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THE CHANGING CLIMATE OF CLIMATE CHANGE ECONOMICS: DOES IT MATTER FOR  
POLICY?

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# The changing climate of climate change economics: does it matter for policy?

## Abstract

Climate change economics is turning four decades old. Most of what it has achieved as a field of academic enquiry can be linked back to issues of integrated assessment modelling and intertemporal discounting. The dominant approach, however, is going through a major change in scope as of the last 5 years. This paper summarizes the recent literature to show that the standard focus on determining optimal mitigation paths based on modelling the social cost of carbon is being enlarged to embrace promising new waves of research. These are: (1) the economics of insurance against catastrophic risks; (2) the economics of trade and climate; and (3) the economics of climate change adaptation. The paper contributes to a broader dialogue between economists and policymakers by showing that the analytical toolkit of climate change economics is being expanded to include more realistic views of climate policy.

**Keywords:** adaptation, carbon, climate change, economics, trade.

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## Introduction

“Can we control carbon dioxide?”

This is the title of William Nordhaus’s seminal work on the economics of climate change, published in 1975. In the forty years since then, economists have approached climate change research mostly by debating technical aspects of integrated assessment modelling. Despite two relevant inflections in the research agenda (one in 1992 when William Cline published *The economics of global warming*, another in 2006 with the Stern Review), the discussion has been largely centred on the use of intertemporal discounting as a methodological procedure to account for events in the distant future in present value calculations. Generations of scholars have been involved in the debate including Kenneth Arrow, Partha Dasgupta, Richard Toll, and David Anthoff, to cite only a few, yet no generally accepted conclusion has emerged. Instead what has come out in the last five years is a new wave of scholarly work that is starting to

broaden the scope of the debate and helping to bring climate change economics closer to the world of policy.

Research on the economics of climate change has seen three major changes in the last five years. I summarize the most recent literature to show that the narrow focus on integrated assessment modelling, issues of intertemporal discounting, and emissions mitigation is being expanded to include three new waves of research: (1) the economics of insurance against catastrophic risks; (2) the economics of trade and climate, including topics such as border adjustments and carbon leakage; and (3) the economics of climate change adaptation. In tandem with these developments, and as the ideal scenario of globally coordinated climate action becomes less and less attainable, increased attention is given in the policy arena to bottom-up approaches to climate cooperation.

The 2009 Copenhagen climate summit marked the rupture of a universalistic paradigm of action in which global coordination and an international enforcement system are seen as premises for the effective control of climate change. Despite strong political pressure by the public and some heads of state in the month leading to the meeting, the results achieved were far from ideal. A polarization between the positions of China and the United States prevented a binding commitment. Global targets were not set, and institutional progress turned out meagre.

In spite of the above, climate legislation moved forward in many countries, including China, Brazil, Argentina and other developing nations. In China, the 12th Five-Year Plan, published in 2011, includes targets to reduce the carbon intensity of GDP by 17% from 2005 levels by 2015. Moreover, emissions trading systems are already being piloted in provinces such as Guangdong and municipalities such as Beijing (Nachmani et al., 2014). In the case of Brazil, crucial climate legislation was passed in 2009. Even without formal commitments at the international level, Brazil established a National Climate Change Policy which provides for reduction of emissions of around 35% of projections for 2020. What is the sense of China and Brazil unilaterally committing to sizeable emission reductions at the very moment when the global climate framework is reversing? How to explain such an initiative in the context of a recognized failure of international negotiations?

In the post-Copenhagen period, action at the national and subnational levels is gaining relevance. Climate policy is increasingly implemented by individual jurisdictions with a view to be subsequently coordinated with other parties at higher geographical scales. Sectorial negotiations, for example in energy, aviation, and forests, are also gaining momentum. The debate is thus shifting from a rigid universalistic approach to a paradigm of individual action subject to some degree of global coordination. This is what International relations scholars and

political scientists have termed a “building blocks” (Falkner, Stephan and Vogler, 2010) or a “polycentric approach” (Ostrom, 2010) (more on this in Section 3).

The first section of this paper provides a short summary of the results of four decades of climate–economy modelling, presenting the controversy around the validity of using aggregated models to determine optimal emission paths. The second section introduces the first trend of the climate change economics literature: assessing the amount of insurance that society must be willing to pay for in order to prevent major climatic disasters. While research in this area is far from establishing a sound methodological basis to deal with the economics of catastrophic, small–risk events, it is reinvigorating the discussion about policy options.

The third section seeks to show that a universalistic approach to climate action – where all countries with significant emissions take binding commitments in a synchronic and coordinated way – has proven unfeasible both theoretically and in practice. This leads to the second trend in research in climate change economics, discussed in Section 4: the economics of trade and climate. The recognition that unilateral action will continue gaining relevance in the future is the basis to a mounting interest for issues such as the impact of climate policy on competitiveness and the role of carbon border adjustments on inducing cooperation.

The third and last important trend is the rising interest for the economics of adaptation. While discussions of climate policy were since the beginning compartmentalized between mitigation and adaptation, the latter was typically given much less attention. In the fifth and last section of the paper, the most recent literature on the economics of adaptation is summarized to show that it is being integrated into mainstream analyses. Given the relevance of adaptation strategies especially for developing countries, this should lead to a more fluid dialogue between climate economists and policymakers.

## **1. Four decades of economic climate modelling**

The model is to climate change what a world map is to Earth: a highly aggregated representation that only captures the essence of its object’s immense complexity. Scientific models are representations of reality on a small scale. Economic models use the findings of biophysical models on possible climate scenarios and their probabilities to try to point out the best scenario of present action, calculating, among other things, the optimal price to be imposed on carbon.

How is that done? First, a set of scenarios for the future costs of climate change is calculated: the costs of inaction, or the so–called social cost of carbon. Second, response costs are calculated, and they come in two main forms: reduction of emissions and adaptation (usually calculated independently). Therefore, three sets of estimates are generated, the results

of which are integrated into a cost-benefit framework to estimate the best course of action. Potential gains and losses are weighted up, and an optimal strategy is determined. The shadow carbon price is the final output.

What do these climate-economy models tell us?

"Very little. A plethora of integrated assessment models (IAMs) have been constructed and used to estimate the social cost of carbon (SCC) and evaluate alternative abatement policies. These models have crucial flaws that make them close to useless as tools for policy analysis: certain inputs (e.g. the discount rate) are arbitrary, but have huge effects on the SCC estimates the models produce; the models' descriptions of the impact of climate change are completely ad hoc, with no theoretical or empirical foundation; and the models can tell us nothing about the most important driver of the SCC, the possibility of a catastrophic climate outcome. IAM-based analyses of climate policy create a perception of knowledge and precision, but that perception is illusory and misleading" (Pindyck, 2013a).

The quote above sets the tone of disbelief that is building upon a specific type of economic model that until recently was considered the epitome of the profession. "The social cost framework is under fire", say (with regret) economists Kenneth Arrow and colleagues (Revestz, 2014).

A well-regarded microeconomist at MIT, Robert Pindyck, who was until recently an outsider to climate change economics, has criticized the way in which these calculations are implemented. Pindyck (2013b) asks the fundamental question of the economist: what should be the price of carbon?, and responds categorically that no one knows, least of all IAMs. For him, the best that can be taken from more than two decades of intense debate around the technicalities of these highly abstract models is a sort of scientific consensus on what the real social cost of carbon may be<sup>1</sup>.

Pindyck's position is not intended to lead to scepticism, but rather to direct the efforts of economists to a more pragmatic study of the economics of catastrophic risk management. While this is indeed an area of enquiry that has gained increased attention, as shall be discussed in Section 2, the bulk of mainstream economics is still devoted to IAMs. When it comes to

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<sup>1</sup> Martin Weitzman (2009, p. 18) is another economist arguing that: "[a]ll of this is naturally unsatisfying and not what economists are used to doing, but in rare situations like climate change where the Dismal Theorem applies we may be deluding ourselves and others with misplaced concreteness if we think that we are able to deliver anything much more precise than this with even the biggest and most-detailed climate-change IAMs as currently constructed and deployed".

quantifying the ideal climate action, IAMs are virtually inescapable, as Pindyck himself (2013b) admits. On his side is also Nicholas Stern (2013), who tacitly admits to not know better options than the gross IAMs.

### Basics of climate–economy modelling

Economists do not boast about having formalized the study of climate change even before climatologists. But they could. William Nordhaus laid the foundational stone of climate change economics well before the first climate conference (Geneva, 1979) and the creation of the IPCC (1988). Yet economic models of climate change had to wait until 1992 to gain notoriety with the publication of William Cline’s *The economics of global warming*. After that, climate–economy models such as Nordhaus’s DICE (Dynamic Integrated Climate–Economy) reigned supreme for around 15 years until shortly after the publication of the Stern Report in 2006.

The most salient result of William Nordhaus’s climate modelling is the idea that the optimal policy should follow a ramp pattern, where social welfare maximization leads to relatively low investments in the short run, allowing time for the price of a “backstop technology” to be reduced, and investments then rise linearly to reach a substantial level in the second half of the current Century (Nordhaus, 2008, p. 98)<sup>2</sup>. This is in sharp contrast with the proposal advanced by the Stern Review, which called for a policy that cut emissions strongly in the short term, with costs up to ten times higher than in Nordhaus’s ramp. Why such striking difference between “optimal” policies?

The answer has three components. First, given that the expected impacts of climate change will take place over the next decades and centuries, the models typically work with extremely long timeframes, 600 years in the case of Nordhaus’s and infinite in the case of Stern’s. This feature of climate models helps to understand Pindyck’s position on IAMs. The confidence level of estimates of GDP and greenhouse gas emissions for twenty years is very low. What to say of a horizon of 6 centuries?

Secondly, a time discount procedure must inevitably be employed with such timeframes. One dollar next year is worth less than one dollar today, as the capital invested today should grow according to a market interest rate. Likewise, the investment made within 100 years cannot be valued the same way as an investment made today. A standardized procedure

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<sup>2</sup> The findings of a panel formed in 2013 by the US government to synthesize the results of the main economic–climate models (US Government, 2013) are consistent with Nordhaus’s DICE estimates.

needs to be adopted for the values at different points in time to be comparable; this is intertemporal discounting.

If the intertemporal discount rate is high, the costs and benefits in the distant future are given minor importance in the present. If it is low or zero, the future has relatively high importance. The Stern Review adopted a very low discount rate based on the premise that future generations should be weighed similarly to the present generation. This argument caused considerable controversy, pushing the debate towards the acceptance of at least a declining discount rate (Arrow et al., 2013; Heal and Millner, 2014).

Timeframe and discounting procedure are interrelated choices. If an infinite timeframe is adopted, a low discount rate leads to a much higher weight to future generations, to the point where the present generation becomes almost irrelevant. Likewise, if combined with a shorter horizon, higher discount rates virtually eliminate the future generations from the modelling effort.

This technical debate cannot be detached from ethical considerations concerning the weight that society should attach to those still to be born. Moreover, climate–economy models face serious within–generation distributional issues (Anthof and Toll, 2007). For example: how fair is it that a poor person contributes in equal measure to a rich person to fight climate change? Such important ethical considerations have been discussed elsewhere (Self-reference) and will not be further developed. What is important here is to note that a rigid stance among economists that decision–making on the climate must be informed by (to some extent) arbitrary climate–economy models is starting to be relaxed. The first wave of research that has emerged in this context is what Simon Dietz (2014) has termed “climate change mitigation as catastrophic risk management”.

## **2. The economics of insurance against catastrophic risks**

Uncertainty, ecosystem thresholds and catastrophe

Uncertainty is the biggest enemy of climate–economic models. It arises when the best possible measure of the odds of an undesired event is a worded qualification. If a probability distribution can be assigned to the event, then uncertainty becomes risk. If, on the other hand, the very event to be modelled is poorly defined, then uncertainty is qualified as fundamental.

There are serious doubts about exactly how much warming a given concentration of greenhouse gases in the atmosphere generates (warming potential); about how much a given level of warming impacts the broader climate; about how changes in the climate impact the economy; and about how human well–being is affected by all of the above. The final output of an IAM is subject to the multiplication of all these layers of uncertainty (Stainforth, 2007).

The role of uncertainty has often been obscured by discussions of intertemporal discounting. Only in the last few years did uncertainty become a central topic in climate change economics, due in part to the seminal work of Weitzman (2007). Uncertainty with respect to a single parameter of IAMs, the exponent of the damage function, leads to a variation of 700% in the estimates of the social cost of carbon in Nordhaus's DICE (Self-reference), having a greater impact than the discount rate. More worryingly, however, is the fact that not only the exponential of the function is uncertain but the function itself has very little or no empirical grounding.

One of the most promising areas of enquiry in economics stems from the debate above: the possibility of climate-related catastrophes and of critical ecosystem thresholds (tipping points) being surpassed. An ecosystem threshold is a theoretical resilience boundary that, when exceeded, can trigger an irreversible qualitative change in the state of ecosystems, causing large-scale damage. It is by definition a hypothetical event, with little foundation in empirical observation. The notion of climate disasters, on the other hand, is more comprehensive and may involve either well-known events – hurricanes, floods – or the (often unknown) consequences of surpassing theoretical thresholds.

A crucial empirical question is whether the economic impact of extreme climatic events has risen and, if so, whether that can be associated to anthropogenic emissions. There are two main challenges to this type of enquiry: first, that there is little data on extreme events (given their low frequency); and second, that even with the data at hand a causal link between emissions and economic damage is difficult to isolate. The IPCC made a detailed analysis of existing studies in this area, and found that extreme events have increased in recent decades (IPCC, 2012). The economic damage arising from these events has also increased, but the report admits with high confidence that most of the damage cannot be linked back to anthropogenic climate change, but rather to an increased exposure to extreme events and to growth of the wealth exposed. The same conclusion is reached by a synthesis of 22 published studies on the subject (Bouwer, 2011).

On the modelling front, Lemoine and Traeger (2012) advance a model that incorporates ecosystem thresholds. They employ the notion of option cost – the price to pay for the possibility of choosing not to exceed a threshold resilience level. In the case of climate change, the benefit of this option is to mitigate the risk of catastrophes. Thus, for example, in the presence of doubt about whether greenhouse gas concentrations above 450 ppm could unleash extreme events, it would be rational to impose such a ceiling concentration (and the respective option costs) until information about the safety of exceeding that threshold should appear. The problem, however, is that option costs are the higher the more uncertain are the

thresholds. At present levels of uncertainty, the results of the model suggest that carbon prices would rise by 40% if the possibility of crossing thresholds is internalized.

A more pragmatic solution was suggested by Pindyck (2011), who calls for a maximin approach, where the risk of the worst case scenario is minimized. He agrees that quantifying such extreme scenarios is virtually impossible, but argues that if there is a theoretical possibility, however small, of a catastrophe to occur when, for example, the 10 °C warming threshold is surpassed, then it is reasonable that measures be taken to avoid such level of warming. The problem, he says, is that the weather is not the only source of possible catastrophes. There are numerous other undesirable events that could require the purchase of long-term insurance: the use of nuclear weapons, the dissemination of mega-viruses, etc. If each of these events can justify expensive precautionary action, it follows that society would rationally be willing to spend all of its resources in insurance.

Take a concrete example. Suppose a given household takes note of all the extreme risks to which it is subjected: house fire, plane crash, etc. Suppose that preventive measures are taken to eliminate those risks. Such measures will be expensive, and at some conceivable point the household will find itself spending all of its income on insurance.

Such was the conclusion reached by Weitzman (2011) in modelling the possibility of extreme climate-related events. He raised the crucial point that the right-hand side of the probability density function of climate damages is intrinsically thick. Since there is no information on situations where global temperatures rose by 10 °C over pre-industrial levels, the (theoretical) probability distribution of the extreme events that may happen as a consequence of such high warming levels is by nature fat-tailed: the probability of occurrence falls less than exponentially with the size of the damage (Pindyck, 2011).

The centre of the distribution – the part that lies near the mean – may be taken as an objective frequency distribution, but the tail is mostly made of ignorance. Given the lack of empirical backing, extreme events are modelled with fat-tailed distributions. But the consequences of assuming one distribution or another are nonnegligible. The standard assumption in a fat-tailed climate damage distribution is that a catastrophic scenario, where a zero consumption situation follows extremely high warming levels, may arise with a high enough probability. In such case, the standard Bayesian analytical framework can yield results that correspond to society spending all of its income on insuring itself against the extreme scenario (Dietz, 2011; Weitzman, 2009). This artefact of the adoption of a fat-tailed probability distribution is known as the dismal theorem.

Conventional IAMs focus on average warming scenarios and derive optimal policies mostly from the centre of the damage distributions. An “anti-disaster principle” (Sunstein, 2004), on the other hand, is an alternative to climate-economy models that informs regulation based on

the scenarios of highest danger, using the economics of insurance against catastrophic risks. While the validity of the dismal theorem would imply that there is little sense in using the conventional expected utility framework to model climate insurance, the discussion is ongoing and the frontier of climate modelling under extreme events is being rapidly pushed forward<sup>3</sup>. Moreover, this relatively new research avenue is bringing climate change economics closer to the world of policymaking by focusing on the scenarios that create the most distress.

In the next section I briefly discuss the economics of climate cooperation to show that a bottom-up approach, in which action is primarily taken by individual states and subsequently coordinated at the global level, is imposing itself in economics as in the real world.

### **3. A non-universalistic action approach**

The economic game of coordination

The atmospheric CO<sup>2</sup> concentration has increased from 375 parts per million (ppm) in 2003 to 396 ppm in 2013 (Scripps Institute, 2014). In face of the generally accepted idea that levels above 400 ppm would be dangerous, the figures above suggest a resounding failure of climate policies. Why after two decades of existence of an international treaty aimed at controlling global warming have mitigation policies not succeeded?

This section provides a short summary of the results of the research on cooperation and global coordination to mitigate greenhouse gas emissions, arguing that the institutional model to control climate change inspired by the Montreal Protocol was doomed to failure since the beginning. Besides being a rare example of success in creating a global environmental regime – for various reasons, including the lack of a cheap and effective technology decarbonisation and the absence of a hegemon country with a stake – the Montreal Protocol cannot be taken as a model for climate action (Keohane and Victor, 2011).

Studies based on game theory have long suggested that cooperation between a large number of players is not feasible in the context of climate change (Barrett, 1994). The attempt to establish a global agreement is based on the simple premise that there is a single atmosphere and emissions in any given country have an equal effect, so there is no point in reducing emissions in country A while they are raised in country B. Yet economic models predict that universal climate agreements, where all or almost all of the relevant parties abide to action, can only lead to one of two equally undesirable outcomes: to set and achieve goals

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<sup>3</sup> Millner (2013) provides an excellent assessment of the current state of the literature, emphasizing the unavoidable ethical considerations involved. A recent article in *Ecological Economics* (Buchholz and Schymura, 2012) frames the discussion in terms the ethics of risk aversion assumptions (“the tyranny of catastrophic risks”).

that fall short of the required action (such as in the Kyoto Protocol), or to set ambitious goals that are not satisfied due to lack of sanction power (Barrett, 2006).

The alternative to universalistic institutional arrangements is a polycentric model (Ostrom, 2010). The idea of institutions dealing with public goods in a decentralized manner was explored by Ostrom from the 1960s, and seems to become increasingly important for the study of climate change. Ostrom cites several scales of climate action, from municipal energy efficiency programs, through the state laws of California and Colorado (United States), to the European carbon trading scheme. For her, as well as for economists such as Nicholas Stern (Hepburn and Stern, 2009) and Scott Barrett (2008), the sum of these polycentric institutions is an important way of tackling climate change. However, she admits that such an approach can only work if all countries integrate some local or regional arrangement.

The work of Finus et al. (2009) makes clear that smaller-scale agreements between countries with common interests are more feasible than universal agreements. Whereas such regional / sectorial arrangements lead to sub-optimal equilibria – abatement levels being lower than could theoretically be achieved under full cooperation – these possible equilibria are still superior to the situation where each country acts individually. Another recent study confirms that small-scale institutions are much more effective in ensuring cooperation than global institutions (Tavoni, 2013).

The validity of the game-theoretical results could not be more obvious in face of the results of the Copenhagen summit. In discussing the apparent failure of the global negotiations, international relations scholars Falkner, Stephan and Vogler (2010) argue that the model intended to create a system with global coordination was a miscalculation that lasted 20 years. They call instead for a building blocks approach, and suggest that the Copenhagen summit has indeed established the basis for such type of arrangement. Examples of the "blocks" are the negotiations on forests and REDD (Reducing Emissions from Deforestation and Degradation), the discussions around an adaptation fund, and the heated debate on technology transfer. The idea is that negotiations will increasingly be made on a sectorial basis, tackling specific issues that involve different sets of concerned countries, and that the complexity of the issues negotiated will increase over time, in an evolutionary model similar to the one that describes the GATT / WTO (World Trade Organization) complex.

Economic models have shown that a universal agreement is unfeasible. The more realistic world of second-best solutions – a middle ground between the ideal and the worst-case scenarios – has imposed itself both in theory and practice (Bosetti and Victor, 2011). The analytical framework of climate change economists is being broadened to include institutions built on a disaggregated basis. In the next section the topic of trade and climate change is

addressed, showing that policies that promote emission reductions despite the lack of global cooperation are seen as increasingly relevant for climate change economics.

#### **4. The economics of trade and climate**

##### Carbon pricing and border adjustments

A first-best climate change mitigation policy is what William Nordhaus calls an internationally harmonized carbon tax (Nordhaus, 2008). Based on the tax system, this approach has the crucial benefit of using an institution that is already embodied in the market. Although taxes can create deadweight losses and reduce allocative efficiency, they may generate a net benefit if designed to attenuate a major market failure such as greenhouse gas emissions. This is perhaps one of the few ideas that have no opponents in the world of climate change economics (Weitzman, 2013).

A well-known variant is the cap-and-trade arrangement. It is also based on imposing a cost on greenhouse gas emissions, but it uses a mechanism of tradable quotas in which a central organization, managed or supervised by the government, distributes tradable allowances. Such schemes already exist in the European Union (EU ETS), in nine states in the United States and Canada (Regional Greenhouse Gas Initiative) as well as in California and the Canadian province of Quebec (California Air Resources Board). Nevertheless, they are often criticized for imposing more distortions than a tax and having delivered questionable results in Europe (Giddens, 2009).

It is difficult to establish whether pure taxes are more popular than tradable quotas. Several countries have implemented carbon taxes: Finland, Sweden, Denmark, UK, Norway, Switzerland, Ireland, Costa Rica and Australia, plus the Canadian province of British Columbia and the City of Boulder (USA). Institutional designs are highly heterogeneous as they adapt to the specific contexts of each location (OECD, 2013). Some of the schemes are in fact more appropriately categorized as hybrid approaches (Hepburn, 2006), where certain aspects of each of the pure pricing approaches – taxes and quotas – are adopted. The goal, however, is always the same: to impose a cost on carbon emissions.

The structure being implemented in Australia, for example, imposes pre-established prices for the ton of carbon emitted, but at the same time distributes emission quotas that initially may not be traded. Companies emitting above their allowance are subject to a price 30% higher for any additional emission. From 2015, the regulator will allow the price to float and companies to market quotas. In addition, the government has implemented a tax recycling scheme, reducing the fiscal burden on the poorest to avoid them being harmed by the carbon price.

The carbon pricing systems that have emerged across the world are not internationally coordinated. Instead, each jurisdiction has unilaterally adopted the most convenient domestic measures (Bosetti and Victor, 2011). Moreover, the actual emission reductions that have been achieved are negligible. Hence the attractiveness of a harmonized tax, which would prevent carbon emissions from being leaked from regulated to unregulated markets. Yet the universalistic route appears to be impracticable in the current context. As document McKibbin et al. (2011), the Copenhagen summit opened up the political path for countries to take unilateral mitigation goals that can be measured on the scale that best suits each jurisdiction. Although the signed document was not legally binding, the political weight of the leaders who personally tailored the agreement has in practice weakened the universalistic trajectory (Green, 2014; Helm, 2012; Weitzman, 2013).

The new direction of economic policy of climate change revolves around how unilateral policies interact with international trade. A first line of research investigates the effects on the competitiveness of the regulated countries, notably in terms of increased imports of carbon-intensive products and delocalization of companies to pollution havens. A second branch of the literature studies the effects of different mechanisms of border carbon adjustment – import taxes and / or subsidies on the export of carbon-intensive products – aimed at harmonizing the price of carbon in a world where a limited number of countries implement regulation.

With respect to competitiveness, recent studies suggest negligible losses even with unilateral policies. For example, Aldy and Pizer (2011) estimate a 1% drop in production in the regulated sectors if a \$ 15 fee is imposed on the tonne of CO<sup>2</sup> in the United States. For the case of Europe, Barker et al. (2007) estimate a small, and possibly negative, leakage of carbon emissions from six countries that have implemented carbon taxes to other European countries. They conclude that technological spillovers from regulated to non-regulated countries may have lowered emissions in both groups. A similar conclusion was reached by Branger et al. (2013) who found that a European carbon tax would have no effect on imports of iron and cement.

Contrariwise, a comprehensive model that studies the impact of environmental regulation in foreign countries on domestic value added shows strong evidence of a pollution haven effect in which non-regulated countries benefit from trade (Feddersen, 2013). More interesting, however, is the conclusion that the production shift resulting from the imposition of environmental regulation is strongly conditioned by the transport cost structure, which follows regionalized patterns, so that the harmonization of regulations between neighbouring countries could solve most of the problem. Even if the unilateral imposition of a cost on emissions can lead to economic losses, coordination at the regional level may be sufficient to eliminate that cost.

Research on the potential trade barriers to be imposed by countries that adopt unilateral actions is a burgeoning area. Imposing a tax on carbon imports corresponds to taxing consumption instead of production of carbon-intensive products. Helm et al. (2012) argue that imposing such a tax could be a game changer in climate negotiations, as the most affected countries – China, Russia and middle-income countries, which have exports with high carbon content – would be forced to respond. For Helm and colleagues, countries or regions wishing to pursue leadership in climate policy have three options: maintain the current system of unilateral policies and risk a loss of competitiveness until an agreement is reached in 2020; accept that the current regime is ineffective and grant exemptions to their own exporters to avoid losses; or impose trade barriers based on carbon trading.

The latter strategy was followed by the European Union when including aviation in its tradable quota system in 2012. There was immediate protest from the United States, China and other countries, as all flights passing through the European Union would have been taxed, even if originating in other countries. This led to a diplomatic dispute that ultimately pushed the International Civil Aviation Organization to discuss the creation of a global structure of taxation of carbon emissions from 2020. Given the relative success of the move, the European Union already has plans to repeat it to the shipping industry (ibid.).

Climate policy has been increasingly created from the bottom up, with countries defining their strategies first and, in a second stage, creating international coordination platforms. Whether or not the climate policy agenda will be merged with the trade agenda should largely depend on the reaction of the WTO to the matter of tariff restrictions on carbon content (Fischer and Fox, 2012). Given the failure of negotiations under the UNFCCC, the climate may well become another front of trade disputes in the near future.

## **5. The economics of adaptation**

### Adaptation as development

The MacMillan dictionary defines resilience as “ability to recover”. In the context of climate change, resilience can be defined as the capacity of the climate system to return to its original qualitative state without suffering severe and unavoidable changes as a result of extreme events. By building resilient systems to climatic conditions, humans were able to colonize the planet and settle in the harshest environments. Such ability to respond to environmental changes is essential for survival, with or without anthropogenic climate change.

The bulk of economic studies on climate change, however, downplay the capacity of families, businesses and communities to develop solutions to address climate change (Hallegatte et al., 2011). But the scenario is changing. Adaptation has entered the UNFCCC agenda

through the adaptation fund, the green fund, and national adaptation plans (Fankhauser and Burton, 2011). The recognition that the climate will not stop changing (especially due to anthropogenic warming), and that an important part of the solution is to continue developing structures and institutions that promote the coexistence with these changes, begins to emerge (Nature, 2013).

Climate adaptation encloses two important aspects. First, it has an eminently local character. Unlike mitigation, which ultimately deals with a spatially homogeneous object – greenhouse gas emissions being physically the same everywhere –, adaptation depends crucially on how climate changes materialize in space and in the economy, and how families and businesses are affected. Second, climate adaptation strategies coincide, in many cases, with other development goals, including poverty reduction and health improvement. Inasmuch as adapting to climate change can also boost development, adaptation strategies can have a legitimacy bonus that may not be attached to mitigation strategies.

The idea of "adaptation as development" has been raised in the context of political ecology (Ayers and Foresyth, 2009; Ayers and Dodman, 2010), but economic studies also indicate that adaptation to climate change can serve larger goals (Fankhauser, 2010a; Fankhauser and McDermott, 2014). For example, analysing agriculture in Ethiopia, Di Falco et al. (2010) found a causal link between climate change adaptation (including new crop varieties and soil conservation measures) and food security. Adaptation strategies were also found to increase crop yields if adopted in isolation, and to be even more effective when implemented in conjunction with other agricultural practices such as water conservation methods (Veronesi, and Di Falco, 2013).

Studies on the global costs of adaptation yield estimates ranging between \$ 25 billion and \$ 100 billion for the period 2015–2030 (Fankhauser, 2010b). Disaggregated estimates yield higher figures for individual countries, with the costs only for the U.S potentially amounting to tenths to hundreds of billions of dollars (Sussman et al., 2014). Analyses based on IAMs show that adaptation is strongly complementary to mitigation, but the most catastrophic warming scenarios can only be addressed by mitigation (Agrawala et al., 2010). The total cost of adaptation is substantially higher than that of mitigation, but it also has the greatest potential for damage reduction (Bosello et al., 2010). Moreover, when adaptation is seen as part of a broader development strategy, its benefits are leveraged.

Climate change adaptation is being brought to the centre of climate policy debates (Petherick, 2012). Studies on the economics of adaptation have hitherto focused on agriculture-related issues (Hertel and Lobell, 2014 provide a current synthesis of the literature), as food production is where adaptation measures are the most obvious and

straightforward. But adaptation is now starting to be considered by economists more widely as an inescapable component of the policy mix to face global warming.

Adaptation to climate change involves the transfer of resources to the most affected countries, and within these, to the most affected communities. When it is seen as increased resilience, it overlaps with development, which bears two implications. From an operational point of view, there exists a network of institutions and organizations dedicated to implementing development projects in the South that can be mobilized for the adaptation effort. From a political point of view, climate policy can gain legitimacy by being seen as an integral part of development policy.

### **Conclusion and policy implications**

Three major research trends have broadened the scope of climate change economics as of the last five years. First, the study of the economic implications of potential climate catastrophes resulting from very high warming levels. This is an important change of direction as the standard models focused almost exclusively on lower warming bands, mostly due to methodological limitations for the analysis of scenarios that fall far apart from the mean of the probability distribution. The second trend is the study of carbon border adjustments – taxing the carbon content embedded in imported goods. Research in this area has been particularly fruitful in the last few years as unilateral climate initiatives by nations and sub-national entities has proliferated, and with them the worry that regulation would crowd out competitiveness. The third stream that opens up is the study of the economics of adaptation to climate change, which includes issues such as costs and benefits of adaptation and the identification of overlaps between climate action and development objectives. This is linked to the increased recognition that optimal mitigation policies are impracticable and that second-best solutions must be envisaged.

Does it matter for policy? The centrality of adaptation is indeed one of the policy measures proposed by Dieter Helm, an economist at Oxford University, in his book *The carbon Crunch* (2012). His policy appraisal is a good illustration of the trends in economic thinking on climate change that were stressed in this paper. Besides giving a central role to adaptation, Helm calls for a carbon pricing system with border adjustments. However, instead of defining the optimal mitigation path and carbon price based on standard climate-economy models, the proposed pricing system would work on the premise that it is not possible to determine "correct" prices, setting instead a "low" starting price. The system would be designed to ensure a rising price in the long run. But given the challenges of a global climate agreement, how could such a pricing system be implemented? For Helm, the doldrums of negotiations

could be broken by forcing the merge between the climate change and the trade agendas: the unilateral imposition of carbon border adjustments (possibly by the European Union) would force hesitating countries to respond.

The post-Copenhagen period has forced a reversal upon climate policy whose scale is still to be fully appreciated. The essence of this change is the recognition that universally coordinated climate policy in the style of the Montreal Protocol is not practicable, and what should come up is a system in which decisions are taken in a decentralized, but not necessarily uncoordinated, way. The imposition of trade barriers based on carbon content is consistent with this approach, as it would drive the negotiations to a sectorial basis. In addition, the orthodoxy of emissions mitigation is being replaced by a policy mix that includes adaptation and mitigation of the risk of the worst case scenario. The focus on adaptation gives climate policy a local and regional character – polycentric –, while minimizing the risk of a catastrophe relies on globally coordinated action.

## References

Agrawala, Shardul, Francesco Bosello, Carlo Carraro, Kelly De Bruin, Enrica De Cian, Rob Dellink, and Elisa Lanzi. 2011. "Plan or react? Analysis of adaptation costs and benefits using integrated assessment models." *Climate Change Economics* 2 (03):175–208.

Aldy, Joseph, and William Pizer. 2011. *The competitiveness impacts of climate change mitigation policies*. National Bureau of Economic Research.

Anthoff, David, and Richard Tol. 2007. On international equity weights and national decision making on climate change. In *Fondazione Eni Enrico Mattei Working Papers*.

Arrow, Kenneth, Maureen Cropper, Christian Gollier, Ben Groom, Geoffrey Heal, R Newell, William Nordhaus, Robert Pindyck, William Pizer, and P Portney. 2013. "Determining benefits and costs for future generations." *Science* 341 (6144):349–350.

Ayers, Jessica, and David Dodman. 2010. "Climate change adaptation and development I the state of the debate." *Progress in Development Studies* 10 (2):161–168.

Ayers, Jessica, and Tim Forsyth. 2009. "Community-based adaptation to climate change." *Environment: science and policy for sustainable development* 51 (4):22–31.

Barker, Terry, Sudhir Junankar, Hector Pollitt, and Philip Summerton. 2007. "Carbon leakage from unilateral environmental tax reforms in Europe, 1995–2005." *Energy Policy* 35 (12):6281–6292.

Barrett, Scott. 1994. "Self-enforcing international environmental agreements." *Oxford Economic Papers* 46 (Special Issue on Environmental Economics (Oct., 1994)):878–894.

Barrett, Scott. 2003. *Environment and Statecraft : The Strategy of Environmental Treaty-Making*. Oxford: Oxford University Press.

Barrett, Scott. 2006. "Climate Treaties and "Breakthrough" Technologies." *American Economic Review* 96 (2):22-25. doi: 10.1257/000282806777212332.

Barrett, Scott. 2008. "Climate treaties and the imperative of enforcement." *Oxford Review of Economic Policy* 24 (2):239-258.

Bosello, Francesco, Carlo Carraro, and Enrica De Cian. 2010. "Climate policy and the optimal balance between mitigation, adaptation and unavoided damage." *Climate Change Economics* 1 (02):71-92.

Bosetti, Valentina, and David Victor. 2011. "Politics and Economics of Second-Best Regulation of Greenhouse Gases: The Importance of Regulatory Credibility." *Energy Journal* 32 (1).

Bouwer, Laurens. 2011. "Have disaster losses increased due to anthropogenic climate change?" *Bulletin of the American Meteorological Society* 92 (1).

Branger, Frédéric, Philippe Quirion, and Julien Chevallier. 2013. *Carbon leakage and competitiveness of cement and steel industries under the EU ETS: much ado about nothing*. CIRED Working Paper Series.

Nature Climate change editorial. 2013. "Adapting to a changing climate." *Nature Clim. Change* 3 (11):939-939. doi: 10.1038/nclimate2048.

Cline, William. 1992. *The economics of global warming*. Washington, D.C.: Peterson Institute.

Di Falco, Salvatore, and Marcella Veronesi. 2013. "How Can African Agriculture Adapt to Climate Change? A Counterfactual Analysis from Ethiopia." *Land Economics* 89 (4):743-766.

Di Falco, Salvatore, Marcella Veronesi, and Mahmud Yesuf. 2011. "Does adaptation to climate change provide food security? A micro-perspective from Ethiopia." *American Journal of Agricultural Economics* 93 (3):829-846.

Dietz, Simon. 2011. "High impact, low probability? An empirical analysis of risk in the economics of climate change." *Climatic Change* 108 (3):519-541.

Dietz, Simon. 2014. "Climate change mitigation as catastrophic risk management." *Environment: science and policy for sustainable development* 56 (6):28-36.

Falkner, Robert, Hannes Stephan, and John Vogler. 2010. "International climate policy after Copenhagen: Towards a 'building blocks' approach." *Global Policy* 1 (3):252-262.

Fankhauser, Samuel. 2010a. "Market and Policy Driven Adaptation." In *Smart Solutions to Climate Change*. Cambridge: Cambridge University Press.

Fankhauser, Samuel. 2010b. "The costs of adaptation." *Wiley interdisciplinary reviews: climate change* 1 (1):23-30.

Fankhauser, Samuel, and Ian Burton. 2011. "Spending adaptation money wisely." *Climate Policy* 11 (3):1037–1049.

Fankhauser, Samuel, and Thomas McDermott. 2014. "Understanding the adaptation deficit: why are poor countries more vulnerable to climate events than rich countries?" *Global Environmental Change* 27:9–18.

Feddersen, John. 2013. *Pollution Havens: Does Third Country Environmental Policy Matter?*

Finus, Michael, M Elena Saiz, and Eligius Hendrix. 2009. "An empirical test of new developments in coalition theory for the design of international environmental agreements." *Environment and Development Economics* 14 (1):117.

Fischer, Carolyn, and Alan Fox. 2012. "Comparing policies to combat emissions leakage: Border carbon adjustments versus rebates." *Journal of Environmental Economics and Management* 64 (2):199–216.

Giddens, Anthony. 2009. *The politics of climate change*. Cambridge, UK: Polity.

Goulder, Lawrence, and Andrew Schein. 2013. *Carbon Taxes vs. Cap and Trade: A Critical Review*. National Bureau of Economic Research.

Green, Fergus. 2014. "This time it's different": the prospects for an effective climate agreement in Paris 2015. In *Grantham Research Institute on Climate Change and the Environment*. London, UK: London School of Economics.

Heal, Geoffrey, and Antony Millner. 2014. "Agreeing to disagree on climate policy." *Proceedings of the National Academy of Sciences* 111 (10):3695–3698.

Helm, Dieter. 2012. *The Carbon Crunch*: Yale University Press.

Helm, Dieter, Cameron Hepburn, and Giovanni Ruta. 2012. "Trade, climate change, and the political game theory of border carbon adjustments." *Oxford review of economic policy* 28 (2):368–394.

Hepburn, Cameron. 2006. "Regulating by prices, quantities or both: an update and an overview." *Oxford review of economic policy* 22 (2):226–247.

Hepburn, Cameron, and Nicholas Stern. 2009. "The global deal on climate change." In *The economics and politics of climate change*, edited by Dieter Helm and Cameron Hepburn, 36–57. Oxford: Oxford University Press.

Hertel, Thomas, and David Lobell. 2014. "Agricultural adaptation to climate change in rich and poor countries: Current modeling practice and potential for empirical contributions." *Energy Economics*.

IPCC. 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation: Special report of the intergovernmental panel on climate change*: Cambridge: Cambridge University Press.

- Keohane, Robert, and David Victor. 2011. "The regime complex for climate change." *Perspectives on politics* 9 (01):7–23.
- Lemoine, Derek, and Christian Traeger. 2012. Tipping points and ambiguity in the economics of climate change. National Bureau of Economic Research.
- McKibbin, Warwick, Adele Morris, and Peter Wilcoxon. 2011. "Comparing climate commitments: a model-based analysis of the Copenhagen Accord." *Climate Change Economics* 2 (02):79–103.
- Nachmany, Michael, Sam Fankhauser, Terry Townshend, Murray Collins, Tucker Landesman, Adam Matthews, Carolina Pavese, Katharina Rietig, Philip Schleifer, and Joana Setzer. 2014. The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries. In GLOBE International and the Grantham Research Institute. London, UK: London School of Economics.
- Nordhaus, William. 2008. *A question of balance: Weighing the options on global warming policies*. New Haven: Yale University Press.
- OECD. 2013. *Climate and carbon. Aligning prices and policies*. OECD Publishing.
- Ostrom, Elinor. 2010. "Beyond markets and states: polycentric governance of complex economic systems." *The American Economic Review* 100 (3):641–672.
- Pindyck, Robert. 2011. "Fat tails, thin tails, and climate change policy." *Review of Environmental Economics and Policy* 5 (2):258–274.
- Pindyck, Robert. 2013a. *Climate Change Policy: What do the models tell us?* : National Bureau of Economic Research.
- Pindyck, Robert. 2013b. "Pricing carbon when we don't know the right price." *Regulation* 36 (2):43–46.
- Revesz, Richard, Peter Howard, Kenneth Arrow, Lawrence Goulder, Robert Kopp, Michael Livermore, Michael Oppenheimer, and Thomas Sterner. 2014. "Global warming: Improve economic models of climate change." *Nature* 508 (7495):173–175.
- Scripps, Institute. 2014. *Atmospheric CO2*.
- Stainforth, David, Miles Allen, Edward Tredger, and Leonard Smith. 2007. "Confidence, uncertainty and decision-support relevance in climate predictions." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 365 (1857):2145–2161.
- Stern, Nicholas, ed. 2006. *Stern Review: The economics of climate change*. Vol. 30. London: HM treasury London.
- Stern, Nicholas. 2013. "The structure of economic modeling of the potential impacts of climate change: grafting gross underestimation of risk onto already narrow science models." *Journal of Economic Literature* 51 (3):838–859.

Sunstein, Cass. 2004. "Cost-benefit analysis and the environment." U Chicago Law & Economics, Olin Working Paper (227).

Tavoni, Alessandro. 2013. "Game theory: Building up cooperation." *Nature Climate Change* 3 (9):782-783.

US government. 2013. Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866. edited by Interagency Working Group on Social Cost of Carbon.

Weitzman, Martin. 2009. "On modeling and interpreting the economics of catastrophic climate change." *The Review of Economics and Statistics* 91 (1):1-19.

Weitzman, Martin. 2011. "Fat-tailed uncertainty in the economics of catastrophic climate change." *Review of Environmental Economics and Policy* 5 (2):275-292.

Weitzman, Martin. 2013. Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality? : National Bureau of Economic Research.