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The costs of climate inaction

A new analysis breaks down the likely social cost of carbon emissions by country, and should make unhappy reading for politicians.

Politics, according to the nineteenth-century German statesman Otto von Bismarck, is the art of the next best. The global approach of politicians to tackling climate change is a sorry example of this.

The problem: destructive storms that hit the United States and south-east Asia this month are the latest reminder of how vulnerable societies across the world are to climate extremes. The best political solution might seem to be to subordinate all policies — domestic and international — to the goal of stabilizing Earth's climate. This is difficult. So, instead, the world must rely on the effectiveness of voluntary actions that nations have agreed on under a non-binding international compromise treaty forged in Paris in 2015.

For all its symbolic power, that Paris treaty is a truly second-best solution. Even if it had worked as advertised, the promised cuts in greenhouse-gas emissions are weak. And now the withdrawal of the United States — and, de facto, of Australia — has substantially weakened the global consensus before the treaty has even come into effect.

Discussions on how and when it will start will resume at a two-week United Nations meeting in December in Katowice, Poland. Those attending would do well to read a study published this week in *Nature Climate Change* that highlights just how irrational it is for the politicians who represent many large economies to settle for next best (K. Ricke *et al. Nature Clim. Change* http://doi.org/ct7x; 2018).

The analysis revisits the concept of the social cost of carbon: the cumulative economic impact of global warming caused by (or attributed to) each tonne of the pollutant sent into the atmosphere. This study goes a step further than previous ones and estimates the likely cost to different countries. In doing so, it reveals the countries projected to take the hardest hits.

China and the United States, the world's two largest emitters of carbon dioxide, will incur some of the highest social costs of carbon of all countries, the scientists report, with respective estimated impacts of US$24 per tonne and $48 per tonne. India, Saudi Arabia and Brazil also feature towards the top. In these countries — unlike in Canada, northern Europe and Russia — temperatures are already above the economic optimum. And climate-induced damage increases with wealth and economic growth, meaning that more-valuable property might sit in harm's way.

Combined country-level costs (and benefits) add up to a global median of more than $400 in social costs per tonne of CO_2 — more than twice previous estimates. On the basis of CO_2 emissions in 2017, that's a global impact of more than $16 trillion. The new analysis is based on a set of climate simulations, rather than a single climate model, and the authors calculated future harm using empirical damage functions that were independently developed for that purpose.

The revised costs are still ballpark figures, based on relatively uncertain assumptions on climate physics, emission trajectories, socio-economic development and climate-driven economic damage. In fact, climate change could also have impacts on international trade, security and human migration that calculations of the social costs of carbon don't capture. But the concept is valuable, nonetheless. Acting like a magnifying glass, it highlights horrendous climate-impact inequality. For example, whereas Canada and Russia are still gaining economic benefits worth up to $10 per tonne of CO_2 from rising temperatures, India is already paying an exorbitant price ($86 per tonne).

It also shows that the way in which society currently prices carbon (as a means of reducing its use and protecting future generations) is an order of magnitude too low. The current price of carbon on the European market is just over $20. And in most other parts of the world, it's effectively zero.

"For all its symbolic power, the Paris climate treaty is a truly second-best solution."

The new analysis sends a powerful message from a future that most people say they want to avoid. In response, will politicians up their ambition and aim for the best — and necessary — solution? The paper unfortunately comes too late to be included in the special report from the Intergovermental Panel on Climate Change on the effects of 1.5 °C in global warming, due to be published next month. But it adds to the growing body of research that unpicks that global effect, and breaks it down into regions and countries. This will be needed to plan mitigation and also to prepare for adaptation.

One government that should pay particular attention to the latest work is that of the United States, where the social cost of carbon has been taken into account in policymaking — for example, in car standards. President Donald Trump's advisers have previously challenged cost estimates used by the US Environmental Protection Agency as being too high. The revised calculations suggest that the opposite is the case. ■

Deal making

European science is already suffering from the damaging effects of Brexit.

So this is how the United Kingdom's relationship with the European Union ends: not with a bang, or even a whimper, but with a series of technical notices published quietly on the website of Her Majesty's Government.

The series of briefings — the latest batch was released earlier this month — discuss the possible consequences should Britain fail to agree terms with the EU on how to remove itself from the bloc. In those circumstances — the 'no deal' scenario — Britain would be ejected from a raft of shared laws and regulations, including those governing the free movement of people, goods and services across borders in the EU. With regulatory systems on either side of the English Channel out of step, experts have warned, the worst-case scenario could see

chaos and disruption to supply chains, transport and daily life.

Scientists are among those who have been anxiously scanning the government notices. The documents include predictions of the effects on research funding (bad), access to satellite-navigation systems (minimal) and warnings about dangerous space debris (cross fingers and hope for the best). Government spokespersons have been at pains to play down the negatives highlighted by their own analyses, but in each case the attempt at reassurance has been the same: 'It won't come to that. We're trying very hard to agree a deal.'

Officials need to do so in just six months: the two-year period since the United Kingdom gave its formal notice to quit the EU expires on 29 March 2019. Most politically pressing is to find a way to distinguish between Ireland (which will remain in the EU) and Northern Ireland (which won't) without erecting a hard border, which, at worst, could reignite violence. But question marks hang over a string of issues, including how the United Kingdom should manage its nuclear research outside the EU, and whether the import of scientific equipment and reagents will be affected.

A sensible assessment of the situation says that the consequences of no deal are simply so bad that neither Britain nor the EU will let it happen. A compromise will surely emerge: either an extension of the deadline or some kind of holding commitment to make agreements in the near future. But numerous obstacles remain, among them that the ruling Conservatives will have to secure a vote in Parliament, and many of the party's hard-liners are in no mood to compromise.

Some sectors are rightly making arrangements for a no-deal scenario. The UK Office for Nuclear Regulation, for example, says it is training staff and developing the IT infrastructure needed to work outside Euratom, the EU umbrella body. And some UK universities are strengthening links with overseas institutions in the hope that this will keep them plugged into European funding streams.

Regardless of whether or not a deal is done, many scientists are already seeing and feeling the impact of Brexit, as we report in a News Feature this week (page 452). Although it might seem on the surface that it is business as usual until key decisions are made, science and scientists in Britain are suffering as a result of the uncertainty. Researchers are less likely to get collaborators on projects, because academics in Europe view them as a risky bet and are teaming up with universities elsewhere. Some are finding it harder to fill key positions. Others feel unable to apply for EU funding, and the country is losing its reputation as an international hub of excellent research. Many scientists are feeling tired and disappointed. The uncertainty is taking a personal and emotional toll.

"Although it might seem that it is business as usual, science and scientists are suffering."

Some UK scientists do see opportunities. Earlier this month, plant scientists pointed out that a no-deal Brexit could spare them from new and controversial moves in Brussels to classify gene-editing techniques as genetic modification, and so subject to all the same strict rules. That might be good for them, but it also reinforces a broader concern about the future of EU policy. On issues from regulation of genetically modified crops to allowing research with embryonic stem cells, the UK government has historically been more bullish than other European nations, and this has helped to forge the continent into a world-leader in many fields. Without Britain's contribution as a moderating and rational voice on key decisions, Europe's attitude to science will suffer.

On this point, the EU can take some concrete steps to keep Britain at the table. UK officials will no longer be able to serve on advisory panels after Brexit, but some 100 UK scientists also work in Brussels in second-tier positions, such as for the Joint Research Centre, which informs EU legislation and regulations in policy areas from environment to migration. As things stand, they will be expected to leave with Brexit. Allowing them to stay on would be a small but pragmatic way for the EU to ease the impact of Britain's departure. More must be sought. A united Europe is a major force in global research. It will be less of one after the United Kingdom goes. ■

In the archives

The discovery of Galileo's long-lost letter highlights the value of physical repositories.

Modern scholars don't always have to physically visit museums and archives around the world to seek secrets of the past. Many collections have been digitized, and much can be done with these online resources. But can anything beat the thrill of being there and finding an item assumed lost to history? That's what happened last month at the London archives of the Royal Society, with the discovery of a letter of great historical importance (see page 441).

Written by Galileo Galilei in 1613, the letter sets down for the first time the scientist's gripes with the Vatican's doctrine on astronomy. His forthright objections launched one of science history's most famous battles, which culminated in the Inquisition's condemnation of Galileo for heresy 20 years later. Different copies of the letter had circulated, and their content has been tirelessly analysed and discussed by historians. But seeing the original for the first time, with its scorings-out and word substitutions, solves a long-standing mystery about whether a version sent to the Inquisition in Rome had been doctored — and, if so, by whom.

Galileo, it now seems clear, doctored his original letter himself, to make the language less aggressive, as soon as he realized the trouble heading his way. This suggests that the editing was not the malign work of theologians trying to make a stronger case against him, as had been assumed by the nineteenth-century scholar Antonio Favaro, whose 20-volume *The Works of Galileo Galilei* is a main reference work.

Discovering an old document that allows a gap in history to be filled is a rare event in the life of a science historian. It makes all those years spent in dusty archives — or squinting at digital archives on a screen — worthwhile. The 1613 Galileo letter could have been found by anyone, given that it was hiding in plain sight in the Royal Society's online catalogue. So the discovery happened by chance, made by a visiting Italian scholar who was filling the last hour of his working day with an unplanned browse. Spotting a reference in the online archive, with mounting excitement, he asked to see it.

Perhaps no scientist in history has been as deeply studied as has Galileo, a prodigious scribe who is widely considered the father of the scientific method. There has been enough analysis of surviving copies of Galileo's letters, documents and books for some scholars not to have been overly surprised that the great scientist might indeed have rewritten a little of his own history. Scholars who have pored over his works for decades, and who understand the context of his life, his personality and turns of phrase, have a feel for these things. But seeing the editing in Galileo's own handwriting adds certainty to the interpretation. And just having the object is itself a tangible cultural gain.

There are many ways to piece history together. Research into the lives of famous people such as Galileo drives much of the knowledge we have about the past. By contrast, the Venice Time Machine (see *Nature* **546**, 341–344; 2017), a massive project to digitize a 1,000-year archive and apply machine-learning techniques, promises to dig out knowledge about the lives of the non-famous. Offline or online, scholarly analysis or machine learning, all of these approaches combine to build a more complete perspective.

Digital resources are of inestimable value to historians, but the discovery of the Galileo letter underlines the need to protect original objects, many of them stored in vulnerable museums and libraries. So does the devastating loss of artefacts in the fire at Brazil's National Museum in Rio de Janeiro earlier this month. We will never know if an equivalent to Galileo's letter perished in the flames there. Some history has been lost. But some, if we can preserve it, is merely waiting to be discovered. ■