10

Decisions! Decisions!

AVERAGING ONE HUNDRED INDEPENDENT GUESSES OF THE NUMBER of jellybeans in a jar usually provides a better estimate of the actual number than does any one guess. More generally, ensemble-averaged forecasts are typically better than best-guess deterministic forecasts. However, when we have to make decisions, simply knowing the expected outcome is often not good enough. We need to know the likelihood of some plausible worst-case scenario. If the consequences of a plausible worst-case scenario are truly dire, we should try to avoid such a scenario at any reasonable cost. For example, COVID lockdown policies were imposed, at great economic cost, to avoid a plausible worst-case scenario in which hospitals were overwhelmed and unable to cope with the number of patients needing treatment. But how plausible is "plausible", and what do we mean by any "reasonable" cost? In this chapter we will look at the use of ensembles for decision-making. This is an area where really exciting new approaches to disaster relief management are being developed and deployed.

A FEW YEARS AGO, before weather apps told us the probability of rain, a friend of mine called. He was having a garden party in ten days' time and had an option to rent a tent (what in British English would be called a "marquee"). However, he had to let the owner of the tent know by lunchtime that day whether he wanted it or not. So, he called me and asked: Is it going to rain in his back garden next Saturday between 2 p.m. and 6 p.m.?

I told him that I would look at the latest forecast but it would be in the form of a probability. I could hear the groan at the other end of the phone line.

"How on earth are probabilities going to help me?" he complained.

"Well, who's coming to your party?"

"What's that got to do with it?" he replied.

"Suppose the Queen is coming. You would not want to risk the Queen getting wet, would you? If the Queen got wet, your chances of that knighthood would go right down the drain—along with the rainwater. So, even if the probability of rain was as low as five percent, say, I guess you would likely still rent the tent. Is the Queen coming?"

"No, of course not!"

"Well, what about the town mayor?"

I sensed he was losing patience. "Look," I continued, "if the town mayor is coming, you would not want him to get wet either. However, you probably wouldn't be quite as bothered about him getting wet as you would the Queen getting wet. Let's say that if the town mayor was coming, perhaps you would rent the tent if the probability of rain exceeded twenty percent, say. Is the town mayor coming?"

"No."

"So, who is the most important person coming to the party?"

He thought about it for a while and replied, "The mother-in-law."

“And how much does it matter if she gets wet? That is to say, what is the smallest forecast probability that your mother-in-law will get wet above which you would decide to rent the tent? If you don’t care whether she gets wet or not, the threshold is one hundred percent. If she’s as important as the Queen, the threshold is five percent. I’m guessing your threshold probability is somewhere between these two.”

Again, he thought about it for a few seconds and said, “About fifty percent.”

“Good, then we have made a decision. I’ll take a look at the forecast. If the probability of rain exceeds fifty percent, then you hire the tent. If it does not exceed fifty percent, then you don’t. OK?”

I looked at the latest forecast. The probability was only around 30 percent. He didn’t rent the tent/marquee. Fortunately, it didn’t rain and everyone was happy.

What’s the essential idea from this story? It’s that probabilities aren’t some wishy-washy things that make forecasts imprecise and difficult to use. In fact, these probabilities help you make better decisions—providing the probabilities are reliable.

Let’s generalise the story. Imagine some weather event which I will call E. E could represent the occurrence of rain or perhaps freezing temperatures or perhaps storm-force winds. However it is defined, E either occurs or doesn’t occur. In the story about the tent, E occurs if it rains.

If E occurs, then Jim, as we will call him, will incur a financial loss, L, if he has taken no measure to protect himself. However, we will assume L can be avoided altogether if Jim takes some kind of anticipatory action. But this anticipatory action will cost him an amount, C. L and C have values in real monetary units such as dollars or euros, but the ratio C / L is just a dimensionless fraction which we can assume lies between 0 and 1 (if it were greater than 1, then there will be no point taking anticipatory action, since it would cost more than the avoidable loss). We call C / L Jim's "cost-loss ratio".

If C / L is small enough, i.e., the cost of anticipatory action is cheap enough relative to the loss, Jim might just as well take anticipatory action regardless of what the weather is likely to be. Conversely, if C / L is close enough to 1, then Jim might just as well never take anticipatory action, and just suffer the loss when the bad weather hits. But if C / L lies between these two extremes, then it's worthwhile for Jim to consult a weather forecast to decide when to take anticipatory action.

If Jim has access to only an old-fashioned deterministic weather forecast, then the decision process is straightforward: take action when the forecast predicts that E will occur; otherwise don't take action. This is all well and good, except, as we have seen, these old-fashioned deterministic forecasts can be unreliable. If E denotes the occurrence of hurricane-force gusts in southern England for the morning of October 16, 1987, then on the basis of the deterministic forecast, on that day no one will have taken anticipatory action (moved cars, secured boats and aircraft, cancelled travel plans). Deterministic forecasts have limited value because they are unreliable.

However, if Jim has access to probabilistic forecasts based on a reliable ensemble prediction system, then he has a much more valuable strategy for deciding when to take anticipatory action. Suppose an ensemble forecast system predicts E with probability p. Then the best decision Jim can make is to take action when p exceeds his cost-loss ratio, C / L. For example, in the case where L is twice the cost of C, then Jim should take action when E is forecast with a probability of at least 0.5, or 50 percent. On the other hand, if L is twenty times the cost of C, then it makes sense for Jim to take precautionary action when E is forecast with a probability of as low as 0.05, or 5 percent.

Fig. 41 shows an estimate of the value of a modern weather forecast system for decisions based on whether it will rain four days into the future. The horizontal axis shows all possible values of C / L between 0 and 1. The vertical axis shows how valuable the forecast system is for deciding when to take anticipatory action. A value of 0 means that the forecast system has no value (you can make decisions that are just as valuable knowing only the climatological likelihood that it will rain in your region). By contrast, a hypothetical perfect oracle of truth has a value of 1; nothing can be better than that. The solid line shows the value of decisions using a deterministic forecast system (i.e., one that predicts that it either will rain or won't rain with 100 percent likelihood). It can be seen that the forecast system has value only for a limited range of cost-loss ratios C / L. Outside this range, it is useless. The dashed line shows the value of an ensemble forecast system. It has value for almost the entire range of cost-loss ratios. Not only that, for any cost-loss ratio where there is value, the value is greater than for the deterministic system[1].

This is all very well, but does it really matter if the Queen gets wet? In any case, she will have an army of staff who, with umbrellas and the like, ensure she never actually gets wet. Indeed. So, let's instead think about a farmer in Bangladesh. We'll call him Ahmadul. In the days before computer-based weather forecasts, individual tropical cyclones would kill hundreds of thousands of people like Ahmadul; as many as half a million individuals on one occasion[2].

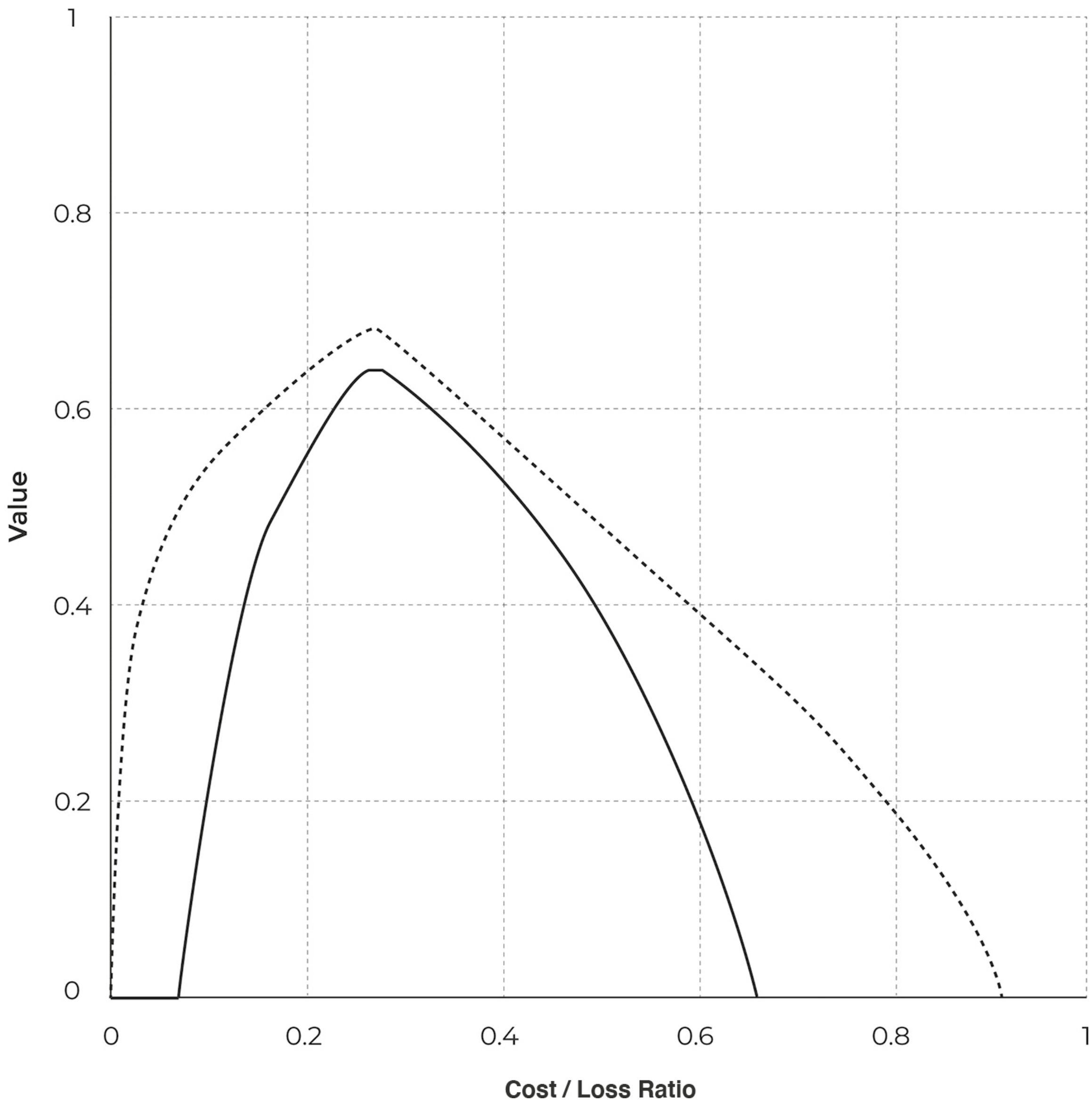

FIG. 41. The potential economic value of operational forecasts from the European Centre for Medium-Range Weather Forecasts for the European/North African region over the period October–December 2020 for the event of rainfall over a six-hour period, four days into the forecast. The lines show the value of two different forecast systems for decision-making, where losses *L* associated with the occurrence of rain can be mitigated at cost *C*. The horizontal axis denotes the user's *C* / *L*. The vertical axis shows the value of the forecast, where 0 is useless and 1 is perfection. The solid line is for a state-of-the-art high-resolution deterministic forecast system. The dashed line is for a lower-resolution ensemble forecast system.

Because modern weather forecasts are so much more skilful, far fewer people get killed by extreme weather events today than in decades past. However, that doesn't mean that we are making the best use we can of these forecasts. Disaster relief and humanitarian aid agencies have tended to react to extreme weather events only after they have hit. It can take many days, perhaps a week or more sometimes, for emergency food, water, shelter and medicines to reach a stricken region. And of course, once an extreme weather event has hit, reaching affected communities is that much harder.

It would be so much better if these agencies were able to be more proactive—to use the forecasts to target aid, allowing action to be taken before the event hits. The problem is that aid agencies aren't flush with cash. Because the old-fashioned deterministic forecasts weren't reliable, if they acted every time such forecasts predicted an extreme event, valuable resources would be spent on weather events that never happened.

Because of ensemble forecasting, one can be much more discerning about when to become proactive. Targeting aid before the event hits is called "anticipatory action" by humanitarian and disaster relief agencies. Like my friend deciding whether to rent a tent based on a probability threshold, aid agencies predetermine a probability "trigger", based on cost/loss estimates, above which it makes good sense to take anticipatory action.

The story starts over thirty years ago. It's not just tropical cyclones that Ahmadul has to worry about. His life's investments are bound up in cattle. Like many in the country, Ahmadul lives in a low-lying area and the land on which his cattle graze is prone to flooding from the nearby Brahmaputra River. The flooding need not be caused by local heavy rainfall; indeed, the rain may have fallen many hundreds of kilometres upstream. But if a major flood occurs without warning, Ahmadul's cattle, and thereby his life savings, will be lost.

My colleague Professor Peter Webster from the Georgia Institute of Technology has had an illustrious research career. He is one of the world's experts on the theory of tropical meteorology[3]. He led a number of observational field campaigns to improve our scientific understanding of the climate of the tropics. However, in 1992, Webster spent a sabbatical year working with me, and during this period he completely changed his research direction. He became a convert to the recently developed ensemble-based forecasts and decided to spend the next years of his career showing how this new way of doing weather forecasting could help people in some of the poorest parts of the world.

Webster began by consulting with local officials in regions in Bangladesh affected by the Ganges and Brahmaputra rivers. Whilst the national meteorological services provided conventional deterministic forecasts a couple of days ahead, the local officials wanted forecasts with more lead time, to allow meaningful anticipatory actions to be taken ahead of possible flooding events. They needed reliable predictions a week or more ahead. With such forecasts, families could store several days' worth of food and safe drinking water. Cattle and poultry, crop seed and other belongings could be secured in safer higher locations. Most important, plans could be made for complete evacuations. Of particular concern were those who lived on river islands called "chars". It was difficult to make such plans when you had only a day or two of warning.

Webster showed it was possible to make skilful probabilistic flood forecasts for the Brahmaputra and Ganges as much as two weeks ahead, by coupling the ensemble predictions of rainfall from the European Centre for Medium-Range Weather Forecasts to hydrological models of these rivers. Flooding would occur when enough rainfall fell in the catchment basins of these rivers. In this way, the combined weather/hydrological ensemble system would predict the probability that one or both of these rivers would flood.

However, could probabilistic predictions of flooding be used by the local communities? Would they be able to make sense of probabilities? It wasn’t obvious. After all, when I was developing these ensemble prediction systems, I had been told repeatedly by weather forecasters that the British public would never understand the concept of probability (despite the fact that many of them bet on horses, where the “odds of winning” are well understood).

Answering these questions would need a field trial. With support from the US Agency for International Development (USAID)[4], Webster began a pilot project to provide probabilistic forecasts to local villages in some of the flood-prone districts in Bangladesh.

The project was an enormous success. It ran for two years—2007 through 2008. There were two prolonged floods in 2007 and a third in 2008. For each of these there was a strong signal in the ensemble forecasts, allowing anticipatory action to be taken. The Asian Disaster Preparedness Center[5] assessed the value of these probabilistic forecasts. Farmers with fish farms or a focus on fishing saved about $130 per household (e.g., from fish farm protection). Mainly agricultural households saved about $190 from early cropping. Households with significant livestock benefitted the most, with an average savings of around $500 from advanced warnings to move livestock to higher ground. More general savings of $270 per household arose from the protection of household assets. At the time, the average income in Bangladesh was $470 per year and half the population existed on less than

$1.25 per day. As such, the savings were substantial indeed.

Webster needn't have worried that the farmers wouldn't understand probabilities. When he asked one farmer whether he could cope with probabilities, the farmer replied:

"That is fine! Only God knows 100 percent what will happen, and he is not telling and you are not God!"

With probabilities, the farmer realised, he had something more valuable than simple guesswork. Peter Webster's groundbreaking study showed that societies faced with environmental catastrophe are indeed ready, willing and able to accept and act on probabilistic forecast information.

The legacy of Webster's work is the approach referred to earlier as anticipatory action. This approach is transforming the way in which disaster preparedness agencies operate. In collaboration with the International Federation of Red Cross and Red Crescent Societies, it is being geared up for application around the world. Associated with such anticipatory action is a scheme called "forecast-based finance" grounded in three essential elements: disaster relief emergency funds, a forecast-based probabilistic trigger to release such funds and a pre-agreed action plan when the trigger conditions are met.

As an early example of this system in action, on July 4, 2020, fed by ECMWF ensemble forecasts, the European Commission's Global Flood Awareness System (GloFAS) predicted a high probability of severe flooding in Bangladesh (which occurred). The probability, combined with an independent assessment by the Government of Bangladesh's Flood Forecasting and Warning Centre, was high enough to trigger the United Nations Central Emergency Response Fund (CERF) to release $5.2 million of funds to a number of local organisations, who then prepared to distribute assistance including cash, livestock feed, storage drums and hygiene kits. This was the fastest allocation of funds since CERF was established in 2005 and the first time it had been done before the peak floods occurred. Ultimately 200,000 people were able to benefit from this anticipatory action.

In September 2021, opening a major conference on anticipatory action, UN secretary-general António Guterres said that CERF had invested $140 million to scale up anticipatory action in twelve countries, noting that "anticipatory action protects lives", and concluded that anticipatory action will become central to the UN's agenda in the humanitarian sector going forward. This is a great legacy of Webster's pioneering field trial and one that would have been impossible without reliable ensemble predictions.

Of course, communication issues remain critical. Most of us experience severe weather in one form or other from time to time, and we need to know when to take notice: the threat to life notwithstanding, such weather can lead to property damage, to travel delays and cancellations or to loss of electricity or water supplies. As a way to communicate the risk of a forecast event, the UK Met Office puts out "yellow", "amber" and "red" warnings of severe weather based on what is called a "warning impact matrix" (see Fig. 42). The weather event *E* is characterised by its estimated impact and by its forecast likelihood. In the warning impact matrix, impact varies along the horizontal axis and likelihood varies along the vertical axis. In terms of the cost-loss model described earlier, we can imagine that moving along the horizontal axis, the loss, *L*, due to *E* gets bigger and bigger. Moving up the vertical axis, the probability, *p*, of *E* gets bigger and bigger. Severe weather warnings are based on the product *pL.* Hence, for example, an amber warning could refer *either* to an event with medium impact but high probability *or* to an event with high impact but only medium probability. The probabilities that determine such warnings are taken from the ensemble forecast systems.

Of course, even when people are well informed, they do not always take action. It was reported that some people did not leave their shoreline homes ahead of the well-forecast, deadly tropical cyclone Idai that hit Mozambique in 2019, for fear their houses would be burgled. In such situations, anticipatory action could include the automatic provision of insurance coverage or of guards to protect houses.

Anticipatory action based on probabilistic thresholds isn’t relevant only for flooding events or storms. There is a growing problem of developing and maintaining global food security. In over 80 percent of the world, farming is rain-fed, meaning that water for agriculture comes principally from rainfall. Many farmers around the world know the importance of planting and harvesting crops when there will be rainfall and when it is dry, respectively. Reliable probabilistic forecasts can help them decide on planting, cropping and harvest strategies in ways for which deterministic forecasts are useless.

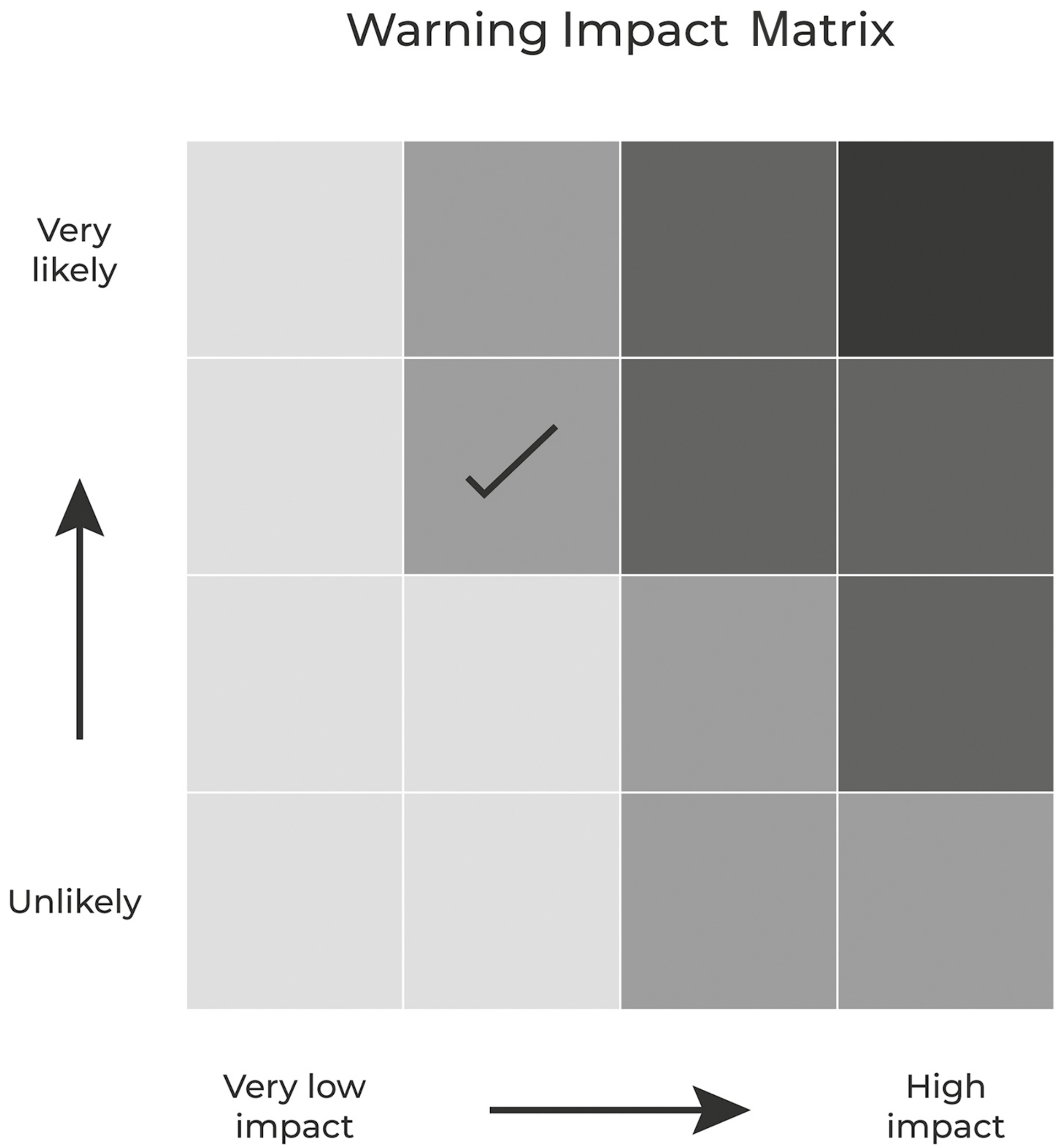

FIG. 42. Risk matrix used to determine severe weather warnings in the UK. Shown in the figure are boxes with four shades of grey, corresponding to “no warning”, “yellow warning”, “amber warning” and “red warning”—the latter being the most severe weather warning. The shading is determined by the product of impact and likelihood of occurrence. For example, an amber warning could mean either a high probability of a medium-impact event or a medium probability of a high-impact event. The probabilities are determined by ensemble forecast systems. The ticked box corresponds to a “yellow warning”.

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CAN THE COST-LOSS MODEL help us to decide whether to take anticipatory action in the light of the threat of climate change?

Let's summarise two possible arguments for and against taking anticipatory action.

On the one hand:

The climate crisis is a manifestation of our overindulgent and profligate way of life. We sowed the wind; nature is now reaping the whirlwind. As written by James Lovelock in his Revenge of Gaia[6]*,*

"Like an old lady who has to share her house with a growing and destructive group of teenagers, Gaia grows angry, and if they do not mend their ways, she will evict them."

We have to rid ourselves of our dependence on fossil fuels as quickly as possible and live a simpler life more in harmony with nature.

On the other hand:

Decarbonising the economies of the world will stunt their economic growth, particularly in relatively poor parts of the developing world, preventing them from attaining the standards of living which the developed world achieved on the back of cheap carbon-intensive energy. And if we hinder the economic growth of these poorer countries, we will lock in their high human fertility rates for many years to come, exacerbating problems of growing population levels and further degrading the planet. All this economic pain is simply not worth it—the impact of unmitigated climate change on global gross domestic product will be minimal. And if climate change means we have to adapt to *new norms of weather, so be it—we can afford it, it's not a big deal.*

Perhaps the cost-loss model I've described could provide a framework for trying to address these issues objectively. Does the likelihood *p* of dangerous levels of climate change exceed the cost *C* of cutting greenhouse-gas emissions to zero divided by the damages *L* associated with climate change? If the costs were small enough or the losses large enough, it would make sense to take action even if the probabilities were small. But are they? If we could boil it down to a seemingly straightforward calculation like this, we'd have a clear-cut strategy on whether and how to deal with climate change.

This was a question addressed by probably the most authoritative study on the impact on the global economy of climate change: the *Stern Review*[7], published in 2006, and authored by the distinguished economist Lord Nick Stern. Using estimated losses *L* and costs *C* based on gross domestic product (GDP), Stern's main conclusion was that the probability *p* of dangerous levels of warming is sufficiently great that it is certainly worth taking action now to cut our carbon emissions. But there were those who criticised the basic assumptions of the *Stern Review*. These critics argued that the science of climate change was not good enough to estimate *p* reliably, that *L* was overestimated (particularly when the future is discounted, as one has to do in any economic calculation about the future), and that *C* was underestimated.

Let's look at each of these issues in turn.

Whilst I fully agree that we could do a better job in estimating *p*—for example, by pooling human and computer resources to build much-higher-resolution global models (e.g., at a "CERN for climate change" as discussed in Chapter 6)—there is no evidence that climate models have overestimated *p*. As discussed in Chapter 6, climate projections from thirty or more years ago have done a good job in predicting observed rates of global warming.

Let's look at *L*—the avoidable damages caused by climate change. We need to be able to quantify *L* in some shape or form. If we can't put a figure in dollars or pounds on *L*, then we won't be able to determine whether the cost *C* of cutting emissions is worth it or not.

As we have seen, economists have tried to estimate the impact of *L* on global GDP. According to the *Stern Review*, without action, climate change could reduce GDP by 5 percent or more per year. Others are not so pessimistic. The Nobel Prize–winning American economist William Nordhaus has estimated that 3°C (5.4°F) of warming would lead to only just over 2 percent reduction of GDP altogether. These are massive differences. Who is right?

One problem is that, as we discussed in Chapter 8, economic models tend to be rather simple. The impact *L* in such models is typically determined by the global-mean temperature change predicted by the climate models. One could argue that they should take the regional changes of climate into account. However, as we have discussed, the rather coarse-resolution climate models do not simulate well the intensity of extreme weather events. On top of this, the economic-impact assessment models do not have the complexity of the agent-based models discussed in Chapter 8, whose form allows them to be driven by regional changes in weather patterns. I hope this rather unsatisfactory state of affairs will change with the development of a CERN for climate change, discussed in Chapter 6.

However, there is another issue. Let's think again about Ahmadul, our hypothetical representative farmer from Bangladesh. How do we quantify the impact of climate change in monetary terms on a representative of a community with a completely negligible impact on global GDP?

We are edging towards a topic which some people might feel is taboo. How much is a human life worth? This is certainly a distasteful topic, but nevertheless it is one that has to be addressed if we are to make progress in this area. One could of course take the view that a human life is priceless. However, there were just short of 25,000 people killed on the UK roads in 2020. If we valued a human life as literally priceless, then it would make sense to impose a ten-mile-per-hour speed limit on all roads. However, most of us probably feel that the extra time it would take to travel is not justified, even if it does save lives. That is to say, we implicitly put a value, in terms of our time, on a human life.

Statisticians have known that it is important to come up with some value of a statistical life (VSL), as it is called, in order to argue either for or against regulatory legislation. In his book *Pricing Lives*[8], W. Kip Viscusi, one of the pioneers in this field, discusses an issue which arose during the Reagan presidency in the 1980s: Should firms be required to label dangerous chemicals in the workplace? At the time, government agencies would estimate the value of life in terms of a person's lost earnings and associated costs if he or she died. On this basis, the US Office of Management and Budget argued that the cost of adding the labelling wasn't worth it, and therefore didn't recommend the legislation that required companies to provide labelling.

Viscusi argued that the value of life was not being calculated properly. Instead, he argued that VSL should be estimated from evidence of how much extra money individuals would require to accept an increased risk of death (or some life-changing disability which could make life a misery). Viscusi presented evidence from US-based statistical data at the time that workers were prepared to accept an annual wage premium of $300 for a job where the extra annual worker fatality risk was 1/10,000. From this, we can use the cost-loss model described earlier to estimate a value of life. That is, if we write $C = pL$ where now C = \$300 and p = 1/10,000, then we have L = \$3 million. That was in 1982. Adjusted for inflation we get a modern figure of VSL in the US as perhaps a little less than \$10 million.

However, we have to face the uncomfortable fact that VSL in the developing world is not as large as that in the US or other wealthy countries. Sadly, workers in developing countries will accept a smaller wage premium for this extra risk of death or disability. How can we adjust for this, so that we can get a figure that applies to both Ahmadul in Bangladesh and Jim in Seattle? Very roughly, a formula that is widely used defines VSL as 100 times the *per capita* GDP in the country of interest[9]. On this basis, we can value Ahmadul's life at 100 times the per capita GDP of Bangladesh.

Remember VSL is based on the monetary premium not only of death but of some life-changing disability. Based on the discussion in Chapter 6, I would say that living in a 4°C (7.2°F) or greater warmer world, a hell on earth (HoE) as far as I can judge, is not too far off the equivalent of a life-changing disability. Simply to be conservative, if VSL is 100 times the per capita GDP, let's estimate the value of avoiding HoE at 50 times the per capita GDP.

How likely is it that we will experience at least 4°C of warming if we do nothing to cut emissions? According to what I have discussed, it is, I would say, around 0.3. It does depend critically on these cloud feedbacks about which our knowledge is currently rather limited. However, if we multiply the probability, p = 0.3, by a loss, L, corresponding to 50 times per capita GDP, we end up with the "risk", pL, of HoE at 15 times per capita GDP.

What is the cost of avoiding HoE? For many years the cost of decarbonising a country's economy was assumed to be a few percent of the country's GDP. However, according to analysis performed by the UK's Committee on Climate Change in its Sixth Carbon Budget Methodology report[10], it seems that the phenomenal drop in the cost of renewable energy (wind and solar) means that the cost could be as low as 1 percent of GDP[11]. But let's assume 2 percent of GDP in general. Hence, for each person, this is a cost, *C,* of 1/50 of GDP, i.e., per capita.

On this basis, *C* is 750 times smaller than the risk, *pL*, of HoE. It seems overwhelmingly worth it to cut our carbon emissions.

However, this conclusion could be undermined by the issue of discount rates. If you had a choice of receiving $100 today or $100 in ten years' time, you would likely prefer to receive it today (inflationary devaluation notwithstanding). For example, you might invest your $100 in some business that you hope will make you several hundred dollars in ten years' time. If one estimates discount rates from the financial markets (e.g., based on financial assets such as shares), then one might discount future losses, *L,* by as much as 6 percent per annum.

Hence, some economists argue that we should compare *C* not with *pL*, but with *pL* discounted by this rate of around 6 percent per annum. On this basis, if *L* occurs sufficiently far in the future, *pL* will effectively be discounted to zero. Then no cost paid today will be worth it.

Does the application of a financial discount rate make sense? As far as I can see, the concept of human suffering makes a mockery of the notion of economic discounting based on financial assets like shares. Human suffering fifty years from now seems no less troubling to me than if it occurs five years from now, or indeed tomorrow.

Some people argue that if we are wealthier, as we may be in the future, then we will be able to cope better with the hell on earth of a 4°C warmer world. I don't buy this.

One should look at pictures of relatively wealthy German couples crying on each other's shoulders after their houses were swept away in the Rhine Valley floods of 2021. It makes you realise that even if in the coming hundred years we brought the standards of living of most of the developing world to those in Germany today, a 4°C warmer world would still be a hell on earth. Raising the per capita income in the developing world by a factor of ten, say, is not going to help much in the face of some devastating storm. And in any case, if the world is heading for a hell on earth, perhaps we will not be wealthier in the future. If that's the case, then perhaps the discount rate should be negative.

Since we have left the strict domain of science, we need to ask one further question: Who should be paying to mitigate the effects of climate change? Should Ahmadul be paying? Well, he played no role whatsoever in causing the problem in the first place. We in the rich, developed world have benefitted from cheap, carbon-rich energy. Perhaps it is time for us to pay some of that back.

Indeed, ethical and altruistic issues aside, it is in the developed world's interest to ensure that Ahmadul's life is not completely unbearable. This is because he and potentially billions like him have another option: rather than suffer and potentially perish from existential heatwaves, storm surges and extended drought, he and his family can try to migrate polewards, where the weather is likely to be more bearable. Historically, migration is how civilisations coped with local changes in climate. Nowadays, such mass migrations will be the source of major conflict, as we have discussed. If the developed world does not like this option, then it can try to ensure Ahmadul and his children can continue to live fulfilled lives where they are currently living. One can think back to the Marshall Plan, when the US provided financial help to war-torn Europe, not necessarily for altruistic reasons, but to prevent Europe turning to communism. We need a climate Marshall Plan for the future[12].

Let's summarise.

If the local weather forecast predicts an intense storm with some significant probability, it's your decision whether to act on it or not. The underlying science of meteorology does not tell you that you must act if hurricane-force winds are predicted for tomorrow. It's not for the weather forecaster to tell you what to do. However, coupling the meteorology to a cost-loss model can help you make a decision, for example, about whether to avoid travelling on a day when hurricane-force winds are predicted with some significant probability.

We can look at climate change in a similar way. Does burning of fossil fuel lead to an increase in carbon dioxide concentration in the atmosphere? According to science, certainly yes. Is carbon dioxide a greenhouse gas? According to science, certainly yes. Will emissions of greenhouse gases increase the risk of dangerous levels of climate change? According to science, certainly yes. Should we therefore cut our emissions of greenhouse gases as quickly as possible? Science itself is agnostic on this last point. The activists who simply say, "Listen to the science", seem to have missed this point. The physicist Sabine Hossenfelder put it in a rather graphic way (apparently referring to something that drunken Germans do from railway bridges): science does not tell you not to pee onto high-voltage electricity lines; it tells you that urine is a good conductor of electricity.

Just as with weather prediction, a cost-loss analysis can help you make a decision about whether to take anticipatory action regarding climate change. However, this requires putting a value on things which do not have an unambiguous value, like living in a future hell on earth. Based on the way we value our own existence in other areas of life, there does indeed seem to be a strong argument that we should act now, uncertainties about future climate change notwithstanding. But this is ultimately a decision which each of us must make, e.g., in deciding which politicians to vote for.