News & views

Climate science

Extreme rainfall slows the global economy

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Excessive rainfall can cause catastrophic socio-economic losses to a community or nation. An analysis of changes in gross regional product identifies ways in which extreme precipitation affects global economic productivity. **See p.223**

In July 2021, record-breaking rainfall brought severe floods to Europe, where 200,000 properties lost electrical power. In the same month, torrential rain with a maximum intensity of 201.9 millimetres in a single hour led to devastating floods (Fig. 1) in Henan province, China, forcing more than one million people to relocate. These flooding events each caused roughly US$12 billion in property damage. Such losses, incurred during or shortly after extreme events, represent a direct negative impact on the economy. But how does excessive precipitation affect macroeconomics indirectly in the longer term? On page 223, Kotz *et al.*[1] report a comprehensive assessment of changes in gross regional product (GRP) relating to excessive precipitation, and conclude that increases in the numbers of wet days and in extreme daily rainfall dramatically reduce worldwide macroeconomic growth rates.

The authors analysed global annual GRP estimates in the agricultural, industrial and services sectors from 1,554 subnational regions across 77 countries, combined with high-resolution records of global daily precipitation over the past 40 years. Most previous assessments of the macroeconomic impacts of excessive precipitation considered seasonal or annual average rainfall, calculated at the national level. Such coarse resolutions in time and space cannot capture the complexities of how local precipitation events affect regional economic activities. By using detailed statistics beyond simple averages, and by correlating these statistics with subnational economic output, Kotz and colleagues showed that incorporating the details of an extreme event — where and when it hits — can have a profound effect on the assessment of its macroeconomic impact.

Natural disasters often have direct negative economic effects when they occur, but they can also affect economic productivity or GRP indirectly over a longer term. Kotz *et al.* demonstrated that increases in the number of wet days and in rainfall extremes generally reduce economic growth rates. They found that high-income nations were harder hit by these increases than were low-income countries — a conclusion that overturns ideas held previously. The prevalent hypothesis is that, in large developed economies with well-funded recovery resources, the impact of natural disasters (including increases in wet days and rainfall extremes) should be small, and sometimes even positive, but that it is generally negative for low-income countries, because they are ill-equipped to respond to catastrophe[2].

The study also suggests that the services and manufacturing sectors are worse off than the agricultural sector when subjected to increases in wet days and excessive precipitation. In fact, Kotz *et al.* found evidence that agricultural productivity is relatively insensitive to climate anomalies — a finding that seems at odds with the conventional wisdom that agriculture is affected by anomalous precipitation. In the United States, excessive rainfall can reduce maize (corn) yields by up to 34%, which is comparable to the loss incurred by extreme drought[3]. Worldwide, climate extremes during the growing season can explain 18–43% of the variance in yield anomalies for maize, soya beans, rice and wheat[4].

The effect of climate on the US agricultural economy was previously examined using estimates of this sector's total factor productivity, which is an economic measure describing the ratio of aggregated outputs to aggregated inputs[5]. The analysis showed that the climate dependence of the sector's economic productivity increased considerably after 1980, and that regional climate anomalies can now explain around 70% of the variance of growth in total factor productivity. Should this trend continue, the productivity of the US agricultural economy could fall to pre-1980 levels by 2050. Another study[6] found that ongoing climate change has slowed the worldwide total

Figure 1 | Flooding in July 2021 caused mass evacuation in Weihui, Henan province, in China.

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factor productivity for agriculture by around 21% since 1961.

Although crop yields are determined by the cumulative result of daily weather conditions over the course of a growing season, a few shocks such as floods or droughts at crucial growth stages can cause severe damage or total loss, affecting gross agricultural productivity. All of these factors suggest that the agricultural sector is vulnerable to extreme rainfall. The fact that Kotz and colleagues estimate the climate dependence of the agricultural sector to be lower than expected might indicate the need for new measures of climate. Improved metrics might capture, for example, an awareness of the importance of growth stages, or consideration of irrigation and other factors that partly mitigate the negative effects of deficient rainfall and high temperature extremes. Land drainage could be another factor that complicates the impact of excessive rainfall.

The causal mechanisms behind these statistical relationships are yet to be determined. Kotz *et al*. defined extreme daily rainfall as the annual sum of rainfall on days exceeding the 99.9th percentile of the distribution spanning 1979 to 2019. This amounts to counting only the rain that fell on the rainiest of 1,000 days. How do these rare and local events cause substantial economic shocks and cascade into long-term effects across all sectors at regional, national and global scales? Is it because they are linked in time and space and, together with other climatic anomalies, produce persistent and widespread impacts on economic activities?

The 2021 floods in Europe and China occurred at around the same time, and it is tempting to assume they were connected. But what about the snow, sleet and freezing rain that accompanied low-temperature extremes five months earlier in Texas? These compound effects resulted in a massive power failure, leaving more than 4.5 million homes and businesses without electricity. In fact, extreme rainfall events are linked through complex networks of global climatic patterns[7], and might also be related to heatwaves, cold surges, droughts, storms and other weather extremes. The integrated result of these compounded factors could lead to substantial economic impacts worldwide. Rainfall extremes might also be related to worldwide economic changes through the globalization of trade – a natural disaster in one location can affect the economy of another if their economies are interdependent. These mechanisms could change local impacts of climate extremes into indirect positive or negative economic effects elsewhere.

The frequency and intensity of precipitation extremes have been increasing in recent decades, and this trend is projected to continue with global warming[8]. In attempting to forecast the impact of these increases, a major problem is that most climate models underestimate extreme precipitation, and so projections are associated with large uncertainties. Such models therefore provide unreliable estimates of the economic effect of events resulting from excessive rainfall. With the help of numerical modelling and machine-learning techniques, further research might uncover the physical mechanisms behind the increase in precipitation extremes, and offer ways to mitigate them[9]. Until then, improved understanding of the uncertainties associated with climate models will enable policymakers to estimate rainfall extremes more accurately and to manage the related economic risks more effectively.

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Biochemistry

Structures show how salt gets a sweet ride

David Drew

Proteins spanning the membranes of cells of the intestine and kidney use sodium-ion gradients to take up glucose, enabling water absorption, too. The structures of these transporter proteins have now been observed in detail. **See p.274 & p.280**

I was close – oh, so close – when I collapsed just outside the stadium with less than one kilometre of the marathon to go. As a biochemistry student, I should have known better, but I had made the mistake of selecting water instead of the electrolyte drinks offered, and so ended up inside an ambulance dehydrated and embarrassed. The discovery that the transport of glucose and sodium ions from the digestive tract into the body is coupled and facilitates the absorption of water was a breakthrough of the twentieth century[1]. A simple salt–glucose mixture has since saved millions of lives, and kept runners from collapsing – well, mostly. Now Han *et al.*[2] (page 274) and Niu *et al.*[3] (page 280) present structures of the membrane-spanning transporter proteins that carry sodium and glucose across cell membranes in humans.

The protein known as sodium-coupled glucose cotransporter 1 (SGLT1) was first shown[4,5] in the 1980s to be responsible for the active transport of glucose across the brush-border membrane that lines the small intestine. The movement of sodium ions down their concentration gradient (from where they are highly concentrated to where they are less concentrated) enables SGLT1 to transport glucose into cells against its concentration gradient, in contrast to other glucose transporters (called GLUTs) that shuttle the sugar passively into the bloodstream[6,7]. SGLT1 also carries water along for the ride – in total, roughly 5 litres a day for an adult human – and thus is essential for oral rehydration therapy[6,8].

A closely related protein called SGLT2 works with SGLT1 in the kidney to reabsorb about 99% of the glucose that the kidney filters out of the blood, to prevent this glucose from being excreted in the urine[7]. Several SGLT2 inhibitors have been approved as drugs to lower blood glucose levels in individuals with type 2 diabetes[7]. Although the structures and computational modelling of a bacterial SGLT (vSGLT) have provided an overall framework for the transport mechanism[6], the structures of the transporters in humans needed to be defined for researchers to fully understand how they act in people and how they can be selectively inhibited by drugs.

The structures of human SGLT1 and SGLT2 were resolved using a technique called