CHAPTER 1

Introduction

Or, Do We Really *Need Another Book on Climate Change?*

The time is out of joint – O curséd spite,
That ever I was born to set it right!

—W. Shakespeare, *Hamlet, I, 5, 188–190*

If a man writes clearly enough anyone can see if he fakes.

—E. Hemingway, *Death in the Afternoon, Chapter 5*

In the run-up to the 1929 market crash financier Joe Kennedy remarked that, when you hear a stock tip from a shoeshine boy, it is time to get out of the market. Similarly, when you notice that the racks of your average airport newsvendor seem to hold more books about climate change than crime thrillers, it is fair to conclude that the market for climate-change books is truly saturated. Yet, I believe that there is room on the rack for one more book. This one. What makes me think so?

There is great uncertainty about the magnitude of the threat posed by climate change, with 'respectable' projections of climate outcomes ranging from the severe-but-manageable to the catastrophic. When many commentators routinely refer to global warming as a climate emergency, yet Yale Prof Nordhaus, an economics Nobel-Prize winner for his pioneering work on the modelling of climate change, recommends that our resources are best spent today on climate research, rather than on hasty and costly abatement, the intelligent reader to whom this book is addressed is understandably perplexed. How has this state of affairs arisen?

Partly this is because, while the science of climate change is reasonably settled, its economics and ethics appear to inhabit the land of 'anything

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goes'. In these 'relativistic' times, this seems to suggest to some that also when it comes to climate change we can interpret the evidence at hand to reach whichever conclusions we want. At the opposite end of the intellectual spectrum, the way the climate-change problem is often framed seems to imply that 'the facts' uniquely determine what we should do. Don't get me wrong: facts *are* extremely important, because they determine what is achievable, and what our real choices are. But facts do not determine ethical choices, and these play a key role in deciding what we should do to curb climate change. Providing facts is the job of scientists. Making ethical choices is the job of open-minded, inquisitive and intellectually honest citizens. The goal of this book is therefore to provide this open-minded, inquisitive and intellectually honest reader, not only with the key facts, but also with a mental compass to navigate the uncertain waters of the climate debate.

As she proceeds through the book, the reader will become progressively aware that making thoughtful decisions about climate change is no easy task. Faced with the attending choices, humans are today forced to make choices whose consequences could end up being farther-reaching than any of the decisions they have had to make in their history, as their actions can affect the outcomes not just for this or that group of people, but for humanity a whole.[1] We may even find it unfair that the responsibility for fixing a situation that, unbeknownst to us, had been getting progressively more serious since the start of the Industrial Revolution, should fall so heavily on our shoulders. Like Hamlet in the quote that opens this chapter, we may feel not just that time is out of joint, but also that it is a curséd spite that setting it right should be up to us. However, it *is* this generation that must make some of the key choices about what to do about climate change: again as in Hamlet's case, no choice is painless, and no choice is easy. But since Hamlet's reluctance to act ended in tragedy, this is where I would like the parallel with his predicament to end. It is exactly because the task is so daunting, and the temptation to do nothing so strong, that with this work I intend to give the reader some tools to make the task more manageable. And, inspired

[1] Searching in my mind for another such example, I can only think of the development of nuclear weapons.

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by the quote by Hemingway that opens this chapter, I have tried to do so using the simplest and plainest language to convey ideas from a technical and specialized field. I have strived to do so because clarity, I strongly believe, is a necessary condition for honesty – whether I succeeded, of course, is an altogether different matter.

Let me manage, not only the reader's, but also my own expectations right from the start. If you are totally convinced that we are living a climate emergency, and that this is our last chance to avert an 'existential threat', you may well ask why we need to *write* more about the subject. Surely, if we are teetering along the edge of a climate precipice, it is now time for action, not for analysis. The only books we need now are 'activist pamphlets', written in the trenches of climate warfare, not the one you are reading. At the opposite end of the ideological spectrum, if you believe that the threat from climate change is an outright 'hoax', or that it has been blown out of all reasonable proportions for political and ideological motives, you will probably conclude that my book is not a dispassionate examination of the climate problem, but a thinly disguised ploy in the climate-change conspiracy. Much as I would like to, I doubt that I will be able to change the minds either of the climate-change deniers, or of the catastrophists-who-entertain-no-doubts. But, I hope, there is a large middle ground of genuinely concerned and perplexed citizens who would like to form a balanced view, based on facts and on clearly identifiable moral choices. This is the readership I strive to reach.

Does my readership really need convincing that swift and large-scale climate action is needed? If we leave to one side Hilary Clinton's 'deplorables' – whose mind probably cannot be changed anyway – aren't we all convinced of the reality and urgency of the climate problem by now? Yes and no. A perplexing narrative has recently gained wide currency, according to which it is the politicians who are dragging their feet, and stubbornly ignoring what 'the people' want: I am sure that Greta Thunberg's 2019 'How dare you' speech at the UN climate summit still resonates in my readers' ears, and the target of her tirade were, of course, the politicians gathered at the summit. Now, to paraphrase Warren Buffet, in the last decade or so politicians worldwide seem to have been hell-bent on discovering new ways to make themselves distrusted, when the old ones were working so well. However, if we exclude China

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and Russia, in the highest-emitting countries the politicians whose responsibility it is to enact measures to curb climate change are put in power by their electorates. Now, at the time of this writing the grand total of Green party representatives in the UK, France and Italy combined is one. Admittedly, in the 2021 elections the German Green party did much better than in the past, but even in its *annus mirabilis* its vote tally only added up to 15 per cent. Voters seem to like the idea of going green, but, when faced with job losses in coal mining communities, increases in fuel tax, restrictions on short-haul flight, or withdrawal of fossil fuel subsidies, they do not cast their votes for the parties that ask for real sacrifices: they vote, if at all, for those who promise big climate changes with little or no pain (planting trees is one of the favourite get-out-jail cards – not surprisingly, the Trump administration, not known for its unwavering commitment to fighting climate change, was a whole-hearted supporter of the Trillion Tree Initiative).[2] Yes, fossil fuel lobbies *are* powerful, but what stops politicians from taking decisive (and painful) climate action is not the fact that they are in the pocket of the oil lobbies, but that, when they present the electorate with unpalatable, if necessary, choices, they are routinely not elected. So, voters (in Europe at least – in the US the situation is far more complex[3]) do not need convincing *in the abstract* that we must act to curb climate change and that there isn't too much time to waste. However, they have been convinced, or have convinced themselves, that the transition can be painless, and the changes in our ways of living can be, if not cosmetic, certainly easily manageable. As I am not a politician, and therefore I do not have to run for re-election,

[2] US Department of the Interior, 13 October 2020, *Trump Administration Furthers Commitment to One Trillion Trees Initiative*. For a brief discussion of the Trillion Tree Initiative, see Chapter 15.

[3] Opinion polls conducted by the reputable Pew Research Centre in 2019 found that 49 per cent of conservative Republicans, who represent the party majority, believe that fossil fuel production must be *expanded*. And only about half of Americans believe that 'human activity contributes a great deal to climate change'. Twenty per cent of all Americans believe that the human action has a negligible impact on the climate (45 per cent when we look at Republicans), and 35 per cent that the main causes of global warming are 'natural'. See, www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and-energy/.

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I intend with this book to change the minds of my readers on this important point, and to convince them not only that the changes ahead are indeed urgently needed, but also that they will have to be deeply upsetting.

How do I plan to achieve this ambitious task? First, I intend to convince my intended reader that, for once, the way economists think about the climate-change problem is both insightful and helpful – and, as an extra bonus, intellectually rewarding. But my contention is stronger. I want to convince the reader that looking at climate change through the lens of economic analysis doesn't just provide an alternative interesting vantage point. I want to argue that we cannot make sense of the abatement choices ahead of us if we ignore what economics has to say about three absolutely fundamental aspects of the climate-change problem: scarcity, externalities and strategic interactions. It is no exaggeration to say that we would not have a climate *problem* in the first place were it nor for scarcity; that the problem has arisen because of a massive-scale market failure (this is the externality bit); and that finding a solution is so difficult because of the free-rider problem (and this is where strategic interactions come to the fore). Dealing with these three features is part of the job description of any economist (but of no other scientist), and the discipline of economics has accumulated over decades valuable insights about how to handle them. Economists, of course, are far from holding all the answers. However, without looking at the problem from an economics perspective none of the answers we come up with is likely to make much sense. This is why I believe that understanding how economists conceptualize the climate-change problem – reductive as their approach may be – is indispensable if my 'model reader' wants to reach her own conclusions on the topic.

1.1 WHAT CAN ECONOMICS OFFER?

Convincing my reader that examining the problem of climate change from the perspective of economics is going to be not just rewarding, but actually necessary, is not an easy sell. Economists do not command the same trust or inspire the same confidence that 'hard' scientists do – and, if one casts one's mind to relatively recent economics-related events,

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it is not difficult to understand why.[4] However, for all its blemishes, economics remains our only port of call if we want to make sense of scarcity, market failures and free-riding. If this sounds a bit like a two-cheers-for-economics endorsement, well, yes, it is. But, blunt and crooked as it may be, economics is still the best tool we have to handle the three root causes of the climate problem.

1.1.1 Scarcity. Let me start from scarcity. Economics has been defined as 'the science which studies human behaviour as a relationship between ends and *scarce means which have alternative uses*'.[5] Or, if we want to put the emphasis on the outcomes of economic policies – exactly what I am going to do in this book – '[e]conomics […] is characterized by the study of how to obtain the best possible result from *scarce* resources.'[6] Indeed, if our resources were unlimited, most of what today we recognize as economics would either not exist, or be extremely boring. The choices economists study with their models are forced upon us by the fact that resources *are* limited, and extracting them is painful. And this is exactly where the link with climate change lies: the decisions we are confronted with when faced with the problem of controlling climate change are hard exactly because our resources are limited. If we could throw infinite resources at the problem, we would not have a climate problem any more: we could remove CO_2 from the atmosphere and store it safely (the technology to do so has been around for decades – it is just rather costly); we could deploy all kind of sources of renewable

[4] In November 2008 Queen Elizabeth II interrupted her scripted speech for the opening of the London School of Economics's New Academic Building to ask the impromptu question 'Why did no one see it coming?' She was referring, of course, to the Great Financial Crisis of 2008 that, just a few weeks before, had just reached one of its defining moments (the default of the American investment bank Lehman's Brothers). As far as I know, she never received a convincing answer.

[5] Robbins (1932), page 15, emphasis added. If the goal of economics is how best to make use of *scarce* resources, problems in economics are naturally cast in terms of *optimization*. The Integrated Assessment Models we will discuss in detail in the rest of the book are exactly an exercise in optimization. Casting the role of economics in terms of optimal allocation of scarce resources is today widely accepted, but it must be acknowledged that before the 1930s this interpretation was not mainstream among professional economists. See Backhouse (2010), page 100 and *passim* for a good discussion.

[6] Forni (2021), page 4, emphasis added.

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energy without worrying about their cost effectiveness; we could throw unlimited resources into research about nuclear fusion, or other energy sources: that is, we could get ourselves the best and cleanest energy that money can buy. Unfortunately, we do not live in such a world of plenty. In reality, we cannot avert future climate damage *and* enjoy the same level of consumption we could have enjoyed had fossil fuels not produced a dramatic increase in the atmospheric concentration of CO_2 (and of temperature as a result).[7] Whoever peddles the fairy tale that we can successfully tackle climate change with little alteration of our lifestyles is either naïve, or ignorant, or in bad faith. If we truly want to bring climate change under control, the commitment to the task must be substantial – I often refer to it as a 'war effort', and I don't use this grim term lightly. It is exactly because the required resource commitment is so large that we must allocate our efforts wisely. And this is why economics – the science of scarcity – can help.

Given this background of resource scarcity, let me give an example of why unstructured abatement action can be counterproductive, even if we believe that the climate-change danger is 'clear and present'. Take the cost of solar panels. This has plummeted by more than 80 per cent over as short a period as ten years.[8] This is excellent news, and gives us real hope that energy from renewables may be able to provide us in the near future with a substantial fraction of our energy needs. However, the very speed with which costs have fallen should give us pause for thought. The lifetime of a solar panel is approximately thirty to forty years. If five to ten

[7] Carbon dioxide is not the only 'greenhouse' gas, nor the most potent. One should actually speak of 'CO_2 equivalent', that is, one should convert the concentrations and emissions of other gases to the equivalent CO_2 concentrations and emissions that would generate the same climate (temperature) change over a specified time horizon. For simplicity, I will mainly refer to CO_2, but one should really talk of CO_2 equivalent.

[8] To be precise, it has fallen by 99 per cent over the last four decades (Chandler 2018). Over the period 2010–2019 Solar photovoltaics (PV) have had a cost decline of 82 per cent. International Renewable Energy Agency (IRENA) (2019), *Renewable Power Generation Costs in 2019*, available at www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019. And as a salutary reminder that all our projections are just that – projections – it should be noted that the 2020 cost of energy per kWh from solar is less than a quarter than the International Energy Agency (IEA) 2010 forecast, and less than half its 2014 prediction.

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years ago we had rushed into the deployment of the then-state-of-the-art panels, we would now be saddled with less efficient photovoltaic devices *for which we would have paid almost ten times as much as we can pay now.* True, those costly and not-so-efficient panels would have still somewhat reduced our emissions in the last five to ten years, and therefore made the climate problem today a bit more tractable.[9] However, deciding where the 'sweet spot' for action exactly lies – to what extent the advantage of waiting until we are 'smarter and richer' is negated by having to deal with a more difficult-to-handle climate problem – is clearly not easy. Thinking at the same time both about the falling prices of solar panels (and wind turbines, and carbon sequestration technologies), and about the increased severity of the climate events we are already observing makes us readily appreciate the nature of the problem, and why its solution is not easy: *since we are resource-constrained*, we must choose carefully how our abatement bullets are used.[10]

1.1.2 Externalities. Let me move to the second reason why looking at the problem of climate change through the lens of economic analysis makes a lot of sense: because the climate mess we find ourselves in directly results from a massive market failure. What does this mean? The green-

[9] Does this automatically mean that we would have been better off waiting and installing more efficient solar panels at a later date? Not necessarily. Solar panels have become as cheap as they have because so many of them have been produced, thereby improving our processes and our technological prowess. Innovations are not 'manna from Heaven', but are the fruit of what economists call 'learning by doing'. So, this example simply shows that, when it comes to abatement strategies, matters are always complex, and decisions have to be nuanced. For a discussion of learning by doing in the context of climate change, see, for instance, Messner (1997), who was among the first to introduce the idea that investment costs of technologies depend on the cumulative installed capacity, and van der Zwann et al. (2002) for a direct application to climate change.

[10] Matters, as usual, are a bit more nuanced. Suppose that we did delay the installation of the solar panels, waiting for more efficient ones to appear. As an anonymous reviewer of this manuscript pointed out, 'the decline in cost is also a result of the scaling and of the learning by doing and thus of someone investing sub-optimally. Could we have the prices of solar panel we have today if someone didn't invest sub-optimally ten years ago? In other words, pursuing the maximum efficiency objective may lead to a coordination problem whereby no one wants to make the first move, as it is suboptimal.' Excellent point.

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house gases that we emit today will affect (negatively) the welfare of future generations, but these future generations are not compensated for the damage inflicted on them. The current price of a litre of gasoline comes from balancing *today's* supply and demand for gasoline (i.e., from the bargaining of today's buyer and seller), but no account is taken in arriving at this price of the huge unpaid bill left for future generations to shoulder. The existence of these 'unpaid bills' is well known in economics and the bills themselves go under the name of externalities. When the idea of externality first developed, the 1879 example was that of English cardiologist who could not hear properly the heartbeat of his patients because of the noise of the confectioner's machinery next door. Today, the textbook example of an externality is the noise the dwellers in the landing flightpath of an airport have to endure, without the ticket price negotiated between the airline and the passenger taking this into account. More generally, externalities arise when a transaction occurs between two parties (the purchase and sale of the litre of gasoline, in our example), but damages accrue to a third party who cannot have her say in the two-party bargain by seeking compensation (in the gasoline case, the third party today is the victim of pollution,[11] and tomorrow's third party are the generations who will have to face the costs associated with living in a hotter world). Economists therefore view as a key goal of the economic analysis of climate change the *pricing* of the externality arising from the emissions of greenhouse gases – a price that should take into account the damage they inflict.[12] Note that economists, being economists, do

[11] The pollution bill is not small: the WHO estimates that 4.2 million deaths per year are attributable to ambient (outdoor) pollution, and that worldwide air pollutants account for 29 per cent of lung cancers, 17 per cent of acute respiratory diseases, 29 per cent of strokes, 25 per cent of heart attacks (ischaemic heart disease), and 43 per cent of chronic obstructive pulmonary disease. We should keep these figures in mind when we discuss the pros and cons of nuclear energy.

[12] As usual, I am simplifying matters a bit here. In the domain of climate change, economists recognize three types of externality: the emission externality that we have just mentioned; the innovation externality; and the network-effect externality. The innovation externality arises because the benefits from innovations in climate abatement area are not fully appropriated by the inventors. This is why subsidies for research, when they fix this market failure, can make *market* sense. And as for network externalities, they are often associated with the building of new infrastructure, which will have to play a major role in the green transition. The classic example is that of electric vehicles and charging stations: installing more charging stations is held back by

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not take a moralistic stance in arriving at this price: it is neither their intention nor their inclination to punish the 'bad' emitters. They simply ask the slightly otherworldly (and a bit 'impolite') question: for what compensation, paid by us today, would future generations accept the damage we are inflicting on them? If this sounds a bit crass and narrowly materialistic (and it is), let's not forget that if today's fuel users actually had to make this compensation payment, a very different equilibrium price for gasoline would be reached, and, as a consequence, we would immediately burn less fossil fuel. This would already be a big step in the right direction towards curbing climate change.[13] In reality the at-the-pump price of the emission externality is currently *negative*: large subsidies are enjoyed by the producers and consumers of fossil fuels – see the discussion in Section 12.4. No wonder we have the climate problem that we have: because we have probably engineered the greatest market failure in the history of mankind.[14] Prof Nordhaus (2021) puts it very clearly:

> Carbon capture and sequestration [CSS] provides a good example of this double externality. Economic returns on the research and

the small number of electric vehicles, and the production of electric cars is hampered by the scarcity of charging stations. In general equilibrium analysis one finds two equilibria: one with a lot of electric cars and charging stations; and one with few of both. Again, subsidies can help the establishment of one equilibrium over the other. For a good discussion see J H Stock (2021), *Driving Deep Decarbonization*, Finance and Development, IMF, September 2021.

[13] Let me be clear here: a market mechanism such as pricing today's emissions, and adding this 'emission tax' to the price of a litre of fuel works well in the idealized textbook world populated by *Homines economici*. Much as I think that market mechanisms, such as the establishment of emission markets, can to some extent help to tackle climate change, I do not think for a second that the invisible hand of the market has all the solutions to the climate-change problem. The reality of the 2017 *gilets jaunes* demonstrations in France are a stark reminder of how wide the gap is between the grubby sub-lunar world we live in and the rarefied world of the economics textbooks.

[14] I cannot be sure whether it is really the biggest market failure ever: however, the total world CO_2 emissions in 2019, including agriculture and land use, were over 40 billion tons. A *very* low estimate of the social cost of carbon puts it at around $30 per ton. (Some estimates are two-to-three times higher.) This means that the 'missing compensation' is at least well over one trillion dollars *per year*. This seems to me pretty large by any standards. To put the number in perspective it is the same size as the 'massive' infrastructure bill approved with bipartisan support by the US Senate in August 2021 – an investment that I do not think will be repeated every year.

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commercialization of CCS spill over to other firms and future consumers. But the captured carbon is worthless in most countries because carbon emissions are drastically underpriced, which makes investments in CCS commercially nonviable – and therefore out of the question in corporate boardrooms. The same logic holds for advanced nuclear power, fusion power, and the burgeoning hydrogen economy: none of them have any advantage over fossil fuels as long as carbon prices remain low.

So, as we shall see, when economic analysis comes up with a way to 'price' this externality (the 'social cost of carbon'), it is not just coming up with an interesting descriptive statistic of the climate-change problem: it is trying to estimate an absolutely key quantity in the effective tackling of climate change. *How* this carbon tax can be levied in practice is a very difficult problem (also about which economics has a lot to say), but the implementation difficulties do not wave the problem away.

1.1.3 Free-Riding. This brings us to the third feature that makes handling climate change difficult, and economic analysis helpful: the free-riding problem. In essence, it all comes down to the fact that the cost of emission reduction is local (is paid by *you* here and now), but the emitted damage is universal – CO_2 molecules know no state boundaries, and mix very rapidly in the atmosphere, irrespective of where they have been emitted. So, even if you stop emitting altogether, your emission-free patch of land does not enjoy a better climate than the land of your polluting neighbour. The temptation, therefore, is for you to hope that your neighbours will curb (at a cost) their carbon emissions, and for you to enjoy the benefits of their sacrifice without doing your bit.

To analyze the multi-party free-riding problem economists have come up with a nice story (the diner's dilemma), that goes along the following lines. Suppose that you decide to go out to dinner with a large number of friends to a restaurant that offers two menus, a cheap-and-ok one, and a good-but-expensive one. You and your friends decide beforehand that you are not going to go Dutch, but you will split evenly the final bill. If you dined at this restaurant on your own, you would not choose the expensive menu, because you don't find that the better quality of the expensive food justifies its cost. But tonight you are out with a bunch of friends, and, you reason, if just this time you chose the expensive menu, its cost would

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be diluted amongst your friends. This being the case, you think, tonight it is worth going for the fancy menu. The fly in the ointment is that all your friends also think the same way, and therefore everybody chooses the expensive menu and ends up with a choice that *nobody* prefers. In the lingo of game theory the expensive-meal solution is strictly dominant – the strategy is better for one player *no matter what the other players choose* – and is a unique Nash equilibrium – meaning that no player has anything to gain by changing her own strategy. Choosing the expensive meal may well be dominant and a unique Nash equilibrium,[15] but the fancy words do not change the fact that it is also the collectively worst solution.[16]

Mutatis mutandis, this setting shares important features with many important real-life situations, such as, say, taxation: we all know that if nobody paid taxes we would have no hospitals, roads, schools, police, etc. This, we all agree, would be the worst possible outcome. However, if everyone else paid their taxes and you didn't, you would still enjoy almost exactly the same hospitals, roads, schools and police, but your current account would show a significantly higher balance: all moral aspects excluded, free-riding would be your ideal choice. Needless to say, if everyone reasoned in the same way, we would quickly end up in the worst state that we all wanted to avoid in the first place. As Prof Nordhaus says, 'the result of pervasive free-riding is that international climate policy has reached a dead end.'[17]

Getting out of the free-riding problem is particularly difficult because, in these situations, perfect rationality, the distinguishing feature of *Homo Economicus*, offers no way out of the impasse: if anything, it is a coldly rational appraisal of the problem that leads us to the bad solution in the first place. How do we get out of this impasse (how do we avoid, that is, the worst-outcome situation)? Perfectly rational actors require, *and*

[15] For the interested lay reader Axelrod (1984) is the most rewarding book on the topic I am aware of.

[16] Individually, someone could be even worse off: that would happen, for instance, if a single diner went for the cheap meal, and everyone else chose lobster with foie gras. In the climate-change context, this would correspond to a single country going for a costly abatement programme.

[17] Nordhaus (2021).

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will ask for, a co-ordinator to 'force them to make the right choice'.[18] This can work well when the problem is local (say, national), and one can therefore empower a national coordinator (the government and the judicial system) to 'force us to make the right choice' – one can think of this as a variation on Hobbes' solution to the Leviathan problem. But when the problem is global, the enforcement of global coordination becomes extremely problematic, as recognized by Nordhaus (2021).[19] Perhaps international institutions such as the World Trade Association could provide the required sticks and carrots, but the difficulty of the task should not be underestimated.

These insights have profound implications when it comes to choosing the right mechanisms to tackle climate change: since the temptation to free-ride is always present (both at the individual and national level), pure market solutions, with no government interventions, would not work *even if every citizen were perfectly informed and unerringly rational*. Yes, in some cases the power of the market can be harnessed, for instance by setting up the trading of carbon permits. But even in this poster case of how markets can help in curbing global emissions, an external rule, that is, stipulating that you need a permit to emit at all, must be put in place and enforced beforehand by the 'co-ordinator' of choice. And since the free-riding problem is pervasive in strategic interactions, not surprisingly economics has a lot to say about all of this.

[18] Some people say that we are not only motivated by our gain in making social choices such as paying our taxes or not. A moral or social code also plays an important part in determining our choices. This is certainly true, but an economist would answer to this that, if part of your utility is derived from observing moral or social norm, then we should change the payoff matrix of the 'game' and, when we do so, we probably no longer have a diner's dilemma setting any more.

[19] 'Countries rely on others to act, a tendency that undermines the strength of climate agreements. Given these […] problems, it cannot be a surprise that the world has made so little headway in slowing climate change. … Noncooperative approaches to issues as diverse as tariffs, ocean fisheries, war, outer space, and climate change lead to outcomes that leave most or all nations worse off. The result of pervasive free-riding is that international climate policy has reached a dead end. The fatal flaw in the 25 UN conferences leading up to Glasgow is that they are essentially voluntary. Countries may agree to take action, but there are no repercussions if they withdraw from the accords or fail to keep their commitments.'

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1.2 GLOBAL WARMING AND INEQUALITY

I debated a lot whether a better title could be found for this section, because, as it stands, it reads like a naked attempt to grab the reader's attention with the two 'trendiest' topics in current social debate. However, the point I want to make here is that there *is* a deep link between tackling climate change and inequality. This being the case, a simple heading that brings the two concepts together is, after all, the most appropriate one.

Inequality has become one of the most pressing topics in economics. If you look up a standard undergraduate textbook in economics written in the closing decades of the last century, you would be hard pressed to find any mention at all of inequality. The new, 1,000-plus-page book by the Oxford Core Team that tries to set the standard for modern teaching of economics introduces inequality on page 3, and, so to speak, its authors never look back.[20] This is certainly a welcome development. What I find surprising is how rarely the economic connection between fighting inequality and fighting global warming is made. In reality, I think that the nexus between the possible solutions of these two problems runs deep. Let me explain why this is the case.

When people talk about inequality, more often than not they refer to the uneven distribution of wealth within a society or a country. It is not surprising that this should be the case: the sight of a homeless person huddling on the pavement a few feet away from where a Bentley is parked has a visceral impact that no statistic about different GDP per person in rich and poor countries can possibly elicit. Yet, the problem of wealth inequality between different parts of the world is every bit as important – if not more so. Every person with no more than a shred of Smith's moral sentiments[21] must hope that these disparities will be soon reduced. As I discuss in Chapter 11, however, we observe that historically improved standards of living have been associated with increased energy

[20] The 'Inequality' entry in its index is, by my informal reckoning, the one with more page references than any other.

[21] 'How selfish soever man may be supposed, there are evidently some principles in his nature which interest him in the fortune of others and render their happiness necessary to him though he derives nothing from it except the pleasure of seeing it.' Adam Smith, *The Theory of Human Sentiments*.

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consumption (see, e.g., Ayres, 2013, 2016, 2017, Smil 2021) *and* with an increase in population. So, from the point of view of energy consumption, there is a double-whammy: if we want the economic conditions of the poorest populations to improve, the energy consumption per person must increase, and, as a result, the number of people will increase as well.[22] This raises the question of where the energy is going to 'come from'. If the developing and numerically growing countries will follow the development steps of the Western world, using old-technology fossil-fuel-based energy sources first, and only progressing to cleaner ways of producing energy at a much later stage, the emission strain on the planet will be very severe, and perhaps unbearable. Simplifying a lot, it would be as if several Chinas appeared on the emission scene all in one go. Things would look very different if the transition of the developing countries to a high-energy, high-standards-of-living condition could be achieved with low-emission sources of energy. Even in this case a cost in terms of increased emissions would have to be paid, but the transition could be managed with greater hopes to keep global warming under control.

When it comes to who should share the abatement burden, there are obvious questions of equity among nations that must be addressed. Saying that the rowdy party must be broken up because some of the guests are now drunk would justifiably strike the late-comers who had not had a sip yet as deeply unfair. Any solution to the international coordination of abatement efforts must therefore take considerations of equity into account to have any legitimacy. Economics, as an instrumental discipline, is silent about these issues. However, even agents deprived of moral sentiments can easily see that bringing all countries on board, if necessary with substantial international subsidies, is in their selfish interest – CO_2 molecules, as I have said, know no boundaries; and migrants who have to flee areas where life has become impossible because of climate change can be restrained by national boundaries with only marginally greater effectiveness.

So, the climate success of the transition ahead of developing countries hinges heavily on finding cost-effective ways of decarbonizing our energy sources. In their attempts to close the economic gap, developing coun-

[22] For a discussion of this important link, see Chapter 11.

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tries will certainly and justifiably use the cheapest means at their disposal. We must make sure that clean energy sources, perhaps with transnational subsidies, will be their means of energy production of choice. This may seem to be a narrow technological problem, but technology is not manna from heaven – it is largely the product of what economists call 'learning by doing'. And economics has important things to say about how learning by doing can be aided by a smart regulatory framework. Conversely, modern economic analysis explains why a clumsy, even if intuitively more appealing, set of climate regulations can not only be ineffective, *but hamper technological development*. We will discuss these questions in greater depth in the body of the book (see, e.g., Chapter 16), but the three points I want to make here are, first, that even selfish agents must be in favour of making climate change actions work *across the world*; second, that economic inequality across countries makes the achievement of the common climate goal more difficult – and probably impossible without substantial help from the richer countries; and, third, that economics has a lot to say about how this can be achieved.

1.3 TWO CHEERS FOR ECONOMICS

Having just made the case for why economics is not just useful, but indispensable, to understand properly our climate-change-related choices, I can already hear some strong objections. Economics deals with, and tries to establish equivalences between, material consumption at different points in time, often enjoyed by different people.[23] In doing so, it embarks on an uncompromisingly reductionist path. In the case of the effects of climate change, this means attributing a monetary value to loss of output or capital – something that may be technically difficult, but that, to an economist, seems to make perfect sense. However, to

[23] It is unfair to say that the key tool of microeconomic analysis, utility, can only handle *material* consumption. In theory, aesthetic pleasure, pleasure derived from altruistic actions, or the enjoyment derived from, say, a more carefree life could be used as input to the utility function economists strive to maximize. In practice, however, the degree of subjectivity required to make these hedonistic conversions is so high and arbitrary, that most economists implicitly agree only to deal with material consumption (stuff that can be *bought or sold*), or, often crudely and at first blush almost callously, attempt to determine a monetary equivalent to the intangible they would like quantify.

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handle the climate-change problem in economics terms, we have to put a price also on, say, the loss of biodiversity, on the forced migrations of populations whose lands are no longer productive, or on the loss of natural beauty. In the calculus of economics, for comparability everything must be translated into a common consumption-related unit ('utility') – a unit about which we will have a lot to say. Doing this comes at a cost of psychological hardening. There should always remain an understandable, natural and, I would say, healthy unease towards even asking questions such as: 'How much consumption should we sacrifice today to prevent the future displacement of a population whose land has been submerged?', or, even more crudely, 'How many migrants is an SUV or an exotic holiday worth?' If pushed in a corner, we may have to resort to establishing these callous equivalences in order to handle the climate-change problem without causing even more unintended damage; but we should never do so lightly.

I have a lot of sympathy for these objections, and I am the first to regard with suspicion the encroachment of economic thinking into areas where 'it does not belong'. I do not look kindly, in other words, on what has been called the 'imperialism' of economics.[24] However, in the last few years, in small part thanks to strands of research to which my research group is contributing, it has become increasingly apparent that even the strongly reductionist approach that economics employs points to very decisive and prompt abatement schedules as the most desirable course of action: we should invest in costly climate-change-abating initiatives, this modern economic research clearly says, *now and in large scale* – and we should do so even if today's sacrifices are far from small. And here is the punch line: *it is exactly because this recommendation comes from such a*

[24] Economic analysis, for instance, ties itself into slightly ridiculous knots when it tries to explain the 'paradox' of why citizens bother to vote. The chance that, even in the most tightly fought electoral contest, a single vote might decide its outcome, the economists' reasoning goes, is so small that no rational utility maximizer should bother to visit the polling station: her 'information costs', in economic jargon, are just too high. The fact that turn-out at elections is always in the double digits, and people often engage in the act of voting at high personal risk or discomfort, ceases to be a paradox the moment we acknowledge that the act of voting – of expressing one's *preferences* – brings to the fore key components of what we consider human worth and dignity – aspects that are simply too difficult to handle with the limited lexicon of utility analysis.

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reductionist and 'heartless' approach such as the one employed by economists that we should take it seriously.

If I had been writing this book just ten years ago, I would have had to qualify strongly this bold recommendation. I would have had to say that, yes, according to some very respectable economists, acting promptly and decisively was the best course of action. But I would also have had to add that other equally respectable economists (among whom one can number Nobel-prize winners) advocated much more gradual abatement strategies. I would, in other words, have been telling yet another version of the 'on the one hand … on the other hand' story that has become a trademark joke about sitting-on-the-fence economists.[25] This is no longer the case. In the last decade or so, a substantial body of research has been developed, that points with increasing clarity towards decisive and rapid emission abatement as the optimal course of climate-change action. What has happened? We shall discuss this at length in the body of the book, but, in essence, ten or fifteen years ago the only way for economists to recommend early and steep abatement schedules was to posit an extremely high degree of altruism, understood as a high willingness to give up present consumption for the welfare of future generations. (The welfare of *future* generation is mainly at stake, of course, because we expect the most severe damage from climate change to happen well into the future.) While noble and in the abstract commendable, this degree of altruism finds little support in the way we seem willing to distribute resources in different but related areas – such as aid from developed to developing countries, or redistributive taxation. With the early analytical tools that were brought to bear on the climate-change problem, in other words, to come up with fast and rapid abatement schedules one had to assume that humans would behave very differently faced with climate-related damage (inflicted on *future* generations) than with virtually all the other aspects of life from which we can glean our degree of altruism. Needless to say, this 'observed degree of altruism' is not a given, and, arguably, could be 'improved upon'. However, the awkward question remains of why this heightened sensitivity should be

[25] As far as I have been able to ascertain, it was US President Harry Truman who pleaded: 'Give me a one-handed economist. All my economists say "on the one hand …", then "but on the other …".'

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called 'climate-change altruism' and not, for instance, for 'developing-countries altruism'.

So, ten or so years ago, unless you assumed a rather implausible, and certainly unprecedented, degree of altruism, the main analytical tools from economics suggested that we should actually wait (until we are smarter and richer) before, say, switching to costly renewables, and that investing heavily in climate-change abating technologies now was tantamount to taxing the poor (us today) to benefit the rich (our richer great-grandchildren). This is no longer the case: as our tools of economic analysis have been sharpened, it has become clear that, let alone a saint, but even your indifferently selfish knave should go for rapid and decisive (and costly!) abatement action now. Once again: what is interesting and important is not that economics is telling us to act now and to 'act big'. It is that *even* hard-nosed, cold-hearted, reductionist economics tells us to do so.

The message is brought home with unparalleled clarity by Fig 1.1, which shows the optimal emission-abatement schedules obtained by the DICE model,[26] by the Stern (2006) approach[27] and using the modern economic models that we shall encounter in this book. We shall look in detail at what information these graphs convey in later chapters, but for the moment we just need to know that the Stern approach posited a saintly degree of altruism in economic agents; that the DICE approach tried to mimic the degree of altruism actually observed in other spheres of life; and that the modern approach does not require exceptionally altruistic agents, but fixes some of the modelling problems that plague both the DICE and the Stern approach. One can then read the various curves in Fig 1.1 as representing the trajectory of the abatement effort in three different worlds: the DICE world, the Stern

[26] DICE model stands for *D*ynamic *I*ntegrated *C*limate and *E*conomy model. The DICE model was first introduced in the academic literature as far back as 1993 by Nordhaus (1993), and has successively undergone many updates, the latest of which took place in 2016.

[27] The *Review of Economics on Climate Change*, to give it its full name, was launched in 2005 by Sir Nicholas Stern, Head of the British Government Economics Service and Adviser to the British Government on the economics of climate change, at the request of the then Chancellor of the Exchequer, Gordon Brown. While the academic credentials of the contributors were impeccable, it was from the start a project that saw the light in a political, rather than academic, environment.

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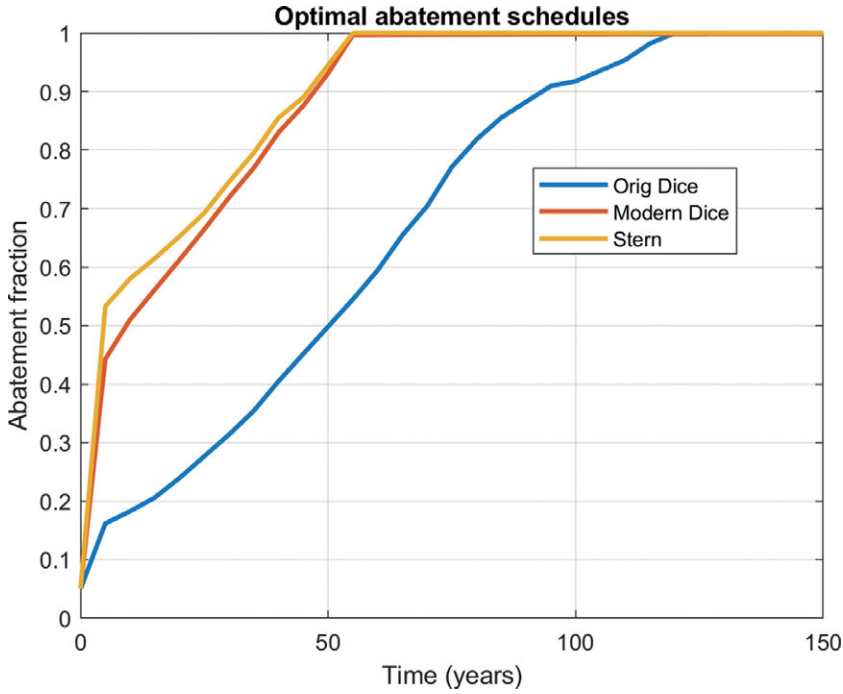

1.1 The abatement schedules obtained by the original Stern and DICE studies (curves labelled 'Stern' and 'orig DICE', respectively), and by the more modern economic models (curve labelled 'Modern DICE'). Note the similarity between the Stern and 'modern' results. These results are illustrative only, and have been obtained for a set of plausible, but not necessarily optimal, parameters for the modern version of the DICE model.

world, and the 'modern-approach' world. Note how gradual the optimal schedule recommended by the DICE model is; how much more rapid the Stern schedule is; but, above all, note how similar the 'modern' and Stern schedules are.[28]

The messages conveyed by these models are radically different: in one case, we should wait and do relatively little; in the two other cases we should act with urgency and in large scale. Why are the conclusions

[28] In the graph presented in Fig 1.1 the Stern and the 'modern' schedules are almost on top of each other. Let me come clean. This is coincidental and a bit tendentious, as the near-coincidence depends on a defensible, but by no means unique, choice of parameters for the modern approach. We shall discuss the robustness of these results in Chapter 12. What *is* robust is the finding that the modern abatement schedule is much steeper – implying decisive action sooner – than the DICE recommendation.

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so different? How can waiting be advisable if we are facing a climate emergency? Who is right? And why is the modern version of the DICE model so radically different from the original one? How this fundamental change has come about, why we should take it seriously, and whether we are convinced of the reasonableness of these new results are some of the key themes of this book.

1.4 SHOULD WE USE MODELS AT ALL?

These developments have very important policy implications. Faced with the apparent arbitrariness of the model parameters that should reflect (among other factors) the degree of intergenerational altruism,[29] as important and influential a body as the International Panel on Climate Change (IPCC) has chosen not to make use of the linchpin of standard economic analysis of projects, cost-benefit analysis.[30] And, given the undeniable uncertainty that surrounds many key areas of the modelling, many top economists (such as Stern, Pindyck, Weitzman and Stiglitz) are either very cautious, or outright opposed to, using the output of Integrated Assessment Models for 'serious' policymaking. What they propose, instead, is that we should use optimization of means, but only after, somehow, *we have chosen our target.* In other words, we should try to attain our abatement goal as efficiently as possible (this is where the optimization bit comes in), but only after the goal has been reached in some other way.

This is indeed the rationale behind policy targets, such as limiting global warming to 1.5–2 °C, as recommended in the Paris Agreement.[31]

[29] *'It is extremely difficult if not impossible to meaningfully estimate discount rates for future costs and benefits'* – IPCC Chapter 1 page 76.

[30] '*Thus standard cost-benefit analyses become difficult to justify (IPCC, 2014a; Dietz et al., 2016) and are not used as an assessment tool in this report.*'

[31] So much has been said about the totemic 1.5–2 °C target, that a few important points should be made. As Knutti, Rogelj Sedlacek and Fisher (2016) point out, while the '2 °C warming target is perceived by the public as a universally accepted goal, identified by scientists as a safe limit that avoids dangerous climate change …[t]his perception is incorrect: no scientific assessment has clearly justified or defended the 2 °C target as a safe level of warming, and indeed, this is not a problem that science alone can address.' As for the more ambitious 1.5 °C target, it was added at the (almost literally) eleventh hour after surviving the gauntlet of the 2015 Paris Agreement

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At first blush, this seems reasonable enough. However, even when we decide to adopt these 'exogenous' targets, cost-benefit analysis makes its way back in through the rear door. If pressed as to why we should strive to limit global warming to X degrees by the end of the century, a policy maker would probably say that, if we did not do so, there is a high chance that we will incur serious damages. For this answer to make sense one must accept that these (discounted) damages would be greater than the costs incurred to avoid them. In addition, the same policy-maker would also point out that there is a high degree of uncertainty, both in the climate outcomes and in their consequences, and this therefore calls for prudence: a very reasonable better-safe-than-sorry attitude. But, if you think about it, this is just cost-benefit-analysis-under-uncertainty by another name, and without the intellectual discipline that an 'auditable' analysis can provide. By this I mean, that, when we use a model, we can all look at the assumptions that went into it; change them as new information becomes available; and run sensitivity analysis – explore, that is, how much the results change when the uncertain inputs change. Which is a lot more than one can do with a 'commonsensical' hunch, inspired as this may be. Model-based decisions make the resulting course of action dynamic and continuously self-correcting: two features that are of key importance when we are navigating the waters of climate change.[32]

climate-change negotiations, at the request of the representatives of the Caribbean states, understandably afraid that a relatively small increase in sea levels could submerge their islands. For a good discussion of how the 1.5–2 °C target was arrived at, see www.desmog.com/2022/12/11/15-2c-history-temperature-target-climate-paris-agreement/.

[32] There is a great deal of controversy about whether the type of cost-benefit analysis that is at the heart of Integrated Assessment models is useful or misguided. As I have said, some serious economists, such as Nobel-prize winner Joseph Stiglitz or Prof Stern (2021), advocate a very different procedure: we should use models, they say, to try to minimize the costs of reaching a 'commonsensical' target, such as limiting warming to 1.5–2 °C by the end of the century, but we should not use Integrated Assessment Models to tell us what these targets should be. I have to say that some of the arguments used to make their point seem at times designed to knock down a straw man: it is emphatically not true, for instance, that all Integrated Assessment Models consider a temperature increase of 4 °C as 'optimal'; some early versions did, almost none of the new models do. And, while it is true that climate scientists appear to be more concerned about damages than economists, it is not a priori clear why their views in this particular domain should be deemed more trustworthy. For a strong and, in my view, clear rebuttal of the argument see Aldy, Kotchen, Stavins and Stock (2021), whose

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This apparently common-sense-based approach may at times seem the only practical way forward, but there is little in the reasoning that led to the commonsensical conclusion that economic analysis cannot handle. If we are uncertain about outcomes, utility theory will tell us to be more prudent – the more so, the more uncertain we are. Some critics complain that the climate damages that are assumed by the economic models are too moderate. This could well be true, but, if there are scientific arguments for doing so, there is absolutely no reason why we cannot include 'tipping points', positive-feedback effects or more severe damage exponents in our economic analysis. And if the discounting (the 'writing off') of future damages just because they happen in the future seems to be so severe as to give rise to absurd recommendations, we should question whether we have modelled our preferences correctly. This is exactly what the new-generation economic models allow us to do. As a result, an important and influential body as the IPCC need not throw its hands up in despair by saying: 'Economic analysis is too incomplete to be of any use for climate change', and can endorse with new confidence targets that are no longer pulled out of a hat. Indeed, as we shall see, temperature targets very similar to the canonical '1.5–2 °C by the end of the century' can be recovered naturally as optimal by the new-generation economic models.

One last point. As I have already said, when their actions are properly modelled, modern economic analysis shows that even indifferently altruistic agents should prefer 'fast and strong' abatement schedules. However, the other blemishes of utility-based analysis (its narrow focus on material consumption and, more generally, what I have called its reductionist character) are still there. And, to make matters worse, Weitzman (2009) presented in 2009 his 'dismal theorem', according to which a standard cost-benefit analysis may break down altogether if there is a possibility of truly catastrophic outcomes (technically, if we have very slowly-decaying tails for the loss distribution).[33] If this is the case, why

position is clearly summarized as follows: 'In the context of climate change, the application of cost-benefit analysis to inform mitigation policies can help to achieve the best outcomes and avoid the worst: spending trillions of dollars but failing to get the job done.'

[33] Weitzman's argument, which I find very compelling, has not gone unchallenged. For a reply to Weitzman's challenge see, Nordhaus (2009).

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should we put our faith in models whose outputs are so uncertain, and that may not be up to the task in the first place? And if somehow we added all the features our modelling leaves out, wouldn't the abatement recommendations become even stronger? Wouldn't the call for action be even more urgent?

I have little doubt that this would indeed be the case.[34] However, the course of abatement action recommended by our flawed models is already so decisive and rapid that it is resolutely hitting against the boundaries of political and practical implementability. Let me give one example. As we shall see, the 'social cost of carbon' is a key output of the economic models used to analyze the climate-change problem – roughly speaking, it can be understood as the optimal tax that should be imposed on fossil fuels to redress the externalities embedded in their use. Now, there is little point in establishing that a tax of many dollars (or euros or pounds) per litre would be 'optimal', when a modest fuel tax of a small fraction of a Euro sparked the gilet jaunes unrest of 2018 in France.[35] I could bring up many similar examples, but my point, I hope, is clear. Yes, almost certainly, if we somehow managed to bring into the economic fold considerations that are currently ill-accommodated by utility-theory analysis, even steeper abatement efforts *would* be recommended. However, between what is desirable and what is achievable there lies a hiatus that is ignored at great political cost. Bluntly put, I am interested in the policy recommendations that have a chance of being implemented – and I am painfully aware that over-ambitious targets end up playing into the hands of climate-change deniers, populist politicians and the advocates of very little change.

[34] For a discussion of what cost-benefit analysis leaves out, and of the prevalent biases embedded in most Integrated Assessment Models, see Stiglitz and Stern (2021).

[35] Fuel taxes in Europe range from eighty cents per litre for the Netherlands to thirty-six cents per litre for Bulgaria. In the US fuel taxes are lower, ranging from seventeen cents per litre in Pennsylvania, to three cents per litre in Alaska. Worldwide, about 20 per cent of world emissions are covered by any carbon tax at all, and less than 5 per cent attract a carbon tax as high as the lowest estimate of a reasonable social cost of carbon (Kuper, 2021). As for the *gilets jaunes* unrest of 2018, it was prompted by a proposed increase in the cost of fuel of about six cents per litre. As is well known, President Macron had to backtrack on his modest, but singularly poorly conceived, tax proposal (the fuel tax had its biggest impact on poorer suburban and rural people, who have few alternatives to switch to public transport).

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