocks can have long-lasting, compounding effects on income. Altogether, this indicates that rising temperatures due to climate change could have enduring and unequal effects across the world, with the largest damages in lower-income countries.

In more developed economies, the brunt of the adverse productivity effects of rising temperatures can potentially be avoided by investing in better workplace temperature control technologies and by providing advisory warnings and flexible work schedules to reduce exposure to extreme heat among workers.

However, substantial adjustments will be necessary to avoid large negative impacts caused by rising temperatures in less-developed agriculture-intensive economies. In this setting, higher temperatures lead to lower agricultural output, which reduces labor demand in that sector, while also decreasing labor productivity in weather-exposed sectors, all of which can ultimately lead to lower incomes, reduced food supply, and worse health outcomes.

Therefore, policymakers should prioritize the development and enforcement of additional pledges for transnational climate financing toward poorer and climate-dependent nations to promote adaptation actions that mitigate the impacts of climate change. For example, wealthy nations have failed in their commitment made at the 2009 United Nations Climate Change Conference, known as the Copenhagen Summit, to provide $US100 billion annually from 2020 onwards to poorer nations. In addition, many have noted that the pledged amounts, even if they had been delivered in full, would fall short of what is necessary to provide sufficient investment in adaptation.

At the national level, enhancing social safety nets by including income support and insurance programs to allow workers and their families to improve consumption smoothing and health investments following temperature shocks that affect both productivity and food supply should produce sizable social benefits.

Acknowledgments

The author thanks the anonymous referees and the IZA World of Labor editors for many helpful suggestions on earlier drafts.

Competing interests

The IZA World of Labor project is committed to the IZA Code of Conduct. The author declares to have observed the principles outlined in the code.

REFERENCES

Further reading

Mackworth, N. H. "Effects of heat on wireless operators." *British Journal of Industrial Medicine* 3:3 (1946): 143–158.

Timperly, J. "The broken $100-billion promise of climate finance—And how to fix it." *Nature* 598 (2021): 400–402.

Key references

[1] Hancock, P. A., J. M. Ross, and J. L. Szalma. "A meta-analysis of performance response under thermal stressors." *Human Factors* 49:5 (2007): 851–877.

[2] Chang, T. Y., and A. Kajackaite. "Battle for the thermostat: Gender and the effect of temperature on cognitive performance." *PloS one* 14:5 (2019).

[3] Park, R. J., J. Goodman, M. Hurwitz, and J. Smith. "Heat and learning." *American Economic Journal: Economic Policy* 12:2 (2020): 306–339.

[4] Dell, M., B. F. Jones, and B. A. Olken. "Temperature shocks and economic growth: Evidence from the last half century." *American Economic Journal: Macroeconomics* 4:3 (2012): 66–95.

[5] Newell, R. G., B. C. Prest, and S. E. Sexton. "The GDP–temperature relationship: Implications for climate change damages." *Journal of Environmental Economics and Management* 108 (2021).

[6] Burke, M., S. M. Hsiang, and E. Miguel. "Global non-linear effect of temperature on economic production." *Nature* 527 (2015): 235–239.

[7] Burke, M., and V. Tanutama. *Climatic Constraints on Aggregate Economic Output*. NBER Working Paper No. 25779, 2019.

[8] Colacito, R., B. Hoffmann, and T. Phan. "Temperatures and growth: A panel analysis of the United States." *Journal of Money, Credit, and Banking* 51:2–3 (2018).

[9] Kalkuhl, M., and L. Wenz. "The impact of climate conditions on economic production. Evidence from a global panel of regions." *Journal of Environmental Economics and Management* 103 (2020).

[10] Zhang, P., O. Deschenes, K. Meng, and J. Zhang. "Temperature effects on productivity and factor reallocation: Evidence from a half million Chinese manufacturing plants." *Journal of Environmental Economics and Management* 88 (2018): 1–17.

[11] Somanathan, E., R. Somanathan, A. Sudarshan, and M. Tewari. "The impact of temperature on productivity and labour supply: Evidence from Indian manufacturing." *Journal of Political Economy* 129:6 (2021): 1797–1827.

[12] Hsiang, S. M., and A. S. Jina. *The Causal Effect of Environmental Catastrophe on Long-run Economic Growth: Evidence from 6,700 Cyclones*. NBER Working Paper No. 20352, 2014.

[13] Barreca, A., K. Clay, O. Deschenes, M. Greenstone, and J. S. Shapiro. "Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century." *Journal of Political Economy* 124:1 (2016): 105–159.

Online extras

The **full reference list** for this article is available from:

https://wol.iza.org/articles/temperature-productivity-and-income

View the **evidence map** for this article:

https://wol.iza.org/articles/temperature-productivity-and-income/map