SILVANA DALMAZZONE

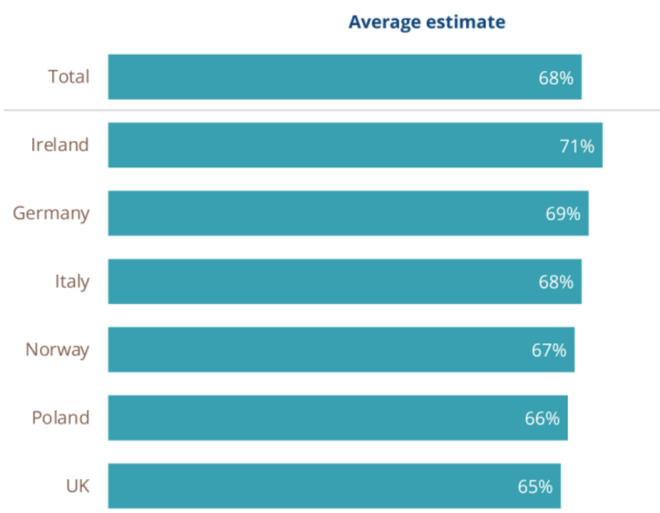
# INTRODUCTION

Thank you for inviting me to open this year's Giorgio Rota Conference dedicated to climate change economics and its knowledge.

What I'm going to do is to offer you a feeling of what's inside the larger, fast-evolving box of climate change economics. A very recent survey, conducted in 2023 by the Policy Institute of the King's College in London as part of the PERITIA Horizon project, investigating public perceptions about climate change in six countries in Europe plus the UK, confirms that there are very wide misperceptions on the scientific knowledge of climate changes.

Regarding the survey's question "to the best of your knowledge, what percentage of climate scientists have concluded that human-caused climate change is happening?", we see that according to a large sample of interviewed Europeans the average proportion of scientists convinced that climate change is taking place and is human-induced is around 68%: enormously lower than the reality which is today of 99.9%.

FIGURE 1 • REPLIES TO PERITIA SURVEY'S QUESTION "TO THE BEST OF YOUR KNOWLEDGE, WHAT PERCENTAGE OF CLIMATE SCIENTISTS HAVE CONCLUDED THAT HUMAN-CAUSED CLIMATE CHANGE IS HAPPENING?"

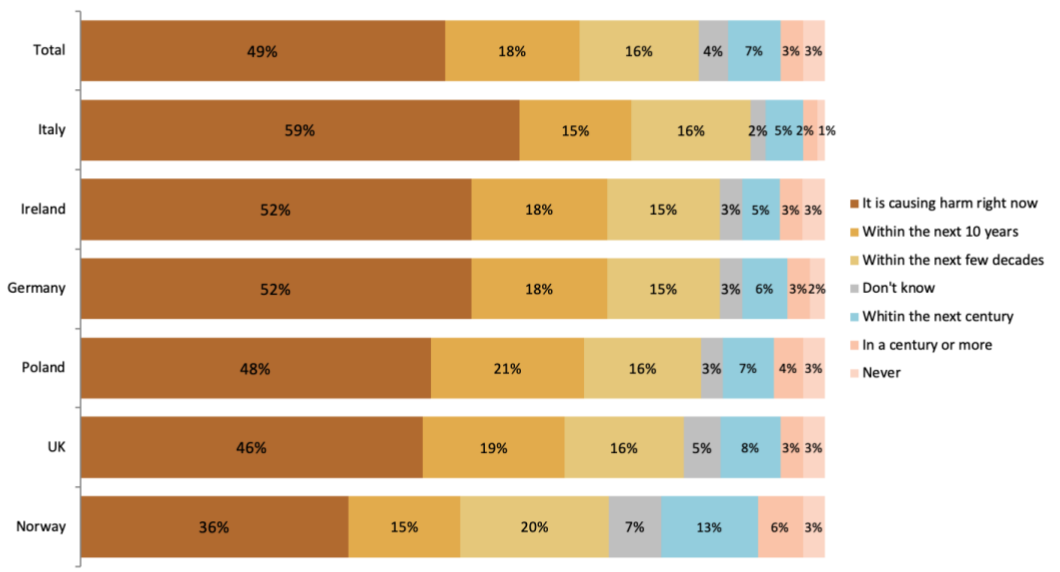



*Source:* https://peritia-trust.eu/.

From another question it emerges that, on average, three-quarters of people, about 74%, say that climate change is mainly caused by human activities, which means that 26% think that it is not. Things go a little bit better in Italy, where the percentage is about 82%. Surprisingly, they go worse in Northern European countries, with 61% of the Norwegian respondents being convinced climate change is human-caused.

Despite remaining misperception and lack of knowledge, the large majority of people are however worried about the impact of global warming on future generations: 81% of people on average, according to PERITIA's survey. The answers also show that 80% of interviewed individuals say they are worried about the impact of global warming on humanity in general. Most people also think climate change is harmful now or will be harmful within the next 10 years. And a remarkable 62% of people say so not just about the world, including developing countries, but also about their own country.

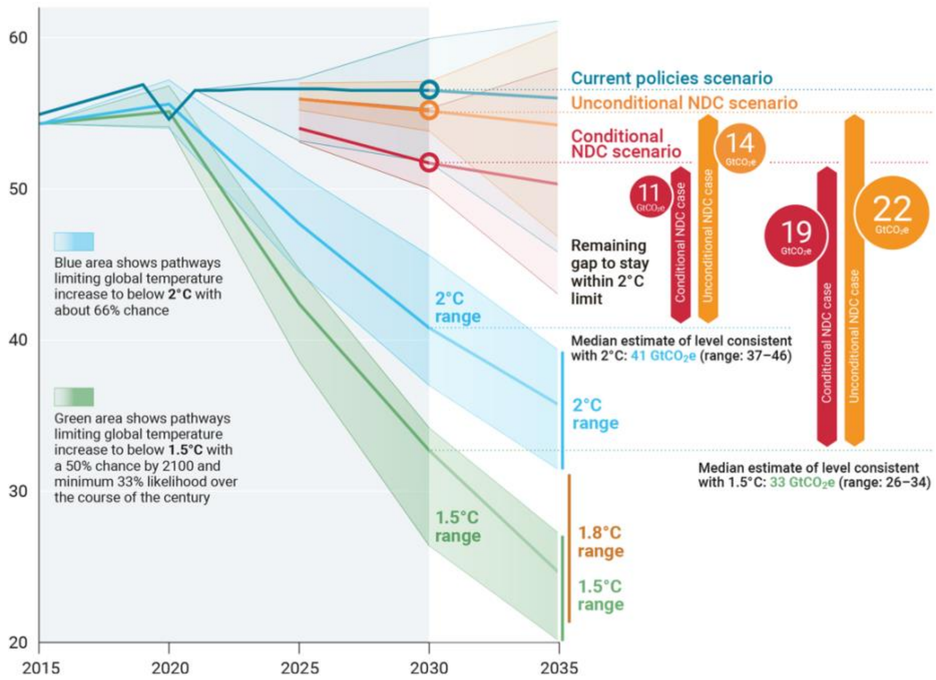
FIGURE 2 • REPLIES TO PERITIA'S SURVEY'S QUESTION "WHEN, IF EVER, DO YOU THINK CLIMATE CHANGE WILL START TO HARM HUMANITY?"




*Source*: https://peritia-trust.eu/.

So, the perception is that there is a serious problem. Yet, actions to mitigate climate change don't match the public perception of how serious the problem is under current policies. There is a remarkable emission gap between the current policies scenario and the emission pathways that would keep global warming under the stated objectives of the last ten years' international agreements (Figure3).

FIGURE 3 • GLOBAL GHG EMISSIONS UNDER DIFFERENT SCENARIOS AND THE EMISSIONS GAP IN 2030 AND 2035 (MEDIAN ESTIMATE AND TENTH TO NINETIETH PERCENTILE RANGE)




*Source*: UNEP, 2023.

The light turquoise line shows the trajectory we need to remain within +2°C of warming (Paris Agreement). The orange trajectory is the one to stay within the +1.8°C warming. And the last one, the dark turquoise one, is the +1.5°C trajectory. Under current policies, we are heading in the graph far higher than all these three trajectories. This means that the emission gap is pretty large and remains larger even with the new pledges made by countries under the Glasgow Climate Pact, plus all the officially announced mitigation pledges for 2030, which were added later on.

Until last year, the Glasgow Climate Pact plus all the official 2030 mitigation pledges reduced the projected emissions to 2030 indicated in the previous unconditional Nationally Determined Contributions (NDCs) by only 7.5%, whereas staying within the Paris Agreement's objectives of +2°C and +1.8°C would require a reduction of 30% with respect to previous pledges. The Glasgow objective of +1.5°C of warming would require a 55% reduction. Indeed, we are moving very, very shyly.

So, why so little? Why so late? Economics may help. Climate change economics does make an effort to help us understand why.

The first reason we are doing so little and going so slowly is obviously the real cost of leaving fossil fuels in terms of jobs, purchasing power, and welfare effects.

A second important answer is that climate change is a global problem, but damage is disjoint from the location of emission sources. The incentive for individuals, and even for individual countries, to refrain from emitting greenhouse gases is very small, and the effort of one country in isolation can be nullified by unmitigated growth of emissions in another country. In addition, countries that unilaterally engage and adopt stricter regulations may face carbon leakage and lose competitiveness in international markets.

A third reason why it is so difficult to act on mitigating climate change has to do with the fact that this particular environmental issue has very intricate distributive implications, between the North and the South and between the West and the rest of the world. Much more intricate, for example, than the ozone layer problem, which we managed to tackle quite effectively and quickly through international cooperation. Industrialized Western countries are mostly responsible for the cumulative emissions that over the last 150 years caused today's greenhouse gas concentrations in the atmosphere. Furthermore, developing countries are going to suffer most and first from the impacts. So, the developing world has so far been very reluctant to accept restrictions. But many of today's richest countries resist the idea of bearing all the costs without the participation of at least those giant Asian countries that now challenge Western economies on world markets.

The last answer that climate change economics is putting forward to explain why it is so difficult to act, pertains to human psychology. Human psychology has an incurable bias towards the present. Decades of behavioral and experimental economics have consistently found evidence of time inconsistency and the use of irrationally high discount rates in people's welfare. In making decisions with impacts that are obviously adverse to people's welfare, we know that individuals are willing to accept smaller immediate rewards over larger delayed rewards, even when the delayed rewards are objectively more valuable. Irrationally high discount rates, or the dictatorship of the present, emerge in individual preferences, corporate decisions, and political processes. For example, we have to force compulsory saving for retirement. There are issues of competitiveness that induce very short-sighted corporate strategies. Even in political processes, which is where a collective and long-term perspective should prevail, there is a structure of rewards that has a short-term view and the pressure from financial markets is high.

Therefore, if we humans find it so difficult even to act rationally in front of our now-to-do questions, such as doing our homework, let's imagine how it works when facing a massive ethical transformation of our socioeconomic system.
Nevertheless, there is a lot that climate change economics can do for us in matter of designing and evaluating climate policies.

First, cost-benefit analyses: we need to know the cost of carrying on business-as-usual and bearing the impacts, and on the other hand the cost of doing what it takes to avoid (or limit) those impacts. Economic assessments of the forecasted socioeconomic impacts of climate change rely on several different approaches. Older studies tend to be enumerative: they consider the largest feasible number of expected impacts in terms of their physical units, multiply them by the evaluated unit cost, and add them up.

Econometric studies make a step forward, allowing us to take into account interactions (for example, due to price changes) and the dynamic aspect of socioeconomic impacts of climate change in the future. A limitation is that they assume that differences in climate existing now between different places, at different latitudes, are a good proxy for differences in climate that will emerge in the future. One advantage is that they do not have to assume anything about, for example, adaptation behaviors, because they observe what has actually taken place over the past in different parts of the world.

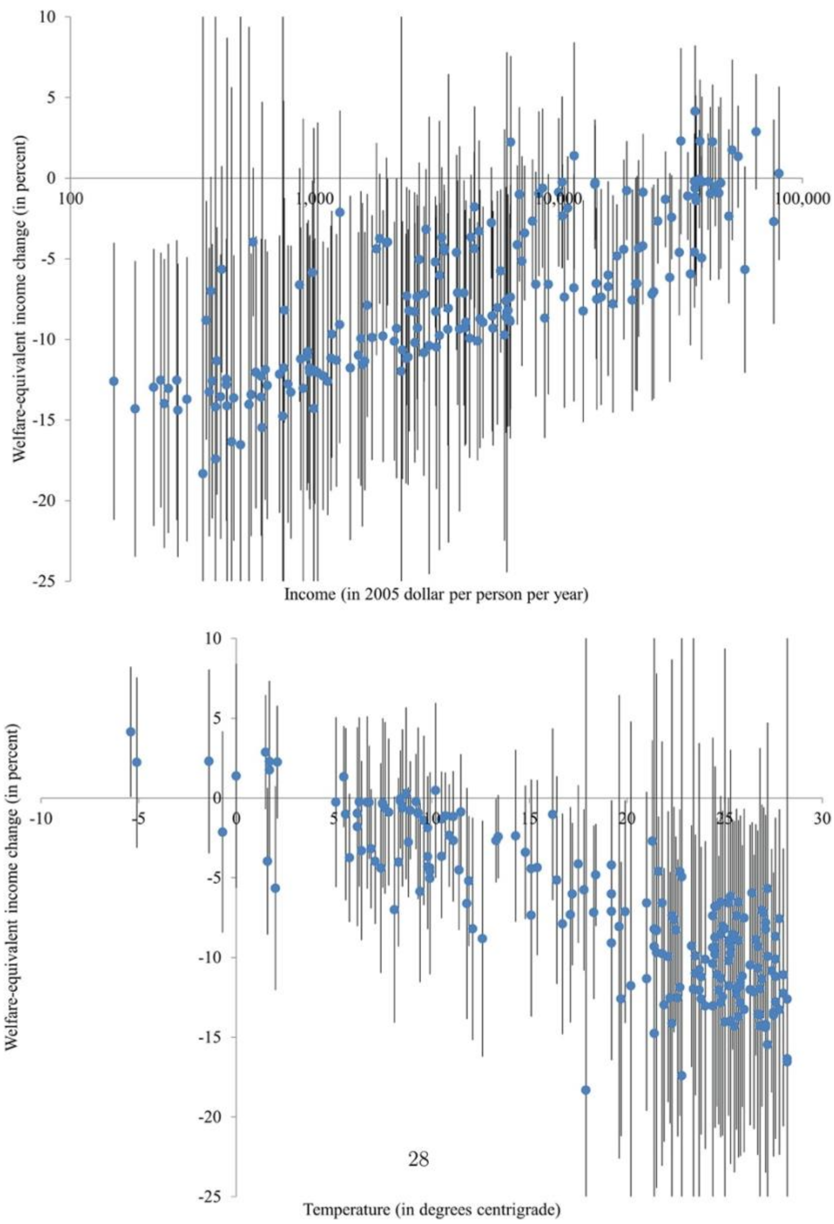
More and more popular in recent years are also the socioeconomic valuations of the impacts of climate change based on computable general equilibrium (CGA) models. These have the advantage of being able to look at the whole economic system and include dynamic changes and interactions between prices and sectors. One issue is that they tend to be based on national accounts, and hence they tend to omit impacts on human health and on ecosystems. Also, they tend to express the results in terms of percentage loss of consumption or GDP, leaving aside other kinds of welfare impacts.

Another important part of the literature relies on integrated assessment models (IAMs), simplified mathematical descriptions of reality that integrate knowledge from two or more disciplinary domains (e.g., climate sciences and economics). They constitute the base, for example, of the evaluations included in the IPCC assessment records.

Lastly, elicitation studies are simply evaluations built on large sets of interviews with experts, investigating and statistically describing their opinions on the dimensions of expected future impacts of climate change.

Recent meta-analyses, for example the one published by Tol (2024) on *Energy Policy,* produces estimates of average negative impacts from all these different approaches and estimates a GDP impact from climate change by 2050 in the range of –2% and –3% losses, if we stay within a +2.5°C increase of the temperature; up to –11% by 2100, assuming we are going to stay under a +3.0°C degrees threshold by that time.

FIGURE 4 • THE ECONOMIC IMPACT OF CLIMATE CHANGE FOR A 2.5 °C WARMING RELATIVE TO PRE-INDUSTRIAL TIMES FOR COUNTRIES AS A FUNCTION OF THEIR INCOME (TOP PANEL) AND TEMPERATURE (BOTTOM PANEL).




*Source*: Tol, 2024: 11.

These results are very sensitive to discount rates, and they generally do not include catastrophic, acute risks (such as those from extreme weather events), but only the chronic impact of raising temperatures on factors productivity. Estimates by insurance companies, which do take into account catastrophic risks, tend to be much higher.

A recent estimate by Swiss Re Institute[1] points a loss of 14% of global GDP by 2050 under a +2.6°C warming scenario and of –18% of global GDP by 2050 under a +3.2°C scenario, and a loss for the European Union between 8 and 10.5% of GDP by 2050.

Certainly, these are global average values. If we look at how these losses are going to be distributed across the world, we find very large disparities between high-income countries and developing countries. Figure 4 (upper diagram), which on the x axis measures GDP per capita and on the y axis the percentage losses of GDP, shows how the losses would be scattered. Countries of the Global South are going to suffer up to –20, –25, and –30% loss of GDP. Poorest countries are going to suffer impacts much higher than the world average. An analogous result emerges from the bottom diagram, showing the correlation between expected percentage losses of GDP and a country's average temperature. Again, cooler countries (the Global North, to simplify a bit) tend to have smaller losses or even moderate gains, whereas warmer and tropical countries suffer much more severe losses.

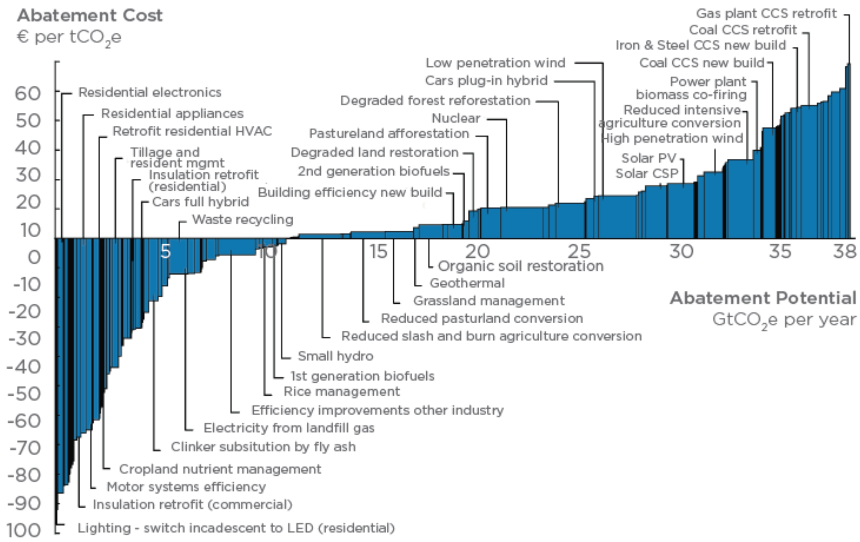
Mitigation can make a difference. For Europe, decarbonization policies limiting warming to +2°C degrees would reduce the welfare losses by 70% compared to a +3.0 °C degree scenarios, while limiting warming to +1.5 °C would lower welfare losses by 90%. We are late and slow, but still on time to avoid the worst.

Decarbonizing our economies involves mitigation direct costs as well as technological, sectoral, and macroeconomic welfare costs, whose assessment relies, again, on an array of methods and models. An important one is the marginal abatement cost of carbon (MACC) curves. MACC curves look like the diagram in Figure 5. The diagram estimates the marginal cost of $CO_{2e}$ emission abatement by technology, which is the height of the column, associated with the relative reduction potential, which is measured by the width of each column. All the technologies that you see in the lower, left-hand part of the diagram are associated to negative costs. It means that on the lifetime scale of these technologies the mitigation cost is negative, i.e., the investment would imply a net saving. Almost a quarter of the total abatement potential required to limit global warming under +2°C could be gained through measures with a zero or negative net life cycle cost. These include, for instance, more efficient lighting systems, motor system efficiency, installation of retrofits, and so on. Conversely, the technologies in the upper,

[1] https://www.swissre.com/media/press-release/nr-20210422-economics-of-climate-change-risks.html

right-hand part of the diagram cost more and more. Technological change is moving fast, and today's most costly technologies that we need to adopt to reach the +2°C objective have a cost of around 40 euro per ton of avoided $CO_{2e}$ emissions.

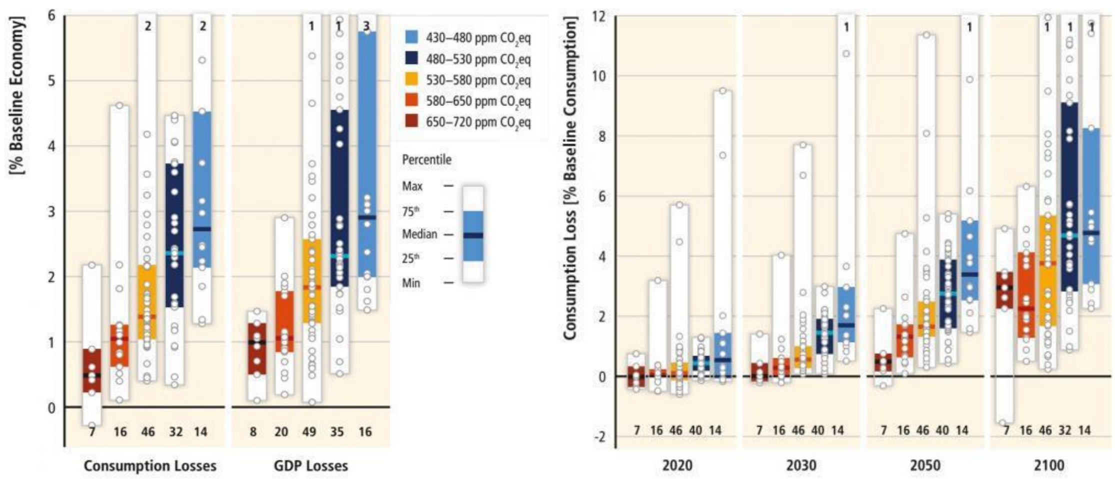
FIGURE 5 • GLOBAL GHG ABATEMENT COST CURVE BEYOND BUSINESS-AS-USUAL (BAU) - 2030/US ENERGY SYSTEM MARGINAL ABATEMENT CURVE




*Source*: McKinsey, 2009: 7.

The diagram in Figure 6 comes from the last the 6[th] assessment report of IPCC, which offers an overview of mitigation options and their estimated ranges of costs and potential in 2030.

FIGURE 6 • GLOBAL MITIGATION COSTS FOR 2015 TO 2100 IN NET PRESENT VALUE (NPV) DISCOUNTED AT A 5% DISCOUNT RATE AND EXPRESSED AS A SHARE OF THE BASELINE ECONOMY




*Source*: Clarke *et al.*, 2014: 450.

The results in general equilibrium models show, not surprisingly, that both consumption and GDP losses increase as our steady state greenhouse gases concentration goal gets more stringent. Costs would be high for a 430-480 ppm target by 2100, implying, by the end of the century, between 2.0 and 5.7 GDP percentage loss. Slightly more in terms of consumption (between –2.2% and –5.8%).

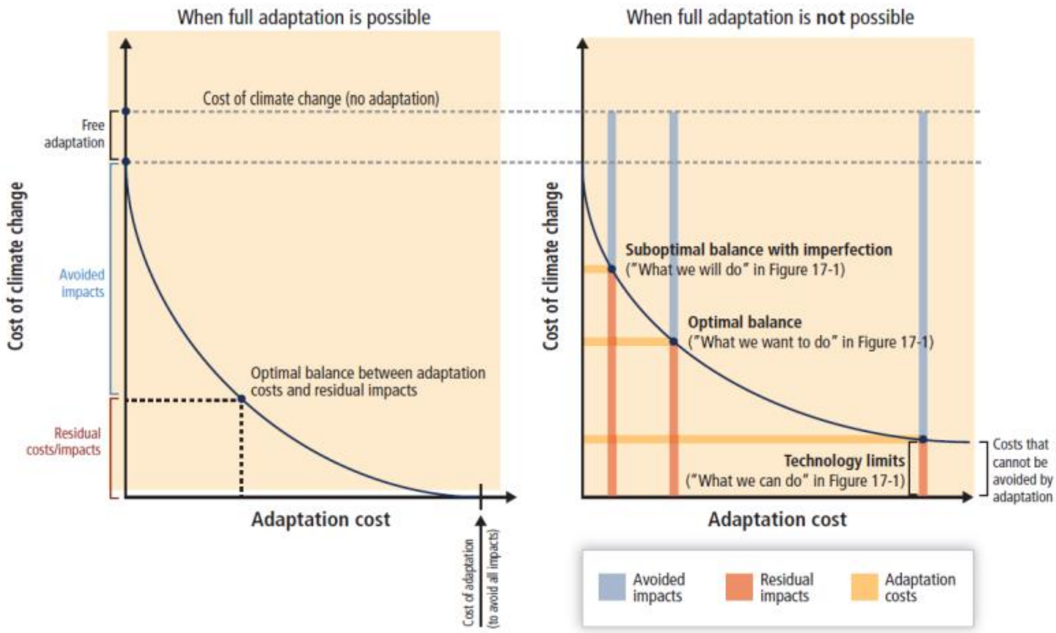
These are mitigation costs calculated as if we started to reduce global emissions right now. But anyhow, what emerges from a pretty large set of literature is that the global economic benefit of limiting warming to +2°C is going to exceed the cost of mitigation in most of the studies assessed by the IPCC report, unless climate damages are going to materialise at the lower end of the range of possibilities, and unless future damages are discounted at very high rates.

Of course, all these estimates are very sensitive to the discount rate used. Economic models also tell us that mitigation costs increase sharply with delays in mitigation: on average, net mitigation cost increases by approximately 40% for each decade of delay in the moment global emissions will peak and start decreasing. They also tell us how much delay we can afford before missing the current climate targets, and how much costlier would it be to start later and accelerate with more stringent policies in subsequent years.

Another part of the climate change literature looks at adaptation. If we also include adaptation, then we can further reduce the losses. Mitigation and adaptation must be coordinated as they compete in the use of scarce resources. Economic theory tells us that the optimal level of adaptation is the one that equalises the marginal adaptation cost and the marginal adaptation benefits, i.e., where the adaptation curve has a slope of 45 degrees (Figure 7). But again, quantifying adaptation raises a lot of conceptual issues. For example, how should we account for the costs of adaptation if it also has other benefits beyond mitigating climate change, such as health benefits or welfare in other forms? What if it would have taken place anyhow? So, a problem of additionality does emerge.

Nevertheless, certainly also adaptation makes a difference. In the EU, for example, mitigating climate change to +1.5°C would half the damages from coastal and river floods, just to take one of the many forms of impact. Adding adaptation would reduce residual damages from river floods by 40 times and by 20 times those from coastal flooding.

FIGURE 7 • GRAPHICAL REPRESENTATION OF LINK BETWEEN THE COST OF ADAPTATION (ON THE X-AXIS) AND THE RESIDUAL COST OF CLIMATE CHANGE (ON THE Y-AXIS).
The left panel represents a case where full adaptation is possible, while the right panel represents a case in which there are unavoidable residual costs




*Source*: Chambwera *et al.*, 2014: 953.

Setting objectives and setting targets is another crucial question. Where do we want to go? How ambitious need we to be in trying to mitigate climate change? Standard economics tells us that we should choose decarbonization targets so as to equalise marginal benefit and marginal damage. This would require, in practise, knowledge of marginal mitigation costs up to the different moments in time, of marginal economic value of impacts, and a collective choice of the discount rate to be used. All this kind of knowledge, which is, as we have seen, very difficult to quantify, makes it difficult to identify analytically at which concentration level, and therefore, given the decay rate, at which emission level, the discounted damage of an additional unit of GHG gases equals the cost of containment. This has been the object of debate in all international climate change conferences.

Eventually, what has been done in the real world is mostly to revert and define the objectives in terms of warming. We first need to decide whether, given the forecasted impact, we aim to stay within +2°C or +1.5°C warming. Then we convert those objectives into corresponding concentrations and thus of remaining carbon budget: to have a 50% chance of staying below 1.5°C, we can only emit 250 billion more tonnes of carbon. That's just six years of our current emissions. For a 50% chance of staying below 2°C, the world could emit 1150 billion tonnes, around 28 years of current emissions.

Uncertainty plays a fundamental role in this, yet we often disregard it. The acceptable probability of meeting (or missing) the desired outcome makes a huge a difference, too. When we talk about staying within a +2.0°C scenario, we always assume to stay within that objective with a given probability. Limiting global warming to +2°C with a 67% probability, or with a 80% probability or with 50% probability, implies a dramatic change in the remaining carbon budget.

Finally – but I will leave this to the presentation of this year's papers winning the 2024 Giorgio Rota Award – climate change economics offers a lot also in terms of designing policy instruments, such as carbon pricing.

In conclusion, a final key point is the question of tackling distributive issues. The previous large scale societal transformations, led by the 19th century industrial revolution and the digital revolution of the last few decades, have been originated by technological change and have been driven by market forces. The ecological transition represents the first time we are facing the task of designing, implementing, and governing a deep, deliberate structural change that is not driven by market forces but will have to be driven by collective action. Also, this structural change is going to take place in a short period: the next 9-10 years, up to 2030, are going to be decisive. These necessary transformations will have no chance of success if they fail to build around them a sufficient strong legitimacy. And this is not going to happen if we are not going to deepen our knowledge of the distributional consequences of climate change and climate change policies, in order to ascertain the political feasibility and foresee the necessary compensatory actions.

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