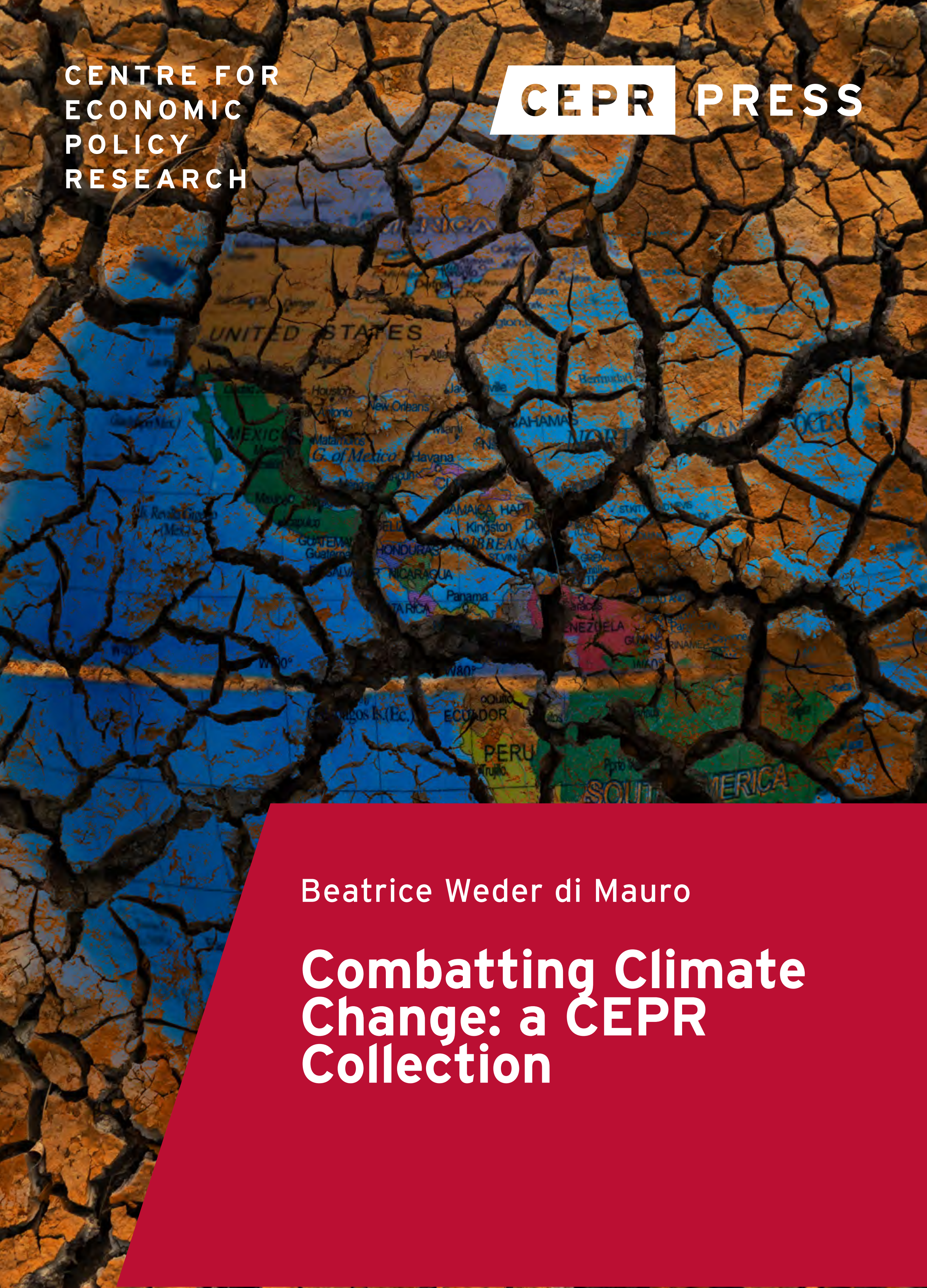

CENTRE FOR
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CEPR PRESS

Beatrice Weder di Mauro

Combatting Climate Change: a CEPR Collection

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Edited by Beatrice Weder di Mauro

CENTRE FOR ECONOMIC POLICY RESEARCH

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Foreword

Concerns surrounding climate change have heightened considerably in recent years, with a universal view emerging that human behaviour is accelerating global warming at an alarming rate. Left unchecked, the current trajectory could result in irreversible damage to our planet and potentially dire consequences for the millions who inhabit it. CEPR, and economics more generally, has devoted more and more attention to understanding the short- and long-term effects of climate change on the economy, migration and inequality, all of which will affect societies worldwide. A greater research focus is now being applied to understanding the costs, benefits, and trade-offs of climate policies. However, as evidenced by this eBook, a comprehensive solution to combatting climate change across sectors remains elusive.

Published during the 2021 COP26 summit in Glasgow, this eBook provides a selection of solution-oriented research studies first featured on CEPR's policy platform VoxEU.org, which highlight key policy issues for governments going forward, as well as detailed analyses of the effectiveness of policies currently in place. The eBook, presenting as it does the columns as they were published, without amendment or updates, also provides a fascinating insight into the evolution of economic research on climate change over the last decade, and most starkly highlights the shift in urgency and appreciation of this daunting threat to humanity.

CEPR is grateful to the authors for their contributions to this eBook and to the editor, Beatrice Weder di Mauro. Our thanks also go to Sophie Roughton for her skilled handling of its production, and Maximilian Konradt for his excellent research assistance.

CEPR, which takes no institutional positions on economic policy matters, is delighted to provide a platform for an exchange of views on this important topic.

Tessa Ogden
Chief Executive Officer, CEPR
November 2021

PART I

A START

Evolution of the economics of climate change

Beatrice Weder di Mauro
Graduate Institute of Geneva, INSEAD, and CEPR

Surely there can be hardly anyone left who truly doubts that climate change is real and that it is here. The recent experiences of severe weather events – floods, fires, droughts, and storms – visibly drive home what scientists have been saying for years: global warming threatens life on a planetary scale; it is man-made, predictable and, although not reversible, its further escalation is mitigable.

Today, it is rare to have conversations of the 'but there was always climate change, and who says that this time is different' type. Instead, both public and private actors seem to be aggressively embracing the fight against climate change. Rare indeed, these days, is the financial institution that does not promote its environmental, social, and governance (ESG) credentials. At the time of writing, world leaders are meeting for the COP26 conference in Glasgow and expectations are simultaneously high and low. There are high expectations for some further progress but low expectations of sufficient progress towards the goal of limiting global warming to 1.5 degrees.

Submerged beneath the flood of information, initiatives, ideas, and pronouncements, it is hard to keep sight of what is needed for this goal. It is easy to get lost, primarily because the science of climate change is complicated, requires very long-run forecasts and involves large confidence intervals. The same is true of the *economics of climate change*: separating the signal from the noise, filtering out the quality research is hard.

Research published by CEPR and our policy platform VoxEU has served this purpose for years: it filters and disseminates the economic research you ought to read.

This eBook is a collection of 45 VoxEU columns on the economics of climate change, mostly published over the past 2-3 years. The sheer quantity is testimony to the acceleration of research, knowledge, and interest in the economics profession. I had to limit the number of columns chosen and to exclude many interesting pieces from this collection. My selection bias was for recent and solution-oriented contributions. However, in a few cases I have included older pieces, those that trace some of the 'history of thought'. Below, I highlight a few selected insights on the economics of climate change as illustrated in this collection, but first I want to focus on the science of climate change.

SCIENCE FIRST: SOME NUMBERS WORTH REMEMBERING

To keep eyes on the goal, a few numbers from the latest report of the IPCC are extremely helpful.[1] **The numbers are: 40, 300 and 2,390**. Forty gigatonnes represents the current yearly emissions of CO_2 at the global level, 300 gigatonnes is the remaining carbon budget of global emissions, if the 1.5 degree goal is to be reached with high (more than 80 percent) likelihood, and 2,390 gigatonnes of CO_2 is the estimate of cumulative historical emissions since 1850, already in the atmosphere.[2] These numbers make an impression for several reasons.

First, the 2,390 gigatonnes show the size of the historical burden: past emissions mean that the world has already almost exhausted the total carbon budget if we are to limit global warming to 1.5 degrees. These emissions will remain in the atmosphere for hundreds of years to come and have already warmed the earth by about 1 degree (over preindustrial levels). It is noteworthy that this historical burden was accumulated almost exclusively by high-income countries.

Second, the 300 gigatonne remaining budget matters because it is absolute. This is all that remains, full stop. This is how much this and any future generations have left if warming is to be limited to no more than 1.5 degrees. At the current rate of 40 gigatonnes per year, the world has about eight years left. To my mind, this simple fact is such a powerful illustration of the challenge: the famous race to net zero needs a fast start if we are to limit global warming to 1.5 degrees. Were the world to give up on the 1.5 degrees target and set the limit to 1.7 or 2 degrees, the remaining carbon budgets would amount to 550 and 900 gigatonnes, respectively. This would allow a bit more time to get to net zero, as illustrated in Figure 1, but it does little to reduce the urgency to act and the environmental costs of any further delays.

If we were to translate the remaining budgets into minutes until midnight, the clock would say that it is 7 minutes to midnight for 1.5 degrees, 11 minutes to midnight for 1.7 degrees and 16 minutes to a midnight of 2 degrees warming. It is worth noting that although the relationship between emissions and warming seems to be near linear, the consequences of higher temperatures are not. Another way of looking at these numbers is to conclude that we need to develop carbon extraction technologies very fast and at scale. Unfortunately, this technology does not seem to be 'just around the corner'.

1 IPCC Climate Change 21, The Physical Science Base
2 See Table SPM.2 . IPCC Climate Change 21, The Physical Science Base,

FIGURE 1A TOTAL CO2 BUDGET TO LIMIT WARMING TO 1.5, 1.7 OR 2 DEGREES

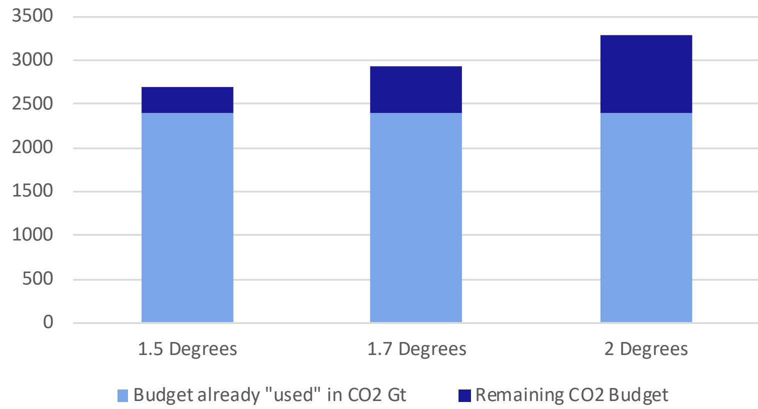
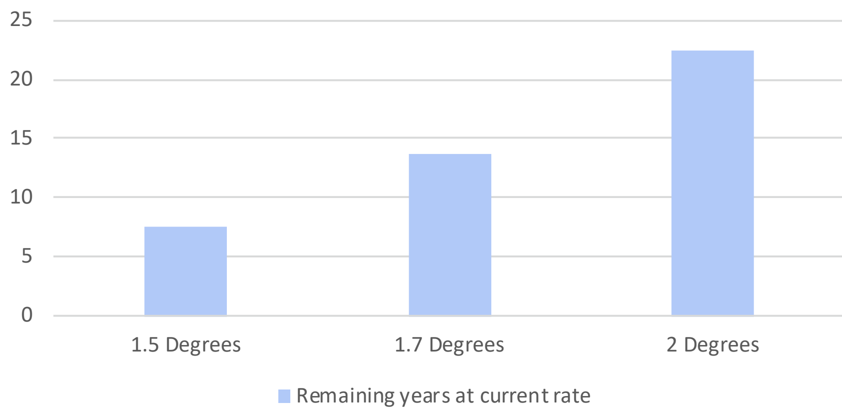


FIGURE 2B REMAINING YEARS AT CURRENT RATE OF EMISSIONS, GIVEN A LIMIT OF WARMING TO 1.5, 1.7 OR 2 DEGREES



Source: Author[s] calculations based on Table SPM.2 . IPCC Climate Change 21, The Physical Science Base,

IS THE ECONOMICS PROFESSION RISING TO THE CHALLENGE?

Given the size of the challenge, what are economists doing? Not much, according to Andrew Oswald and Nicolas Stern (Chapter 1). They look at the number of articles on climate change published in top economics journals and conclude that the economics profession has been failing the world. According to their count, the *Quarterly Journal of Economics* (QJE), for instance, had not published even one article on the economics of climate change until 2019 (a quick Google search for climate and QJE suggests that this may be unchanged, although it did reveal one QJE article published in 1917 on climate change as an element in the fall of Rome).

Not all economists can be accused of staying silent on the issue. Some of the most prominent economists were working on solutions years ago, as shown in Section I of the book. In several VoxEU columns from 2007-2009 (Chapters 2-7), Nicolas Stern, Geoffrey Heal, Jean Tirole, Michael Spence, Jeffrey Frankel and Philippe Aghion (with Reinhilde Veugelers and David Hemous) engage and put forward proposals on how to achieve a global deal. These pieces are worth re-reading for the historical record but also because some of issues they raise remain relevant today.

1. Fixing the price of carbon

Among the core issues, carbon pricing has attracted most attention from economists, and rightly so. Starting from Weitzman's 1974 "Prices versus Quantities", economists have been debating, over the last 50 years, the best way to price carbon under uncertainty. Robert Stavins' 2019 obituary for Martin Weitzman, calls him the gift that keeps on giving. The columns collected in (Chapters 8-19) are part of this literature, on cap-and-trade, carbon taxation and the social cost of carbon. Some earlier contributions showcase the debate among experts regarding the optimal discount rate, the magnitude of the social cost of carbon and the need to advocate against those who 'do not believe in climate change'. For instance, Rezai and van der Ploeg in 2015 estimated the optimal global carbon price at about 15 dollars per tonne of CO2, which from today's perspective would seem a low number. And in 2018, after the election of Donald Trump, these same authors engage 'climate change deniers' by showing that even a high probability of the views of such deniers being correct does not change the optimal policy of carbon pricing, because the risks still dominate.

After the Paris agreement of 2015, the expert debate on carbon pricing changed in a fundamental way. It moved from a *Pigouvian internalisation* approach to carbon pricing (i.e. estimating the present value of the flow of marginal damages of one tonne of CO2) to a *maximum quantity approach* (i.e. estimating the carbon budget which results from the optimal dynamic path for the shadow carbon price compatible with the set budget (Gollier, Chapter 15)). In determining this carbon price path, the two main variables are the initial level and its rate of increase of the price. Most integrated assessment models (IAMs) use a relatively low initial level of carbon prices and then a steep increase of 8% or more. Gollier uses an asset-pricing approach, with uncertainty about technology and economic growth, and finds a much lower growth rate for the optimal carbon price (4% plus inflation). This, in turn, implies a much higher price for carbon today to satisfy the maximum carbon budget.

The question of the optimal dynamics of carbon pricing is also important from a political economy perspective: policymakers may prefer a strategy of 'start with low carbon prices and then promise a steep increase', inviting all the usual problems of credibility and time inconsistency. It may also raise the further question of whether carbon taxes should vary over the cycle, as suggested by Benmir et al. in Chapter 16.

Carbon prices/taxes are already in place in many countries, and in some they are sizeable. In Switzerland a tonne of carbon is taxed at more than 100 Swiss francs.[3] In the largest cap-and-trade system, the European Trading System (ETS), a permit costs about 60 euros now, more than double the price in 2018-19. Carbon leakage therefore becomes a real issue, and two contributions here show that in the cases of Holland (Hoogendoorn, Chapter 17) and California (Bartram et al., Chapter 19) it can be substantial. A mechanism to deal with differences in carbon prices at the border – a Carbon Adjustment Mechanism (CBAM) – therefore becomes essential, as advocated by the French-German council of economic advisors (Chapter 13).

2. Harnessing green finance and green monetary policy

Prominent voices, from Mark Carney to Bill Gates, have calculated the necessary sum of investments needed to achieve net zero by 2050 at 3-5 trillion dollars per year. Clearly such sums will not be reached through public funding alone, private finance will need to flow into climate investment. At the same time, the financial industry seems to be embracing ESG finance whole-heartedly. Virtually all major asset managers have made commitments towards net zero and are advertising ESG-integrated products. This in turn raises a question for researchers: is it working? Is all the green finance having a positive impact on the climate?

The columns collected in Chapters 20-28 paint a mixed picture. On the positive side are Bolton et al. (Chapter 28), who find that the cost of equity for companies with higher emissions tends to increase as investors seek compensation for carbon transition risk. They conclude that stock market pricing may be acting as another form of carbon pricing. Altunbaş et al. (Chapter 23) find that European banks have shifted lending away from more polluting firms. Similarly, Delis et al. (Chapter 20) find that, after 2015, bank loans started to price climate transition risk for firms holding large fossil fuel reserves. On the sceptical side are Elmalt et al. (Chapter 22), who conclude that ESG criteria are not enough, since they do not link tightly with emissions growth for major emitters. Ehlers et al. also find no clear evidence that firms issuing green bonds reduce carbon intensities, nor that they have lower intensities than firms that did not issue green bonds.

From the financial risk perspective there is more agreement: climate change can represent severe risks for the balance sheets of financial intermediaries or, as Timo Löyttyniemi (Chapter 24) puts it, '[c]limate change is a new serious threat to financial stability'. Paul Hiebert (Chapter 25) shows how modelling climate risk for the EU financial system is progressing at the ECB, by mapping firms' climate exposures to financial exposures of banks, insurance companies, and investment funds.

3 A further increase of the tax to 200 Swiss Francs and expansion of coverage to the transport sector was voted down in a popular referendum in summer 2021

Any researcher who has ventured into the of forest of ESG finance will quickly have discovered that it is a jungle, with hundreds of standard setters, metrics, ratings, self-declarations, etc. Regulators have been trying to catch up by designing taxonomies and setting standards, which are themselves very complex. Ahead of COP26, therefore, Bolton et al. (Chapter 28) argue that a simple measure of carbon emissions for scope 1 should be made mandatory; every firm should have to publish its carbon footprint in absolute terms, in tonnes of CO_2. It is quite surprising that this simple metric is not easily available today.

Harnessing green monetary policy has been more controversial. However, some of the same arguments made for pricing climate risk in financial intermediaries also apply for the portfolios of central banks. The main debate has been whether green monetary policy should tilt asset purchases towards green assets, moving away from a 'market neutral' allocation. Dirk Schoenmaker (Chapter 29) points out that the market-neutral approach does not really avoid market distortions, since buying corporate bonds in proportion to today's market share means that the ECB's asset and collateral base will have a carbon-intensive bias. Similarly, Bartholomew and Diggle (Chapter 34) advocate abandoning the benchmark of neutrality, given the high stakes.

Less controversial is the fact that central banks will need to augment macro-modelling in order to be able to forecast and respond to physical and transition climate risks. For instance, they need to know in detail how carbon pricing will impact inflation. My study with Maximilian Konradt (Chapter 31) suggests that the answer is not obvious, at least not when looking at past CO_2 taxes, which have sometimes even been slightly deflationary. The response made by monetary policy will matter. Dietrich et al. (Chapter 32) point out that climate risks may present a very immediate challenge for monetary policy, if the expectation of climate-induced disasters affects people's behaviour today.

3. Dealing with global distributional issues

The chapters in the final section deal with some of the most difficult issues, those to do with distribution. What are the differential effects of climate change across the globe? Who will be on the winning and who on the losing side? How can we overcome the political economy obstacles? Will there be a huge international climate refugee flows? How should some of the low-income countries, already struggling with unsustainable debt burdens and high exposure to climate change, cope? This raises deep questions of fairness and inequality across the world and across generations, for which we do not have good answers.

I will not summarise all articles in this part, but there are some results that bear highlighting:

- Chancel and Piketty (Chapter 37) calculate global personal carbon inequality. They find that, "*the top 1% richest Americans, Luxemburgers, Singaporeans, and Saudi Arabians are the highest individual emitters in the world, with annual per* *capita emissions above 200tCO2e. At the other end of the pyramid of emitters lie the lowest income groups of Honduras, Mozambique, Rwanda and Malawi, with emissions 2,000 times lower, at around 0.1tCO2e per person per year* ", and suggest that progressive levies be targeted at the individual top emitters to fund climate adaptation.

- Cruz and Rossi-Hansberg (Chapter 40) show that the effects of climate change differ widely across regions. "*While some regions will be significantly negatively impacted, others may benefit from warmer temperatures. (..) The losers are today's poorest locations.*" In their baseline scenario, welfare can increase by as much as 15% in regions of Canada and Siberia, but areas in Central and South America, Central Africa, India, and Southeast Asia can suffer welfare losses of between 10% and 15%.

- A somewhat surprising result is found by Cattaneo and Peri (Chapter 36): international climate migration flows are contained in their model, and mostly internal rather than international. The reason is depressing: "*A decline in agricultural productivity, causing a decline in rural income, seems to have a depressing effect on the possibility of emigration in extremely poor countries where individuals live on subsistence income*". Burzyński et al. (Chapter 39) concur that massive international flows of climate refugees are unlikely, but climate change might displace between 210 and 320 million people, mostly within their own countries.

- Avinash Persaud (Chapter 45) points out that "*in countries on the frontline in the war against climate change, there is a nasty nexus between climate change and debt.*" He suggests breaking this climate–debt nexus by redistributing special drawing rights (SDRs) towards the most vulnerable, recapitalising regional development banks with unused SDRs, and incorporating lending clauses in official lending, which would automatically suspend debt service following a natural disaster.

- Klenert and Hepburn (Chapter 38) start from the observation that the preferred instrument of economists, namely carbon pricing, is politically unpopular. They suggest that lump-sum dividends to citizens may make it more palatable. Furceri et al. (Chapter 44) also focus on the political economy of implementing policies to fight climate change when it is politically costly. To increase popular support, they suggest adopting stricter environmental policies in times of low oil prices, providing social insurance for those adversely affected by climate mitigation, and emission limits or 'feebates', rather than market-based emissions pricing. This last conclusion seems, much to the chagrin of economists, to be widely shared among policymakers and non-economists.

CONCLUSION

The purpose of this collection of articles on climate change, plucked from the recent crop of CEPR/VoxEU material, is threefold. First, it is intended to provide an overview of some of the key issues in climate change from the economist's perspective. Second, it aims to stimulate further research, since the answers to many key questions on global distributional issues are still wide open. Finally, it serves to demonstrate that CEPR is fully engaged with this central debate of our times, and that we will use the power of this network to promote excellent research and relevant policy. We take very seriously the warning from Andrew Oswald and Nicholas Stern (Chapter 1) that opened this collection: "*If we do not move quickly, we think the discipline will be judged harshly by the humans of the future – including by our own offspring.*"

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CHAPTER 1

Why are economists letting down the world on climate change?[1]

Andrew Oswald, Nicholas Stern[2]
University of Warwick; London School of Economics

Action on climate change is arguably the greatest challenge for public policy of our times. But despite economic forces being the major driver of the carbon dioxide problem, this column argues that economists have so far been too silent on the subject. For example, the Quarterly Journal of Economics, the most-cited journal in economics, has never published an article on climate change. Good economics can and should play a fundamental role in guiding the policy framework that will influence investment decisions in the coming years, so it is important that the profession dramatically increases its work now.

We are sorry to say that we think academic economists are letting down the world. Economics has contributed disturbingly little to discussions about climate change. As one example, the *Quarterly Journal of Economics*, which is currently the most-cited journal in the field of economics, has never published an article on climate change.

In this column we give other bibliometric data, for a range of 'general' economics journals, to illustrate what is a major failing of our profession. We propose that some form of intervention is now urgently required – by editors and senior professors – to break out of what appears to be a dismal Nash equilibrium. Otherwise history will judge our profession severely. And unfortunately, it should.

Action on climate change is arguably the greatest challenge for public policy of our times. For at least 50 years (Benton 1970, Madden and Ramanathan 1980), the balance of the scientific evidence has supported the view that the world is warming and that it is because of human activity. Natural scientists have been doing their job.

Now it is predominantly a form of social science problem. Economic forces have largely created the carbon dioxide problem, yet currently our discipline is hardly visible. As we shall show, the published articles in our leading journals are disturbingly few and far between, and nowhere near commensurate with the magnitude of the problem and the

1 This column first appeared on VoxEU 17 September 2019 https://voxeu.org/article/why-are-economists-letting-down-world-climate-change

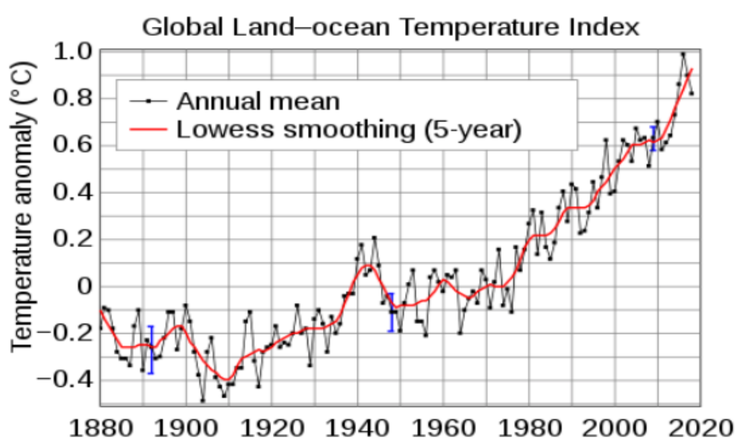
2 Authors' note: The authors write in a personal capacity. They are grateful to Amanda Goodall of Cass Business School for helpful discussions.

potential and necessary contribution of economics. We are sorry to say that we believe economists are failing human civilisation, including their own grandchildren and great-grandchildren.

This is a moment (as we argue in Oswald and Stern 2019) for our discipline to engage in a careful discussion of priorities and what it can contribute. Here we try to summarise a few of the ideas from our longer article.

Atmospheric concentrations of carbon dioxide are now over 400 parts per million (ppm), and the last time that occurred the average global surface temperature was around 3°C above the late 19th century (the usual benchmark). Sea levels were then 10-20 metres higher than now. That was roughly three million years ago; *homo sapiens* has been here for around 250,000 years. Our basic civilisations, with the cultivation of grains and associated human settlements and surpluses, rose during the Holocene period, since the warming after the last ice age, covering roughly the last 10,000 years. That benign period saw, approximately, plus or minus 1°C. We are now, at 1°C, on the edge of that experience. Further, we are adding 2ppm CO_2 per year and thus likely heading for 3°C or more in the next century or so, unless we make radical and rapid change to our processes of production and consumption.

FIGURE 1 TEMPERATURE OVER 140 YEARS



Notes: Global mean surface temperature from 1880 to 2018, relative to the 1951–1980 mean. The black line is the global annual mean, and the red line is the five-year local regression line.

The report of the Intergovernmental Panel on Climate Change of October 2018 showed that the difference in impact between 1.5°C and 2°C was very large. That 0.5°C increase would imply that, for example, the length of droughts would double, the occurrence of extreme weather events would more than double, and all the coral would be gone. That is why the UNFCCC Paris Agreement (COP21) of December 2015 – to which more than 190 countries have subscribed – wisely set the target of holding temperature increases to "well below 2°C" with efforts to hold to 1.5°C.

To have a reasonable chance of holding below 2°C, we have to cut emissions by around 40% absolutely in the next two decades. Much bigger cuts are necessary for 1.5°C.

These simple numbers indicate very clearly the scale and urgency of the necessary change. The investments of the next two decades are decisive for the planet and the future of our children and their children. These investments will be settled by decisions taken in the coming few years. Good economics can and should play a fundamental role in guiding the policy framework that will influence those decisions. That is why it is so important that our profession accelerates its work now.

The required change must be radical but it can deliver, over the next few decades, strong and inclusive growth and poverty reduction. It can boost output (in a demand-constrained world) and sharpen supply in the short to medium term. It is already setting off a wave of Schumpeterian technical progress, which will be powerful over the coming decades. And we know there is no long-run high-carbon growth story. It would self-destruct on the very hostile environment it would create.

None of this can happen without good policy. That is where economics must play its role. In addition, it should be clear that we need analytical contributions from right across our subject. Much of this will be about political will and institutions – political economy is central. And behavioural change is fundamental. Sadly, far too much of the economic modelling has treated the problem in this way. We should not shoehorn the problem into familiar structures just because they are familiar. That approach simply fails to capture the issues at stake. Further, we have to take the ethics and moral philosophy seriously.

We surely have a duty to get involved. At the same time, the issues and analyses are fascinating. It is not just their importance that makes them exciting but also their analytical content. Persuasive evidence on the causal implications of the natural environment for human wellbeing has begun to emerge (e.g. Luechinger 2009, Levinson 2012). There are new ways to put an explicit value on environmental influences. See also, for example, the articles implicitly listed in Table 1, which includes many papers by important contributors such as William Nordhaus and Martin Weitzman, and see too perhaps the recent work of Atkinson et al. (2012), Maddison et al. (2019), Clayborn and Brooks (2019), and Stern (2015, 2018).

TABLE 1 THE PAUCITY OF CLIMATE CHANGE RESEARCH IN MAINSTREAM ECONOMICS JOURNALS

Journal name	Number of articles ever published on climate change
Quarterly Journal of Economics	0
Economic Journal	9
Review of Economic Studies	3
Econometrica	2
American Economic Review	19
Journal of the European Economic Association	8
Economica	4
Journal of Political Economy	9
American Economic Journal - Applied	3

Notes: These are chosen as 'general' economics journals. Total articles by these journals (all topics) = 77,000 approx.

Source: Own calculations using the Web of Science (Clarivate Analytics). Search done in August 2019.

If one looks at the main academic journals of economics, it is hard to avoid the view that economists are letting down the world. Table 1 gives some numbers and has troubling implications. Notably, the *Quarterly Journal of Economics*, currently the most-cited journal in our discipline, has published zero articles. The table also provides data for the *Economic Journal*, the *Journal of Political Economy*, the *Review of Economic Studies*, the *American Economic Review*, *Economica*, *Econometrica*, *American Economic Journal – Applied Economics*, and the *Journal of the European Economic Association*.

For the technical record, we did our search on the Web of Science, beginning with the composite search term "Climate OR Carbon OR Warming", because that is a way to pick up multiple combinations of the key words that might be relevant. Then we went through the list by hand, and thus could excise articles about the climate of industrial relations, warm-glow altruism, and so on. We neglected Presidential Addresses, the AER Papers-and-Proceedings volumes, book reviews, comments, replies, and special issues. It should be emphasised that we did not make these deletions because we view such contributions as of little value. Rather, our aim was to provide a picture of what might be thought of as standard, representative economics as portrayed in the leading journals of our profession.

We would accept that there are likely to be small errors, and occasional debatable aspects, in our classification system. But we hope readers might agree that these are unlikely to matter for the thrust of our current argument.

This lack of research on climate-change issues by economists and social scientists was pointed out in a more general way a decade ago in an article by Goodall (2008). Goodall and Oswald (2019) make the related point that since the year 2000, the 50 journals that count towards the FT Research Rank list have published only 11 articles on species decline and bioversity (out of 47,000 articles).

We suspect that modern economics is stuck in a kind of Nash equilibrium. Academic economists are obsessed with publishing per se and with pleasing potential referees. The reason there are few economists who write climate change articles, we think, is because other economists do not write climate change articles.

IN CONCLUSION

It is time for our profession to live up to its responsibilities. Economists have been too silent on the greatest problem of our age. If we do not move quickly, we think the discipline will be judged harshly by the humans of the future – including by our own offspring.

We need to break out of the dismal prevailing Nash equilibrium. Action by the editors of journals and senior professors in our universities is required. New incentives are needed. Now, not tomorrow.

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Nicholas Stern is the IG Patel Professor of Economics and Government and Chairman of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics. He was President of the British Academy (from July 2013-2017) and was elected Fellow of the Royal Society (June 2014). Professor Stern has held academic appointments in the UK at Oxford, Warwick and the LSE and abroad including at the Massachusetts Institute of Technology, the Ecole Polytechnique and the Collège de France in Paris, the Indian Statistical Institute in Bangalore and Delhi, and the People's University of China in Beijing. He has been a crossbench member of the House of Lords since 2007.

He was Chief Economist of the European Bank for Reconstruction and Development, 1994-1999, and Chief Economist and Senior Vice President at the World Bank, 2000-2003. He was Head of the UK Government Economic Service (2003-2007), Second Permanent Secretary to Her Majesty's Treasury (2003-2005). He also produced the landmark Stern Review on the economics of climate change (2005-2007). He has published more than 15 books and 100 articles, including "*Why are We Waiting? The Logic, Urgency and Promise of Tackling Climate Change*" (MIT Press, 2015). A recent book is "*Standing up For a Sustainable World: Voices of Change*" (Edward Elgar, 2020).

PART II

ADVOCATES AND EARLY VOICES

CHAPTER 2

Climate Change, ethics and the economics of the global deal[1]

Nicholas Stern
London School of Economics

Targets and trading must be at the heart of a global agreement to reduce greenhouse gas emissions, according to Sir Nicholas Stern delivering the Royal Economic Society's 2007 annual public lecture today, ahead of next week's world summit on climate change in Bali.

The problem of climate change involves a fundamental failure of markets: those who damage others by emitting greenhouse gases generally do not pay. Climate change is a result of the greatest market failure the world has seen. The evidence on the seriousness of the risks from inaction or delayed action is now overwhelming. We risk damages on a scale larger than the two world wars of the last century. The problem is global and the response must be a collaboration on a global scale.

Rich countries must lead the way in taking action. That means adopting ambitious emissions reduction targets; encouraging effective market mechanisms; supporting programmes to combat deforestation; promoting rapid technological progress to mitigate the effects of climate change; and honouring their aid commitments to the developing world.

Next week the world gathers at Bali for the meeting of the Conference of the Parties of the United Nations Framework Convention on Climate Change. In thinking about global action to reduce greenhouse gas emissions, we must invoke three basic criteria:

- Effectiveness: the scale must be commensurate with the challenge – which means setting a stability target (or its equivalent in terms of an emissions reduction path) that can keep the risks at acceptable levels.
- Efficiency: we must keep down the costs of emissions reduction, using prices or taxes wherever possible.
- Equity: the problem is deeply inequitable with the rich countries having caused the bulk of current stocks of greenhouse gases and the poor countries being hit earliest and hardest – which means that the rich countries must take the lead.

1 This column first appeared on VoxEU 30 November 2007 https://voxeu.org/article/climate-change-ethics-and-economics

What should the main elements of a global deal look like, what sort of a deal should it be, and how should it be built and sustained? My proposal is for a six-point programme with two groups of elements, the first three concerning targets and trading:

- First, the overall targets of 50% reductions in global emissions by 2050 (relative to 1990) agreed at the G8/G5 summit in Heiligendamm in June this year are essential if we are to have a reasonable chance of keeping temperature increases below 2 or 3°C. While these targets involve strong action, they are not over-ambitious relative to the risks of failing to achieve them. Fixed quantity targets are crucial for the management of risk. Within these global targets, even a minimal view of equity demands that the rich countries' reductions (direct or purchased) should be at least 80%.
- Second, there should be substantial trade between countries, including rich and poor countries, in greenhouse gas emissions. This will promote efficiency – in other words, the cheapest ways of achieving cost reductions. At the same time, the flow to poor countries will help them cover their costs of greenhouse gas reduction, thereby giving them an incentive to join a global deal. Trade in emissions reduction has a double benefit: efficiency and glue for a global deal.
- Third, there should be a major reform of the Clean Development Mechanism, a Kyoto mechanism that allows developing countries to sell emission reductions, but does not penalise them for emissions themselves (a 'one-sided' trade mechanism). This is much too cumbersome for the scale required and omits key technologies. In the next stage, its successor should be based on sector and technological benchmarks against which reductions can be measured. In this way, it can move to 'wholesale' and build confidence in a flow of private sector finance to developing countries to help build low-carbon economies that can grow strongly. Demonstrating the viability of these flows is crucial to any acceptance, eventually, of overall targets by developing countries.

The second group of proposals for the global deal involves public funding:

- Fourth, there should be a coherent, integrated international programme to combat deforestation, which contributes 15-20% of greenhouse gas emissions. For $10-15 billion per year, a programme could be constructed that could stop up to half the deforestation.
- Fifth, there needs to be promotion of rapid technological advance for mitigation. The development of technologies must be accelerated and methods found to promote their sharing. Carbon capture and storage (CCS) for coal is particularly urgent since coal-fired electric power is currently the dominant technology round the world and emerging nations will be investing heavily in these technologies. For $5 billion a year, in terms of feed-in tariffs (which could be reduced as carbon prices

rise), it should be possible to create 30 commercial scale coal-fired CCS stations within seven or eight years. Unless the rich world demonstrates, and quickly, that CCS works, developing countries cannot be expected to commit to this technology.

- Sixth, rich countries should honour their commitments to 0.7% of GDP in aid by 2015. This would yield increases in flows of $150-200 billion per year. The extra costs developing countries face as a result of climate change are likely to be upwards of $80 billion per year and it is vital that extra resources are available for new initiatives. Adaptation to a changing climate is part of good development and is not separate from it.

This programme is one that can be built if rich countries take a lead in Bali on their targets, the promotion of trading mechanisms and funding for deforestation and technology.

Within different countries, there will be different choices of instruments – such as taxes, trading and standards – and different technological mixes. In all countries, there is scope for energy efficiency, which both reduces emissions and saves money. But trading must be a central part of the story because it can provide the international incentives for participation, and promote efficiency and equity, while controlling quantities of emissions.

With leadership and the right incentives on carbon finance and technologies, developing countries will join. The starting point is deeply inequitable, and developing countries feel this inequity very strongly. Poor countries will be hit earliest and hardest by climate change, but rich countries have created the bulk of past emissions and thus the stock of greenhouse gases. Currently US emissions are more than 20 tonnes of CO_2 equivalent per annum, Europe 10-15 tonnes, China 5 or more tonnes, India around 1 and most of Africa much less than 1.

For a 50% reduction in global emissions by 2050, the world average per capita must drop from 7 tonnes to 2-3 tonnes. An 80% target for rich countries would bring equality of only the flow of emissions around the 2-3 tonnes per capita level. In fact, they will have consumed the big majority of the "available space in the atmosphere". Notwithstanding this great inequity, developing countries know they must be strongly involved in global action.

The building of the deal and its enforcement will come from the willing participation of countries driven by the understanding of the people that action is vital. It will not be a "wait-and-see" game as in World Trade Organisation talks, where nothing is done until everything is settled. The necessary commitments are increasingly being demonstrated by political action and elections around the world. A clear idea of where we are going as a world will make action at the individual, community and country level much easier and more coherent.

These commitments must, of course, be translated into action. There is a solution in our hands. It will not be easy to build. But the alternative is too destructive to accept. Bali is an opportunity to draw the outline of the common understanding or framework, which will both guide action now, and build towards the deal.

The last few years have seen a deepening understanding of:

- Climate change and particularly the risks the world faces – see the fourth assessment report of the International Panel on Climate Change published this year, and summary document two weeks ago.
- The challenges of adaptation that the developing world faces – see the United Nations Human Development Report published this week.
- The scale of the response required in terms of reductions of greenhouse gas emissions and the economic and technological instruments that can support and drive these reductions – see the Stern Review on the economics of climate change.
- Business too is becoming clear about what is necessary, as demonstrated in this week's publication on climate change from the UK's Confederation of British Industry.

This understanding is increasingly reflected in public demand for responsible action and in country after country, this is being demonstrated in the political and electoral processes. It is public demand that will promote and sustain action at the individual, community, national and international levels.

This is a problem that is global in its origins and global in its impacts. Action is urgent if we are to avoid the stocks of greenhouse gases building to levels that involve unacceptable risks. Because this is a flow-stock process – we can control only the flows of greenhouse gases and once the stocks are there, they are very difficult to remove – any delay will build up stocks making subsequent action to stabilise at acceptable levels much more costly.

Price mechanisms for greenhouse gases will be central to correcting the market failure, but the urgency and risk of the problem and inertia in behaviour imply that policy must go further. This means bringing forward technologies, deepening an understanding of what responsible behaviour means, overcoming other market failures that inhibit energy efficiency and innovation, and combating deforestation. We now have fairly clear idea of what to do and how to do it.

My six-point programme satisfies the requirements of effectiveness, efficiency and equity. It would allow all countries of the world to pursue their development aspirations via low-carbon growth. The necessary greenhouse gas reductions would cost around 1% of world GDP per annum over coming decades.

These costs are fairly modest relative to world wage differentials and medium-term exchange rate movements. For the most part, they do not raise serious issues of competitiveness; where they do they can be handled directly. On the other hand, new technologies can create great opportunities and provide impetus for new growth. Low-carbon growth is the growth strategy. Weak action will eventually stifle growth.

The costs of action are a small price to pay for the grave risks it would avert. The world would thereby greatly reduce the additional future expenditures necessary on adaptation, although substantial extra expenditure in both rich and poor countries would be unavoidable.

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Nicholas Stern is the IG Patel Professor of Economics and Government and Chairman of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics. He was President of the British Academy (from July 2013-2017), and was elected Fellow of the Royal Society (June 2014). Professor Stern has held academic appointments in the UK at Oxford, Warwick and the LSE and abroad including at the Massachusetts Institute of Technology, the Ecole Polytechnique and the Collège de France in Paris, the Indian Statistical Institute in Bangalore and Delhi, and the People's University of China in Beijing. He has been a crossbench member of the House of Lords since 2007.

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CHAPTER 3

Climate economics[1]

Geoffrey Heal
Columbia Business School

One the world's leading environmental economists argues that the economic case for prompt and powerful measures to mitigate climate changes is overwhelming once discounting and equity concerns are properly modelled.

While the science of climate change is settled, there is still some dispute about climate economics. The UK Government's Stern Review caused a furore: it argued, contrary to prior conventional wisdom, that there is an economic case for prompt and powerful measures to mitigate changes in climate. This led to extensive sparring between the two camps. Here I want to review the recent debate and try to indicate where the argument is going. The debate revolves around three predictable topics: the choice of a discount rate, the weight one places on equity, and the measurement of the costs of climate change.[2]

THE DISCOUNT RATE

The discount rate matters because of the timescale: even if the benefits of stopping climate change were to massively outweigh the costs, the fact that they occur many decades from now, while the cost start now, might mean that in present value terms the costs are greater. There are two discount rates that are relevant in any long-term economic analysis, the pure rate of time preference (PRTP) and the consumption discount rate (CDR). The former is the rate at which we discriminate against future people just because they are in the future. Ethically I regard discrimination against the future as indefensible, as do most economic theorists and philosophers, and so I take the PRTP to be zero. So does Stern, though most of his adversaries pick a much higher rate. The CDR is the rate of change of the valuation of an increment of consumption, and depends on the rate at which consumption is rising (or falling) and the rate at which the valuation of an increment of consumption declines with increasing consumption.

There has been a lot of discussion of the fact that the CDR, under certain assumptions, is equal to the return on capital: if this were so then it would help us to get some idea of the right value for the CDR. But the assumptions needed here are too strong to be palatable:

1 This column first appeared on VoxEU 9 June 2008 https://voxeu.org/article/climate-change-economics
2 I am not mentioning how one deals with uncertainty, which is another and rather technical topic. See Heal (2008).

- no external effects – an odd assumption in the context of climate change which Stern rightly called "the greatest external effect in history",
- perfect foresight in capital markets – also odd at a time of financial crisis arising precisely from lack of foresight, and
- a single homogeneous consumption good.

The relevance of the first two to an analysis of climate economics is clearly questionable. The real issue behind the third is that in the face of climate change the levels of consumption of different goods may move in different ways. Goods that depend on the productivity and health of the natural environment – ecosystem services, agriculture, recreation – will fall in availability, so consumption will decline. But produced goods that do not use nature as an input will continue to be abundant. So different types of consumption will move in different ways, meaning that we cannot work with aggregative one-good models.

The bottom line: the PRTP should be zero, and if we recognize that there are many different types of goods whose consumption trends are different, then there will be as many different CDRs, none of which will equal a return on investment even with heroic assumptions about external effects and perfect foresight. They will depend on how fast the valuations of various different goods fall with respect to their own consumption levels and with respect to those of other goods. Here it will matter, for example, whether non-environmental and environmental goods are complements or substitutes.

EQUITY AND CLIMATE CHANGE

Let's talk about equity and climate change. There are two ways in which they are connected. Suppose the marginal utility of consumption falls more rapidly, so that we place more weight on equity. If consumption is growing over time, then this means that the marginal utility of future generations falls more rapidly and therefore we are less concerned about benefits or costs to future generations. We place less value on stopping climate change. A stronger preference for equality leads to a less aggressive position on the need for action on climate change.

There is a second offsetting effect, not visible in an aggregative model. Climate change is an external effect imposed to a significant degree by rich countries on poor countries. The great majority of the greenhouse gases currently in the atmosphere were put there by the rich countries, and the biggest losers will be the poor countries - though the rich will certainly lose as well. Because of this, a stronger preference for equality will make us more concerned about taking action to reduce climate change.

So the impact of a stronger preference for equity on our attitude towards climate change is ambiguous, with two offsetting effects. Current models capture only the first of these.

COSTS AND BENEFITS OF MITIGATING CLIMATE CHANGE

Finally, the costs and benefits of mitigating climate change. On the cost side, there is not a lot of disagreement: the latest IPCC report estimates the cost of keeping CO2 equivalent concentrations below about 450 parts per million (ppm) as less than 3% of world GDP by 2030 and less than 5.5% by 2050. The Stern Review estimates the costs of keeping these concentrations at less than 500-550 ppm as being within the range -1% to +3%, with a best estimate of 1%. And a recent McKinsey Global Institute study finds numbers that are consistent with 1-2% of GDP. So it's reasonable to assume that we can solve the problem for 1 or 2% of national income.

On the costs of climate change, which double as the benefits of stopping climate change, there is more of a range. Most of the integrated assessment models suggest costs of climate change of the order of 1-2% of national income. Stern suggests a larger number, at least 5% and possibly as much as 20%. His numbers are the annualized costs of climate change. I am inclined to think that Stern is much nearer the mark: it is impossible to read the IPCC reports and believe that the consequences of climate change along the business as usual (BAU) path are only 1 or 2 percent of national income. 1% is almost within the margin of accounting error, and the IPCC certainly gives the impression that climate change will have a far-reaching impact on many human activities, which is not consistent with so small a value. Recent work by Hanemann, Fisher and Schlenker (2006) suggests that climate change under the BAU scenario will have a dire impact on US agriculture, reducing the value of output by as much as 70% by the end of the century. Cline [2007] also suggests that climate change will have a severe harmful impact on agricultural output in many countries[3]. And while agricultural output accounts for only a small fraction of GDP in the US, if food were to become scarce it is clear that prices would rise to the point where this could change drastically. Our current spending on food greatly understates our willingness-to-pay for food.

The Stern Review presents 5% of GDP as the lower bound for the cost of climate change under the BAU scenario, noting that "The estimated damages would be much higher if non-market impacts, the possibility of greater climate sensitivity, and distributional issues were taken into account." So the Review leaves out any impact not reflected in market transactions, assumes a rather conservative value for the key climate sensitivity parameter, and does not take in to account the fact that many of the costs of climate change will fall most heavily on the poor. Stern has emphasized that if he and his team were to rewrite the Review today, given what we have already learned about the impacts of climate change since its publication, their estimates of the cost of climate change would be larger.

3 A recent paper by Guiteras (2007) looks at the impact of climate change on Indian agriculture and predicts significant loss of output.

It is easy to see the kinds of issues omitted by not considering non-market effects of climate change. The IPCC estimates that about one third of all species could be driven to extinction along a BAU scenario. This would be a radical transformation and impoverishment of our biological environment, with far-reaching implications for the flow of ecosystem services to human societies as well as major ethical implications. Do we have the right to condemn to extinction many of the species with which we share the planet? For many people it is one of the most important issues associated with climate change.

Where does this leave us? With a zero PRTP, a concern for equity properly modelled, and estimates of the costs of climate change that are anywhere in the range suggested by Stern, the economic case for prompt and powerful measures to mitigate changes in climate is overwhelming.

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CHAPTER 4

Climate change negotiations: Time to reconsider[1]

Jean Tirole

Toulouse School of Economics, Jean-Jacques Laffont Foundation, and CEPR

The Copenhagen Summit could be crucial for the future of climate change. This column says negotiators should aim to agree on a global emissions target for 2050, the rapid deployment of a satellite system to measure country emissions, a worldwide cap-and-trade system, governance providing incentives to join the agreement, and a subsidiarity principle with permits allocated domestically by the countries themselves. The negotiation for 2015 could then focus on the worldwide allocation of free permits.

The Copenhagen Summit in December will be crucial for the future of the fight against climate change. The outcome, in a nutshell, will be "too little, too expensive".

The Kyoto Protocol was symbolically an important step, but it failed to deliver a major effort toward greenhouse gas reductions. In the absence of a new mindset, the Copenhagen Protocol will bring us eleven more years of the same waiting game. Countries will continue free-riding. They will also realise that staying carbon-intensive will put them in a strong position to demand compensation to join an agreement in 2020.

Of course, there will be some progress. Carbon permits markets exist or will be created in Europe, the US, and Japan. Emerging economies are taking some action as well. A mixture of collateral damages (the emission of SO_2, a local pollutant, jointly with that of CO_2 by coal plants), the direct impact of own CO_2 pollution for large countries like China, and the desire to placate domestic opinion and avoid international pressure will all lead to some carbon control. But not enough. The countries' reluctance to enter binding agreements is telling.

The outcome of Copenhagen will also be too expensive, as the inefficient patches (sectoral negotiations, standards and other command-and-control approaches, clean development mechanism), to which both industrial lobbies and Kyoto have made us accustomed, will keep being used to address global warming.

1 This column first appeared on VoxEU 16 November 2009 https://voxeu.org/article/climate-change-negotiations-time-reconsider

Reaching a satisfactory international agreement will not be a piece of cake. Even so, it is striking how little progress has been made since Kyoto. The negotiation has failed to address the compensation issue head-on. The G77 proposal asking developed countries to make a financial transfer of up to 1% of their GDP (and to commit unilaterally to stricter abatement targets) has the merit of putting the compensation issue on the negotiating table, but it fails to defend the interests of emerging countries. Rich countries did not abide by their development aid and AIDS promises. Any plan to increase financial transfers will have to confront the publics' low tolerance for financial transfers to foreign countries and looming financial tightening.

Economists almost unanimously recommend that the price of carbon be the same for all countries, all sectors and all actors; distributional issues need to be taken care of, as they always have been, through the allocation of permits, not by making abatement overly expensive. Simple? Perhaps, but why make things simple when one can make them complicated?

What steps should negotiators be seeking in Copenhagen instead? They should aim to agree on some early actions and on some broad principles, and a negotiation timetable toward an agreement in 2015-2016:

- a global emissions target for 2050 in conformity with the IPCC's consensus view,
- the rapid deployment of a satellite system able to measure country-level emissions,
- a long-term, worldwide cap-and-trade type system, leading to a unique carbon price and therefore consistent with the minimisation of the abatement cost; this system would make the agreement sustainable and would provide long-term visibility for those who hesitate to deploy green equipments or to engage in green R&D;
- governance providing incentives to join the agreement (including the eventual demise of the clean development mechanism) and to abide by it: for example, by treatment of countries' resulting environmental debts as sovereign debt (monitored by the IMF), a global trade-environment deal (involving the WTO), partial withholding of permits awarded to countries, naming & shaming, and other possibilities;
- a subsidiarity principle, with permits allocated domestically by the countries themselves, on the grounds that a) to be on board, governments must be able to build a consensus at home, and b) only a country's global greenhouse gas emissions matter to the international community and so domestic policies can be delegated to countries, which will be made accountable for their emissions.

The negotiation for 2015 would then focus on a single dimension; the allocation of free permits to countries so as to get everyone on board; this would involve for example a generous allocation to emerging countries. Complex as it is, the negotiation would still be simpler than the multi-dimensional one that we are engaged in; it would also lower substantially the global cost of abatement. In the current situation, reaffirming and committing to good governance would be a significant step forward.

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He has published over 200 professional articles in economics and finance, as well as 12 books including *The Theory of Industrial Organisation*, *The Theory of Corporate Finance*, *Game Theory* (with Drew Fudenberg), *A Theory of Incentives in Procurement and Regulation* (with Jean-Jacques Laffont), *The Prudential Regulation of Banks* (with Mathias Dewatripont), Competition in Telecommunications (with Jean-Jacques Laffont) and the wide-audience book Economics for the Common Good.

CHAPTER 5

Climate change and developing country growth[1]

Michael Spence
Stanford University, Hoover Institution

In fifty years, 3.4 billion people in developing countries will approach advanced country income levels with consumption, energy use, and emissions patterns to match. In this column, Nobel Laureate Michael Spence argues that advanced countries should lead the way with technology and a global strategy to reduce the carbon intensity of their economies. That will lay the groundwork for developing economies to follow a sustainable path as they graduate to higher income levels.

The climate change debate is extraordinarily complex because the issue is. Most agree that there remains considerable uncertainty about long-term temperature shifts.

- Some claim it is not a demonstrated problem.
- The majority at this point are convinced there is a significant fat-tailed risk down the road (time horizon on the order of 50 to 75 years) and that we should "buy" insurance by planning to reduce carbon emissions now. The questions are how much and who pays.
- Still others believe the time horizons are shorter and that adaptation rather than mitigation should be the central focus.

The attention devoted to adaptation is entirely justified. There is a different but important tail risk here. In addition, mitigation and adaptation are connected. Adaptation options and costs are crucial inputs to proper mitigation benefit calculations. But for this column, I focus on mitigation.

1 This column first appeared on VoxEU 11 September 2009 https://voxeu.org/article/climate-change-and-developing-country-growth

BASIC CARBON FACTS

On the mitigation/insurance strategy, the world is trying to figure out by how much emissions should come down, on what time path, who should do it, and how the costs should be absorbed. What exactly should be the practical content of respecting principle of "common but differentiated responsibilities," embodied in the United Nations Framework?

The developing countries are an increasingly important part of the picture because of their growth. In the future, they will be a dominant influence. Currently, developing country per capita emissions are low but their populations are large. Their aggregate emissions are high and rising.

Global emissions are now about 31 billion tons of CO_2 per year, about twice the IPCC safe level. Of that total:

- 21% is North America (with per capita output of 20 tons);
- 23% is the rest of the advanced countries (with per capita emissions of 11 tons), and
- The remaining 46% is the developing world with 5.4 billion people.
- Developing world per capita output is just over 3 tons per person; the corresponding figure for advanced countries is close to 14 tons per person.

These differences are important. Energy consumption and carbon emissions increase with income.

THE HIGH-GROWTH DEVELOPING WORLD CHALLENGE

The high-growth part of the developing world accounts for about 3.4 billion people. On a 50 year time horizon, they will achieve or come close to advanced country income levels with consumption, energy use, and emissions patterns to match. Added to the current advanced country population of 1 billion, there will be on the order of 4.4 billion people (out of a global population of 6.5 billion) with energy use and emissions patterns like the US, Europe, and Japan.

Without a global mitigation strategy and even if the high-growth developing countries hit the current "European" per capita emission levels (as opposed to the higher North American ones), global emissions will almost double over 50 years to about 58 billion tons a year; per capita emissions will go from the current 4.8 tons to about 8.7 tons per person. Almost all of the increment is associated with developing country growth. This path would be extraordinarily risky and is unlikely to be the path we take.

DELAYED GROWTH: AN UGLY STALEMATE

If developing countries were to agree to cap their emissions at current levels or even some other relatively low number, their growth would be negligible or delayed by several decades while the technology to make possible the achievement of advanced country incomes with much lower energy consumption and carbon emissions is developed. Going down this path is likely to result in an ugly stalemate with delayed progress, and the real risk of the negative fallout for the openness of the global economy.1[2] Even if advanced countries absorb most of the mitigation costs in developing countries, energy consumption and emissions will rise for some time. That does not mean that the game is lost, but rather that it will take time and persistence to get there.

So we have two broad sets of forces at work globally.

- Growth in countries (with over 3 billion people) that are still relatively poor will raise energy consumption and emissions.
- Incentives, the rising marginal cost of energy augmented by the declining cost of alternatives, technology and public policy to support the latter, and aggressive advanced country programs to reduce the carbon intensity of their economies will alter the technological base and reduce the carbon intensity of economies at all levels of per capita income (first in the advanced countries and with a lag in the developing world).

In the short run, the first will dominate.

On a 50 year time horizon, a substantial fraction of the high growth developing world will have graduated to advanced country status. At that point whenever it occurs, they will need to line up with the then prevailing norms for advanced countries. In addition, anticipating that transition, developing countries will be absorbing the energy- and carbon-reducing technology on the way. That will not impede their growth, but it will slow the rate of increase of their emissions. What impedes (and creates risk to) growth is capping emissions now with current technology.

A reasonable depiction of the time path of per capita and global emissions is shown in Figures 1 and 2.

2 The Waxman-Markey bill in the version that passed the house is complex and has many positive features but includes a provision for tariffs based on carbon emissions.

FIGURE 1 PER CAPITA EMISSION ON PATH TO SAFE TARGET

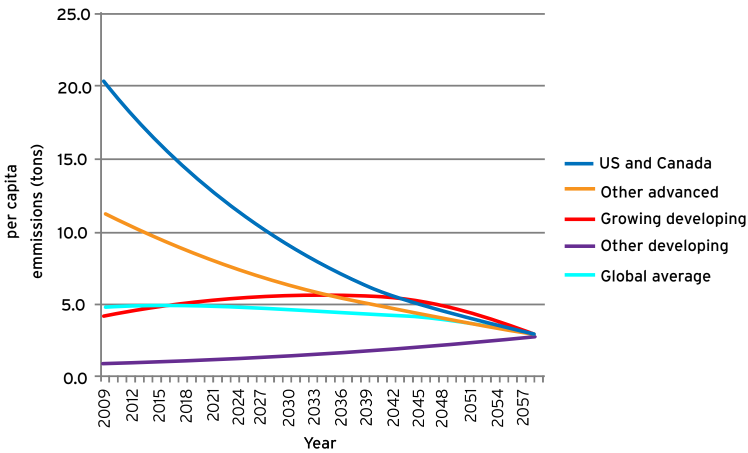
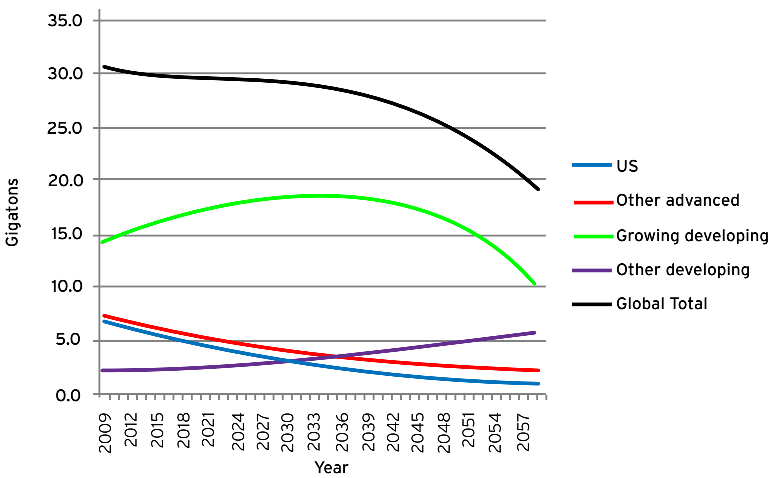


FIGURE 2 TOTAL EMISSIONS



All this is intertemporally complex. And the numbers are daunting. Currently in the advanced countries, a ton of CO_2 emissions is the by-product of generating 2000 to 3000 dollars of income. To get into the neighbourhood of the safe level globally of 2.3 tons per person, that inverted carbon intensity number of 2-3 thousand, has to go to around 11,000 dollars of income per ton of CO_2. It is a huge change.

ADVANCED COUNTRIES HAVE TO GET THERE FIRST

There is an important point of agreement that serves as a guide to creating a viable framework. It is that the advanced countries have to get there or no one else will be able to do so. They will have the lead in technology. For a considerable period of time, they will also have higher emissions per capita, but the emissions will be coming down. The developing countries will experience rising energy consumption and carbon emissions and start to catch up. But in the coming decades, they will absorb (and help develop) technology that will dampen their emissions growth and eventually decrease emissions as they line up with the advanced countries and approach that status themselves.

Something like this pattern will accommodate developing country growth and has a reasonable chance of approaching the long-run global emissions targets.

WHAT ARE THE KEY INGREDIENTS IN A RECIPE THAT GETS US THERE?

We are at the start of a long process and don't know how things will evolve four and five decades out, with respect to population, technology, and other factors. There will be many iterations. Persistence will have a high payoff, and we will learn much as we go along. The challenge now is to head in the right direction with a viable framework and not get hung up arguing about the precision of estimates five decades from now. If we get started in the right direction, I would expect there to be many midcourse corrections on the way, as we go through the collective sequential decision making process with learning.

In a recent paper, I picked a global, 50-year target of 3 tons per person not because it was the right number but because it would cause movement in the right direction in the early decades and if achieved would substantially reduce risk.

Advanced countries (with due recognition given to quite different starting points in per capita terms) take the lead and set medium-term targets or strong incentives for energy efficiency and reduced carbon emissions. The goal would be to decrease emissions at a rate of 2% to 4% per year, depending on the per capita levels at the start.

As soon as possible, the targets and incentives system should be augmented (and partly replaced) by an advanced country global carbon credit system (sometimes unfortunately referred to as "cap and trade" – caps are OK for advanced countries but not developing countries), with entitlements based on population and with properly calculated adjustments for climate and size and other factors. A global price of carbon (the time-dated marginal cost of mitigation) is an important informational tool for investors and an efficiency-enhancing underpinning for a cross-border, international offset or CDM-like mechanism.

An increasingly effective cross-border mechanism is crucial, along with a supporting monitoring and accounting system. This allows mitigation to be credited to the entity (and eventually the country) that pays for it rather than to the country in which it occurs. It is a crucial part of achieving both efficiency (lowest possible cost) mitigation and equity or burden sharing (a pattern of cost absorption that allows developing countries to grow and reduce poverty). There are cases in which cross-border mitigation may distort the incentives within developing countries with respect to their own emissions trajectories. These need to be identified and addressed separately.

Developing countries should plan for and expect energy demand and emissions to grow along with growth, but as little as possible. A focus on energy efficiency, including removing widespread historical energy subsidies, is pro-growth and low-carbon friendly. A second and related priority for developing countries is inbound technology transfer that enables growth with a relatively and increasingly low-energy and low-carbon profile over time.

In addition, developing countries have to participate actively in the creation and implementation of the monitoring system and the cross-border mechanism. Mitigation must occur in developing countries. This is generally described as an issue of efficiency. It is that. But it is more than that. As we progress, advanced country targets or their embodiment in a carbon credit system probably cannot be met without cross-border mitigation, and certainly not at an economically and politically acceptable cost.

GRADUATION TO ADVANCED COUNTRY STATUS

Finally, developing countries need to agree to graduate to advanced country status and responsibilities. The criterion for graduation is an important current element of negotiation. It has to be fair, not terribly high-risk for developing countries, and create the right incentives. I favour a criterion based on gross or net emissions per capita reaching the advanced country average. These have the advantage of creating incentives for low-carbon growth paths and the latter also adds an incentive to be an active supporter of the cross-border system. One can argue that for risk-mitigation purposes, a minimum per capita income threshold should be met as well, though this may somewhat reduce the incentive for a low-carbon growth path.

OFFSHORING OF CARBON-INTENSIVE PRODUCTION

There is a related and legitimate concern. A global strategy that allows for developing country growth embodies asymmetries in the roles and incentives for different groups of countries. As a result, it runs the risk of distorting certain kinds of incentives. Of these risks, a potentially serious one is an incentive for high-energy, high-carbon industries that produce tradables to migrate to developing countries. Offshoring of these industries will produce local but not global mitigation. It is not clear how great the risk is empirically. Countervailing forces include transport costs, local environmental regulation, and the anticipation of graduation later. Nevertheless, attention to the potential problem is warranted.

To eliminate the distorted incentives, a global agreement to tax the carbon output of these industries regardless of their location would help remove distorted location incentives and under-pricing of the final output. The tax would be levy on final output and be based on carbon content at the then-prevailing global carbon price, or an estimate of it before the global carbon price is established via the trading of carbon credits.

Will this work? An international agreement around a framework like this with-built in asymmetries has a chance of being acceptable, as it allows the developing countries to grow and their citizens to prosper. It defines responsibilities and creates incentives for participants in various classes, and it deals with the timing issues. It recognises that there is much that is not known now that will be learned as we go along.

DEFINING SUCCESS AT COPENHAGEN

There are other dimensions of global strategy not covered here. Advanced countries must deal with their own targets, incentives, entitlements, and related competitive issues. Important estimates of technologies, costs, and timing are being developed to underpin private and public sector investment decisions with respect technology investment and subsidisation. In short, the pieces of the puzzle for the starting point of a potential coordinated global plan are falling into place. This may not all get done in time to wrap it up in Copenhagen in December. But that is not essential. Copenhagen will be a success if we emerge with a shared understanding about most of the pieces of a framework for embarking on viable path. The complex intertemporal piece that involves the developing countries growth and emissions paths is crucial.

In the long run, the truth is that at this stage none of us know whether the last 15% to 30% of the emissions reduction is going to be achievable at a cost that our children and grandchildren are going to be willing to pay. The technological distance between then and now is too great. We will know much more when we or they get closer in time, provided we do what we can now.

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Michael Spence, a Nobel laureate in economics, is Professor of Economics Emeritus and a former dean of the Graduate School of Business at Stanford University. He is Senior Fellow at the Hoover Institution, serves on the Academic Committee at Luohan Academy, and co-chairs the Advisory Board of the Asia Global Institute. He was chairman of the independent Commission on Growth and Development, an international body that from 2006-10 analysed opportunities for global economic growth, and is the author of *The Next Convergence: The Future of Economic Growth in a Multispeed World*.

CHAPTER 6

How to set greenhouse gas emission targets for all countries[1]

Jeffrey Frankel
Harvard Kennedy School

Is a credible multilateral climate change agreement feasible? This column says that such global cooperation is necessary and attempts to address the political hurdles. The proposed emissions reduction plan develops formulas to cap atmospheric concentrations of carbon dioxide at 500 ppm while obeying political constraints regarding cost, fairness, and timing.

The effects of a changing global climate show up gradually, decade by decade. The effects of a changing US political climate have also been showing up gradually, year by year. A watershed was reached June 25, when the US House of Representatives for the first time approved a bill to limit emissions of greenhouse gases, by a vote of 219 to 212. But the Senate hurdle will be tougher. The attempt to address climate change still has a very long way to go.

THE PROBLEM

Climate change is, of course, a global externality. Due to the free-rider problem, no single country, especially the United States, is likely to act on its own. The best solution is a multilateral treaty in which all countries commit to serious action together. In December, a Conference of Parties to the UN Framework Convention on Climate Change will meet in Copenhagen, in the hope of negotiating a successor treaty to the Kyoto Protocol.

Three critical attributes were missing from the Kyoto Protocol. These attributes need to be included in any realistic attempt to reduce greenhouse gas concentrations to levels considered less dangerous by scientists by 2100.

Three critical attributes were missing from the Kyoto Protocol. These attributes need to be included in any realistic attempt to reduce greenhouse gas concentrations to levels considered less dangerous by scientists by 2100.

1 This column first appeared on VoxEU 18 July 2009 https://voxeu.org/article/designing-politically-feasible-multilateral-climate-change-agreement

- Comprehensive participation – that is, acceptance of quantitative limits on emissions – by all major countries, including the US and developing countries.
- A credible framework that can establish a path for emissions reductions extending through the century, not just five years ahead.
- Some reason to think that all countries will be willing to join and then comply. This precludes targets that impose enormous economic costs on any major countries in any decades relative to the alternative of dropping out of the treaty.

For ten years – since I worked on Kyoto in the Clinton Administration – I have been thinking about how to design such a framework for assigning quantitative limits across countries. I now have a complete proposal to offer. It builds on the foundations of Kyoto, in that it accepts the framework of national targets for emissions and internationally tradable permits. But it attempts to solve the most serious deficiencies of that agreement: incomplete country participation, the need for long-term targets, and the economic incentive for countries to fail to abide by their commitments.

Although there are many proposed successors to the Kyoto Protocol, the existing proposals are typically based on just one or two of the following three philosophical approaches:

- science (e.g., capping global concentrations at 450 ppm),
- equity (e.g., equal emissions per capita across countries), or
- economics (weighing the economic costs of aggressive short-term cuts against the long-term environmental benefits).

My emissions reductions plan is a bid to offer a more practical alternative – in addition to those three considerations, it is based heavily on politics. More specifically, any future climate agreement must in practice comply with six important political constraints.

- The US will not commit to quantitative targets if China and other major developing countries do not commit to quantitative targets at the same time, due to concerns about economic competitiveness and carbon leakage.
- China and other developing countries will not make sacrifices different in character from those made by richer countries that have gone before them.
- In the long run, no country can be rewarded for having "ramped up" its emissions high above the levels of 1990.
- No country will agree to participate if the present discounted value of its future expected costs is more than, say, 1% of GDP.
- No country will continue to abide by targets that cost it more than, say, 5% of GDP *in any one budget period.*

- If one major country drops out, others will become discouraged and the system may unravel.

THE PROPOSAL

The proposed plan sets the emissions caps using formulas that assign quantitative emissions limits to countries in every five-year period from now until 2100.[2] Operationally, four political constraints are particularly important in specifying the formulas.

- First, "carbon leakage" is precluded, by including all countries from the beginning
- Yet developing countries are not asked to bear any cost in the early years.
- Even later, developing countries are not asked to make any sacrifice that is different from the earlier sacrifices of industrialised countries, accounting for differences in incomes.
- Finally, no country is asked to accept targets that cost it more than 1% of GDP cumulatively, nor more than 5% of GDP in any given budget period.

Under the formulas, rich nations immediately begin to make emissions cuts in line with targets to which their leaders have already committed (Figure 1). Developing countries *agree to maintain their business-as-usual emissions in the first decades* but over the longer term agree to binding targets that ultimately reduce emissions well below business-as-usual.

This structure precludes energy-intensive industries from moving operations to developing countries (i.e., leakage) and gives industries a more level playing field. However, it still preserves developing countries' ability to grow their economies; they can even raise revenue by selling emission permits. In later decades, the emissions targets for developing countries become stricter, following a numerical formula (Figure 2). However, these emissions cuts are no greater than the cuts made by rich nations earlier in the century, accounting for differences in per-capita income, per-capita emissions, and baseline economic growth.

2 The detailed proposal is "An Elaborated Proposal for Global Climate Policy Architecture: Specific Formulas and Emission Targets for All Countries in All Decades," NBER WP 14876, April 2009. Forthcoming, 2009, in a volume edited by Joe Aldy & Rob Stavins for the Harvard Project on International Climate Agreements, Cambridge University Press. Editors' summary of the volume is at Post-Kyoto International Climate Policy, Cambridge University Press. (See also Stavins' blog, especially, for analysis of the Waxman-Markey bill.)

FIGURE 1 OECD EMISSIONS

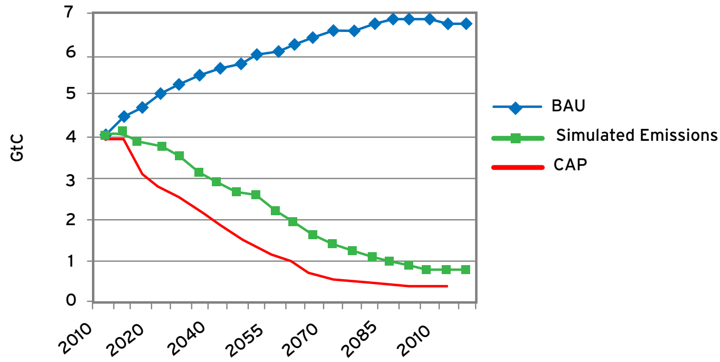
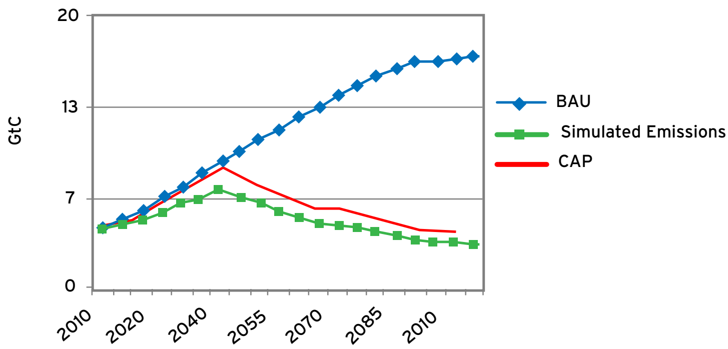


FIGURE 2 NON-OECD EMISSIONS



More specifically, the formula incorporates three elements: a progressive reductions factor, a latecomer catch-up factor, and a gradual equalisation factor.

- The progressive reductions factor requires richer countries to make more severe cuts (relative to their business-as-usual emissions) than poor countries.
- The latecomer catch-up factor requires nations that did not agree to binding targets under Kyoto to make gradual emissions cuts to account for their additional emissions since 1990. This factor prevents latecomers from being rewarded with higher targets or being given incentives to ramp up their emissions before signing the agreement.
- Finally, the gradual equalisation factor addresses the fact that rich countries are responsible for most of the carbon dioxide currently in the atmosphere. During each decade of the second half of the century, this factor moves per capita emissions in each country a small step in the direction of the global average of per capita emissions.

The formulas, for some convenient parameter values, turn out to imply that global emissions peak around 2035 (Figure 3.) This targets result in a world price of carbon dioxide that reaches an estimated $20-$30 per ton in 2020, $100-$160 per ton in 2050, and $700-$800 per ton in 2100, according to economic simulations using the WITCH climate model courtesy of Valentina Bosetti. Most countries sustain economic losses that are under 1% of GDP in the first half of the century, but then rise toward the end of the century. The simulations also show that atmospheric concentrations of CO2 stabilize below 500 ppm in the last quarter of the century, and world temperatures increase by about 3 degrees (Figures 4 and 5). Each of the six political constraints listed above is satisfied.

FIGURE 3 WORLD INDUSTRIAL CARBON EMISSIONS

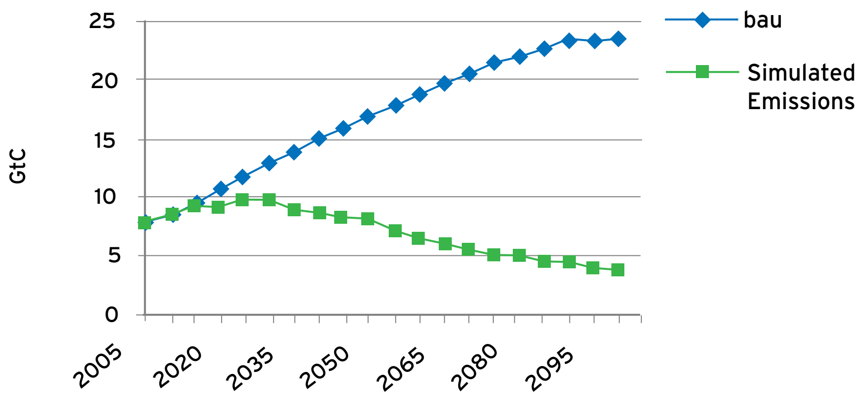


FIGURE 4 ATMOSPHERIC CONCENTRATIONS OF CO2

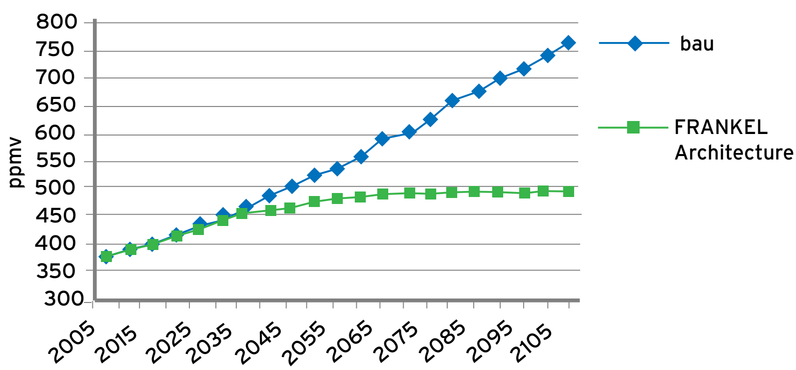
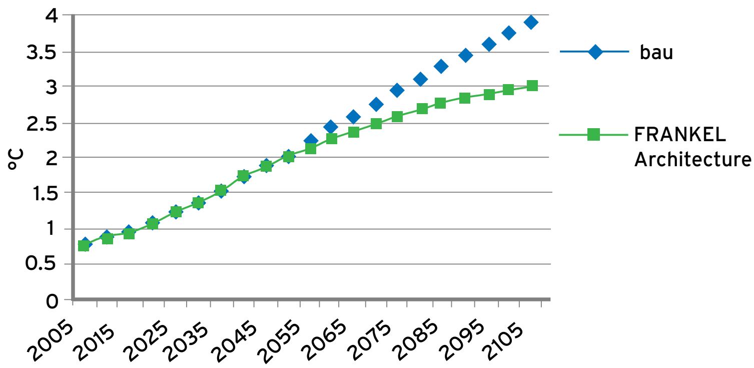


FIGURE 5 WORLD TEMPERATURE INCREASE



CONCLUSION

The framework here allocates emission targets across countries in such a way that every country is given reason to feel that it is only doing its fair share, comparable to what others have done before it. Furthermore, the framework – a decade-by-decade sequence of emission targets determined by a few principles and formulas – is flexible enough that it can accommodate major changes in circumstances during the course of the century. The hope is that only such a combination of continuity and flexibility can make the process dynamically consistent, i.e., credible.

Most climate scientists say that 500 ppm is not a sufficiently aggressive goal. Bosetti and I have not yet been able to achieve year-2100 concentrations of 450 ppm while obeying the same political-economic constraints. But we are still working on it. Stay tuned.

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Jeffrey Frankel is James W. Harpel Professor of Capital Formation and Growth at Harvard Kennedy School. He is a Research Associate of the National Bureau of Economic Research, where he is also co-chairs the International Seminar on Macroeconomics. Professor Frankel served at the US President's Council of Economic Advisers in 1983-84 and 1996-99; he was appointed by Bill Clinton as CEA Member with responsibility for macroeconomics, international economics, and the environment.

Before moving east, he had been Professor of Economics at the University of California, Berkeley, having joined the faculty in 1979. His research interests include currencies, crises, commodities, international finance, monetary and fiscal policy, trade, and global environmental issues. He was born in San Francisco, graduated from Swarthmore College, and received his Economics PhD from MIT.

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CHAPTER 7

Kick-starting the green innovation machine[1]

Reinhilde Veugelers, Philippe Aghion, David Hemous

KU Leuven and CEPR; Collège de France London School of Economics, and CEPR; University of Zurich and CEPR

Mitigating climate change while maintaining economic growth will require a wide portfolio of technologies. This column says too little has been done to turn on the "green innovation machine". It says governments in developed economies should price carbon, subsidise research, and facilitate technology transfer to developing countries.

The reality of climate change is no longer a contentious issue. The debate concerns the growth consequences of climate-change containment. Economists have not tackled this debate very well, largely disregarding the innovation factor by ignoring the fact that the portfolio of technologies available tomorrow to adapt to and mitigate climate change depends on what is done today.

TECHNOLOGY IS THE KEY

Recent economic simulations (e.g. Bosetti et al 2009) suggest that technology will be the key. To keep the costs of mitigation and adaptation manageable while maintaining reasonable economic growth, we need to put into operation a sufficiently wide portfolio of technologies. "Backstop technologies" – those that are zero-emission and not dependent on constrained resources – are particularly important for dealing with the longer-term and worst-case scenarios of climate change. These technologies are not yet available or still far from commercialisation.

Unfortunately, too little has been done so far to turn on the "green innovation machine". In Aghion, Veugelers, and Serre (2009), we take a look at the recent performance of the private green innovation machine. The available empirical evidence is disappointing. Despite a recent spurt, only 2% of total patents applied for worldwide are environment-related (2001-2006). Japan is the clearest positive outlier, holding 35% of all environmental patents; the US accounts for "only" 15%. And when it comes to the diffusion and adoption

1 This column first appeared on VoxEU 9 December 2009 https://voxeu.org/article/kick-starting-green-innovation-machine

of green technologies, little is happening. This is particularly (but not exclusively) true in the field of electricity generation and distribution, the business sector accounting for the highest level of CO_2 emissions.

NEW INSIGHTS FOR THE GREEN POLICY AGENDA

The private green innovation machine is not up to the challenge. It needs government intervention to address a combination of environmental and knowledge externalities. Economists have long emphasised the importance of carbon prices as policy instrument to use. Properly factoring in *directed* technological change, i.e. taking into account that research will be directed to the most profitable projects, delivers new insights for the green policy agenda. Building on an endogenous growth model on innovation and environment developed by Acemoglu, Aghion, Bursztyn, and Hemous (2009), we discuss how government intervention should be designed to effectively turn on the private green innovation machine and, more generally, to fight climate change at the lowest possible cost for growth.

Researchers choosing to direct their innovation activities at improving either clean or dirty technologies will typically target innovation towards the most profitable sector, taking into account the current state of technology in both sectors and government taxes and subsidies. In this directed-innovation perspective, governments need to address not only the standard environmental externality but also imperfections in the research sector, particularly those whereby past advances in old, dirty technologies make future production and innovation in clean sectors relatively less profitable. This introduces a new cost-benefit analysis to policy intervention. The cost of supporting the cleaner technology is slower economic growth while innovation switches from the more technologically advanced dirty sector to the technologically immature clean sector. These costs will be born initially. It will take a certain period before these losses will be recovered through their benefits in the form of higher and cleaner growth, once the clean sector is innovating.

Factoring in directed innovation will change our assessment of

- the costs of delaying policy intervention,
- the optimal mix of policy instruments required for efficiently fighting climate change, and
- the terms of a global policy dialog and coordination between developed and developing countries.

THE COST OF DELAYING POLICY INTERVENTION

Factoring in directed technical change reinforces the case for immediate intervention. Delaying intervention not only leads to further deterioration of the environment, it allows dirty innovation to continue to outpace clean innovation, widening the gap between dirty and clean technology. That lengthens the time required for clean technologies to catch up to and replace dirty technologies. As this catching-up period is characterised by slower growth, the costs of delaying intervention, in terms of foregone growth, will be higher.

Calibrations from the Acemoglu, Aghion, Bursztyn and Hemous (2009) model show the cost of delaying intervention, computed as the "lost" consumption in each period expressed as a percentage of the level of consumption which would result from "best-timed" policy intervention, can amount to 6% for a delay of 10 years and a discount rate of 1%.

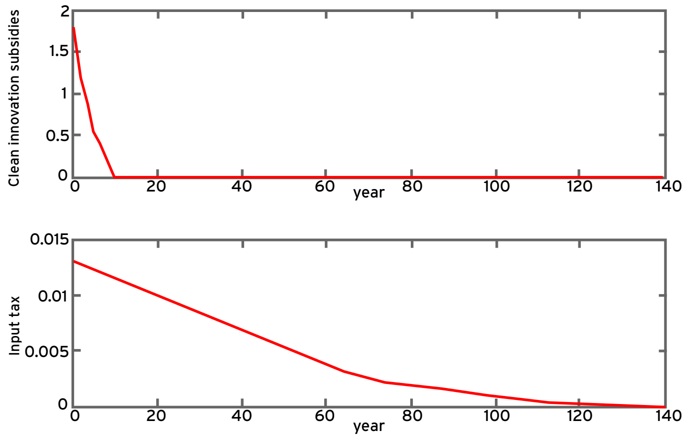
INSTRUMENTS FOR GREEN INTERVENTION: CARBON PRICES AND DIRECTED RESEARCH SUBSIDIES

The Acemoglu, Aghion, Bursztyn and Hemous (2009) model shows that the *optimal* policy involves using (i) a carbon price, an input tax (or cap–and-trade policy), on dirty technologies to deal with the environmental externality; and (ii) direct subsidies to clean R&D (or a profit tax on dirty technologies) to deal with the knowledge externality. Relying on the carbon price alone leads to excessive consumption reduction in the short run and would therefore be a more "costly" policy scenario. And because the two-instrument policy reduces the short-run cost in terms of foregone short-run consumption, it reinforces the case for immediate implementation even for values of the discount rate under which standard models would suggest to delay implementation.

Calibrations show that the cost of using only a carbon tax instead of the combination between a carbon tax and a subsidy to clean R&D, can amount to 1.33% for a discount rate of 1%. This cost is again expressed as the percentage of reduced consumption every period from the optimal policy equivalent.

The good news is that government intervention (pricing carbon and subsidising clean technologies) can be reduced over time. Figure 1 shows that (i) subsidies for new clean technologies should be allocated immediately but can be quickly reduced as soon as innovation has taken off for these technologies and (ii) the carbon price can decrease over time. With the emergence of perfectly clean backstop technologies that have zero emissions and with the innovation gap between clean and dirty technologies eliminated and the stock of past emissions diminishing, the environmental externality gradually disappears, thus reducing the need for a carbon price over time. Unfortunately, totally clean technologies will take time to become available, which in turn implies deferring the phasing out of carbon pricing.

FIGURE 1 PHASING OUT GREEN INTERVENTION



Source: Calibrations from the Acemoglu, Aghion, Bursztyn and Hemous (2009) model.

Note: Results are for a discount rate of 1.5%. Taxes and subsidies are proportional. Scales should be read as follows: for input taxes 0.015 reflects a tax of 1.5% on the price of the dirty input; for subsidies 1.5 reflects a 150% subsidy to profits derived from clean technologies

DEVELOPED COUNTRIES SHOULD SMOOTH ACCESS TO CLEAN TECHNOLOGIES FOR DEVELOPING COUNTRIES

At the heart of the current environmental debate in the run up to Copenhagen is the issue of how to organise the international coordination of policy interventions. What if other countries are not intervening to support a switch to clean technologies? Does it still pay to intervene unilaterally? This holds particularly with respect to the developed countries' commitment being made conditional on the engagement of large emerging countries like China, India, and others.

Factoring in trade introduces a more cautious stance on unilateral climate change actions. In a free trade world, having a country or region adopt unilateral environmental policies by taxing its dirty technologies, might create a pollution haven effect in other countries or regions (de Melo, Grether, and Mathys 2009). We should prevent such perverse effects by making clean technologies available and affordable to all countries worldwide. Once clean technologies are made available to all countries at low cost, carbon tariffs (or the threat of them) may come into play to prevent countries from specialising in large-scale production and export of dirty goods, which would defeat the whole purpose of the unilateral environmental policies.

Developed countries directing their own technical change towards clean technologies and then facilitating the diffusion of new clean technologies would go a long way towards overcoming global climate change. In particular, it may not be necessary to tax dirty input production in the "South" in order to avoid a global environmental disaster; unilateral government intervention in developed countries would turn on the green innovation machine there, which would activate the green "imitation" machine in the "South" to adopt cleaner technologies developed elsewhere. The higher the spillovers from the developed green innovation machine to the developing green imitation machine, the more active the green "imitation" machine in the "South". This makes a case for unilateral policy intervention by the developed countries even if the developing countries will not take any actions, greater technology transfer, and improved absorptive capacity in developing economies.

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ARE GOVERNMENTS CURRENTLY DEPLOYING THE RIGHT POLICIES?

We examine in detail the record of green government policies and conclude that we are still a long way off. Overall, public budgets for climate change R&D are very low, with only a few promising signs coming very recently. These low budgets come on top of the lack of clear long-term consistent price for carbon. Environmental taxes in the EU27 averaged a mere 6.4% of total tax revenues in 2006. In addition, there is high dispersion in the level of carbon taxes across EU countries, thus jeopardising their effectiveness. At EU level, the first phases of the EU's Emissions Trading Scheme have established a carbon market, but the carbon price is low and volatile. The carbon price, as measured on the ECX EUA Futures Contracts, reached their highest level of €32.90 in April 2006 but were only €8.20 in February 2009.

FIGURE 2 THE EU PRICE OF CARBON

Source: ECX Historical Contracts Data (Daily Futures, Futures & Options)

Long-term consistency is particularly important for the carbon price to serve as an incentive for green innovations. The US and other major emitting countries are even further away than the EU from establishing an innovation-inducing carbon price. And the limited evidence available suggests that insufficient action is being taken with regard to technology transfer to developing countries. Although the Clean Development Mechanism framework was designed to trigger technology transfer, only a limited number of these projects in fact involve technology transfer.

Although past evidence on green private R&D and innovations showed low activities and not much dynamics, there seems to be a momentum being created more recently, most clearly observed in the market for clean-tech venture capital. Deloitte's 2009 survey on Global Trends in Venture Capital reports that, despite the crisis, 63% of surveyed venture capitalists anticipate an increase in their investment in clean-tech, the highest percentage among all sectors considered. But as this optimism of venture capitalists seems to be based on anticipated government support for clean-tech, are we merely looking at a bubble that will collapse when governments do not get their green policies right?

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PART III

CARBON PRICING AND CARBON TAXATION

CHAPTER 8

Distributional impacts of carbon pricing: A general equilibrium approach with micro data for households[1]

Sebastian Rausch, Gilbert Metcalf, John Reilly

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Many policy proposals to limit greenhouse-gas emissions revolve around efforts to tax carbon emissions. But many studies point out that such energy taxes are regressive. This column models the distributional impacts of carbon pricing on over 15,000 US households, challenging the view that the policy by itself is regressive.

The distributional impacts of energy and climate policies can be assessed across a number of dimensions. Goulder and Parry (2008) note that two dimensions in particular have attracted attention:

- the impact on energy-intensive industry; and
- the impact across households of differing incomes.

The latter dimension plays a particularly significant role in policy circles given the results from a large number of studies indicating that energy taxes – and by extension carbon pricing policies – are regressive.

Studies that have documented the regressivity of energy taxes include Bull et al. (1994), Metcalf (1999), Dinan and Rogers (2002), West and Williams (2004), and Bento et al. (2009) among others. These various studies make an important set of points, two of which stand out.

- First, how energy tax revenue is used affects the ultimate incidence of the green tax reform.

The incidence of an environmental or energy tax reform can differ significantly from that of the tax considered in isolation. The use of the revenue can undo any regressivity in the environmental or energy tax through a progressive use of funds.

1 This column first appeared on VoxEU 10 June 2011 https://voxeu.org/article/distributional-impacts-carbon-pricing

- Second, regressivity impacts are sensitive to assumptions about whether households are ranked over an annual or lifetime income measure.

Lifetime income measures reduce the regressivity of energy tax and carbon pricing policies as shown by Poterba (1989, 1991), Hassett et al. (2009), and others.

In previous work, we have used a new simulation model of the US economy to explore distributional implications of various ways of distributing allowances from a cap-and-trade system (Rausch et al. 2010a) and alternative schemes for returning revenues from an auctioned cap-and-trade system or equivalently a carbon tax (Rausch et al. 2010b). In a recent study, we have extended the model to endogenously incorporate 15,588 households from the US Consumer and Expenditure Survey within a general equilibrium framework (Rausch et al. 2011). This allows us to explore the distributional impacts of carbon policy over a number of new dimensions that have previously not been explored.

RECENT RESEARCH USING MICRO DATASETS

We consider a climate policy with an equilibrium carbon price of $20 per ton carbon dioxide-equivalent and distinguish three revenue distribution schemes.

- In the first scenario, labelled inctax, revenue from auctioning of permits is used to lower marginal income tax rates to provide efficiency benefits as discussed in a large literature on the Double Dividend (see Goulder 1995 for a description of the literature).
- The second scenario (percapita) distributes the revenue to households on an equal per-capita basis.
- A third scenario (capital) allocates the revenue to households in proportion their capital income approximating the free allocation of permits.

Variation in impacts from carbon pricing arises for three reasons. First, households differ in how they spend their income. Carbon pricing will raise the price of carbon-intensive commodities and disproportionately impact those households who spend big on these commodities. In a general equilibrium setting, carbon pricing also impacts factor prices. Households that rely heavily on income from factors whose factor prices fall will be adversely impacted. In the public finance literature on tax incidence, the first impact is referred to as a “uses-of-income impact” while the latter a “sources-of-income impact” (see, for example, Atkinson and Stiglitz 1980 for a discussion of incidence impacts). Third, regional differences in the composition of energy sources affect the carbon content of various commodities, most notably electricity.

Our analysis shows a number of results.

- First, how proceeds of a carbon pricing policy are used affects both the efficiency and equity of the policy. Using revenues to cut tax rates has beneficial efficiency consequences but can come at the cost of higher regressivity (see Figure 1). Such is the case when comparing a reduction in income tax rates to a uniform lump-sum distribution of revenues. On the other hand, certain distributions have adverse consequences on both efficiency and equity. On these grounds, and abstracting from political economy motives, we cannot find an easy justification for the free distribution of allowances in a cap-and-trade system to industry.

- Second, previous policy analyses have been carried out using models with a single representative agent or a small number of households. This analysis uses a model with a large number of households and therefore provides finer level detail on distributional impacts of various policies.

FIGURE 1 AVERAGE WELFARE IMPACTS BY INCOME GROUP

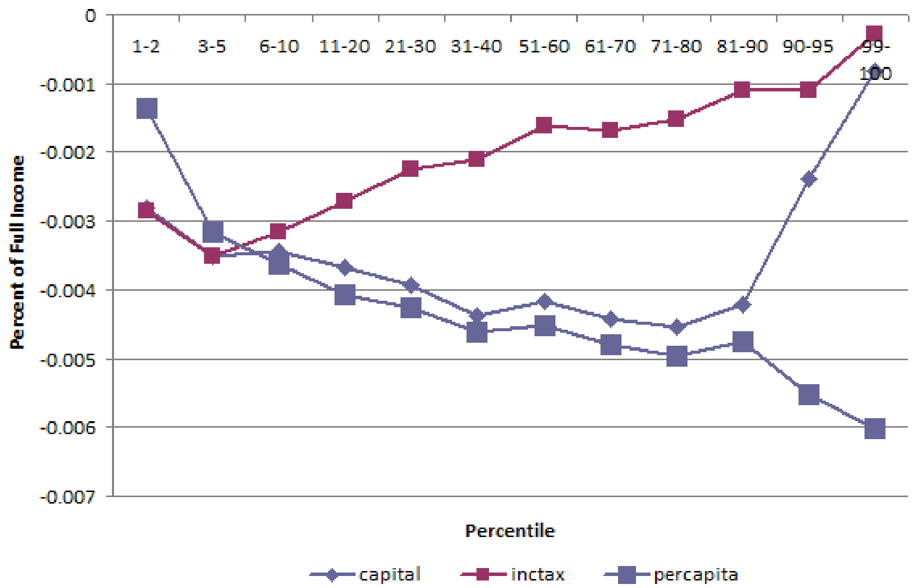
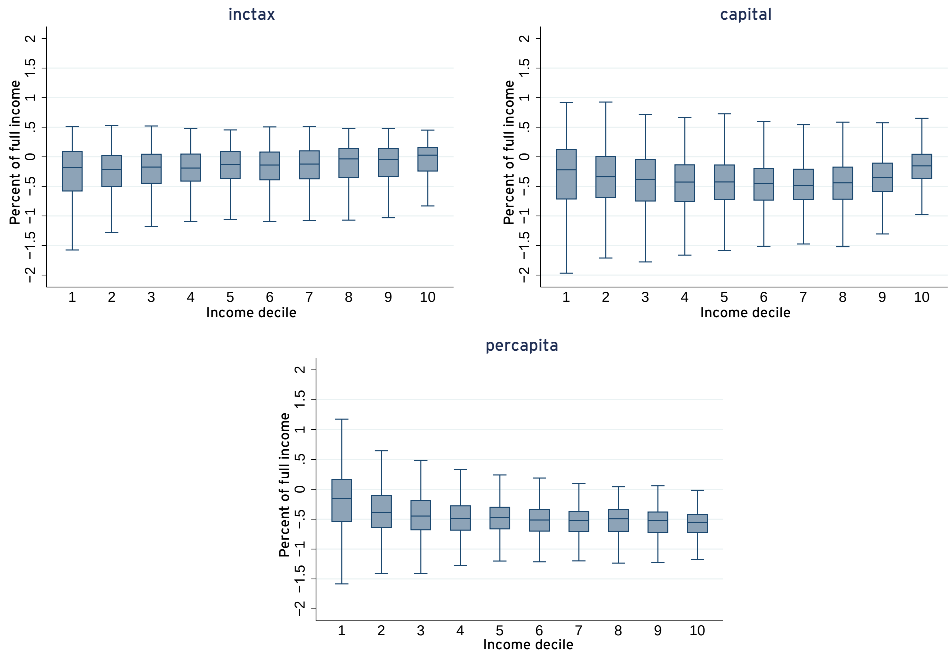


Figure 2 illustrates the point that variation in impacts within broad socioeconomic groups may swamp average variation across groups. For example, if the carbon revenue is recycled through marginal income tax rates we find that over one quarter of households in each income decile benefits while the largest negative burdens within 1.5 of the inter-quartile range are about 1% of annual income.

FIGURE 2 BOX PLOTS BY INCOME DECILE



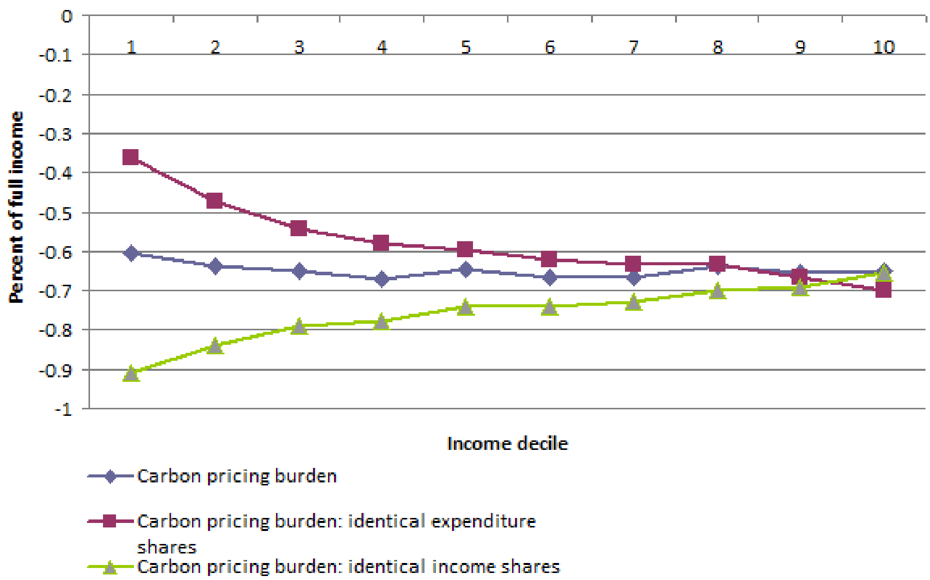
- Third, we provide two measures to proxy for lifetime income to address the criticism that studies using annual income bias carbon pricing towards greater regressivity. Using a proxy that restricts attention to households where the head of the household is in the prime working age and a measure that classifies households according to educational outcome, we do not find evidence of such bias in our analysis.

- Fourth, we note that source-side impacts of carbon pricing have typically been ignored in the literature. Doing so biases distributional studies towards finding carbon pricing to be regressive. We find that progressivity on the source side is sufficiently strong to offset regressivity on the use side so that carbon pricing is proportional to modestly progressive.

We trace our result to the dominance of the source-side over the use-side impacts of the policy. It stands in sharp contrast to previous work that has focused only on usage, and has hence found energy taxation to be regressive. The treatment of transfers is also important in driving this result. Lower-income households derive a large fraction of income from government transfers and, reflecting the reality that over 90% of transfers in the US are explicitly indexed (Fullerton et al. 2011), we hold the transfers constant in real terms. As a result this source of income is unaffected by carbon pricing, while wage and capital income is affected.

Figure 3 shows the roles that source- and use-side heterogeneity play in driving the burden impacts across households. The blue line shows the actual carbon pricing burden when we ignore the distribution of allowances and allowance value. The red line shows a counterfactual distribution where we assume all households have the same expenditure shares on different consumption goods regardless of income. Any differences in burden then are driven by differences in sources of income across income groups. The green line shows a counterfactual distribution where we assume all households have the same factor income shares regardless of income. Any differences in burden then are driven by differences in uses of income across income groups. Use-side impacts (green line) show the regressive result found in previous analyses. Sources-side impacts, in contrast, are progressive.

FIGURE 3 RELATIVE SOURCES-SIDE VS. USES-SIDE IMPACTS ACROSS INCOME DISTRIBUTION



Finally we note that advances in computing power and numerical techniques make solving numerical general equilibrium models with large numbers of households quite tractable. This analysis contributes to a growing literature on the impacts of climate policy on households, and it provides a brief look at the possibilities for understanding differential impacts of policies across different socioeconomic dimensions. The general equilibrium analysis improves on previous analyses that focus on uses side impacts only. Differential impacts on income will be important and this study should help guide researchers in thinking about burden impacts more fully in future work.

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John Reilly is an energy, environmental, and agricultural economist who focuses on understanding the role of human activities as a contributor to global environmental change and the effects of environmental change on society and the economy. A key element of his work is the integration of economic models of the global economy as it represents human activity with models of biophysical systems including the ocean, atmosphere, and terrestrial vegetation. By understanding the complex interactions of human society with our planet, the goal is to aid in the design of policies that can effectively limit the contribution of human activity to environmental change, to facilitate adaptation to unavoidable change, and to understand the consequences of the deployment of large scale energy systems that will be needed to meet growing energy needs.

CHAPTER 9

Global carbon taxation: Intuition from a back-of-the-envelope calculation[1]

Armon Rezai, Rick van der Ploeg

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The failure of markets to price carbon emissions appropriately leads to excessive fuel use and induces global warming. This column suggests a new, back-of-the-envelope rule for calculating the global carbon price. The authors find that fighting global warming requires a price of around \$15 per ton of emitted CO2, or \$0.13 per gallon of gasoline. The rule also highlights the importance of economic indicators, such as GDP, for climate policy.

The biggest externality on the planet is the failure of markets to price carbon emissions appropriately (Stern 2007). This leads to excessive fossil fuel use which induces global warming and all the economic costs that go with it. Governments should cease the moment of plummeting oil prices and set a price of carbon equal to the optimal social cost of carbon, where the social cost of carbon is the present discounted value of all future production losses from the global warming induced by emitting one extra ton of carbon. Our calculations suggest a price of \$15 per ton of emitted CO2 or 13% per gallon gasoline. This price can be either implemented with a global tax on carbon emissions or with competitive markets for tradable emission rights and, in the absence of second-best issues, must be the same throughout the globe.

The most prominent integrated assessment model of climate and the economy is DICE (Nordhaus 2008, 2014). Such models can be used to calculate the optimal level and time path for the price of carbon. Alas, most people, including policymakers and economists, view these integrated assessment models as a 'black box' and consequently the resulting prescriptions for the carbon price are hard to understand and communicate to policymakers.

1 This column first appeared on VoxEU 15 January 2015 https://voxeu.org/article/global-carbon-taxation

NEW RULE FOR THE GLOBAL CARBON PRICE

This is why we propose a simple rule for the global carbon price, which can be calculated on the back of the envelope and approximates the correct optimal carbon price very accurately. Furthermore, this rule is robust, transparent, and easy to understand and implement. The rule depends on geophysical factors, such as dissipation rates of atmospheric carbon into oceanic sinks, and economic parameters, such as the long-run growth rate of productivity and the societal rates of time impatience and intergenerational inequality aversion. Our rule is based on the following premises.

- First, the carbon cycle is much more sluggish than the process of growth convergence. This allows us to base our calculations on trend growth rates.
- Second, a fifth of carbon emission stays permanently in the atmosphere and of the remainder 60% is absorbed by the oceans and the earth's surface within a year and the rest has a half-time of three hundred years.

After three decades, half of the carbon has left the atmosphere. Emitting one ton of carbon thus implies that $LEFT_t = 0.2 + 0.4 \times 0.8(1-0.0023)^{t-1}$ is left in the atmosphere after *t* years.

- Third, marginal climate damages are roughly 2.38% of world GDP per trillion tons of extra carbon in the atmosphere.

These figures come from Golosov et al. (2014) and are based on DICE. It assumes that doubling the stock of atmospheric carbon yields a rise in global mean temperature of 3 degrees Celsius. Hence, the within-period damage of one ton of carbon after *t* years is $0.0238 \times GDP_t \times LEFT_t$

- Fourth, the social cost of carbon is the discounted sum of all future within-period damages.

The interest rate to discount these damages *r* follows from the Keyes-Ramsey rule as the rate of time impatience *p* plus the coefficient of relative intergenerational inequality aversion (IIA) times the per-capita growth rate in living standards *g* (Foley et al. 2013). Growth in living standards thus leads to wealthier future generations that require a higher interest rate, especially if the intergenerational inequality aversion is large because current generations are then less prepared to sacrifice current consumption.

- Fifth, it takes a long time to warm up the earth. We suppose that the average lag between global mean temperature and the stock of atmospheric carbon is 40 years.

We thus get the following back-of-the-envelope rule for the optimal social and price of carbon:

$$SSC = \left(\left[\frac{0.2}{r} + \frac{0.32}{r + 0.0023} \right] \times 0.0238 \times GDP \right) \times \left(\frac{1}{1 + r \times 40} \right),$$

where $r = p + (IIA - 1) \times g$ Here the term in the first set of round brackets is the present discounted value of all future within-period damages resulting from emitting one ton of carbon, and the term in the second set of round brackets is the attenuation in the social cost of carbon due to the lag between the change in temperature and the change in the stock of atmospheric carbon.

POLICY INSIGHTS FROM THE NEW RULE

This rule gives the following policy insights:

- The global price of carbon is high if welfare of future generations is not discounted much.
- Higher growth in living standards g boosts the interest rate and thus depresses the optimal global carbon price if the intergenerational inequality aversion is larger than 1. As future generations are better off, current generations are less prepared to make sacrifices to combat global warming. However, if the aversion is less than 1, growth in living standards boosts the price of carbon.
- Higher intergenerational inequality aversion implies that current generations are less prepared to temper future climate damages if there is growth in living standards and thus the optimal global price of carbon is lower.
- The lag between temperature and atmospheric carbon and decay of atmospheric carbon depresses the price of carbon (the term in the second pair of brackets).
- The optimal price of carbon rises in proportion with world GDP which in 2014 totalled 76 trillion USD.

The rule is easy to extend to allow for marginal damages reacting less than proportionally to world GDP (Rezai and van der Ploeg 2014). For example, additive instead of multiplicative damages resulting from global warming give a lower initial price of carbon, especially if economic growth is high, and a completely flat time path for the price of carbon. In general, the lower elasticity of climate damages with respect to GDP, the flatter the time path of the carbon price.

CALCULATING THE OPTIMAL PRICE OF CARBON FOLLOWING THE NEW RULE

Our benchmark set of parameters for our rule is to suppose trend growth in living standards of 2% per annum and a degree of intergenerational aversion of 2, and to not discount the welfare of future generations at all (g = 2%, IIA = 2, r = 0). This gives an optimal price of carbon of $55 per ton of emitted carbon, $15 per ton of emitted CO_2, or $0.13 per gallon of gasoline, which subsequently rises in line with world GDP at a rate of 2% per annum.

Leaving ethical issues aside, our rule shows that discounting the welfare of future generations at 2% per annum (keeping g = 2% and IIA = 2) implies that the optimal global carbon price falls to $20 per ton of emitted carbon, $5.5 per ton of emitted CO_2, or $0.05 per gallon gasoline.

If society were to be more concerned with intergenerational inequality aversion and used a higher aversion of 4 (keeping g = 2%, r = 0), current generations would have to sacrifice less current consumption to improve climate decades and centuries ahead. This is why our rule then indicates that the initial optimal carbon price falls to $10 per ton of carbon. Taking a lower intergenerational inequality aversion of 1 and a discount rate of 1.5% per annum as in Golosov et al. (2014) pushes up the initial price of carbon to $81 per ton emitted carbon.

A more pessimistic forecast of growth in living standards of 1 instead of 2% per annum (keeping IIA = 2, r = 0) boosts the initial price of carbon to $132 per ton of carbon, which subsequently grows at the rate of 1% per annum. To illustrate how accurate our back-of-the-envelope rule is, we road-test it in a sophisticated integrated assessment model of growth, savings, investment, and climate change with endogenous transitions between fossil fuel and renewable energy and forward-looking dynamics associated with scarce fossil fuel (for details see Rezai and van der Ploeg 2014). Figure 1 below shows that our rule approximates optimal policy very well.

Table 1 also confirms that our rule predicts the optimal timing of energy transitions and the optimal amount of fossil fuel to be left unexploited in the earth very accurately. Business as usual leads to unacceptable degrees of global warming (4 degrees Celsius), since much more carbon is burnt (1640 Giga tons of carbon) than in the first best (955 GtC) or under our simple rule (960 GtC). Our rule also accurately predicts by how much the transition to the carbon-free era is brought forward (by about 18 years). No wonder our rule yields almost the same welfare gain as the first best while business as usual leads to significant welfare losses (3% of world GDP).

FIGURE 1 CALCULATING THE SOCIAL COST OF CARBON OVER TIME

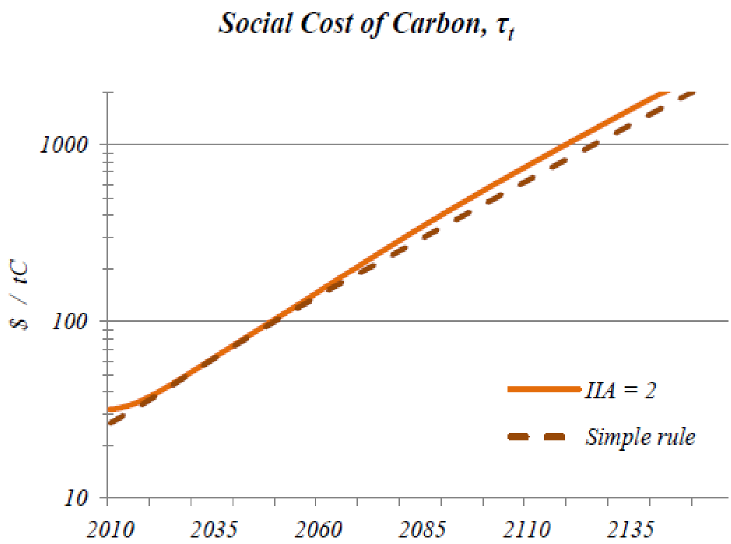

TABLE 1. TRANSITION TIMES AND CARBON BUDGET

		Fossil Fuel Only	Renewable Only	Carbon used	maximum temperature	Welfare loss
IIA=2	First Best	2010-2060	2061	955 GtC	3.1 °C	0%
	Business as usual	2010-2078	2079	1640 GtC	4.0 °C	-3%
	Simple rule	2010-2061	2062	950 GtC	3.1 °C	-0.01%

Recent findings in the IPCC's fifth assessment report support our findings. While it is not possible to translate their estimates of the social cost of carbon into our model in a straight-forward manner, scenarios with similar levels of global warming yield similar time profiles for the price of carbon.

Our rule for the global price of carbon is easy to extend for growth damages of global warming (Dell et al. 2012). This pushes up the carbon tax and brings forward the carbon-free era to 2044, curbs the total carbon budget (to 452 GtC) and the maximum temperature (to 2.3 degrees Celsius). Allowing for prudence in face of growth uncertainty also induces a marginally more ambitious climate policy, but rather less so. On the other hand, additive damages lead to a laxer climate policy with a much bigger carbon budget (1600 GtC) and abandoning fossil fuel much later (2077).

CONCLUSION

In sum, our back-of-the-envelope rule calculates the optimal global price of carbon and gives an accurate prediction of the optimal carbon tax. It highlights the importance of economic primitives, such as the trend growth rate of GDP, for climate policy. We hope that as the rule is easy to understand and communicate, it might also be easier to implement.

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Although most of his work has been on macroeconomics and public finance, he currently works on the economics of natural resources with side interests in higher education reform and economics of art and culture. He earned his Ph.D. in Engineering from the University of Cambridge and is editor of the Basil Blackwell *Handbook of International Macroeconomics*, co-author of the OUP textbook *Foundations of Modern Macroeconomics*, and author of numerous articles in academic journals and the popular press.

CHAPTER 10

Discounting climate change investments[1]

Stefano Giglio, Matteo Maggiori, Johannes Stroebel, Andreas Weber

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While some of the costs of climate change won't be incurred for centuries, the actions to mitigate them need to be taken today. Over such a long timespan, small changes in discount rates can drastically change the attractiveness of such investments. This column presents estimates of appropriate discount rates for very long time horizons. The long-run discount rate for one important risky asset class – real estate – is estimated at 2.6%. This provides an upper bound on long-run discount rates for climate change abatement, one that is substantially lower than some of the rates currently being employed.

Many of the costs associated with climate change occur hundreds of years into the future, yet actions to mitigate those long-run costs have to be taken today, as evidenced only recently at the United Nations conference on climate change in Paris.

In evaluating the trade-off between immediate costs and potentially uncertain long-run benefits, even small changes in discount rates can dramatically alter policy conclusions. As an example, assume that an investment to reduce carbon emissions costs $3 billion, and is expected to avoid environmental damages worth $100 billion in 100 years. At a discount rate of 3%, the present value of those damages is $5.2 billion and the project seems appealing. At an only slightly higher discount rate of 5%, the present value of the investment drops by an order of magnitude to $760 million, and the project no longer appears attractive.

With little direct empirical evidence on the way households discount payments over very long horizons, academics and policymakers have mostly resorted to theoretical arguments or have tried to infer discount rates from realised returns of traded assets such as private capital, equity, bonds, and real estate. Not only has this approach produced

1 This column first appeared on VoxEU 23 January 2016 https://voxeu.org/article/discounting-climate-change-investments

widely varying discount rate suggestions, ranging from close to 1% (Stern 2006) all the way up to almost 5% (e.g. Gollier 2013, Nordhaus 2013), it also tends to ignore important considerations regarding the maturity and risk properties of such investments.

To develop this point, we may think of any asset as a portfolio of claims to single payments at specific horizons. For example, consider an investment that pays off some cash flows for the next ten years. It can be thought of as a portfolio of claims to ten single yearly cash flows. Asset pricing theory teaches us that the rate at which each of these expected payments should be discounted depends on the situation in which the payment is realised – payments that materialise primarily when investors are doing relatively well anyway are less desirable and hence more risky. They should therefore be discounted at a higher rate. Since such risks may vary by horizon, each of the single payments of the portfolio might have a different per-period discount rate. The average rate of return to an asset only captures the value-weighted average discount rate applied to all its payments. Therefore, it is not necessarily informative for discounting the payments of climate change investments, which tend to occur at much longer horizons and might have substantially different risk profiles.

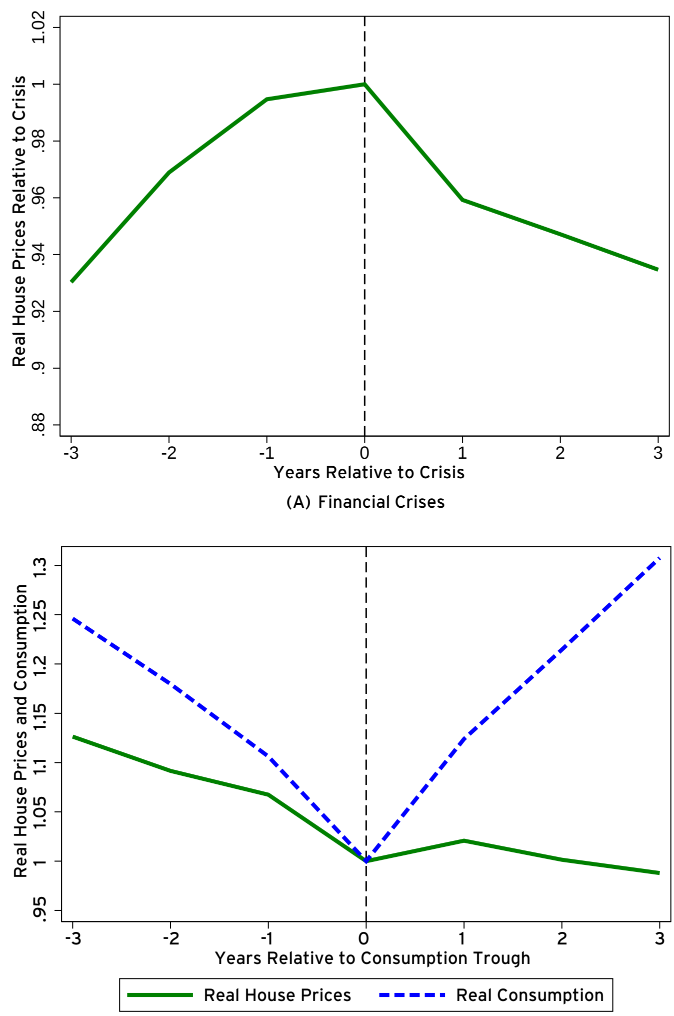
ESTIMATING A TERM STRUCTURE OF DISCOUNT RATES

In recent work, we provide estimates of the term structure of discount rates for an important asset class – real estate – over a horizon of hundreds of years (Giglio et al 2015a). We start by estimating the average return to real estate, which we find to be above 6%. In combination with recent estimates from Giglio et al (2015b), who find discount rates for real estate payments 100 or more years into the future to be around 2.6%, this implies a downward-sloping term structure of discount rates for real estate.

To estimate the average return to real estate for the US (1953-2012), the UK (1985-2012), and Singapore (1989-2012), we employ two complementary approaches. The balance sheet approach is based on information from the three countries' national accounts. It combines the total value of residential real estate and housing with the total value of real estate and housing services consumed by households (the 'dividend' from the real estate and housing stock). After controlling for the growth of the real estate and housing stock over time, we obtain a return series for a representative property. The price-rent approach constructs a time series of returns by combining a house price and a rental price index with a price-rent estimate for a baseline year. After adjusting both results for inflation and subtracting maintenance costs, depreciation, and any tax-related decreases in returns, we obtain real expected returns for real estate that are above 6% for the countries we consider.

These return estimates are above the risk-free rate and imply a positive real estate risk premium. Consistent with the notion of real estate as a risky asset, Panel A of Figure 1 shows the average reaction of real house prices to financial crises. Financial crisis dates for 20 countries over the period 1870-2013 are based on Schularick and Taylor (2012), Reinhart and Rogoff (2009) and Bordo et al. (2001). The onset of a crisis is normalised as time zero and the house price level is normalised to one at the beginning of the crisis. On average, house prices rise in the three years leading up to a crisis, peak just before the onset of the crisis, and fall by up to 7% in the following three years. Similarly, Panel B of Figure 1 shows the average behaviour of house prices during rare disasters as identified by Barro (2006) and Barro and Ursua (2008). Consumption reaches its trough (normalised as time zero) after declining for three years. House prices fall along with consumption over these first three years, but fail to recover along with consumption over the following three years. We also demonstrate that real house prices are positively correlated with consumption growth in general. Both of these patterns contribute to the riskiness of real estate as an asset.

FIGURE 1 HOUSE PRICE RISKINESS

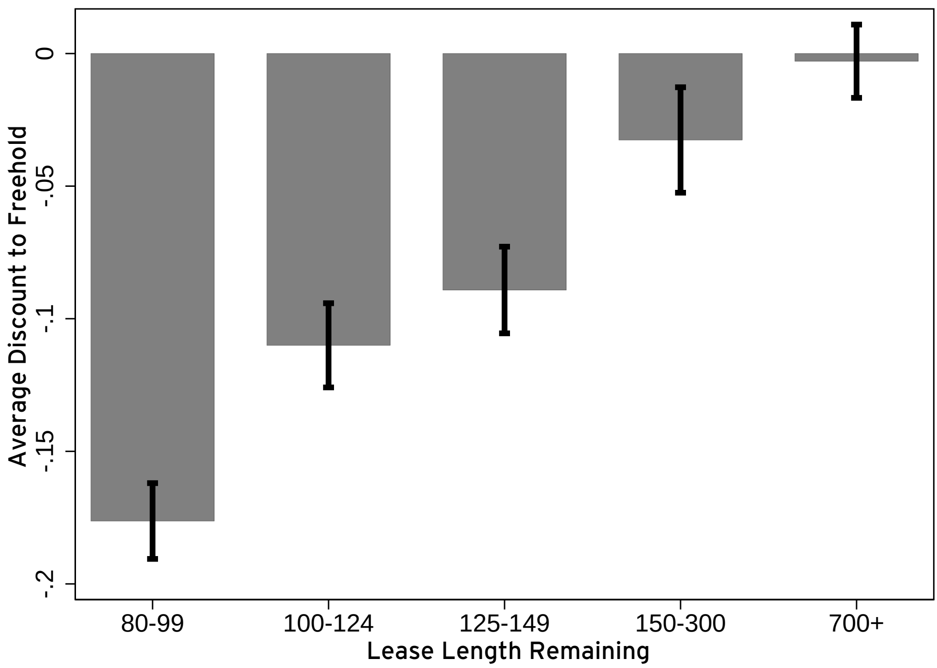


(B) Consumption Disasters

For an estimate of the long-run discount rate hundreds of years into the future, we rely on recent work by Giglio et al (2015a). In the UK and Singapore, residential properties trade either as freeholds, which are permanent ownership contracts, or as leaseholds, which are pre-paid and tradable ownership contracts with finite maturities between 99 years and 999 years. By comparing the relative prices of leasehold and freehold contracts for otherwise identical properties, they estimate the present value of owning a freehold after the expiration of the leasehold contract. Figure 2 reports the estimates from the authors for the UK between 2004 and 2013. It shows that price discounts of leaseholds are strongly associated with maturity. In particular, leaseholds with remaining maturities between 100 and 124 years trade at a discount of 11% as compared to infinite-maturity freeholds. Put differently, at least 11% of the value of a freehold is due to payments accruing more than 100 years into the future. After ruling out alternative explanations, the authors conclude that this implies a discount rate of 2.6% for payments more than 100 years into the future. In combination with an average rate of return of more than 6%, this implies a downward-sloping term structure of discount rates for real estate.

This result indicates that for a major asset class, i.e. real estate, the term structure of discount rates is very different across maturities, highlighting the importance of using horizon-specific discount rates when thinking about discounting the distant future.

FIGURE 2 ESTIMATED LEASEHOLD DISCOUNTS FOR THE UK



THE DISCOUNT RATE FOR LONG-RUN CLIMATE HEDGING INVESTMENTS IS BELOW 2.6%

Our empirical evidence shows that real estate is a risky asset. Its returns are positively correlated with consumption growth and it performs particularly poorly in times of disaster. Therefore, appropriate discount rates for each of its payments have to be *above* the risk-free rate at all horizons. For any long-run investment in climate change abatement that acts as a hedge against climate disasters on the other hand, discount rates have to be *below* the risk-free rate, and hence below the long-run discount rate of 2.6% that we estimated for risky real estate. This is a simple yet informative result.

Indeed, climate change abatement investments are often considered as hedges in the literature (Barro 2013, Lemoine 2015, Wagner and Weitzman 2015, Weitzman 2012). Our estimate also provides a tight bound that is only consistent with the lowest of the three certainty-equivalent constant discount rates of 2.5%, 3%, and 5% per year suggested by the interagency group tasked with valuing reductions in carbon dioxide by the US government (Greenstone et al 2013). Finally, this upper bound is also lower than numerous estimates in the existing academic literature on climate change abatement that are as high as almost 5% (Nordhaus 2013, Gollier 2013). It is more consistent with a discount rate of 1.4% suggested by Stern (2006), or long-run discount rates close to the risk-free rate (Weitzman 2012).

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CHAPTER 11

Transition to clean technology[1]

Daron Acemoğlu, Ufuk Akcigit, Douglas Hanley, William Kerr

MIT and CEPR; University of Chicago and CEPR; University of Pittsburgh; Harvard Business School and CEPR

Substantial headway has been made in the transition to clean technology, but recent political developments threaten this progress. This column examines the transition process using a microeconomic model of competition in production and innovation between clean and dirty technologies. The results suggest that production taxes can deal with dirty emission externalities, while research subsidies are sufficient to redirect innovation towards clean technologies. However, delaying intervention will drastically slow down the overall transition.

It wasn't long ago – just last year, in fact – that a German car executive described Tesla Motors as "a joke that can't be taken seriously compared to the great car companies of Germany" (Kirschbaum 2016). These days, Telsa has a higher market cap than Ford Motor company, and we see rapid progress in many sectors towards better environmental technology. Exactly when the clean revolution will reach a critical mass will be of utmost importance to policymakers and investors alike, with many standing to benefit from this shift in the way we produce and innovate. Sadly, with Donald Trump pulling the US out of Paris Climate Agreement, questions are surfacing as to the implications of delay. To consider such questions, a deeper understanding of the mechanisms underlying the transition from dirty to clean technology is necessary.

Recent economic research recognises the importance of the transition to clean technology in reducing fossil fuel emissions and potentially limiting climate change, while empirical evidence suggests that innovation may switch away from dirty to clean technologies in response to changes in prices and policies. Popp (2002) finds that higher energy prices are associated with a significant increase in energy-saving innovations, while and Aghion et al. (2016) find a sizable impact of carbon taxes on the direction of innovation in the automobile industry and further provide evidence that clean innovation has a self-perpetuating nature, feeding on its past successes. Based on this type of evidence, Acemoğlu et al. (2012) suggest that a combination of (temporary) research subsidies and carbon taxes can successfully redirect technological change towards cleaner technologies.

1 This column first appeared on VoxEU 5 July 2017 https://voxeu.org/article/transition-clean-technology

Questions remain, however, concerning the combined role of carbon taxes and research subsides in securing a transition to clean energy, as well as the optimal speed of this transition.

In recent work, we develop a microeconomic model in which clean and dirty technologies compete in production and innovation (Acemoğlu et al. 2016). If dirty technologies are more advanced to begin with, the potential transition to clean technology can be difficult both because clean research must climb several steps to catch up with dirty technology and because this gap discourages research efforts directed towards clean technologies. We estimate our key model parameters from firm-level microdata in the US energy sector, using regression analysis and SMM. Our model performs fairly well in matching a range of patterns in the data that were not directly targeted in the estimation, giving us confidence that it is useful for the analysis of the transition to clean technology in the US energy sector.

MODEL DESCRIPTION

In our model, which we view as an abstract representation of the energy production and delivery sectors, intermediate goods can be produced either using a dirty or clean technology, each of which has a knowledge stock represented by a separate quality ladder. Given production taxes – which differ by type of technology and thus can act like a 'carbon tax' – final good producers choose which technology to utilise. Profit-maximising firms also decide whether to conduct research to improve clean or dirty technologies. Clean research, for example, leads to an improvement over the leading-edge clean technology in one of the product lines, with a small probability of a breakthrough which will build on and surpass the dirty technology when the latter is the frontier in the relevant product line.

Research and innovation decisions are impacted both by policies and the current state of technology. For example, when clean technology is far behind, most research directed towards that sector will generate incremental innovations that cannot be profitably produced, except in high carbon tax scenarios. However, if clean research can be successfully maintained for an extended period, it gradually becomes self-sustaining, as the range of clean technologies that can compete with dirty ones expands as a result of a series of incremental innovations.

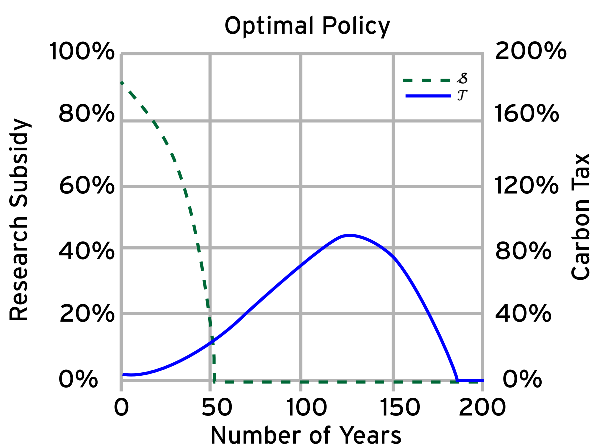
EMPIRICAL STUDY

We estimate parameters of this model using microdata on R&D expenditures, patents, sales, employment, and firm entry and exit from a sample of US firms in the energy sector. The data used for this exercise come from the Census Bureau's Longitudinal Business Database and Economic Censuses, the National Science Foundation's Survey of Industrial Research and Development, and the NBER Patent Database. We design our sample around innovative firms in the energy sector that were in operation during the period 1975-2004, using our sample to estimate two of the key parameters of the model with regression analysis using R&D and patents.

We then combine this structure with a flexible model of the carbon cycle (also used in Golosov et al. 2014) for the analysis of optimal policy and for a range of counterfactual policy experiments. It is intuitive to expect that carbon taxes should do most of the work in the optimal allocation, as they simultaneously reduce current emissions and encourage R&D directed towards clean technologies. However, we find a major role for both carbon taxes and research subsidies. The research subsidy is initially more aggressive and then declines over time, while we find that optimal carbon taxes are back-loaded (but also start declining after about 130 years). Research subsidies are powerful in redirecting technological change, and given this, it is not worth distorting initial production too much by introducing very high carbon taxes. It is important to emphasise that research subsidies are not used simply to correct a market failure in our research. Under our model structure, in the absence of externalities from carbon, or in the special case in which there is only a dirty or a clean sector, a social planner would not have a reason to use research subsidies. This is because a scarce factor (i.e. skilled labour) is being used only for research, and thus the social planner cannot increase the growth rate by subsidising research.

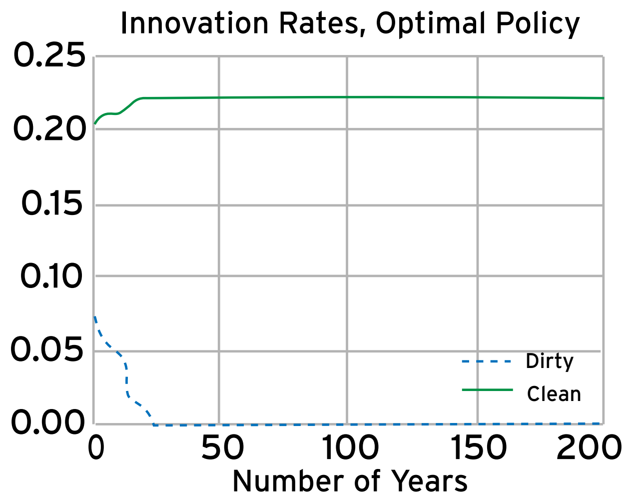
Figure 1 shows that optimal policy relies on a very high level of subsidies towards clean research, especially during the first few decades. The social planner would like to divert R&D from carbon-intensive dirty technologies towards clean technologies. She can do so by choosing a sufficiently high carbon tax rate today and in the future, as this would reduce the profitability of production using dirty technologies and secure both a switch to clean production and subsequently to research directed at clean technologies.

FIGURE 1 OPTIMAL POLICIES (CARBON TAXES AND RESEARCH SUBSIDIES) UNDER BASELINE PARAMETERS



However, this is socially costly because given the current state of technology, switching most production to clean technology has a high consumption cost (because the marginal costs of production of clean technologies are initially significantly higher than those of dirty technologies). Hence, the social planner prefers to use the carbon tax (tau) to only deal with the carbon emission externality and to rely on the research subsidy(s) to redirect R&D towards clean technologies. Figure 2 shows that the research subsidy is indeed sufficient to rapidly switch innovation from the dirty to clean technology.

FIGURE 2 INNOVATION RATES UNDER OPTIMAL POLICIES



We analyse several counterfactuals, one of which is unfortunately becoming more relevant –delaying intervention for 50 years before choosing the optimal policy thereafter. Somewhat paradoxically, delaying the start of optimal policies by 50 years can lead to less aggressive policies from that point onwards. This is because the intervening interval has generated a larger technology gap between the clean and dirty sectors, making a rapid switch from dirty to clean technologies even more painful. Under the baseline carbon cycle framework, this delays the full transition by almost 250 years and results in important welfare loss. If one assumes a more aggressive carbon cycle impact on temperatures, the implications are far worse. Our hope from the model's framework is that our world finds ways to support clean energy research, which is the most critical input at present, especially considering the lack of support coming from the Trump administration.

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CHAPTER 12

How to deal with climate change deniers: Price carbon![1]

Rick van der Ploeg, Armon Reza

University of Oxford and CEPR; Vienna Institute for Institute for Ecological Economics, Vienna University of Economics and Business (WU)

Trump's election has brought climate change deniers to the centre of global policymaking. This column uses Pascal's wager as a model to explore optimal policy given uncertainty over the fundamental causes of global warming. This agnostic approach finds that assigning even a high probability to climate change deniers being correct has insignificant effects on policy. Pricing carbon is shown to be optimal in either case, and robust to whether policymakers want to maximise global welfare, or minimise regret in the worst case.

The US appointment of an outspoken climate sceptic, Scott Pruitt, to the head of the Environmental Protection Agency has thrown global climate policy against the ropes. Only on 9 March 2017, Pruitt stated "[…] I think that measuring with precision human activity on the climate is something very challenging to do and there's tremendous disagreement about the degree of impact. So no, I would not agree that it's a primary contributor to the global warming that we see."

But even climate change deniers have some doubt about whether man-made emissions really don't contribute to global warming. Prudent science should therefore deal with the error that a model is falsely assumed to be correct. To reflect the two opposing views of the climate-economy interaction – one in which human emissions contribute to climate change, and one in which the climate follows exogenous projections of committed warming – we extend what is probably the best-known integrated assessment model of the economy and the climate – the DICE model (Nordhaus 2014). We then let agnostics choose climate policy under 'climate model' uncertainty.[2]

1 This column first appeared on VoxEU 5 January 2018 https://voxeu.org/article/how-deal-climate-change-deniers-price-carbon

2 The 'scientific' model corresponds to version DICE-2013R of the DICE model. Strictly speaking, the International Panel on Climate Change allows for a very small probability that deniers are right but we will call the 'science' view the one which says that all anthropogenic carbon emissions contribute to global warming. The 'denier' model corresponds to a variant of DICE-2013R where anthropogenic emissions are assumed not to enter the atmosphere and the climate evolves independently of the economy, responding to exogenous and past emissions already in the system.

Climate change denial can be addressed using such an agnostic approach to policy where the scientific uncertainty that climate change deniers could be right after all is accounted for. It is important to be clear about terminology – 'climate change deniers' are 100% certain that global warming has only natural causes, 'climate change believers' (or non-sceptic scientists) are 100% certain that anthropogenic carbon emissions contribute to global warming, and 'climate change sceptics' or 'agnostics' attach a (small) positive probability to climate change deniers being right or at least acknowledge the possibility that global warming is not caused by anthropogenic carbon emissions at all. In the political debate, climate change deniers are sometimes euphemistically referred to as 'climate sceptics'.

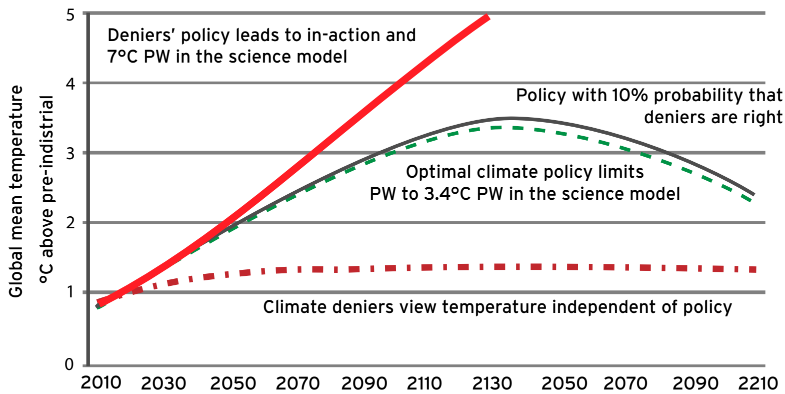
PASCAL AND THE CHALLENGE OF CONDUCTING CLIMATE POLICY IN PRESENCE OF SCEPTICS

In the 17th century, the French philosopher Blaise Pascal pioneered decision making under such fundamental uncertainty by asking if one should believe in (the Christian) God if one cannot prove His existence using scientific methods (Pascal 1910). His recommendation for agnostics was assertive – believe in God if you hold the slightest prior belief that God might exist. The rationale is that the cost of wrongly believing in God is minimal or at least finite, but the cost of wrongly not believing is infinite (eternal damnation and burning in a lake of fire). We use similar reasoning to argue that climate agnostics, who cannot fully discount the position that science has got it all wrong, should push for stringent climate policy nonetheless. Acknowledgment of scientific uncertainty about our understanding of climate change thus leads to only minimal downward revision of optimal mitigation efforts.

Figure 1 plots the temperature profiles for both views of the climate. The dashed green line with temperature peaking at 3.4°C corresponds to the science view where decision makers price carbon at \$14.7/tCO2 today to avoid climate change. In fact, the optimal price of carbon increases to \$18 and \$73/tCO2 if marginal damages rise rapidly with global warming and policymakers use a lower discount rate than private agents (van der Ploeg and Rezai 2017). Under the deniers' view global temperature is unrelated to human emissions and peaks at 1.3°C regardless of whether carbon is priced or not.

We also plot temperature outcomes where one type of policy (price carbon or don't price carbon) is implemented in the other type of climate view (science or denier). In the science (don't price carbon) case, the absence of a carbon price leads to rapidly rising temperature, peaking at 7°C (solid red line). This scenario is commonly called 'business as usual'. In the denier (price carbon) case, human emissions fall (not plotted) but temperature is unchanged due to the decoupling of global mean temperature and emissions.

FIGURE 1 TEMPERATURE IN THE SCIENCE AND DENIER'S MODELS UNDER EITHER POLICY



Notes: The climate model of deniers has temperature peaking at 1.3°C, independent of anthropogenic emissions and climate policy. In a scientific climate model, policy limits peak warming to 3.4°C. Policy inaction as favoured by deniers leads to temperature increases of 7°C. Agnostic policy ascribing a 10% chance that deniers are right only increases peak warming by 0.1°C relative to the science view.

Table 1 summarises the four scenarios in terms of global welfare gains relative to the welfare predicted by the science view under business as usual in percentage of current world GDP. The first row assumes that the climate scientists' view is correct. Wrongly not pricing carbon involves unfettered growth in emissions, temperature peaking at 7°C, and severe consequent damages to the world economy. However, if carbon is priced, temperature is stabilised and welfare is increased by 17% of world GDP. The second row assumes that climate change deniers are right. Temperature increases to 1.3°C regardless of policy and the economic future under business as usual is much brighter than what doomsayer scientists think. The benefit of removing severe climate change damage amounts to a 41% of world GDP. In a denier's world, wrongly and unnecessarily pricing carbon and rebating the revenues introduces efficiency losses and a drag on economic growth equivalent to a 7% drop in world GDP.

TABLE 1 DECISION MATRIX UNDER SCIENCE AND DENIER CLIMATE VIEWS

Climate view	Price carbon	Don't price carbon
Science	17%	0%
Denier	34%	41%
min welfare	17%	0%
max regret	7%	17%

Notes: Welfare improvements relative to 'business as usual' are presented for the science and the deniers' view of global warming (rows) and the corresponding two type of policies (columns). An agnostic policymaker prices carbon if the probability that deniers are right and global warming has only natural causes is smaller than 70%. The worst outcome for both climate policy and no climate policy occurs under the science model. Doing the best under all worst possible outcomes (max-min) is thus to price carbon. Climate change deniers do not tax carbon as they view climate change as exogenous. The corresponding outcomes (top-right entries in the table) are commonly called 'business as usual' if the science view turns out to be correct.

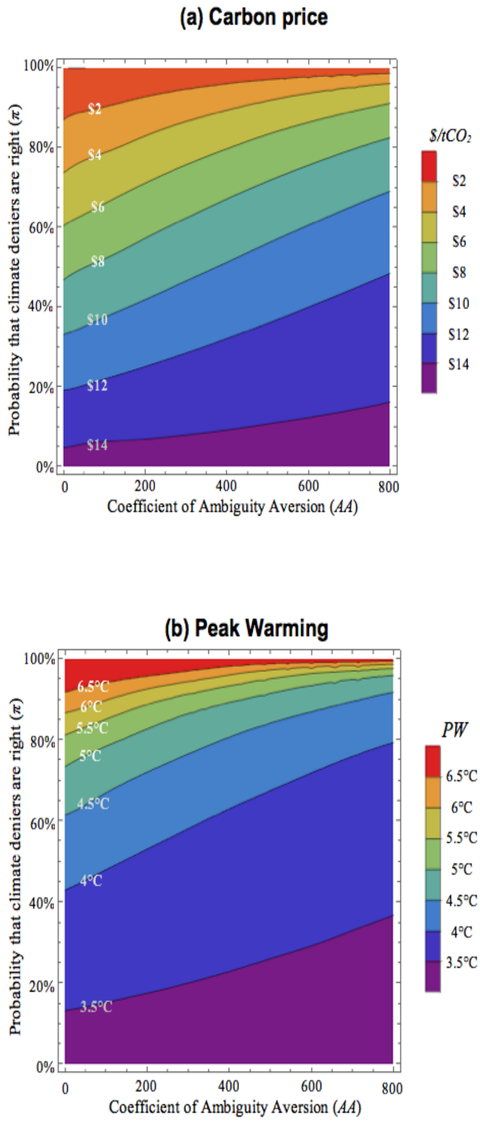
If one follows Pascal and adopts the expected welfare approach with only these two policies, it is optimal to price carbon if the probability that deniers are right is less than 70% and not to price carbon otherwise. Since 97% of scientists and 58% of the general public in the US say that human activity is a significant contributing factor in changing mean global temperature (Doran and Zimmerman 2009), one can assume this threshold for pricing carbon is met. Agnostic policymakers who maximise welfare under the worst possible outcomes (i.e. the max-min decision criterion of Wald 1945) also choose to price carbon, because the resulting efficiency losses are much lower than the deleterious effects of future severe climate change (and 7°C peak warming). The same logic and climate policy applies if policymakers minimise maximum regret (Savage 1954). Both max-min and min-max-regret policies are the classical policy responses to model uncertainty. They maximise welfare or minimise regret under the worst possible view on the causes of global warming.

So far, we have only considered an either/or choice (one either believes in God or doesn't), but the modern expected-welfare approach allows for a continuous range of policy options. We find that maximising expected welfare with a 10% probability that deniers are correct does not alter the purely science-based optimal climate policy much – the initial carbon price falls from $14.7 to $13.3/tCO2 and expected peak warming rises by a mere 0.1°C (solid black line in Figure 1). If we take 3% for the climate specialists and 42% for the general public, as suggested in (Doran and Zimmerman 2009), the carbon prices are $14.3 (even closer to the figure chosen by the non-sceptic scientist) and $8.7 per tonne of emitted CO2, respectively.

AMBIGUITY AVERSION

Modern decision theory extends the expected utility framework to allow for aversion to ambiguity about what the right climate model is (Klibanoff et al. 2005). This approach accounts for irreducible uncertainty and puts a premium on playing it safe when venturing into domains where different models give different outcomes. Accounting for ambiguity aversion (AA) effectively introduces caution by adjusting the probability that sceptics are right downwards (Millner et al. 2013), thereby nesting both the expected welfare approach (with AA = 0) and the extremely cautious max-min approach (with AA infinite) which pushes the probability that climate change deniers are correct right down to zero (Gilboa and Schmeidler 1989).

FIGURE 2 CARBON PRICE AND PEAK WARMING FOR VARYING PRIORS THAT CLIMATE CHANGE DENIERS ARE RIGHT AND VARYING DEGREES OF AMBIGUITY AVERSION



Notes: The initial carbon price decreases and peak warming increases in the probability that climate change deniers are right (vertical axis) from \$14.7 to \$0/tCO2 and from 3.4°C to 7°C, respectively. Aversion to scientific uncertainty (AA, horizontal axis) lowers the willingness to tolerate high levels of warming. As AA approaches infinity, the initial carbon price increases to \$14.7 and peak warming falls to 3.4°C regardless of prior probabilities and gives rise to the max-min policy.

Figure 2 shows iso-peak-warming curves for combinations of the subjective prior probability that climate change deniers are right (vertical axis) and the AA (horizontal axis). If AA = 0, peak warming increases by more than 0.5°C only for priors that deniers are right greater than a third. If AA = 800, this cut-off for the prior rises to 70%. Aversion to ambiguity about what the right climate model is biases priors toward the non-sceptic scientist and encourages more ambitious climate policy. This effect is small for low AA, but large for high AA. Even if policymakers assign a 50% (90%) chance to climate change deniers being right, allowing for a high degree of robustness but less than for the max-min policy biases this chance down to 20% if AA = 800 (2,000). This implies an initial price of carbon of $11.9/tCO2 and peak global warming of 3.6°C.

CONCLUSION

We conclude that the cost of avoiding the most harmful aspects of climate change is small compared with the cost of inaction, so robust policies – such as doing the best or minimising regret under the worst possible outcomes – call for pricing carbon. Even for less cautious policies than the max-min policies with finite but substantial degrees of ambiguity aversion towards climate model uncertainty, and subjective prior probabilities that climate change deniers are right as high as 20%, the price of carbon is close to the non-sceptic, scientifically optimal one. In fact, even if the subjective probability of climate change deniers being right were 50%, possibly due to the influence of the coal and shale gas lobbies, the end of the fossil fuel era would be delayed by only 30 years relative to the rational science-based view. This delay shortens as the prior probability that climate change deniers are right falls, or aversion to ambiguity, about whether scientists or deniers are right, increases. Agnostic decision makers might not want to make an assessment of the prior distribution of the different views of the climate as it is fundamentally unknown. In that case, the max-min solution, and thus the science-based policy, are appropriate.

Not pricing carbon benefits current generations by avoiding the economic burden of climate regulation, giving politicians the subterfuge to avoid painful restructuring of carbon-based industries. Our results, however, discredit this wait-and-see approach. We have not set out to disprove or prove either the climate change deniers' or scientific view, but have used modern decision theory to show that agnostics should decarbonise the economy rapidly as the consequences of erring on the 'wrong' side are too grave. The agnostic policymaker's response to climate change deniers is thus strikingly simply – price carbon.

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CHAPTER 13

Pricing of carbon within and at the border of Europe[1]

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The EU has announced reaching carbon neutrality by 2050 as the key target of its Green Deal strategy. The best coordination signal in this endeavour would be a uniform and encompassing price on carbon. To ascertain that all goods consumed in the EU face the same carbon price, it would be sensible to credibly prepare the implementation of border carbon adjustments applied to imported goods. This column argues, however, that the EU should refrain from exempting exports from carbon pricing, and should consider a border carbon adjustment mechanism only after having established a credible uniform carbon-pricing mechanism within its jurisdiction. This could provide incentives to other countries to join a far-reaching international alliance for carbon pricing.

The EU can become the world leader in the energy transition. It should be the explicit aim of this effort to provide the path towards an effective global approach to climate policy. To tap into a fruitful division of labour, research and investment projects entailing high European value added and policy instruments for setting incentives for the greening of the European economy should be coordinated at the European level. Previous work by the French Council of Economic Analysis (CAE) and the German Council of Economic Experts (GCEE) (GCEE 2019, CAE and GCEE 2019), as well as the interdisciplinary work of the German national academies of science (acatech et al. 2020), advocated the pricing of carbon as the leading instrument of European climate policy.

1 This column first appeared on VoxEU 6 May 2021 https://voxeu.org/article/pricing-carbon-within-and-border-europe

UNIFORM CARBON PRICING: A CORNERSTONE OF EUROPEAN CLIMATE POLICY

As explained, for example, by Schlögl and Schmidt (2020), in the diverse and decentralised economic system that characterises the EU, the best coordination signal corresponding to this principle would be a uniform price on carbon that encompasses all actors, sectors, regions, and technologies. Separate pricing systems for different sectors or for different countries can only be interim solutions. Correspondingly, while separate target values for sectors and member states can serve as important gauges of actual developments, it is not advisable to interpret them as binding restrictions. Voluntary participation by all member states in the uniform pricing mechanism might require financial transfers to member states whose energy systems still rely more heavily on fossil resources.

In principle, several pricing mechanisms could be employed to implement a uniform European carbon price – both price (taxes or surcharges) or quantity (emission certificates) schemes. As this already provides a functional and effective system, the best strategy would be widening the scope of the European Emissions Trading System (EU-ETS). Currently, the EU-ETS only covers the industry and energy sectors, and it is pursuing a joint European reduction target for these sectors. For other sectors, the burden-sharing agreement instead stipulates a set of national target values for 2030. With this compartmentalised approach, the EU is foregoing any possibility to enact the principle of division of labour in emissions reduction.

It might be sensible to fortify the EU-ETS with a minimum price floor over an extended time horizon, and also to engage in an extensive reform of national energy taxes and surcharges to support the uniform carbon pricing. In practice, it will take time to integrate EU-ETS and non-EU-ETS sectors; the aim should be to form an integrated EU-ETS well before 2030 and, in parallel with this, to dismantle the multiple national climate policies. The longer the implementation of a uniform coordination signal by a fully integrated EU-ETS takes, leaving the coordination of transformation efforts in the non-EU-ETS sectors to separate (national) pricing schemes, the higher the overall cost of transition.

As long as carbon prices remain too low and limited in scope[2], the EU should regularly estimate and make public the shadow price of carbon that supports its climate ambition[3]. It should be used in the cost-benefit analyses that need to be conducted on its portfolio of existing non-price climate policies, such as bans, norms, standards, and subsidies. By providing additional public revenue, moving to carbon pricing will also help alleviate the regressivity inherent in climate policy. This is a national responsibility of the member

2 This may be due to social acceptability issues in Europe, as shown by Oswald and Nowakowski (2020).

3 A shadow price associated to a collective constraint is defined as the price signal necessary to satisfy the constraint. It would have to be estimated by employing an integrated assessment model.

states (CAE and GCEE 2019), and this revenue would enable member states to fund redistribution schemes[4], energy price reforms and infrastructure investments, according to their individual preferences and institutions.

Arguably, Europe will only be able to contribute to the objective of reaching global climate neutrality if it manages to design its own transition path in a way that combines climate neutrality with unimpeded prosperity growth. Taking action unilaterally is endangering the international competitiveness of energy-intensive European firms, which are facing serious competition from outside the realm of European climate policy ('carbon leakage'). So far, the EU-ETS has not led to serious carbon leakage problems, but the carbon prices emitters hitherto had to pay were moderate (aus dem Moore et al. 2019). It seems likely that this innocuous result will change at the higher carbon prices that will correspond to the ambitions of the Green Deal.

CLIMATE NEUTRALITY AND THE EUROPEAN GREEN DEAL: GREAT AMBITIONS

In December 2019, the European Commission proclaimed the European Green Deal as its principal growth strategy, announcing as its key target reaching carbon neutrality for the EU by 2050 (European Commission 2019). This ambitious long-term objective has important repercussions for the EU's climate target for 2030; Europe is set to pledge to cut emissions by some 55% compared with their 1990 levels, a substantial accentuation of the previous target of 40%. The Green Deal comprises a wide range of measures to cut emissions in areas such as energy systems, mobility, heating, and agriculture. Most importantly, the Commission is considering the implementation of an encompassing carbon-pricing mechanism covering all relevant sectors.

To implement uniform carbon pricing, the Commission announced its intention to widen the scope of the EU-ETS by 2021 to beyond the industry and energy sectors (European Commission 2020a). The ensuing uniform carbon price would serve as the desperately needed principal coordination signal for the massive public investment and, to an even larger extent, private investment needed to meet the more ambitious European climate targets by 2030. Arguably, carbon prices will have to rise steeply over time in order to meet these targets (Gollier 2021). Moreover, their effect in incentivising investments today already stands and falls with the credibility of their installation as an unalterable coordinating signal.

Until a fully integrated EU-ETS is implemented, reducing emissions in the non-EU-ETS sectors will remain a national affair. France and Germany, in particular, have so far not pursued a joint strategy for the non-EU-ETS sectors. In previous years, with less ambitious transition objectives, the losses in terms of prosperity from disregarding possible efficiency gains were limited. With the announcement of the European Green

4 See, for example, the proposals by Dominique Bureau, Fanny Henriet and Katheline Schubert in CAE (2019).

Deal, however, the setting has changed dramatically: member states will have to increase their efforts to reduce emissions in the non-EU-ETS sectors. To avoid these efforts being prohibitively costly, it is highly advisable to speed up the process of integrating national pricing schemes into the EU-ETS.

Steeply increasing (shadow) prices of carbon will endanger the competitiveness of European companies vis-à-vis their competitors that do not fall under the realm of the EU's ambitious climate policy. As the costs of those emissions-intensive domestic producers who are trading on global markets increase ever further, they might relocate increasing shares of their production to sites outside of Europe. This carbon leakage would be harmful to European jobs and economic prosperity, and it would also hurt the overall cause of climate change mitigation, countervailing the EU's ambitions. The issue of how to incentivise other countries to adopt ambitious carbon emissions reduction targets through carbon pricing is therefore of utmost importance.

Under the EU-ETS, the international competitiveness of domestic producers has so far been protected quite successfully by the free allocation of certificates to emissions-intensive firms facing international competition in, for example, the steel, cement and chemical industries, based on a benchmarking system. Yet, with increasing carbon prices this might change. Outsourcing decisions motivated by rising cost differentials would be difficult to reverse ex post, due to the long investment cycles in the industry sector. Thus, the aim should be to avoid these decisions ex ante. A promising alternative to the cost-free allocation of certificates may be the installation of a border carbon adjustment (BCA) mechanism.

NEW CHALLENGES: TOWARDS REDUCING CARBON EMISSIONS FROM IMPORTS

The principal idea behind the BCA mechanism would be to levy a charge on imported goods equivalent to the carbon payment of the same domestically produced good. Ideally, all goods consumed in the EU would face the same carbon price, irrespective of globally diverging climate policies. As it seems far too complicated to impose the BCA on all imported goods, the system could instead be restricted to very energy-intensive and very tradable goods. Limiting the BCA to applying only to imports would, however, not address the distortion caused by less stringent climate policies outside the EU to the competitiveness of EU companies in external markets and, accordingly, would induce the risk of carbon leakage.

Alternatively, the EU might opt to implement a full-fledged symmetric variant of the BCA, in which exporters would receive a corresponding remuneration. Consequently, goods consumed abroad would face the carbon price determined by the country where they are consumed. The system would then be reminiscent of a value-added tax, where imports are taxed and exports are exempt. This is not the route to take: by implementing a symmetric BCA, the EU would contradict its own communication and forfeit control over the extent of carbon emissions generated in the region, since EU carbon pricing would only curb emissions caused by the production of goods and services actually consumed in Europe.

To preserve the EU's self-conception of taking responsibility for the global climate, it will be necessary to present the BCA not as a trade, competition or industrial policy, but as an environmental policy. Its proclaimed ultimate objective should therefore be reducing global carbon emissions, not increasing the competitiveness of European industry. Thus, it should be restricted to applying only to imported goods. This fundamental dilemma between climate protection and preserving competitiveness would be less prevalent if the international alliance for carbon pricing were to grow, obviating the need to impose a BCA on products being imported from (and exported to) other members of this 'carbon club'.

Following the initiative of the French and German governments, the European Council has not only emphasised a BCA mechanism as an instrument to prevent carbon leakage, in contrast to our appraisal, but also announced in the conclusions of its meeting in July 2020 that starting from 2023, a BCA could be used as a source of revenue for the EU budget. The explicit objective of the BCA should, however, be to induce a reduction of carbon emissions, not to serve as an instrument to raise public revenues. Contrary to a popular view, such a tax on imports would not be paid by foreign producers; due to a high pass-through of import taxes, it is European consumers who would bear the majority of the burden.

While the principal idea of a BCA is reminiscent of the well-established concept of value-added taxes, a sizeable number of technical, regulatory, and legal challenges would have to be overcome (Mehling et al. 2019). Accurately measuring the carbon content of individual goods is far from easy (Droege and Fischer 2020), since one would have to capture all of the carbon emissions caused throughout the good's entire value chain. This is costly, since for the same good there are many possible production processes with varying carbon intensities. Simply applying the benchmarks employed for the cost-free allocation of EU-ETS emission certificates is precluded, since those only measure the direct carbon emissions caused during the production process.

A related issue concerns the question of possible exceptions. Which exporting countries will be subject to the BCA – all countries outside the regulated area, or just countries with no 'equivalent' climate policy? If the EU opted to take the latter approach, it would have to make up its mind on how to define an equivalent climate policy. While, in principle, this could be a policy inducing at least a shadow carbon price of similar magnitude as in the EU, in a real-world application it is very difficult to estimate the underlying carbon value of the wide range of implemented regulatory measures. It will therefore be difficult to prevent countries subject to the tax considering it as a political choice, and therefore contesting it.

Furthermore, if the EU would not only be levying charges on imported goods but also offering rebates to exporters, this might also endanger conformity with GATT rules and lead to protracted trade disputes. This risk would be all the more grave the more openly the EU views the BCA scheme as a device to ascertain economic competitiveness, instead of for global climate protection (Droege et al. 2018)[5]. Irrespective of the sophistication with which any legal obstacle might be circumnavigated, EU trading partners might interpret any unilaterally introduced BCA as a protectionist measure anyway (GCEE 2020). Nevertheless, it could be possible to implement a BCA mechanism that is compatible with the existing body of law (European Commission (2020b).

The chances of avoiding a severe trade conflict would likely rise substantially if the EU, instead of introducing the BCA unilaterally, were to take this action in a joint effort with other trading partners, especially the US. However, the EU should consider a BCA mechanism only after having established a clear and credible uniform carbon pricing mechanism within its jurisdiction. This credibility is key to provide incentives to other countries, the US and China in particular, to join a far-reaching international alliance for carbon pricing (Nordhaus 2015). Most specifically, trade partners could be invited to join the EU-ETS mechanism. The chances of a successful courtship will increase as the number of countries pricing carbon grows.

Authors' note: This is a condensed version of a report by the Franco-German Council of Economic Experts (2021).

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CHAPTER 14

Pollution permits and financing costs[1]

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Effective environmental policy should consider the behaviour of financiers of polluting firms. In 2013 the EU Emissions Trading System implemented a reform, which translated to higher compliance costs for producers. This column discusses that, in contrast with possible program intentions, loan spreads fell on average by 25% starting in 2013, and this dynamic partly undermined the expected reduction in CO2 emissions. It identifies a key role of permits storage in driving the fall in loan spreads for affected firms.

According to the World Wide Fund for Nature (WWF 2020), the momentum around climate change is now positive. Polluting firms must be disincentivised directly for releasing CO2 emissions, so that social costs of carbon are reflected into prices. A policy instrument widely implemented is cap-and-trade (ICAP 2020). Interestingly, a recent debate calls for higher indirect costs through increased loan or bond spreads by banks and other financial institutions to the polluting firms and sectors. Most of the anecdotal evidence suggests that, at least until recently, this has not been the case, with the banking sector continuing to finance heavily polluting activities (e.g. RAN 2020, Financial Times 2020, Guardian 2019).

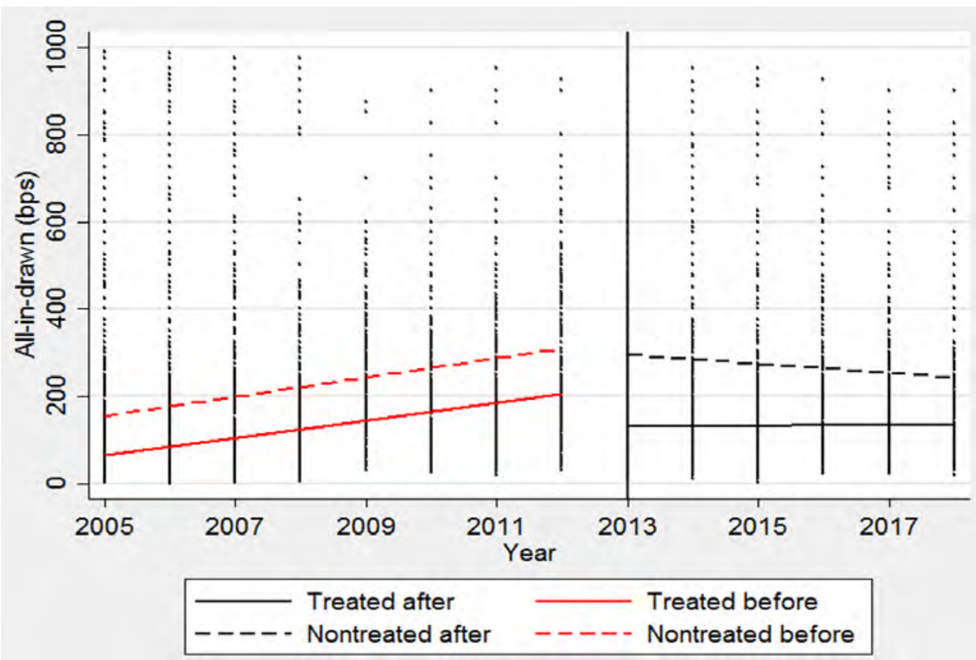
The most well-known fully operational cap-and-trade system is the EU Emissions Trading System (EU ETS), launched in 2005. In 2013, along with the initiation of phase III, there have been important structural changes in the scheme. In particular, emission permits (allowances) were offered at a decreasing rate of 1.74% per year and participating firms were granted a lower proportion of allowances for free, while the rest had to be purchased from the market or via auctioning with few exemptions (European Commission 2015). This reform aimed to increase the cost of carbon for the polluters so that they decrease their carbon footprint. Given that the scheme and the regulatory framework became tighter, implying higher costs for the polluting firms, we expect that the corresponding financial terms reflected in the loan spreads must have internalised this risk after 2013.

1 This column first appeared on VoxEU 16 December 2020 https://voxeu.org/article/pollution-permits-and-financing-costs

However, anecdotal evidence of loan spreads around phase III of the EU ETS shows a different picture. Figure 1 plots regression lines for loan spreads of syndicated loans (DealScan) amongst the treated group (firms participating in the EU ETS) and control group (nonparticipating firms), before and after the initiation of phase III in 2013. The figure shows parallel trends in the loan spreads between the treated and control groups before the program. This is consistent with the flexibility of the syndicated loan market, as lending terms of a loan facility can be easily readjusted. The rising trends in both lines up to 2013 are mainly due to the higher financing costs induced by the global crisis and the European debt crisis. From 2013 onward, loan spreads fell for the treated firms, while remaining approximately at their 2012 level for the nontreated firms.

Our recent study (Antoniou et al. 2020) illustrates that a firm has an incentive to act proactively to deal with potential tighter future regulation. To this end, treated firms may store permits, or hold any offsets with a similar role, to facilitate future regulatory compliance. Then, when the treatment materialises, stored permits lower the demand for costly allowances and therefore reduce the cost of compliance. This, in turn, lowers the risk that the lender faces, inducing a lower loan spread in the second period. In addition, a collective outcome is obtained once we aggregate individual decisions. The oversupply of permits in the post-treatment period reduces the permits price, which also drives down compliance costs. Risk is lower and the loan spread falls.

FIGURE 1 LOAN SPREAD FOR THE TREATMENT AND CONTROL GROUPS



We empirically examine these theoretical propositions, using a novel hand-matched dataset that brings together data on syndicated loans to European firms (DealScan), firm-year characteristics (Compustat), pollution permits to specific firms (EU ETS), and the Carbon Emission Allowances-EUA price (EEX market). Our identification strategy examines the behaviour of loan spreads before and after the implementation of phase III of the EU ETS scheme in 2013 for treated firms (those participating in the program) and nontreated firms (those that do not participate). Phase III of the EU ETS program is the most important for lenders because it introduced costly permits for most polluters (until then the lion share of permits was freely allocated to specific firms).

We find that loan spreads fall by 25% on average starting in 2013, which is equivalent to a reduction by 25.4 basis points. To provide a perspective for the reduction in the total loan cost, the 25.4 basis points correspond to a reduction in interest expenditures by €5.56 million for the loan with an average size and maturity. Notably, we also collect data on corporate bond yields (from SDC Platinum) and show that bond spreads also decreased for the treated firms from 2013 onward. Thus, bond markets also align their incentives with banks, yielding an overall picture of more competitive financing costs for polluting firms after phase III of the EU ETS policy.

We next identify the key reasons for the reduction in loan spreads due to the EU ETS policy. We find that the effect is most negative when the EUA price is particularly low, which is the case in the period 2013-2017 (Figure 2). Further, the decline in loan spreads is much smaller for treated firms that are net buyers of permits in the current or the previous year, showing that these firms have not stored enough allowances and thus are more exposed to the enactment of the program. Indeed, anecdotal evidence in Figure 3 suggests that many firms were proactive in being net buyers of permits in the period just prior to phase III of EU ETS.

FIGURE 2 EUA PRICE OVER THE SAMPLE PERIOD

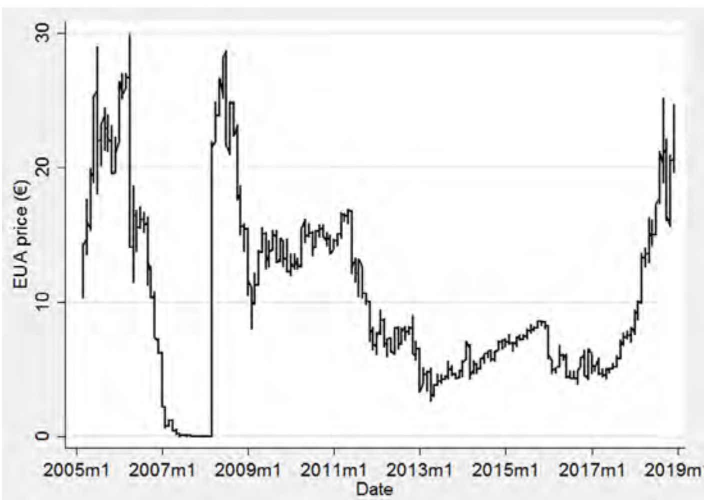
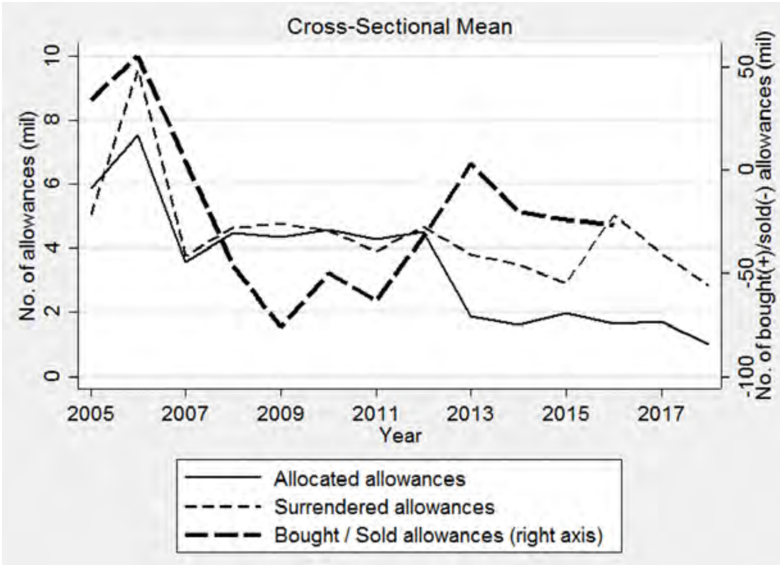


FIGURE 3 NUMBER OF ALLOWANCES OVER THE SAMPLE PERIOD



Our analysis, placing financing costs at the heart of the effect of environmental policy, has real implications for the polluting activities of firms. By identifying lower financing costs of polluting firms after the implementation of phase III of the EU ETS program, we essentially show that any increased costs from that program might have been compensated by decreasing financing costs for the treated firms. We document a significant negative association between loan spreads and the treated firms' verified CO_2 emissions, which together with our main findings suggests that the declining CO_2 emissions (e.g. Bayer and Aklin 2020) would have in fact been even lower if financing costs did not decline. Our estimates show that there would have been a further 7.9% decline in CO_2 emissions if there was no decrease in loan spreads.

Our findings uncover a strategic role for commitment, through permits storage or equivalent actions, so that future interest rates are distorted downwards. Without disputing the proclaimed advantages of permits storage, such as cost smoothing over time, the strategic incentive presented here can be detrimental in terms of pollution. Our results can also provide an empirical corroboration for stability reserves in permit markets, such as the EU ETS market stability reserve introduced in 2019 (see ICAP 2020) where the regulator might withdraw permits in case of excessive surplus of allowances. Our rationale relies on the fact that when there is a surplus of allowances, along with the permits price reduction, this also reduces the loan spread which, in turn, leads to even higher emissions. Permits withdrawal deters the banks from relaxing their interest rates. Therefore, the exact level of the boundaries is instrumental for financing costs and firms' associated response to emissions or their investments in general.

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Christos (Chris) Tsoumas was Assistant Professor in Financial Management in the School of Social Sciences, Hellenic Open University. Sadly, since this article was published he has passed away His contribution in developing this project has been substantial and inspiring. We hereby honour his memory. May he rest in peace

CHAPTER 15

Efficient carbon pricing under uncertainty[1]

Christian Gollier
Toulouse School of Economics and CEPR

Any global temperature target must be translated into an intertemporal carbon budget and an associated cost-efficient carbon price schedule. This column uses an intertemporal asset-pricing approach to examine the impact of uncertainties surrounding economic growth and abatement technologies on the dynamics of efficient carbon prices. It finds evidence of a positive carbon risk premium and suggests an efficient growth rate of expected carbon prices of around 4% plus inflation. This is lower than the growth rates found in many public reports and integrated assessment models, and justifies a higher carbon price today in order to satisfy the carbon budget.

The EU will come to the 26th United Nations Climate Change Conference (COP26) in Glasgow in November this year with a new ambitious climate commitment. Rather than promising to reduce emissions by 40% in 2030 (compared to 1990), it will now reduce them by 55%. Nobody knows exactly how this target can be attained, what the costs will be, and whether it is aligned with the long-term objective of 2°C. The EU Green Deal under discussion in Brussels will certainly produce a cocktail of climate measures combining an extension of the EU Emissions Trading System (EU-ETS) market for emission permits with a myriad of new norms, standards, bans, and subsidies. Because of the reluctance of EU citizens to sacrifice their welfare to fight climate change (Oswald and Nowakowsky 2020), it is crucial to attain our climate goal at minimal cost. These climate actions will thus require measuring their costs per tonne of CO2 saved, which will have to be compared to the shadow value of carbon associated to the carbon budget. What should the level of this carbon value be, and at what rate should it increase over time? I examine these questions in a recent paper (Gollier 2021).

1 This column first appeared on VoxEU 6 April 2021 https://voxeu.org/article/efficient-carbon-pricing-under-uncertainty

HOTELLING RULE IN CARBON PRICING

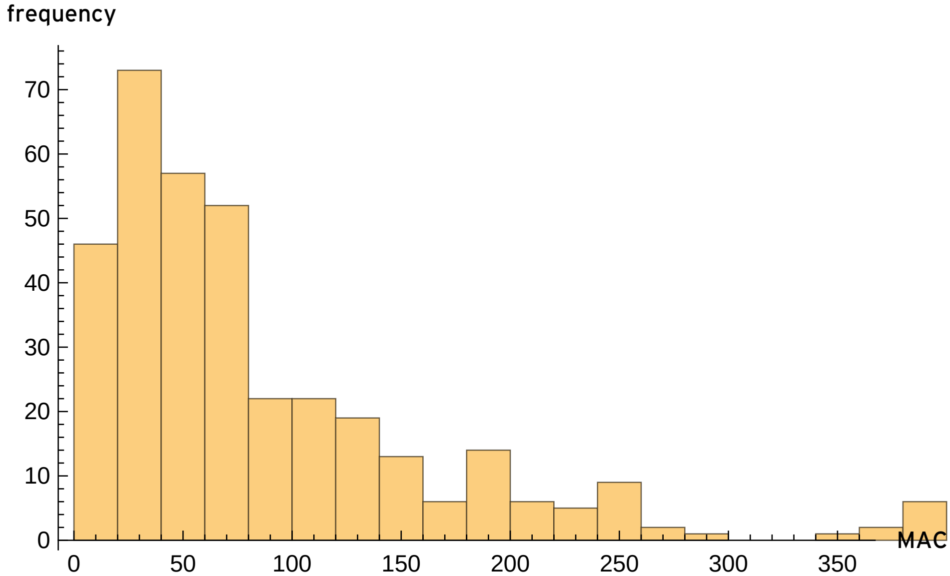
The Pigouvian approach to carbon pricing consists in estimating the present value of the flow of marginal damages of one tonne of CO_2 emitted now. But today, under the auspice of COP21 and the Paris Agreement, the issue is no longer one of aligning private interests with the common good by forcing people to internalise the damage by a Pigouvian tax. Rather, the issue is to find a pathway of shadow carbon prices that are compatible with the 2°C target. Because this target can be translated into an intertemporal carbon constraint, the problem of the speed of decarbonisation and of carbon pricing becomes isomorphic to the 'Hotelling problem' of the optimal extraction of a natural resource.

Under this cost-efficiency approach to carbon pricing, along any path compatible with the intertemporal carbon budget, what is abated today need not be abated tomorrow. This simple observation implies that the rate of return of frontloading the abatement effort equals the growth rate of the marginal abatement cost, i.e. of the carbon price. Under certainty, a growth rate of this carbon price that is above the interest rate signals that not enough abatement efforts are being made today. Along the optimal path, the growth rate of the carbon price should equal the risk-free rate. This is the well-known Hotelling rule.

This recommendation is not being applied in practice. In the UK, the carbon price recommended by the BEIS (2019) is 15% per year for the next ten years. In France, the Commission Quinet (2019) recommended a schedule for carbon prices that grow at 8% per year. And in the fifth report of the Intergovernmental Panel on Climate Change (IPCC), the carbon value also has a mean growth rate of 8%! This suggests that we are all playing the waiting game, with too low a carbon price today, and too high a carbon price in the future. This delay in reducing emissions will be costly (Furman et al. 2015).

But the necessary energy transition is surrounded by deep uncertainties. Nobody knows what a fully decarbonised world will look like in 2050. In the absence of a huge R&D effort to reduce the cost of green technologies, the price of carbon will have to grow fast to induce people to reduce their consumption of brown goods and services. On the contrary, if we find cheap solutions to capture and sequester atmospheric CO_2, or if we succeed in solving the mass electricity storage problem in the face of the intermittency of renewable electricity, it could be possible to decarbonise our economy with a very limited carbon price in the future. This technological unpredictability means that an efficient climate policy has an important dimension of risk management, and in the future the carbon price will need to be adjusted to the evolution of the marginal abatement cost (MAC) function. This large uncertainty is documented in Figure 1, in which I draw the histogram of the 2030 carbon price compatible with the 2°C target estimated by 374 integrated assessment models (IAMs) from the IPCC database.

FIGURE 1 HISTOGRAM OF THE WORLD MARGINAL ABATEMENT COSTS FOR 2030 (IN USD2005/TCO2) EXTRACTED FROM THE IPCC DATABASE



Sources: Gollier (2021) and IPCC database (https://tntcat.iiasa.ac.at/AR5DB)

CARBON PRICING UNDER UNCERTAINTY

Thus, the future carbon price is uncertain by nature if we want to be serious about the EU carbon constraint. How does this affect the timing of the mitigation effort and of the Hotelling rule for carbon pricing? Because frontloading the mitigation effort becomes an investment with an uncertain social return, its expected rate of return should be adjusted for risk. The key insight of modern asset-pricing theory is that one should collectively favour actions that reduce the macroeconomic risk, i.e. those actions whose net benefit is negatively correlated to aggregate consumption. Let me apply this idea to the problem of the timing of our mitigation efforts. If the future MAC is negatively correlated with aggregate consumption, abatement frontloading will save a larger MAC in the future when consumption will be smaller; it is thus a more socially desirable policy. In that case, the consumption-based capital asset pricing model (CAPM) beta of green investments is negative. This justifies a higher carbon price today, and a lower expected growth rate for this price. In contrast, if the MAC is positively correlated with aggregate consumption, abatement frontloading does not hedge the aggregate risk, and the expected growth rate of carbon prices should be adjusted upwards, above the interest rate.

What can we say about the statistical relationship between future MAC and consumption? I may propose here two opposing stories. In the 'negative beta' story, I suppose that the main source of uncertainty is the intensity of green innovations. If this is greater than expected, the MAC will be smaller when consumption is larger (because we will have to spend less to decarbonise). This yields a negative correlation between MAC and consumption. In the 'positive beta' story, suppose alternatively that the main source of uncertainty is the future prosperity of our economy (for example, measured by the total factor productivity). If this is greater than expected, consumption will be higher, emissions under 'business as usual' will be higher too, and more abatement efforts will be required. Because the MAC curve is increasing, this yields a positive correlation between MAC and consumption.

To solve the ambiguity over the sign of this correlation, I calibrate a simple two-period mitigation optimisation problem with uncertainty affecting both technological progress and economic prosperity. This realistic calibration yields a consumption CAPM (C-CAPM) beta for mitigation efforts that is very close to one. The positive beta story dominates. This is related to the observation that during economic downturns, the equilibrium carbon price on emissions trading system (ETS) markets goes down because of the reduced demand for allowances. This justifies recommending a growth rate of expected carbon prices close to the average cost of capital in the economy – around 4% plus inflation.

CONCLUSION

By almost systematically exhibiting a growth rate of carbon prices of 8% or more for the next few years and decades, IAMs and public reports on carbon prices that are compatible with the 2°C target imply playing a waiting game that I believe should be reserved for our politicians. I show that the growth rate of expected carbon prices should be higher than the interest rate because carbon allowances are a risky asset whose return is positively related to the business cycle. But this rate of return should be around 4% per year. Compared to the recommendation by the IAMs, this reduced growth rate justifies recommending a much higher carbon price today in order to satisfy the carbon budget.

My model also shows that this Hotelling approach to carbon pricing yields a much larger price uncertainty than when using the Pigouvian approach to the social cost of carbon. Indeed, if the necessary green innovations do not materialise in the future, a steep increase in carbon prices will be needed. In contrast, if great green innovations allow us to produce renewable energies at a cost no higher than that of fossil fuels, the carbon price could converge to zero in the future, thereby ruining many green entrepreneurs who have bet on a large carbon price to make their investment profitable. In my model, this justifies compensating this green investment risk with a risk premium. The alternative (second-best) approach would consist of imposing a carbon price floor and ceiling (Metcalf 2018).

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CHAPTER 16

A time-varying carbon tax to protect the environment while safeguarding the economy[1]

Ghassane Benmir, Ivan Jaccard and Gauthier Vermandel
London School of Economics; European Central Bank; Dauphine University - PSL

Climate change is one of the most pressing issues of our time. The challenge for policymakers is that climate policies could have a negative impact on the economy in the short term. This column discusses how this trade-off between fighting climate change and ensuring a stable business cycle affects the design of environmental policies. The authors argue in favour of a time-varying carbon tax that is increased during booms and decreased during recessions.

Climate change is a classic example of a negative externality. Indeed, a fundamental problem is that the cost for society of activities that emit greenhouse gases into the atmosphere is not reflected in market prices. Emissions cause climate change, a phenomenon that hurts society as a whole, but this social cost is typically not taken into account by carbon emitters. Moreover, since the consequences of climate change will largely be suffered by future generations, the implementation of climate policies is often postponed until later.

This constitutes a market failure, the source of which is the absence of a market price on emissions. Consequently, policies that substitute market mechanisms by putting a price on emissions can address the root cause of the problem (see Hoogendoorn et al. 2021 for an application to Dutch industry). In contrast, laissez-faire strategies that rely exclusively on market mechanisms to determine prices are not suited to addressing the challenge posed by climate change.

1 This column first appeared on VoxEU 20 August 2021 https://voxeu.org/article/time-varying-carbon-tax-protect-environment-while-safeguarding-economy

ASSET PRICING THEORY CAN PUT A PRICE ON EMISSIONS

Putting a price on emissions can be achieved by introducing a carbon tax. This price should represent the cost for society caused by greenhouse gas emissions. The main challenge, therefore, is to design a carbon tax that reflects the social cost of emissions. In our recent study (Benmir et al. 2020), we argue that asset pricing theory can provide useful insights into this question.

Indeed, the pricing of carbon emissions shares some key similarities with asset pricing. Carbon emissions have a long duration in the sense that they remain in the atmosphere for very long periods of time. Consequently, the price of carbon not only needs to reflect the current damage caused to the environment. The price must also reflect the impact that carbon emitted into the atmosphere will have over the entire course of its lifetime. To obtain this value, we need to convert a sum of future costs – in our case the costs caused by carbon emissions to society – into a present value. In finance, the tool that allows us to convert future flows into a present value is the discount factor. The discount factor reflects the weight that agents assign to future outcomes when making decisions today.

Discounting plays a central role in climate economics. As illustrated by the debate between William Nordhaus (Nordhaus 2007) and Nicholas Stern (Stern 2007), the choice of a discount factor has a critical impact on the outcome of cost and benefit analyses. In risk assessment studies, the discount factor can for example determine whether extreme policies are immediately needed. If a high weight is assigned to short-term costs, the need for adopting measures is less pressing. In contrast, immediate action becomes critical if a higher weight is assigned to long-term costs that are expected to materialise in a distant future.

Our approach incorporates recent advances in asset pricing theory into the study of environmental policies. Discount factors are a cornerstone of modern finance (e.g. Cochrane 2011, 2017). Building on this knowledge, we introduce a novel discount factor specification that bridges the gap between finance and environmental economics. The novelty of our approach is to introduce a link between climate change and attitudes towards risk, where the presence of an environmental externality induces time variation in risk aversion.[2]

THE OPTIMAL POLICY IS A CARBON TAX THAT VARIES OVER THE CYCLE

We find that the optimal policy to counter climate change embeds a trade-off between environmental protection and safeguarding the economy. There is now a consensus that immediate action to combat climate change is urgently needed. The challenge, however,

2 This time variation in risk aversion enables our model to reproduce a risk premium on long-term bonds of a realistic magnitude. Environmental policies are therefore studied within a framework immune to some well-known asset pricing anomalies, such as the bond premium puzzle.

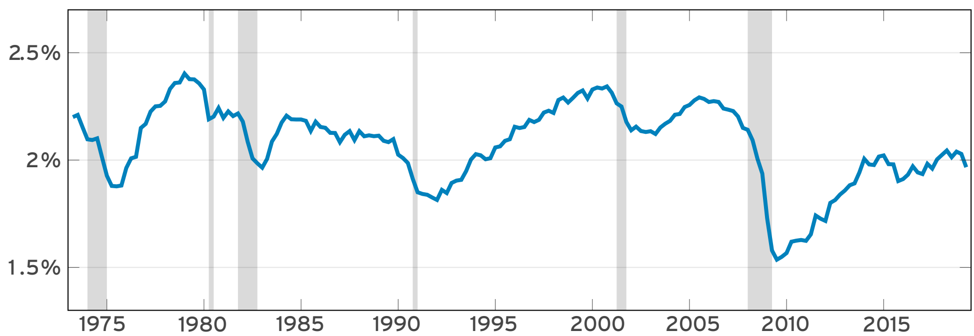
is that curbing emissions cannot be achieved without costs. Indeed, there is evidence that an increase in the price of emissions can have a negative impact on the economy in the short term (e.g. Bijnens et al. 2021, Känzig 2021). Our theory shows that a carbon tax that is optimally designed takes this dimension into account.

Combining our theory with econometric techniques allows us to provide an estimate of the optimal carbon tax over the cycle. In Figure 1, we report the results of a counterfactual exercise that estimates the historical evolution of the revenues of an optimal carbon tax for the US economy (expressed in percent of GDP), as predicted by our theory.

We propose that in crisis times macroeconomic stabilisation should be given priority over environmental protection. Indeed, as illustrated in Figure 1, the optimal policy should be used to mitigate the effect of severe recessions. For example, it would have been optimal to reduce the carbon tax sharply during the great recession of 2007-2009. During booms, in contrast, curbing emissions should be the prime concern. As emissions in the data are strongly procyclical, combating climate change is optimally achieved by raising the carbon tax during expansions. Carbon emitters therefore bear the burden of an increase in taxation during booms, but not during recessions.

Our policy recommendation is robust to variations in specification. The novelty of our approach is to highlight the possible impact of climate change on attitudes towards risk. However, studies that focus on the damage caused by climate change to production reach a similar conclusion (e.g. Heutel 2012). Environmental policies should be time-varying and prudential.

FIGURE 1 COUNTERFACTUAL ENVIRONMENTAL TAX BILL IN % OF GDP FOR THE US ECONOMY



Note: Gray shaded areas are NBER dated recessions.

IMPLICATIONS FOR EQUILIBRIUM REAL INTEREST RATES

We find that climate policies and climate change could affect equilibrium real interest rates, i.e. the rates that equate saving and investment. According to our theory, the reason is that climate change raises risk aversion. Since risk aversion amplifies the effect of uncertainty on economic decisions, climate change stimulates precautionary savings. The increase in the supply of savings induced by this mechanism then lowers equilibrium real interest rates.

Consequently, policies that mitigate the effect of climate change could raise equilibrium real interest rates. Indeed, the optimal policy set out in our theory reduces the uncertainty caused by climate change. The key is that this reduction in uncertainty lowers the need for precautionary saving. This lower willingness to save in turn puts upward pressure on real interest rates, as the availability of funds declines.

This result is potentially relevant for monetary policy. Indeed, low real interest rates increase the likelihood of hitting the effective lower bound on nominal rates, i.e. the point where nominal interest rates can go no lower. Policies that increase equilibrium real rates therefore help monetary policy by alleviating this constraint.

CONCLUSION

Climate change is a long-term phenomenon. However, as our results suggest, climate policies have implications for the short and medium term. One main takeaway from our analysis is that the optimal carbon tax should vary substantially over the cycle. In practice, however, constraints related to political economy considerations[3] or the difficulty in assessing the state of the economy in real time could make the optimal policy difficult to implement. One possible solution would be to delegate this function to an independent institution endowed with sufficient resources[4].

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3 Indeed, decisions to increase taxes are typically unpopular and may therefore affect re-election prospects of politicians.
4 As suggested by Delpla and Gollier (2019), this institution could for instance take the form of a "carbon central bank".

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CHAPTER 17

Carbon pricing and relocation: Evidence from Dutch industry[1]

Sander Hoogendoorn, Arjan Trinks, Johannes Bollen

CPB Netherlands Bureau for Economic Policy Analysis; CPB Netherlands Bureau for Economic Policy Analysis; CE Delft

Pricing carbon and placing a tax on industrial emissions could be a centrepiece of national climate policies going forward. This column uses simulations from a global trade model to show that the introduction of a substantial carbon tax for Dutch industry strongly reduces domestic emissions, while production losses remain modest. However, significant carbon leakage of up to around half of the emissions reduction achieved in the Netherlands occurs to mainly non-European countries such as China and India.

Pricing carbon is a cost-effective instrument to achieve emission reduction targets. The introduction of a substantial tax on industrial carbon emissions could be an important part of future climate policy. Tax rate proposals of €100 or €200 per tonne of CO2e in 2030 on top of the carbon price in the EU Emissions Trading System (EU ETS) are not uncommon. However, implementing a national carbon tax has proven to be politically difficult (Stiglitz 2019, Dolphin et al. 2020). A key concern is that such a tax may hurt domestic industrial activity. Another concern is carbon leakage – i.e. the emission reduction achieved domestically could (partly) be offset by an increase in carbon emissions in foreign countries with more favorable tax regimes.

In a recent paper (Bollen et al. 2021), we quantify both effects using the computable general equilibrium (CGE) model WorldScan, which includes global trade effects at a relatively detailed sector level. More specifically, we simulate the impact of four policy scenarios featuring a national carbon tax of €100/tCO2e or €200/tCO2e in 2030, with tax revenues either being returned as a lump sum to households or used as a targeted subsidy for carbon emission reduction in Dutch industry. In the latter case, the additional costs of the carbon tax are partly offset, mitigating the cost price increase and production loss for industrial companies. We assess the robustness of the effects for several model parameters, including trade elasticities, abatement costs, and EU ETS prices.

1 This column first appeared on VoxEU 13 July 2021 https://voxeu.org/article/carbon-pricing-and-relocation-evidence-dutch-industry

A COST-EFFECTIVE WAY TO REDUCE DOMESTIC CARBON EMISSIONS

Table 1 shows the environmental effects of a €100/tCO2e carbon tax[2]. Carbon emissions of Dutch industry drop by about 40%. That is, the tax leads industrial emissions to decline from 58 Mt CO2e in 2018 to 21 Mt CO2e in 2030, which is a 40% reduction relative to the no-tax case (36 Mt CO2e). This substantial emission reduction reflects that industrial companies have significant options to reduce emissions against relatively low costs[3]. Moreover, the rate of carbon emission reduction increases further if the tax revenues are redirected back to industry in the form of a targeted subsidy for emission reduction. The emission reduction effects are in line with recent empirical results on the EU ETS (Dechezleprêtre et al. 2018).

TABLE 1 CARBON EMISSION REDUCTION DUE TO A €100/TCO2E CARBON TAX FOR DUTCH INDUSTRY, RELATIVE TO THE NO-TAX CASE, IN 2030 (%)

Tax revenues are returned to:	Households	Industry
Total emission reduction	**40**	**46**
by abatement measures	27	37
by structural changes in industry*	9	6
by production reduction industry	4	3

Notes: * Composition effect from decreasing activity share of the relatively carbon-intensive subsectors within industry. ** Effect from decreasing activity share of industry as a whole.

PRODUCTION LOSSES FOR INDUSTRY ARE MODEST

A €100/tCO2e carbon tax has only modest economic effects. The production loss for Dutch industry is 2-3% (see Table 2)[4]. This result is driven by the fact that energy costs turn out to be only a relatively small part of total input costs and the abatement curve being strongly convex (i.e. a large amount of emissions can be reduced with relatively inexpensive abatement options such as carbon capture and storage). For chemicals and basic metals, the production losses are about twice as large as the rest of industry since

2 The economic and environmental effects of a €200/tCO2e carbon tax are included in Bollen et al. (2020).

3 We verified the potential and costs of these carbon emission reduction techniques by conducting a review of the most recent literature on emission abatement technologies in Dutch industry.

4 Since industrial companies cannot fully pass on the extra costs of the carbon tax to their customers, the market price for industry as a whole increases by 0.4%. As a consequence, Dutch industry loses market share in world production, represented by a decline of exports (-2.4%). The degree to which exports react to a price change depends on the price substitution elasticity – the Armington elasticity – which, according to recent empirical estimates, is about 6 for industry as a whole (Bollen et al. 2018, 2020). The decline of exports (i.e., production loss) therefore equals 6 (Armington elasticity) times 0.4 (market price increase).

these sectors are more carbon-intensive and more sensitive to international competition. Prior empirical studies have also found no or negligible competitiveness effects of carbon pricing (Dechezleprêtre and Sato 2017, Verde 2020).

TABLE 2 PRODUCTION LOSS DUE TO A €100/TCO2E CARBON TAX FOR DUTCH INDUSTRY, RELATIVE TO THE NO-TAX CASE, IN 2030 (%)

Tax revenues are returned to	Households	Industry
Industry as a whole	**3**	**2**
subsector Chemicals	6	3
subsector Oil and gas	3	2
subsector Basic metals	8	6

CARBON LEAKAGE REMAINS A POTENTIAL CONCERN

Despite the limited production loss for Dutch industry, we find a substantial leakage of carbon emissions to foreign countries (see Table 3). At a carbon tax rate of €100/tCO2e, the leakage ratio indicates that 61% of the emission reduction achieved domestically is offset by an increase in carbon emissions elsewhere. The leakage effect is relatively large because the loss of production is mainly taken over by non-European countries with no binding or relatively mild emission caps, such as China and India. Carbon leakage to these countries can be significant due to differences in the carbon intensity of industrial activities and the additional demand for fossil energy[5]. Nevertheless, carbon leakage can be reduced by about a third when tax revenues are used as a targeted subsidy for emission reduction. Sensitivity analyses that include different trade elasticities, abatement costs, and EU ETS prices by and large confirm the pattern of a limited production loss for Dutch industry as well as a substantial carbon leakage to foreign countries. All in all, our results are somewhat larger than recent empirical estimates for the EU ETS (Verde 2020) though close to prior trade-model estimates that consider the effects of substantial carbon price shocks (Branger and Quirion 2014, Carbone and Rivers 2017).

5 A carbon tax for Dutch industry will reduce the export of carbon intensive products to other European countries. Subsequently, these countries have to increase their own industrial production and lower their exports to meet domestic demand. In response, non-European countries such as China and India also increase their industrial production to maintain consumption levels. However, China and India so far do not have binding emission caps and the carbon intensity of industrial activities is on average 2.5 times higher than in Europe. Moreover, the additional production of industrial products will be accompanied by a greater demand for electricity that is often generated through the use of fossil energy. As a consequence, carbon emissions in non-European countries such as China and India can be five times higher than in Europe. Finally, the additional production in these countries also generates GDP growth, which leads to extra traffic (often based on fossil fuels) and demand for services.

TABLE 3 CARBON LEAKAGE DUE TO A €100/TCO2E CARBON TAX FOR DUTCH INDUSTRY, RELATIVE TO THE NO-TAX CASE, IN 2030

Tax revenues are returned to	Households	Industry
Carbon leakage ratio (%)*	61	40
Leakage to other European countries	6	4

Note: * Defined as (carbon emission increase outside of the Netherlands/carbon emission reduction in the Netherlands) x 100%.

CONCLUDING REMARKS

The carbon taxes analysed for the Dutch case are substantial (€100 and €200/tCO2e) and our analysis thus contributes to a better understanding of the impact of intensified climate policies around the world. In particular, the tightening of the EU ETS, as envisaged by the European Green Deal, may drive up carbon prices to, for example, €100 per ton of CO2e. Our study suggests that targeted subsidies for carbon emission reduction may help to lower the leakage ratio in the European case as well. Future work on other anti-leakage measures, such as border tax mechanisms, is needed to enhance the effectiveness of carbon pricing instruments.

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CHAPTER 18

The social cost of carbon and inequality[1]

David Klenert, Marc Fleurbaey

European Commission; CNRS, Paris School of Economics

The social cost of carbon is a monetary metric for the damage caused by the emission of an additional tonne of CO2. Previous literature has shown that accounting for inequality between countries significantly influences the social cost of carbon, but mostly omits heterogeneity below the national level. Using a model that features heterogeneity both between and within countries, this column demonstrates that climate and distributional policy can generally not be separated. In particular, it shows that a higher social cost of carbon may be called for globally under realistic expectations of existing inequality.

As one of his first actions after taking office, US president Joe Biden signed an executive order that re-established a working group to provide updated estimates for the social cost of carbon (The White House 2021). The social cost of carbon attaches a price tag to carbon emissions, representing the economic damage to society of an additionally emitted ton of CO_2. This central measure is used as a guideline for climate policy in regulatory impact assessments (Environment and Climate Change Canada 2016, Greenstone et al. 2013, Watkiss and Hope 2011). It is considered as a shadow price for mitigation options, determining their financial viability, but can also be translated into an appropriate carbon price level.

The social cost of carbon is usually determined using integrated assessment models such as the dynamic integrated climate-economy (DICE) model or the framework for uncertainty, negotiation, and distribution (FUND) model (e.g. Anthoff and Tol 2010, Gillingham 2018). These models couple a macroeconomic model with a climate module. There have been insightful estimations using this approach, varying different parameters, refining the climate modules, and incorporating additional macroeconomic insights (e.g. Anthoff and Emmerling 2019, Foley et al. 2013, Golosov et al. 2014, Greenstone et al. 2013, Metcalf and Stock 2017, Nordhaus 2017, Rezai and Van der Ploeg 2016, Stern 2008, van den Bijgaart et al. 2016). This led to the Nobel Prize for William Nordhaus based on his work on the DICE model (Nordhaus 2018).

1 This column first appeared on VoxEU 28 April 2021 https://voxeu.org/article/social-cost-carbon-and-inequality

These models usually aggregate the global economy to one representative agent (Nordhaus 2014, 2017, van der Ploeg and Rezai 2019) or use Negishi weights[2] in regionalised studies, which render the existing level of inequality optimal within the global social welfare function (Nordhaus and Yang 1996). This level of aggregation, however, neglects important climate change related distributional effects and possible interactions between them and the level of the social cost of carbon. It has been shown, in fact, that accounting for income differences between countries and regions critically influences the level of the social cost of carbon (Adler et al. 2017, Anthoff et al. 2009, Anthoff and Tol 2010, Azar and Sterner 1996).

Yet, distributional effects between individuals within these regions are neglected, even though their effect on the social cost of carbon could be substantial (e.g. Burke et al. 2016). In our recent paper (Kornek et al. 2021), we therefore account for heterogeneity both between and within countries to estimate the size and direction of this effect. In contrast to all previous studies, we take into account that household inequality is not a given characteristic. Instead, allocation between households is determined by distributional policies of national governments (Wang et al. 2012).[3] The key question here is whether the inclusion of additional distributional effects leads to an increase or a decrease in the social cost of carbon.

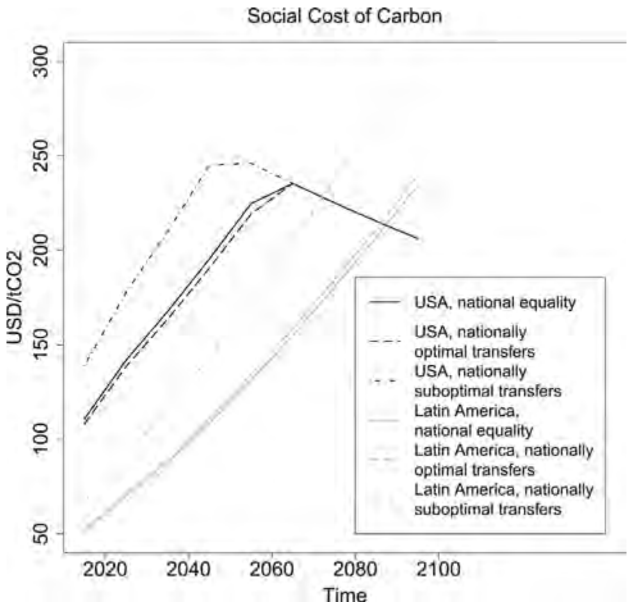
To provide a tentative answer to this question, we compare the social cost of carbon from two scenarios that differ in how national governments redistribute between households, with the social cost in the representative agent case (i.e. no within-country heterogeneity as in most previous literature). In the first redistribution scenario, national governments compensate households for climate-related damages and costs. We find that the social cost of carbon remains roughly unchanged compared to the representative agent. In the second redistribution scenario, national governments do not take the distribution of climate damages and abatement costs into account when distributing between households. We find that, when low-income households experience large and uncompensated climate damages while abatement costs are proportional to income, the social cost of carbon tends to increase globally.

We quantify these effects numerically for a standard range of parameter values, using a modified version of the NICE model,[4] a variant of the regionalised version of the above-mentioned DICE model. In Figure 1, we illustrate the main results for the example of Latin America and the US. In Figure 2, we show that the social cost of carbon can be up to four times larger for some regions compared to the representative agent case (labelled 'equality') when national redistribution is suboptimal and the households in each region

2 Negishi weights are inversely proportional to the marginal utility of consumption.
3 This is in fact the key difference from the few studies that consider inequality at the subnational level in the context of calculating the social cost of carbon (Anthoff et al. 2009, Anthoff and Emmerling 2019, Budolfson et al. 2017, Budolfson and Dennig 2020, Dennig et al. 2015).
4 See Dennig et al. (2015) for a detailed description of the NICE model.

experience the same absolute and uncompensated climate damage. Conversely, if national governments compensate households for climate-related damages and costs, the social cost of carbon changes only moderately, with a maximum increase of roughly 40%.

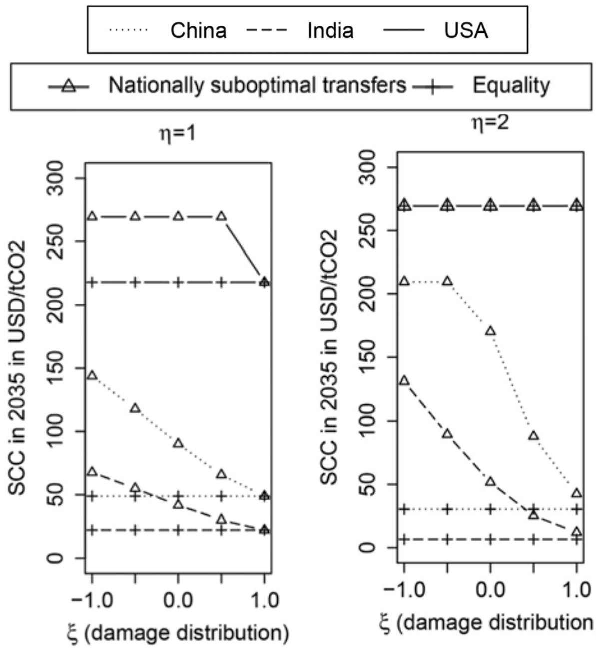
FIGURE 1 THE SOCIAL COST OF CARBON OVER TIME IN THE US AND LATIN AMERICA



Notes: The social cost of carbon over time for the US and Latin America for the following cases: equality between quintiles in each country (i.e. the representative agent case), inequality and nationally optimal transfers, inequality and nationally suboptimal transfers. The income elasticity of damages is $\xi = 0$, hence we are looking at the case in which damages fall disproportionately on low-income quintiles.

Climate change mitigation and the reduction of poverty and inequality are top political priorities, but the two goals are often portrayed as contradictory. Our results demonstrate that accounting for heterogeneity between and within countries is crucial for determining the social cost of carbon, as large interactions between the two exist. Our results cast doubt on the idea that climate policy ambition should be lowered due to inequality concerns. In contrast, we demonstrate that a higher social cost may be called for on a global scale under realistic expectations of existing inequality, specifically, that many countries might not have the capacity to reimburse poor households for disproportionate climate damages.

FIGURE 2 THE SOCIAL COST OF CARBON FOR CHINA, INDIA, AND THE US



Notes: The social cost of carbon in the year 2035 in China, India, and the US for different values of the elasticity of marginal felicity η and different damage distribution parameters ξ. We compare the scenario of nationally suboptimal transfers with the case of equality (i.e. the representative agent case). If damages are proportional to income (ξ = 1), the social cost of carbon diverges only moderately from the case of equality. When all quintiles experience the same absolute damage (ξ = 0), the social cost increases notably compared to the representative agent case. The magnitude of change is especially pronounced when η increases to 2, where the social cost of carbon is more than four times higher compared to equality.

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CHAPTER 19

Tackling climate change requires global policies[1]

Söhnke M. Bartram, Kewei Hou, and Sehoon Kim

University of Warwick and CEPR; Ohio State University; University of Florida

How effective are climate change policies, and what are the important considerations to ensure they are effective? This column shows that firms respond to climate change policies with regulatory arbitrage so that localised policies aimed at mitigating climate risk can have unintended consequences. Studying the impact of the California cap-and-trade programme, it shows that firms without financial constraints do not reduce their emissions in response to the policy. In contrast, financially constrained firms shift emissions and output from California to other states. In fact, contrary to the policy objective, these firms increase their total emissions after the cap-and-trade rule.

Given increased concerns about climate change risk, governments around the world are considering regulations to curb greenhouse gas (GHG) emissions in various shapes and forms. However, to date there is no consensus on what the optimal policy approach might be. Consequently, climate policies are highly fragmented across different jurisdictions (Figure 1). This has important implications for the success of localised policies. As a case in point, in 2013, California became the first US state to implement a multi-sector cap-and-trade system to regulate all industrial GHG emissions. It was launched as a pragmatic approach to manage the amount of GHGs produced by companies within the state. This column examines the impact of the cap-and-trade rule in California and reveals some of its unintended consequences.

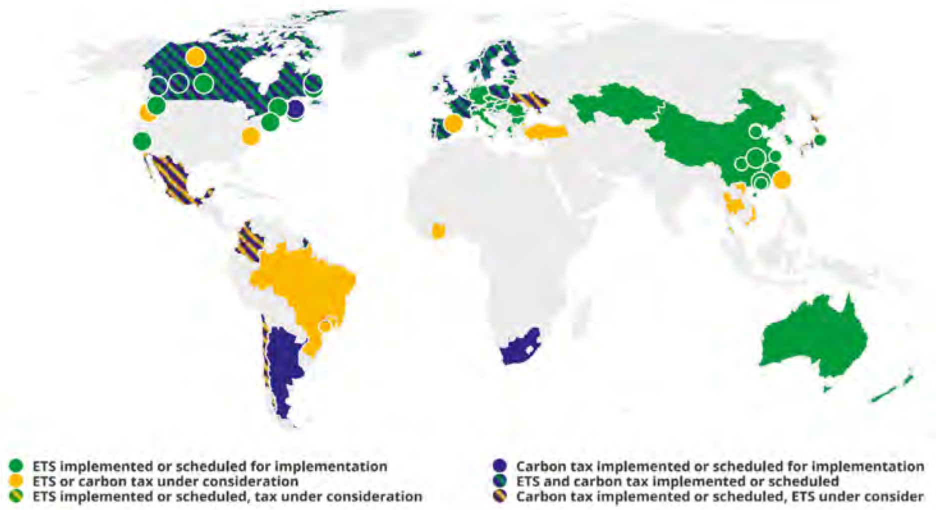
HOW DO CORPORATIONS RESPOND TO CLIMATE POLICIES? WE KNOW ONLY LITTLE…

Policy responses to remedy climate change risk are heatedly debated. Such policies have important implications for the behaviour of private industrial firms and how they respond to regulatory frictions, which are of key interest to financial economists. Understanding

1 This column first appeared on VoxEU 3 May 2021 https://voxeu.org/article/tackling-climate-change-requires-global-policies

these effects are important to guide policy makers to internalize externalities that may otherwise result in unintended consequences and more effectively coordinate solutions to climate change.

FIGURE 1 THE SEGMENTED WORLD OF CLIMATE CHANGE POLICIES



Source: World Bank

However, the economic consequences of climate change have only recently garnered much interest among financial economists (e.g. Bolton and Kacperczyk 2021, Khanna et al. 2021). Fewer studies link financial incentives and corporate environmental policies. For example, Forster and Shive (2020) find that short-termist pressure for financial performance from outside investors forces public firms to emit more GHGs than private firms. Kim and Xu (2020) also show that financial constraints exacerbate toxic pollution by firms due to the costs of waste management, and that this effect is stronger when regulatory monitoring is weak. Similarly, Akey and Appel (2021) find that firm subsidiaries are more likely to increase toxic emissions when parent companies have better liability protection for their subsidiaries' environmental clean-up costs, consistent with the binding effects of higher financial burdens associated with abatement. How such incentives may affect corporate responses to climate policies remains an unanswered yet important question.

EMISSION REDUCTION OR REALLOCATION?

In a recent paper (Bartram et al. 2020), we examine detailed plant-level data on GHG emissions and parent company ownership made available by the US Environmental Protection Agency. Our dataset includes 2,806 industrial plants and 511 publicly listed firms over the sample period, 2010 to 2015. We focus on the behaviour of industrial corporations around 2013, when the California cap-and-trade policy was introduced.

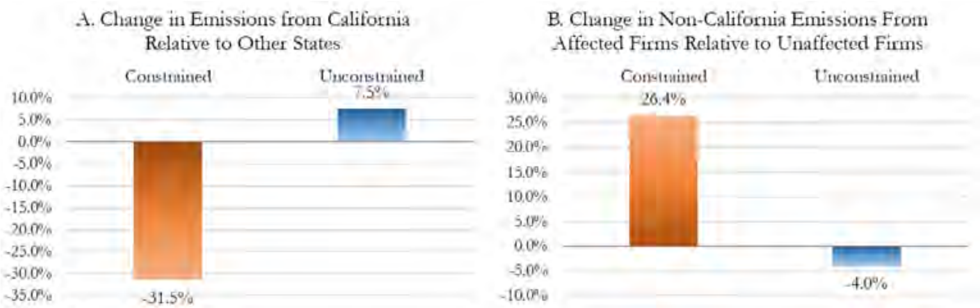
To illustrate, a major producer of transportation fuels vehemently opposed the adoption of the cap-and-trade policy, as it was still reeling from the financial crisis a few years earlier. When the policy was announced, the firm reduced its emissions at one of its largest California refineries by 8% over the next three years. However, it also increased emissions by more than 10% at some of its largest refineries in other states. Our study investigates whether this kind of response has been typical across companies.

FINANCIAL CONSTRAINTS MATTER

We document significant differences in how firms respond to the policy, depending on their financial constraints. As shown in Figure 2, financially constrained firms (typically small and medium-sized companies with limited access to capital) reduce GHG emissions at their plants located in California by 32% relative to plants they own in other states. However, these companies also increase emissions by 26% at plants in other states, compared to plants in those states owned by firms without a presence in California. In contrast, companies with easy access to capital (i.e. financially unconstrained firms) do not adjust plant emissions at all in response to the new cap-and-trade regulation — not in California nor in other states.

The above findings suggest that the regulation is not costly enough for big companies with deep pockets, but is rather just a slap on the wrist. In contrast, the policy has a large distortionary impact on smaller companies or those having a hard time raising capital to finance their projects. Some of these companies choose to move their emissions elsewhere because they cannot afford the incremental costs of the cap-and-trade. Based on back-of-the-envelope calculations, the additional costs of emissions to constrained firms under the California cap-and-trade rule is equivalent to a 9% increase in tax expenses or 4% increase in interest expenses. For the subset of firms that reallocate their emissions the most in response to the policy, the impact of the policy on costs is more severe, equivalent to a 15% (11%) increase in tax (interest) expenses.

FIGURE 2 CHANGES IN EMISSIONS AFTER THE CALIFORNIA CAP-AND-TRADE RULE

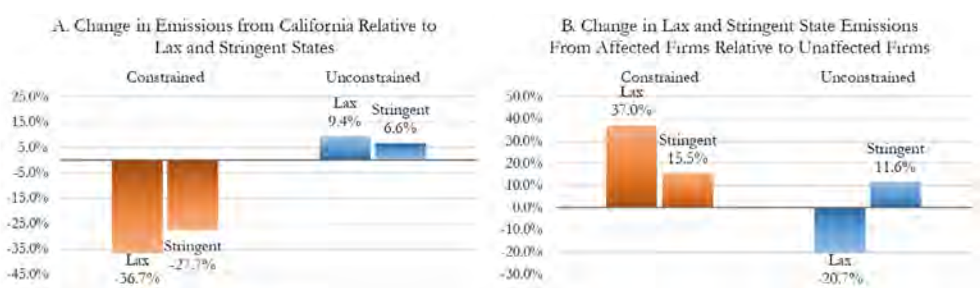


WHERE DO FIRMS SHIFT EMISSIONS TO?

We explore the economic mechanisms for our results and find that constrained firms reallocate their emissions from their plants in California primarily to plants with similar functions in other states, rather than to plants that play different roles within their organisational structure. In response to the cap-and-trade rule, these firms tend to reallocate their emissions toward plants outside of California with greater excess capacity, avoiding large fixed costs associated with capacity adjustments. We find that such emission reallocations across plants are the result of changes in production activity rather than carbon efficiency.

This response partially reflects the appeal of cheaper, less-stringent regulatory environments available to financially constrained companies in other parts of the country (Figure 3). It also reflects the reallocation by companies that had not been investing in clean technologies and thus were not readily prepared to shield themselves from the new regulatory costs. While financially constrained companies are likely behaving optimally from a shareholders' point of view, this is an adverse outcome from a social and environmental perspective.

FIGURE 3 STRINGENCY OF ENVIRONMENTAL REGULATIONS IN TARGET STATES



LOCAL POLICIES DON'T WORK

A critical policy implication of this reallocation is that the cap-and-trade may not lead to the desired reduction in GHG emissions globally. To the contrary, we find that financially unconstrained firms do not respond to the policy, while constrained firms with plants in California and in other states increase their total emissions by 21% as a result of their reallocation, undermining the goal of the cap-and-trade (and of climate policies in general) to combat climate change at the global level.

The data supports our hypothesis that, for firms with limited access to capital, it is more attractive to reallocate their GHG emissions and plant ownership away from California to avoid the heightened regulatory costs that make doing business in the state expensive. This unintended consequence corresponds to an increase in emissions in less-regulated states and regions throughout the country, while resulting in a reduction in economic activity in sectors within California that are required to curb emissions, as evidenced by a 14% decline in emission-heavy sector employment.

WHAT IT MEANS FOR CLIMATE POLICY DESIGN

In conclusion, climate policies designed and implemented at the local level (such as the California cap-and-trade rule) are unlikely to be effective at tackling climate change. Increased regulatory costs from the cap-and-trade rule only raise the burden for less financially capable businesses. They discourage them from investing and producing in states with costly climate change policies and incentivizse them to shift their emissions to plants they own in less-regulated states.

Our study illustrates the interplay between climate policy and firm behaviour and highlights the potential externalities from regionally segmented climate policies. If localised climate policies are not effective within one country, they are unlikely to have the intended effect of reducing emissions across countries. Consequently, climate change solutions at the local level must recognise and account for regulatory differences regionally and globally.

Our findings point to two policy guidelines: (1) climate policies should be harmonised across jurisdictions in order to minimise leakages; and (2) policymakers should carefully devise appropriately differentiated subsidies to mitigate distortions from implementing climate policies.

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PART IV

GREEN FINANCE: IS IT WORKING?

CHAPTER 20

The carbon bubble and the pricing of bank loans[1]

Manthos Delis, Kathrin de Greiff, Steven Ongena

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Neglecting the possibility that fossil fuel reserves can become 'stranded' could result in a 'carbon bubble' as fossil fuel firms become overvalued. This column studies whether banks price the climate policy risk of fossil fuel firms. Prior to 2015, banks did not appear to price climate policy risk. After 2015, however, the risk is priced to a certain extent, especially for firms holding more fossil fuel reserves.

The 2015 Paris Climate Agreement to limit the rise in global warming to 2°C compared to pre-industrial levels requires massive reductions in CO2 emissions in the next decades and near zero overall greenhouse gas (GHG) emissions from the next century onward. The limiting of total carbon emissions will leave the majority of fossil fuel reserves as 'stranded assets' (Carbon Tracker Initiative 2011, 2013, McGlade and Ekins 2015), with companies owing fossil fuel unable to use most of their reserves. The large fraction of potentially unburnable fossil fuels poses substantial financial risk to fossil fuel companies. Nevertheless, fossil fuel firms still largely invest in locating and developing new fossil fuel reserves (Carbon Tracker Initiative 2013). This ongoing investment, together with the already large fraction of potentially stranded assets, suggests that financial markets neglect the possibility that fossil fuel reserves become 'stranded' resulting in a 'carbon bubble', i.e. that fossil fuel firms are overvalued.

The potential effects of a carbon bubble on financial stability have been recently discussed in the academic literature (Weyzig et al. 2014, Schoenmaker et al. 2015, Batten et al. 2016) and are increasingly appearing on the agenda of regulators and supervisors (Bank of England 2015, Carney 2015, ESRB 2016). However, there is no clear evidence if whether, and to what extent, investors price the risk of unburnable carbon. Studying equity markets, recent research identifies an insignificant impact of climate/technology news on fossil fuel firms' abnormal returns (Batten et al. 2016, Byrd and Cooperman 2016). This insignificant impact could be due to investors' difficulties in assessing credible future climate policies and their impact on carbon-intense sectors, to investors believing in

1 This column first appeared on VoxEU 27 May 2018 https://voxeu.org/article/carbon-bubble-and-pricing-bank-loans

climate policy inaction, or to already accurately priced risk of climate-related stranded fossil fuels (Batten et al. 2016, Byrd and Cooperman 2016). Thus, we are missing insights into the effect of climate policy risk on the pricing of financial products.

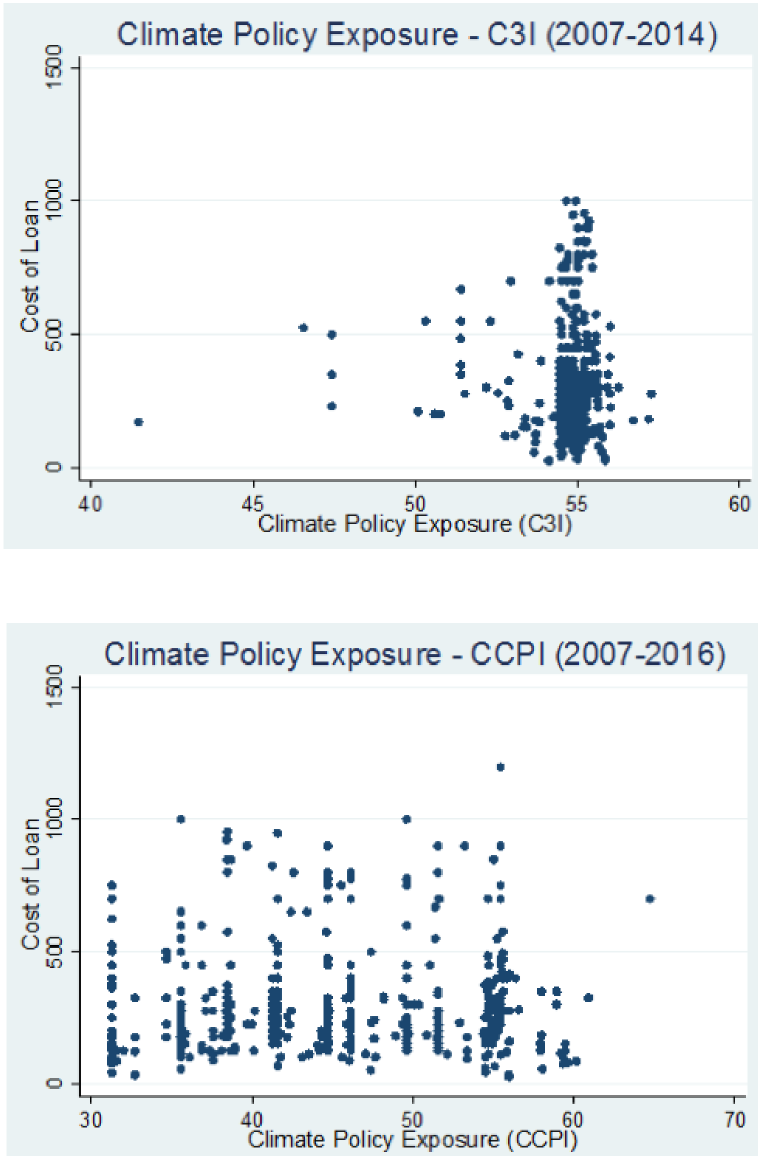
IS THERE A CARBON BUBBLE IN THE CORPORATE LOAN MARKET?

In a recent paper, we provide the first evidence for climate policy risk pricing, using evidence from the corporate loan market (Delis et al. 2018). Carbon-intensive sectors are largely debt financed, implying that the impact of stranded fossil fuels can easily spill over to the banking sector. This almost naturally generates the question of whether banks consider the risk that fossil fuel reserves will become stranded when originating or extending credit to fossil fuel firms. Essentially, this implies that if banks thoroughly consider the risk of climate policy exposure in the pricing of corporate loans, then no carbon bubble exists in the credit market.

Ideally, our main explanatory variable illustrating climate policy exposure would be the amount of stranded assets of a fossil fuel firm. However, such detailed estimates are not available. In principle, a devaluation of fossil fuel reserves can be caused by changes in regulation (policies), technologies, or carbon prices. Climate policies involve direct environmental regulations (e.g. pollution outputs and inputs) as well as stimulating the development of alternative technologies (for example, by subsidising instruments. The probability of stranded fossil fuel reserves is thus higher in countries with higher climate policy stringency. Therefore, we proxy the risk of stranded fossil fuel reserves by the risk of climate policy stringency, i.e. whether a country places considerable effort in climate change policies. A fossil fuel firm owing exploration rights for reserves in a country with strict climate policy faces a higher probability of reserves being stranded than a firm with fossil fuel reserves in a country with loose climate policy.

This implies that we require information on the total amount of fossil fuel reserves of firms across countries. As these data are not readily available in conventional databases, we hand-collect them from firms' annual reports. Some firms hold fossil fuel reserves in more than one country, so we construct a relative measure of reserves for each firm, in each country, and in each year. Finally, we generate a firm-year measure of climate policy exposure (risk) from the product of relative reserves and either one of the Climate Change Cooperation Index (C3I) by Bernauer and Böhmelt (2013) or the Climate Change Policy Index (CCPI) by Germanwatch. These country-year indices, respectively available for the periods 1996-2014 and 2007-2017, reflect environmental policy stringency and thus risk.

FIGURE 1 CLIMATE POLICY EXPOSURE AND THE COST OF LOAN



Note: The cost of loan in basis points is defined as the loan spread plus any facility fee.

Our baseline analysis compares the loan pricing of fossil fuel firms to non-fossil fuel firms and the loan pricing among fossil fuel firms based on their climate policy exposure. We strengthen the validity of this model via the fielding of many control variables and fixed effects (e.g. loan type and purpose, bank*year, and firms' country fixed effects). As relevant environmental policy initiatives are recent, our analysis covers the period 2007-2016. We identify further differences in loan pricing by comparing, in the pre- and post-2015 periods, the terms of lending of fossil fuel to non-fossil fuel firms based on their climate policy exposure. The year 2015 signals a turning point because of the Paris Agreement and the intensified discussion of a carbon bubble.

OUR RESULTS: NO EVIDENCE OF PRICING OF CLIMATE POLICY RISK PRIOR TO 2015, SOME PRICING OF RISK AFTER 2015

Our results from the full 2007-2016 sample are consistent with a carbon bubble in the corporate loan market.

- We find no evidence that banks charge significantly higher loan spreads to fossil fuel firms.
- We find some evidence for higher loan fees to fossil fuel firms, but even these results are economically small and not robust across different specifications.
- However, when looking into the post-2015 period, we find the first evidence that banks increased their loan spreads to fossil fuel firms that are significantly exposed to climate policy risk. The economic significance is rather small: a one standard deviation increase in our measure of climate policy exposure implies that risky fossil fuel firms from 2015 onward are, on average, given a 2-basis points higher AISD compared to less-exposed fossil fuel firms, non-fossil fuel firms, and themselves before 2015.

To give an impression of the magnitude of this effect, the 2-basis point increase implies an increase in the total cost of the loan with a mean amount ($19 million) and maturity (four years) of around $200,000. Then, we hand collect data on the dollar value of fossil fuel reserves and find that the mean fossil fuel firm in our sample holds approximately $4,679 million in such reserves. Thus, it seems unlikely that the corresponding increase that we identify in the post-2015 period covers the potential losses from stranded assets.

We further investigate this finding by using the actual value of the holdings of proved fossil fuel reserves, instead of simply examining average differences between the fossil fuel and non-fossil fuel firms. Retaining the dichotomy between the pre-2015 and post-2015 periods, we find that a one standard deviation increase in our measure of climate policy exposure implies an AISD that is higher by approximately 16 basis points for the fossil firm with mean proved reserves scaled by total firm assets in the post-2015 period versus the non-fossil fuel firm. This implies an increase in the total cost of borrowing for the mean loan of $1.5 million. This extra cost of borrowing represents noticeable evidence that banks are aware of the climate policy issue and started pricing the relevant risk post-2015.

We also document a direct negative effect of climate policy exposure on the maturity of loans to fossil fuel firms in the post-2015 period. Moreover, we show a tendency of fossil fuel firms to obtain slightly larger loans compared to non-fossil fuel firms when environmental policy becomes more stringent. Even though the respective increase in loan amounts is economically rather small, our finding is in line with a substitution effect due to higher environmental policy risk from 'lost' access to equity finance toward bank credit. Finally, we document a slightly higher loan pricing to fossil fuel firms by 'green banks' (i.e. those participating in the United Nations Environment Programme Finance Initiative) when climate policy risk increases.

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CHAPTER 21

Green bonds and carbon emissions: Exploring the case for a rating system at the firm level[1]

Torsten Ehlers, Benoit Mojon, Frank Packer, Luiz A. Pereira da Silva
Bank for International Settlements

Projects financed by green bonds have not always resulted in decreased carbon emissions at the firm level. This column – published on the 5th anniversary of the Paris Agreement – outlines three features of a simple rating system that could both encourage firms to reduce their carbon footprint and provide a useful signal to investors. By focusing on firms' carbon intensity (emissions relative to revenue), this system would complement existing green bond labels while embracing the features most conducive to decisively lowering carbon emissions.

Five years ago, on 12 December 2015, nearly 200 countries committed to achieving the Paris Accord's climate goals, including one of its three main objectives: "making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (United Nations 2015). Green finance instruments have a key role to play in mobilising private capital, and green bonds are perhaps the most successful of these instruments thus far. Global issuance has been growing rapidly in recent years and in 2019 surpassed $250 billion, or about 3.5% total global bond issuance ($7.15 trillion).

On the investors' side, an increasing number of private and public sector entities have explicit mandates for portfolio allocations that support the mitigation of climate change. These considerations have grown – including in the central banking community, through the Network for Greening the Financial System (NGFS) – as the link between climate change, systemic risk, and financial stability has become clear (Fender et al. 2020, Bolton et al. 2020).

A context in which investors' preferences are evolving and demand for 'green' instruments is rising makes it even more important to clarify taxonomies and ensure the 'greenness' of proposed investment alternatives. In a recently published article (Ehlers et al. 2020), we assess whether corporate green bonds are issued by less carbon-intensive firms, and if

1 This column first appeared on VoxEU 12 December 2020 https://voxeu.org/article/green-bonds-and-carbon-emissions-exploring-case-rating-system-firm-level

green bond issuance leads to a reduction in carbon intensity of the issuer. We show that green bonds[2] have so far been disappointing in both respects. We then outline desirable properties for a rating system that could help spur the mitigation of climate change.

WHAT GREEN BONDS ARE DESIGNED TO DELIVER

Green bonds differ from 'normal' bonds in only one (non-financial) aspect: they carry a green label.

The green label is a signal that the proceeds of the bond are used for environmentally beneficial projects. The range of environmental benefits of green bonds is not limited to climate change mitigation (e.g. reduction of greenhouse gas emissions) and covers a broader range of benefits such as climate change adaptation, water security, or waste reduction.

While there are no global regulatory minimum standards for green bonds – or how environmentally beneficial projects are defined (Ehlers and Packer 2017) – the private sector has developed the high-level green bond principles (GBPs) as well as more specific voluntary 'standards' based on the GBPs (e.g. CBI 2019). A major development in setting official standards for green bonds is the proposed EU green bond standard (EU TEG 2019a), based on the EU sustainable finance taxonomy (EU TEG 2019b).

However, even if issuers were to strictly adhere to the currently voluntary standards, these standards do not ensure beneficial environmental outcomes. Hence, green bonds should not necessarily be expected to lead to a reduction in carbon emissions at the *firm level*. We argue that this is desirable if green bonds are to help achieve the financing of green projects and, at the same time, of high-level climate goals.

GREEN BONDS AND CARBON INTENSITY OF FIRMS

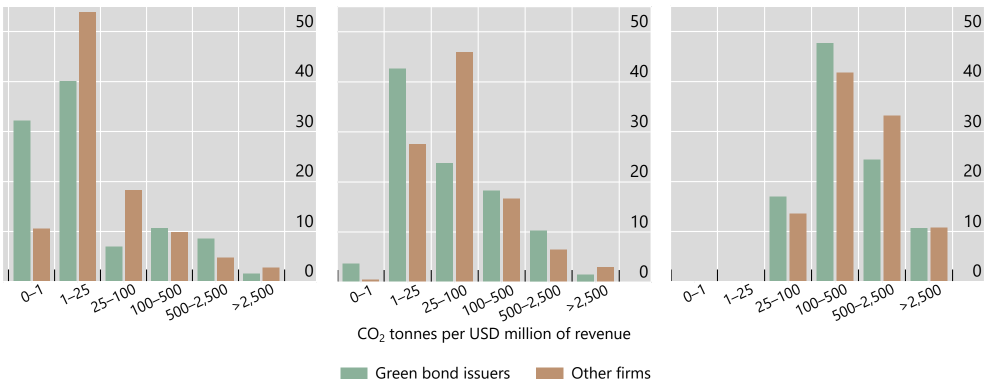
Our preferred measure of firm 'greenness' is carbon intensity, or the ratio of carbon emissions to revenue. Unlike a simple absolute measure of carbon emissions, this ratio measures the firm's carbon efficiency. Firms that use greener technologies and energy can achieve lower carbon emissions *at the same level of economic activity and size*. Our sample is based on around 16,000 listed firms (>99% of global market cap) using S&P TruCost data.

Less informed investors might expect firms with very high carbon intensities to be disqualified as issuers of green bonds. However, Graph 1 indicates that for Scope 1 (direct emissions emanating from the firms' own resources) and Scopes 1-2 (Scope 1 plus indirect emissions from consumed energy), a greater fraction of green bond issuers than other

2 Our study is solely focused on corporate bonds. Sovereign green bonds are another important segment of the green bond market.

issuers have a carbon intensity above 100 tonnes of CO2 per million dollars of revenue. For Scopes 1-3 carbon intensities (Scopes 1-2 plus all indirect emissions from upstream and downstream activities), firms with the highest carbon intensity comprise virtually equal shares of green bond issuers and others.

FIGURE 1 DISTRIBUTION OF CARBON INTENSITIES: GREEN BOND ISSUERS VERSUS OTHER FIRMS, FY2018

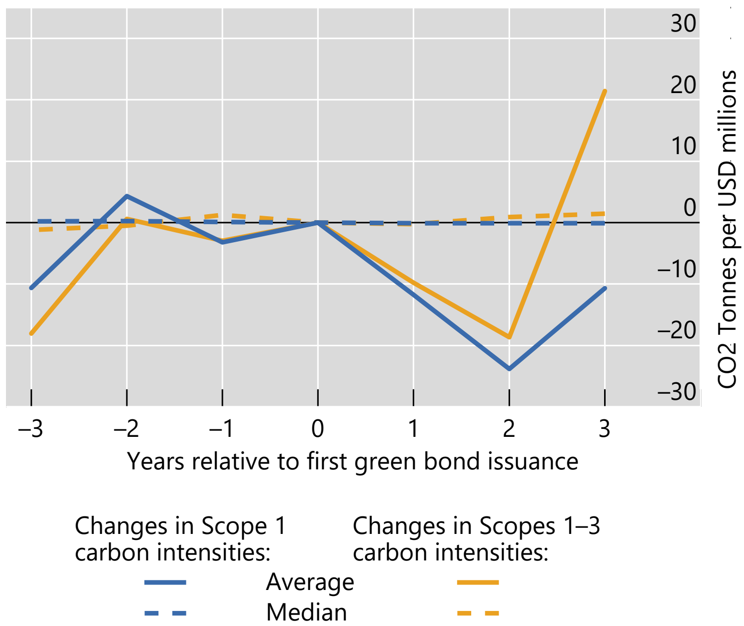


Comparing the carbon intensities of green bond issuers with those of other firms buttresses two important points previously made in Ehlers and Packer (2017). First, even if bond proceeds flow into green projects (e.g. renewable energy), issuers may be (and often are) heavily engaged in carbon-intensive activities elsewhere (e.g. coal power plants). Second, the wide range of varying green bond standards allows a very broad assortment of firms to issue green bonds, each deemed to be green for different reasons.

There is also no clear evidence that green bond issuance is associated either with a reduction in carbon intensities over time at the firm level (Graph 2), or with lower intensities than firms that did not issue green bonds (see Ehlers et al. 2020)[3]. Around 60% of green bond issuers in our sample show a reduction in Scope 1 carbon intensities after three years; but only about 30% show a reduction when looking at broader Scopes 1- 3 intensities.

3 The standard deviations are several multiples of the mean changes presented in Figure 2 and hence not shown.

FIGURE 2 GREEN BOND ISSUANCE AND CHANGES IN ISSUERS' CARBON INTENSITY



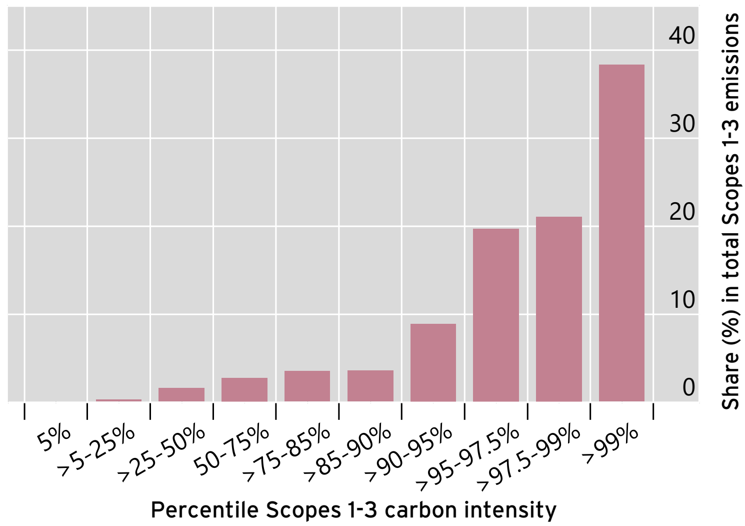
DESIRABLE PROPERTIES OF A COMPLEMENTARY GREEN RATING SYSTEM

What are the desirable properties of a rating system to support the transition to a low-carbon economy? We highlight a few key properties here and refer to our article for a more comprehensive discussion.

We argue that a firm-level rating is better suited to deliver this property than a project-based classification. The firm is the decision-making unit when it comes to the carbon footprint of economic activity: that is, the production process, choices of inputs, outputs and means of distribution.

Further, rather than focussing on firms in the lowest end of the carbon intensity distribution, green ratings should focus on the activities of high polluters, as their improvement will yield the highest gains in the overall reductions of carbon emissions. In fact, the 1% of firms with the highest carbon intensities (>99% percentile) are responsible for close to 40% of aggregate Scopes 1-3 emissions (Figure 3).

FIGURE 3 ABSOLUTE CARBON EMISSIONS BY CARBON INTENSITY PERCENTILE, FY2018



The rating of 'greenness' should be based on simple verifiable outcome-based measures, such as the carbon intensity of firms. This is an easy measure for potential investors to understand, and its availability across a wide range of firms allows for straightforward verification. To avoid firms exploiting loopholes, including by outsourcing their carbon-intensive activities, we propose using the broadest possible range of scopes (currently Scopes 1-3), which covers indirect emissions from the inputs used as well as distribution and usage of products. By doing so, we can achieve a win-win wherein green projects can be financed while firms are given more incentives to reduce their overall carbon intensity.

EXAMPLE OF A FIRM-LEVEL CARBON-INTENSITY RATING

As an illustration, we develop a simple example of a firm-level carbon-intensity rating (Table 1). One of its key features is the higher granularity of rating buckets for firms with high carbon intensities, which gives those firms a better chance and stronger incentive to improve their ratings – more so than would a binary green rating or certification. The carbon intensity cut-off points of our rating are fixed over time and allow firms to gradually improve, in the spirit of high-level climate goals.

The simple illustrative rating system has further beneficial properties, such as a certain degree of stability of ratings over time (a key requirement for investors) and simplicity. It would be easy to implement and hence low-cost.

TABLE 1 GREEN RATING: CARBON INTENSITY CUT-OFF POINTS

	Rating label									
	GGGGG	GGGG	GGG	GG	G	P	PP	PPP	PPPP	PPPP
Percentile of carbon intensity distribution	5th	25th	50th	75th	85th	90th	95th	97.5th	99th	>99th
Threshold Scopes 1-3 carbon intensity[1]	50	133	401	985	1,847	3,112	6,293	9,128	16,812	>16,812
Rounded threshold Scopes 1-3 carbon intensity[1]	50	130	400	1,000	1,800	3,100	6,300	9,100	17,000	>17,000

Note: 1 In tonnes of CO_2 per USD million of revenue. Includes bot upstream and downstream Scope 3 data.

Sources: S&P Trucost United ©Trucost 2020; authors' calculations.

CONCLUSIONS

Green bonds have played an important role in developing the market for sustainable finance instruments. Its rapid growth is a testament to investors' demand for such instruments, which is likely to grow further. *Complementary* ratings to current green certifications could help to convert market trends into much needed reductions in carbon emissions.

A simple rating system based on firms' carbon intensities, such as the one discussed here, could help to inform investor allocation decisions not only for bonds but also for stocks. Various other related efforts are under way, such as standardised impact reports for green bonds, which could include an assessment of achieved (or expected) carbon reductions. New types of bonds – such as sustainability-linked bonds, climate-aligned or transition bonds – also focus on outcomes, including carbon emission reductions (CBI 2020, ICMA 2020). But such efforts are still in their infancy. In order to contribute to reducing the huge risks related to climate change, we need to improve information and clarity for potential investors.

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CHAPTER 22

Limits to private climate change mitigation[1]

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Sustainable investment incorporating environmental, social, and governance concerns is increasingly used as an emissions-reducing policy. However, little is known about its effectiveness. This column examines the relationship between ESG metrics and emission growth across 20 countries and finds little evidence to suggest that higher ESG metrics are associated with reduced emission growth.

As climate change looms ever larger (IPCC 2018a, Furman et al. 2015), economists have coalesced around the need for climate policies centring around Pigouvian taxes cushioned by transfers to vulnerable households (IMF 2020, Gollier 2021)[2]. However, carbon taxes and related policies face deep political constraints (Nordhaus 2015, Gillingham and Stock 2018). As a complement to policies directly targeting carbon emissions, many look to sustainable investing – increasingly identified with the incorporation of environmental, social, and governance (ESG) concerns in investment strategies – as part of the way forward (Krueger et al. 2020, Hong et al. 2021). In recent work, we examine whether such market forces can help make meaningful progress in addressing climate change (Elmalt et al. 2021).

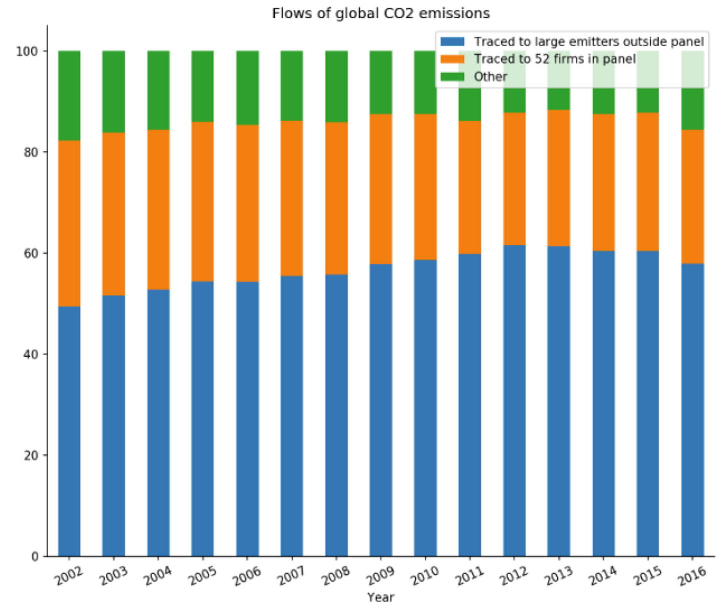
While climate change is a global challenge, much of the global stock of carbon emissions can be traced to a remarkably small set of firms: just 96 firms located upstream in production chains reliant on carbon emissions (largely fossil fuel producers) have accounted for 70% of global carbon emissions since 1850 (Figure 1). This striking concentration motivates us to focus on the potential for ESG investing to shift production incentives within these 'climate-crucial' firms.

To assess scope for ESG-conscious investing to affect production decisions, we combine firm-level data on emissions for large emitters with data on ESG metrics and other firm characteristics and end up with a panel covering 52 investor-owned firms in 20 countries

1 This column first appeared on VoxEU 23 June 2021 https://voxeu.org/article/limits-private-climate-change-mitigation
2 See a 2019 Wall Street Journal statement by a group of prominent economists in support of carbon taxes with lump sum rebates

accounting for close to 30% of global emissions since 2002[3]. Industry-level comparisons suggest that these firms are attuned to ESG considerations – they receive better overall ESG ratings than listed firms in other industries.

FIGURE 1 FLOW OF GLOBAL CARBON EMISSIONS TRACED TO LARGE EMITTERS



Notes: This figure shows the flow of global carbon emissions, breaking out emissions attributable to the 52 large emitters in our baseline panel and to the remaining large emitters tracked in our firm-level emissions data (Heede 2014a, 2014b). Emissions are shown as shares of the total flow in each year.

A WEAK LINK: ESG SCORES AND EMISSIONS

In principle, concerned investors wishing to shift production incentives for these large investor-owned emitters could strongly condition their investment decisions on ESG indicators (Oehmke and Opp 2020)[4]. A basic prerequisite for such a strategy to be effective is that changes in these firms' contributions to climate change need to be reflected in ESG scores. Large emitters that cut – or promise to cut – their emissions would then receive high ESG scores, attract fresh funds from ESG investors, and lower their cost of capital. Conversely, firms that continue to make 'dirty' investments, penalised via poor

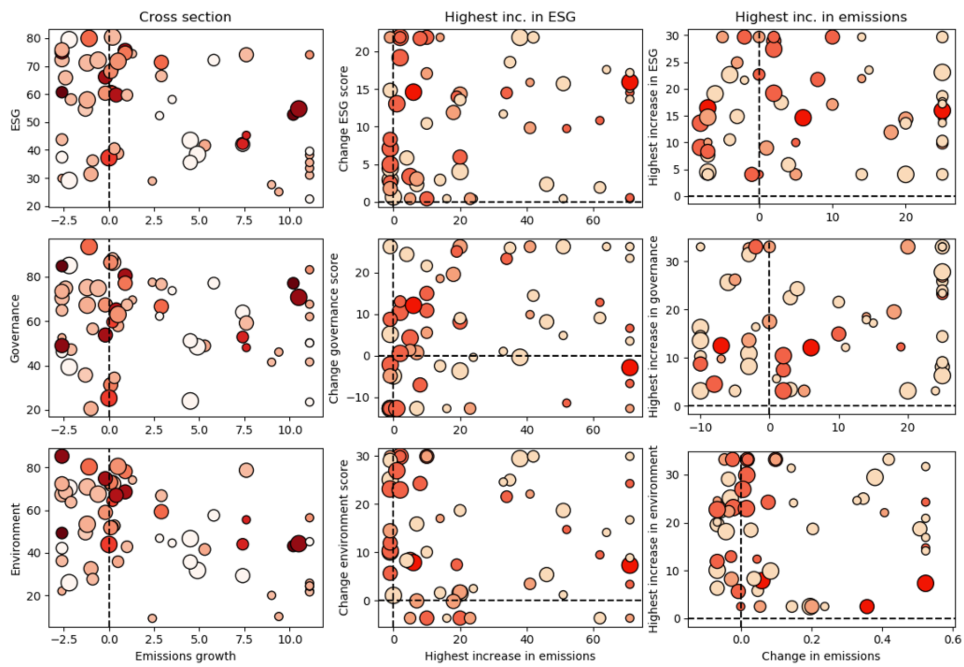
3 We exclude large emitters directly controlled by national governments. These firms are largely unaffected by sustainable investing.

4 Broccardo et al. (2020) refer to this approach as exit. Alternatively, shareholders could also use voting power (their 'voice') to influence emitting firms' actions. As many investors focused on climate change risks pay attention to ESG ratings (Krueger et al. 2020, Matos 2020), our results are relevant for both approaches.

ESG scores, would face higher costs of capital due to waning interest from ESG investors. This dynamic could generate a virtuous cycle in which firms with higher ESG scores have slowing emissions and vice versa.

Discouragingly, ESG scores do not appear to capture differences in emissions growth across large emitters. ESG scores and emissions growth do vary significantly within the panel. The interquartile range of emissions growth across large emitters is 10.4% (meaningful even in comparison to countries' Paris agreement pledges to slow emissions growth) (Carbon Brief 2017). However, ESG scores appear largely unrelated to emissions growth (Figure 2). This lack of relationship does not depend on whether we focus on the overall panel, on large changes in ESG scores or emissions, or on similar comparisons based on emissions scaled by revenues or assets.

FIGURE 2 ESG AND EMISSIONS GROWTH IN THE CROSS-SECTION



Notes: This figure shows ESG scores and emissions growth in the cross section. The first row shows overall ESG scores. The second and third rows show scores for the Governance and Environment pillar respectively. The left column shows averages over the full sample. The middle column shows averages for the four year period with the largest increase in emissions. The right column instead shows averages in the four year period with the largest improvement in ESG scores. Bubble sizes represent the average absolute size of emissions. Shading indicates economic conditions: darker red represents slower economic growth. Outliers are trimmed.

More formal analysis uncovers at best a weak relationship between ESG scores and emissions growth. Our baseline regressions examine the link between emissions growth and ESG scores at the firm-year level, controlling for firm characteristics, macroeconomic conditions, and year fixed effects. Large emitters with better ESG scores do display somewhat slower emissions growth (this link is largely tied to governance scores rather than environment scores). But the link between ESG scores and emissions growth is substantially attenuated if we rely on within-country or within-firm variation. The lack of a within-firm connection is important: large emitters that reduce (increase) emissions growth do not appear to be consistently rewarded (penalised) by better (worse) ESG scores.

ESG IS NOT ENOUGH

Next, we consider a thought experiment. To the extent there is a connection between ESG scores and emissions growth, is its scale meaningful relative to the climate change problem? Ongoing rapid growth in ESG investing may incentivise large emitters to improve their ESG scores by cutting their emissions. Unfortunately, even with our largest estimates, the reduction in emissions associated with a hypothetical large collective improvement in ESG scores would do little to meaningfully help mitigate climate change. According to scenarios prepared by the IPCC (2018b), with emissions growing in line with historical trends, in just 14 years the odds that warming can be limited to one point five degrees Celsius would be worse than even. Allocated proportionately, even a two standard deviation improvement in ESG scores would correspond to slowing emissions growth enough to buy only two more years before this climate objective would be out of reach.

ESG investing has grown dramatically in recent years, in large part motivated by growing attention to climate change (see Starks 2020 and Cornell and Damodaran 2020 for engaging reviews of the burgeoning academic literature on ESG investing). Signatories to the Principles for Responsible Investing – with some US$80 trillion in assets under management in 2019 – report that ESG considerations are integrated into investment decisions for three-quarters of assets under management (Matos 2020). Many of these investors appear to actively target portfolio allocations towards firms with higher ESG scores (Gibson et al. 2020). Particularly relevant for our work, large asset managers cognisant of climate risks report that they are strongly focused on firms' ESG ratings (Krueger et al. 2020). Indeed, the cost of capital rises for firms with poor environment pillar scores with prominent shifts in the global climate policy discussion (Seltzer, Starks & Zhu 2020).

However, our findings suggest that there is limited scope for sustainable investing strategies conditioned (solely) on ESG indicators to meaningfully shift production incentives for large emitters. ESG scores overall—as well as environment pillar scores—do not link tightly with emissions growth for major emitters, suggesting that these scores may not deliver what investors expect them to. This could reflect fundamental constraints with data availability due to the lack of consistent reporting. The multidimensional nature of the ESG approach may also place constraints.[5] Some investors may also not

5 Several researchers have noted disagreements across providers of ESG scores (Berge et al. 2020, Gibson et al. 2021, IMF 2019, Christensen et al. 2019), albeit with smaller disagreements about environment pillar scores than on other pillars (Gibson et al. 2021).

be aware that important components of ESG scores often compare firms to competitors in the same industry, providing relative rather than absolute rankings. Environmentally conscious investors and policymakers should approach ESG investing with caution.

CONCLUSIONS

Many commentators and policymakers have called for more robust disclosure requirements for climate risk (IMF 2019). More attention to consistently reported measures directly connected to contributions to climate change is likely to help (e.g. Ehlers et al. 2020). While consistent reporting standards and requirements for all firms would be valuable, sustained efforts from third-party researchers mean that data is not a key constraint for the important set of firms we study: Investors concerned about climate change can directly focus on emissions growth to evaluate both these firms and asset management products that incorporate them.[6] However, such approaches continue to face important challenges, highlighting the need to continue to build consensus towards effective economy-wide policies to address climate change.

Authors' note: The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management.

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CHAPTER 23

Financing climate change: International agreements and lending[1]

Yener Altunbas, David Marques-Ibanez, Alessio Reghezza, Costanza Rodriguez d'Acri, Martina Spaggiari

Bangor Business School; European Central Bank; Bangor Business School; European Central Bank; European Central Bank

The Paris Agreement explicitly recognises the need to "make finance flows compatible with a pathway toward low greenhouse gas emissions and climate-resilient development". This column looks at the impact of the agreement on bank lending and finds that following the agreement, European banks reallocated credit away from polluting firms. In the aftermath of President Trump's 2017 announcement of a US withdrawal from the agreement, lending by European banks to polluting firms in the US decreased even further. The findings suggest that the announcement of green policy initiatives can have a significant impact combating climate change via the banking sector.

Climate change poses major risks to the global economy. The Intergovernmental Panel on Climate Change (IPCC) concluded that the level of emissions observed since the mid-20th century will probably lead to global warming causing long-lasting changes, increasing the likelihood of a severe, pervasive and irreversible impact on people and ecosystems (IPCC 2018).

Policymakers have recognised climate change as a major and pressing threat (Carney 2015). In this vein, the Paris Agreement is the most significant global climate agreement to date. Signed in December 2015, it represents the first major comprehensive climate deal that explicitly recognises the need to "make finance flows compatible with a pathway toward low greenhouse gas emissions and climate-resilient development". In the absence of legally binding emission targets and as countries are supposed to assess their own progress, moral suasion plays an important role.

1 This column first appeared on VoxEU 21 May 2021 https://voxeu.org/article/financing-climate-change-international-agreements-and-lending

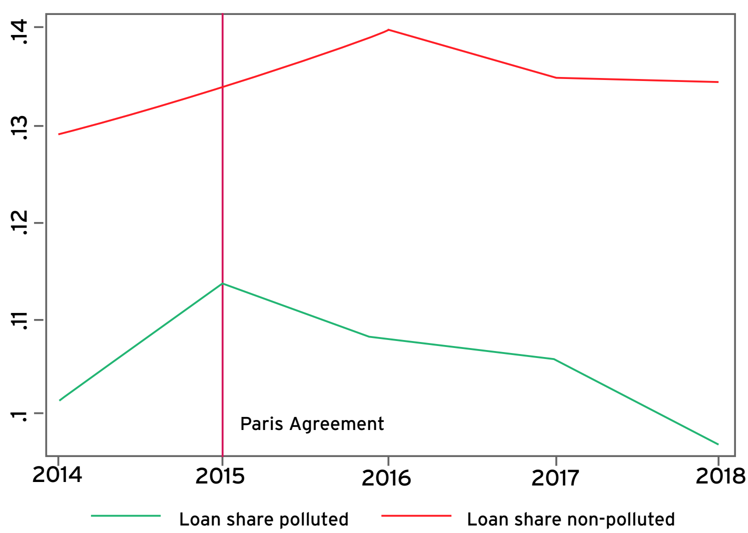
THE PARIS AGREEMENT AND BANK LENDING

As a major provider of credit, the banking sector is, potentially, a key player in these efforts. At the same time, these green initiatives are happening in a period in which banks themselves face new risks, some of them also linked to climate change. As a result, lending away from polluting firms might be very costly. In a recent paper (Reghezza et al. 2021) we ask whether climate-oriented regulatory policies affect the flow of credit towards polluting corporations. We do this by examining whether European banks changed their relative lending towards polluting firms following the Paris Agreement.

We focus on two main hypotheses. The first poses that the Paris Agreement might have encouraged banks to increase their lending to the more polluting firms. As banks are not directly legally constrained by the agreement, they might have a greater incentive to 'cream off' the market and step up their lending to more polluting firms while they are still allowed to do so. According to the second hypothesis, COP21 might have had suasion effects on banks, driving them to lend less to polluting firms, also in anticipation of more stringent climate risk-related policies, or increased awareness by banks of climate change related risks.

To this end, we matched granular information on European banks' large exposures to individual counterparties – taken from supervisory reporting – to firm-level greenhouse gas emission intensities and employ several loan-level differences-in-differences (DiD) estimations. Preliminary graphical evidence already highlights a decline in the lending share towards polluting firms following the agreement (Figure 1).

FIGURE 1 LOAN SHARE TOWARDS POLLUTING AND LESS POLLUTING FIRMS, 2014-2018



We find that, European banks' loan share towards more polluting firms decreased significantly – by about 3 percentage points – after the announcement of the Paris Agreement. Less profitable banks and those with lower credit quality drive our main findings.

TRUMP'S WITHDRAWAL

We then consider an added policy 'shock' in the opposite direction – namely, President Trump's announcement of withdrawal from COP21. This shock allows to better interpret possible reverse patterns in banks' lending decisions across climate-related policies. Interestingly, European banks' loan share to more polluting US corporations also decreased (by around 2.4 percentage points) after President Trump's June 2017 decision not to uphold the Paris climate commitment. We argue that this could be due to US banks stepping up their lending to polluting firms in the US following the agreement and thereby crowding out European lending to those firms.

KEY MESSAGES

We contend that recent climate change initiatives, pushed European banks out of climate-sensitive sectors towards greener firms. Improved awareness of climate change-related risks, and the anticipation of more stringent policies are probably behind our findings. Our results underline the pivotal role of banks in the implementation of significant climate change policies.

Authors' note: The views expressed in this column are those of the authors only. They do not necessarily represent the views of the ECB, its Executive Board or the ECB management.

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CHAPTER 24

Integrating climate change into the financial stability framework[1]

Timo Löyttyniemi

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Financial stability is at the core of central banking. This column assesses the various risks to financial stability stemming from climate change, which arise from physical risks, transition risks, and the chosen transition path towards a net zero economy. Additional risks arise from the changes in government policies, risks in green investments, mispricing of assets, and potential changes in metrics. The channels for financial instability are, as usual, the sustainability of government debt, the vulnerability of banking, and the volatility and liquidity of securities markets. Awareness of these additional financial stability risks could increase financial stability.

The concept of financial stability can be easily seen when there is a state of financial instability. In this column, I try to incorporate climate change into the concept of financial stability. Climate change is not in itself a financial stability matter, but it may cause and trigger financial stability concerns via channels which are commonly understood as most vulnerable. Government debt financing is prone to crises, the banking sector is vulnerable to runs, and securities market price and liquidity fluctuations may cause financial instability.

Financial stability is at the core of central banking. The central banking community has widely incorporated climate change risks as part of central banking discussions. It is widely accepted that climate change could pose such risks that central banks need to evaluate the risks within their current mandates. Mark Carney (2015) has been the leading advocate for incorporating climate change risks in financing decisions. He raised concerns regarding the tragedy on the horizon as business cycles, political cycles, and technocratic authorities may reduce the incentives of the players to fix the problem.

1 This column first appeared on VoxEU 8 July 2021 https://voxeu.org/article/integrating-climate-change-financial-stability-framework

The Network for Greening the Financial System's (NGFS) initiative, Bolton et al. (2020), FSB (2020), and the 2021 Bank for International Settlements (BIS) Green Swan Conference have recently brought the seriousness of climate change as a financial stability matter to the attention of central banks and market participants.[2]

Recently, Bolton et al. (2021) suggested that the climate change risk is to be included in the mandates of central banks. However, central banks are not the main engines for change, but they are part of all the financial players taking climate change into their calculations. Governments throughout the globe are the key players in making the necessary policy changes to accommodate the necessary changes for a carbon neutral world.

Gore and Blood (2013) popularised the term 'stranded assets' to highlight the economic impact of the transition to a low-carbon economy. Recently, Giglio et al. (2020) reviewed the climate finance literature and pricing of financial assets and real estate assets due to climate change risks.

Distinguishing normal changes and fluctuations in the economy from crises and instability-triggering developments is hard to tell ex-ante. Most negative economic trends and variability will be naturally washed away by market adjustments and balancing acts by economic agents. Some negative trends will be reversed by active government and central bank policies. Extraordinary and non-conventional policies are called upon if normal policies are not sufficient for restoring stability in the economy.

DEFINITION OF FINANCIAL STABILITY

There is no widely accepted definition of financial stability. The concept of stability can be best seen in the presence of instability. However, one could define financial stability in the following manner:

> Financial instability is a real or expected danger in financial markets or financial institutions due to an event which, if not reacted upon by public authorities, could potentially cause a severely negative impact on the real economy, non-functioning of the monetary economy (payment system), and/or non-functioning of financial markets (funding).
>
> Acts of financial stability are actions to prevent, resolve or restore financial stability in the presence of real or expected threats of financial instability.

Acts of financial stability include prevention, resolution, and restoration. Prevention includes setting up policies and regulation, but it also includes monitoring and supervision for safeguarding correct action by economic agents. Resolution means orderly acts of

2 The Network for Greening the Financial System (NGFS) was created in 2017 and NGFS published its first Comprehensive Report in 2019. The Green Swan 2021 Global Virtual Conference gathered key central banks and financial community to discuss consequences of climate change. The author participated in the panel on financial stability where he made some of the comments presented in this paper.

financial stability in times of crisis. There may be rules in place to give extra powers to resolution authorities.[3] Restoration could be seen as a state in which the crisis has already hit the economy or financial markets, and it has had an impact, but public authorities still need to restore stability by their extraordinary policies or acts.

This definition of financial stability is not changed by the presence of climate change. Climate change is a risk and a potential trigger for causing financial instability via various channels which are vulnerable for causing severe instability.

Challenges in government debt, the banking sector (financial institutions), and abrupt changes in the securities market may cause disruptions for financial stability. This instability may lead to a lower level of trust in currency (money). The use of fiat money is based on it being trusted as a means of exchange, a store of value, and as unit of account. The purpose of financial stability acts by governments and central banks is to enable stable real economic growth and the functioning of the monetary system, but ultimately these acts are to protect the existing fiat money. The further the danger is for financial instability the closer the monetary system and fiat money is under potential mistrust. The mandates of central banks are defined in various ways and wordings.

NEW CLIMATE CHANGE TRANSITION PATH RISKS

Typically, climate change risks are divided into physical and transitional risks. Physical risks are associated with extreme weather, floods, heat, hurricanes, storms, drought, or other similar phenomena stemming from changes in the climate. Transition risks are risks arising from long-term climate change impacts to economic agents directly or indirectly with or without policy changes, and these impacts will be governed by government policy changes and mitigation acts. Economic agents are forced to adjust their behaviours along the way.

In addition to these traditional climate change related risks, there are also other transition path related risks. Transition path risks could arise from investments, mitigation policies, discounted pricing, and the choice of metrics. These come from the expected and chosen transition paths which economic agents are aiming to guess. Each economic agent is estimating the future path. These estimates may turn out to be right or wrong. There is no perfect foresight for the future. Estimates change and the collective synthesis of those estimates will determine the economic impacts.

3 See as an example for banking and financial sector coordinated resolution policies by FSB (2011).

Transition path risks are the following:

1. Mitigation policy risks

Government policies are imperfect solutions even though the aim is good. Due to wrong policies or practical compromises, governments may not take the right actions which are needed or expected by economic agents, or they may change the policies taken. These abrupt policy changes or misalignments to expectations by economic agents may cause turbulent changes in values. An example is the race to zero carbon economies. The path towards the right goal may take a longer or shorter time and may encompass abrupt changes in policies or policies not aligned with expectations. Regime changes are taking place, but they are hard to predict.

2. Investment risks

New green innovations, technologies, and related investments could include some 'wrong' choices. These wrong choices or the timing of these choices could turn out to be bad investments, therefore leading to difficulties for the economic agents and vulnerabilities for the channels and financial instability accelerators.

3. Discounted pricing risks

Present values of current and future green investments are high with a low interest rate environment. This will accelerate the change towards green economies. In these circumstances sensitivities to changes of values and prices are possible and may be intensified with interest rate changes. In addition, the green revolution may create a 'hype cycle' witnessed during the ICT-boom at the turn of the century or a 'green bubble' advocated in the pre-Paris Agreement era. New technologies could see a cycle of euphoria and reality. Asset price bubbles may emerge.

4. Risk metrics

Reporting on climate change metrics has taken enormous steps during recent years. This development makes it possible to make informed decisions on what is considered good and what is bad. For example, carbon intensity is widely used by investors. There is a risk that the available metrics will be developed further as economic agents collect wisdom. Changes in metrics may cause decisions which could look wrong in hindsight.

These transition path risks could be marginal or significant in comparison to the risks arising from physical and traditional transition risks (Table 1). The future transition path may be bumpy. Climate change as a phenomenon is well supported by scientists and must be taken seriously by all despite possibilities for mistakes along the way.

TABLE 1 CLIMATE CHANGE RISKS

	Physical risks	Transition risks	Transition path risks
Key risks	Extreme weather events, floods, heat, hurricanes, storms, drought, or other similar events	Climate change causing direct impacts on economic agents	Government mitigation policy changes (policy change, magnitude, and timing)
		Government policies to mitigate climate change (carbon tax, regulation etc.	Investment risks (wrong innovations, technologies, or timing).
		Carbon intensive countries and industries become vulnerable (e.g. stranded assets) due to global/ government policies and actions/preferences by economic agents.	Discontinued pricing risks (e.g. hype cycle, low interest rates, asset price bubbles)
			Risk metrics (changes in metrics, e.g. carbon)
		New technologies will emerge finding solutions to climate change	

Transition path risks may cause financial instability via government debt, financial institutions, or securities markets. These transition path risks may cause, in addition to physical risks and transition risks, the financial stability channels and accelerators, such as government debt, banking, and securities market, to be more prone to crises in the coming decades.

For instability to take place the impact needs to be large enough in relation to the prevailing circumstances and the timing needs to be 'perfect'. Typically risks will materialise if many risks take place at the same time, increasing vulnerabilities manyfold. In Table 2 the key financial instability channels are illustrated as crisis accelerators, integrating those with the physical risks, transition risks, and transition path risks.

TABLE 2 CLIMATE CHANGE RISKS AND FINANCIAL INSTABILITY CHANNELS

Financial instability channels	Physical risks	Transition risks	Transition path risks
Government debt	Extreme weather events and major government suport needs, which could exceed a tipping point for a crisis.	Carbon-intensive countries may be under threat, due to lower income and higher global carbon taxes.	Government mitigation policy may cause severe funding gaps for government debt. Government mitigation policy changes may cause vulnerabilities for economic agents in the country
Banks (financial institutions)	Extreme weather events causing local systemic banking crisis, which could lead to wide shocks through interdependence..	Carbon-intensive countries and corporations may be dragged into difficulties causing severe vulnerability for financial institutions.	Government mitigation policy changes may cause vulnerabilities for economic agents. New green investment risks (wrong innovations, technologies, or timing).
Securities markets (funding)	Extreme weather events causing severe price falls inasset prices locally or more widely, which could disrupt funding channels.	Carbon-intensive countries and corporations may be dragged into difficulties causing vulnerability for severe securities market price changes.	Government mitigation policy changes may impacrt prices. Low interest rates bring future into today with potential for excess valuations. Interest rate changes may cause severe changes in these values. ''Hype cycle' causing variation in prices.

HOW TO MITIGATE FINANCIAL STABILITY RISKS?

Financial stability risks from climate change are mitigated by prevention, resolution, and restoration. Mostly the existing processes for prevention, resolution, and restoration associated with government debt, banking (financial institutions), and securities markets are valid in the context of climate risks. If risks arise slowly, the mechanisms have enough time to be adjusted accordingly. If risks are abrupt, the solutions may be more difficult to get adjusted.

A global crisis may call for global solutions. Local and global crises of various magnitudes and probabilities require sufficient transparency of risks and needed buffers by economic agents. Transparency and disclosure reduce information asymmetries and speed up adjustments and mitigation measures.

Transparency of government policies

Approaches to government support and state aid will need to be agreed globally. This calls for ex-ante transparency of government policies regarding not only grey industries but green industries as well. Carbon taxes should be implemented at the national and international level and at the borders.[4]

In times of crisis the approaches to resolution for corporations and financial institutions may need to be further aligned across borders. The doom-loop between banks and governments needs to be further reduced to increase the resilience of financial systems to absorb shocks.

Use of multiple metrics

Transparency and exposure analysis are the best tools to detect the risks. Exposures are not only exposures to physical and transition risks but also potential risks from the chosen transition path. Institutions should be using multiple metrics to assess their positions and base their decisions. Reporting and metrics need to be developed further for investors and supervisors to compare companies and make correct assessments.

Security markets as store of value

The securities market is a liquidity and funding provider, in addition to primary market capital raising more so as a store of value and a source for money via security market transactions (liquidity). Sharp market-to-market reactions may be seen as the climate change trend progresses. New financial instruments will be created along the way. Today's environmental, social, and governance (ESG) and low-carbon products are just the beginning. Markets will find new products and regulators will need to follow and adjust. The most recent example is the crypto currencies which may be using levels of energy which are not aligned with the global climate change trend.

4 Peszko et al. (2020) analysed the impact of various transition paths to fossil fuel dependent countries. They also looked at various diversification strategies and resilience to mitigate the transition to a decarbonising world. They supported the wellhead taxation at the producer level instead of latter stage taxation. This is one example of the global coordination needed to find global solutions for the common goal.

Financial institutions need to be aware of the abovementioned transition path risks which arise from investment risks, mitigation policy risks, discounted pricing risks, and risk metrics. There is a need for further global coordination of various mechanisms and risks which will arise in the coming decades. Restoring financial stability is hopefully not needed if prevention and resolution mechanisms are working properly.

CONCLUSIONS

Climate change is a new serious threat to financial stability. Even though the definition of financial stability or channels may not change due to climate change, potential new risks exist in addition to traditional physical and transition risks associated with climate change.

New risks arise from the transition path chosen by the society and the expectation of economic agents. Government policies and regimes may change as more information is gathered and decision makers fine-tune their choices. Economic agents will make mistakes in their innovations and investments. The investment market will price the prospects of financial assets with euphoria and pessimism. Green investment values could potentially be changed abruptly due to changes in technologies and government policies.

These potential risks of climate change may take place even though the transition path towards greener societies is strong. Carbon prices may rise to new highs, as most economists expect. Fossil fuel industries could be in difficulties and some assets could be potentially stranded. The path to get to net zero societies is unclear and no-one has the perfect foresight. Therefore, the financial stability concern arises not only from physical and transition risks, but also from the chosen and constantly changing transition path.

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CHAPTER 25

Climate change will unevenly impact the European financial system[1]

Paul Hiebert
European Central Bank

Climate change will impact those parts of the financial system most exposed to its disruptive effects. This column analyses a new financial stability risk mapping for the EU financial system, linking financial exposures of thousands of banks, insurance companies, and investment funds to millions of firms subject to climate risk. It highlights a high level of risk concentration, both in European regions subject to climate hazards as well as economic sectors with diverse carbon emission intensities. Long-term scenario analyses suggest that the risks will be best addressed through proactive policies that directly contain global temperature rises.

Accurate measurement of the prospective impacts of climate change on financial stability rests on a detailed mapping of its disruptive potential, both over space and time. This requires first a careful linking of climate risk drivers, and their granular region-, sector- and firm-specific impacts on the economy, to financial exposures (Cruz and Rossi-Hansberg 2021 underscore the unequal impacts of climate change across regions). It also requires modelling long-dated risk of a possibly insidious nature, assessing the prospective benefits of foregone financial sector losses from natural hazards accompanying the pace of global temperature rises, against costs in the form of measures taken to mitigate them (Bolton et al. 2021 argue for a combination of public interventions and private sector mitigation strategies to reduce the long-term implications of climate-related events).

The ECB and European Systemic Risk Board (ESRB) have joined forces to measure financial stability risks from climate change for the EU. Initial work focused on how existing data and models of central banks and supervisors could be deployed for climate risk analysis (ESRB–ECB 2020). A new report focuses on deepening granular measurement of climate risk drivers, while extending the horizon of models for long-term scenario analysis (ESRB–ECB 2021a). In particular, a granular topology of current financial risk exposures stemming from both physical and transition risk aspects of climate change has been constructed for millions of global firms, as well as thousands

1 This column first appeared on VoxEU 13 July 2021 https://voxeu.org/article/climate-change-will-unevenly-impact-european-financial-system

of financial intermediaries in the EU. Long-dated scenario analysis has leveraged this risk topology to model future credit and market risk losses, to gain insights into path dependence of climate hazards associated with an ongoing rise in global temperatures on the stringency of action to mitigate carbon equivalent emissions.

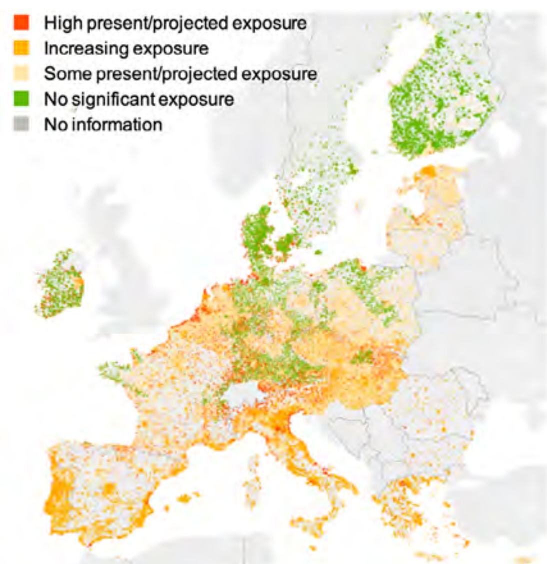
Results from this work suggest that, while the aggregate financial system seems able to weather first order impacts of climate change, its resilience will both vary spatially and evolve temporally.

FINANCIAL VULNERABILITY COMES FROM COMPOUND PHYSICAL RISK EVENTS, NOTABLY RIVER FLOODING RISKS COMBINED WITH POTENTIAL FOR PRONOUNCED HEAT AND WATER STRESS IN SOME REGIONS

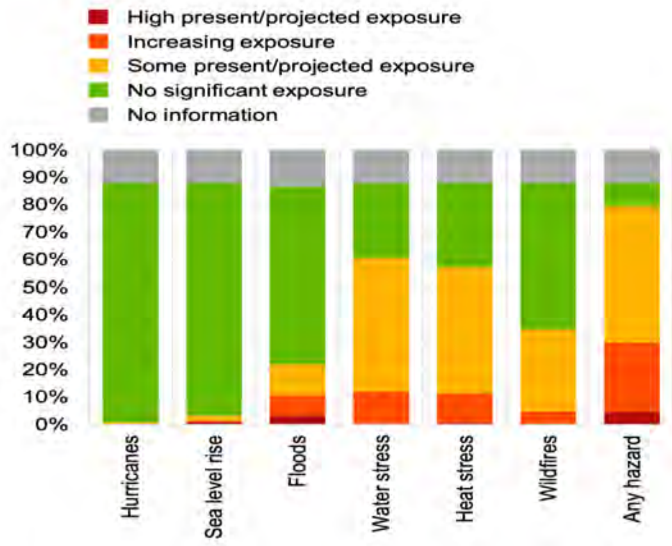
A concentration of vulnerabilities across EU regions related to physical climate risk implies stranding risks in case of a coalescing of hazards. Looking over the next 20 years, a combination of riverine floods with wildfires, heat stress, and water stress could generate strong localised impacts, and leave a collective 30% of euro area bank exposures to firms at risk. Rising sea levels could significantly add to credit exposures later this century. Losses from climate-related hazards might be amplified by protection gaps – relating either to compromised physical collateral (backing the majority of secured exposures), or insurability (noting a starting point of only 35% of economically relevant climate losses estimated to be currently insured in the EU).

FIGURE 1 PHYSICAL CLIMATE RISKS

A) Maximum firm exposure to physical hazards



B) Share of euro area banks' credit exposures to firms by corporate physical risk level (percentages of total bank exposures to firms)



Sources: Four Twenty Seven, an affiliate of Moody's, AnaCredit and ECB calculations.

Notes: The location of firms' headquarters and that of their largest subsidiaries are used as proxies for firm location. Data coverage varies by country, selected firms may not be representative of all firms within the country. Top panel: Based on 1.5 million firms in Europe. Each dot stands for one firm, its colour refers to the maximum exposure level across six hazards, including hurricanes, sea level rise, floods, water stress, heat stress and wildfires. Bottom panel: Bank loan exposure is taken from AnaCredit and matched with Four Twenty Seven data at corporate level. Credit exposures to NFCs above €25,000 are considered; total exposures amount to €4.2 trillion. 31% of exposures can be matched directly, 58% are matched using postcode-level aggregates of the Four Twenty Seven corporate level indicators and 11% cannot be matched this way due to missing geo-locational information in AnaCredit ("no information" in bottom panel).

VULNERABILITY TO FINANCIAL MARKET REPRICING NOT ONLY ACROSS SECTORS, BUT ALSO WITHIN SECTORS

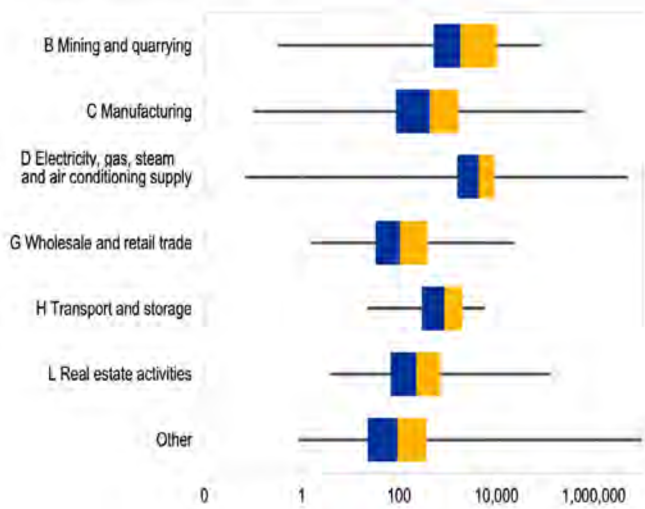
A holistic view of carbon emission intensity of firms (including also downstream emissions) suggests a concentration of vulnerabilities both across and within sectors. Exposures to highly emitting firms occupy 14% of collective euro area banking sector balance sheets, and are concentrated in the manufacturing, electricity, transportation, and construction sectors. Perhaps more importantly, 10% of bank balance sheets exposed to firms whose emissions efficiency varies enormously could be vulnerable to credit ratings downgrades, should carbon prices rapidly adapt to Paris-aligned levels (Klusak et al. (2021) warn of climate-driven ratings downgrades in the next decade).

CLIMATE RISK EXPOSURES ARE ALSO CONCENTRATED WITHIN CERTAIN FINANCIAL INSTITUTIONS

There is also concentration of vulnerabilities at the level of financial institutions. For transition risks of climate change, nowhere does the vulnerability seem higher than for investment funds, where over 55% of investments are tilted toward high-emitting firms, and an estimated alignment with the EU Taxonomy at only 1% of assets. While direct holdings of institutional investors such as insurers appear to be manageable given well diversified portfolios, indirect losses could result from investment fund cross-holdings estimated at around 30%. As for physical risks of climate change, exposures to hazards appear to be concentrated in the hands of only two dozen banks, holding up to 70% of exposures to areas of high or increasing risk over the next two decades. Perhaps more worryingly, such exposures may aggravate pre-existing vulnerabilities, with physical risk exposures skewed toward weakly capitalised and/or less profitable banks in the euro area.

FIGURE 2 TRANSITION CLIMATE RISKS

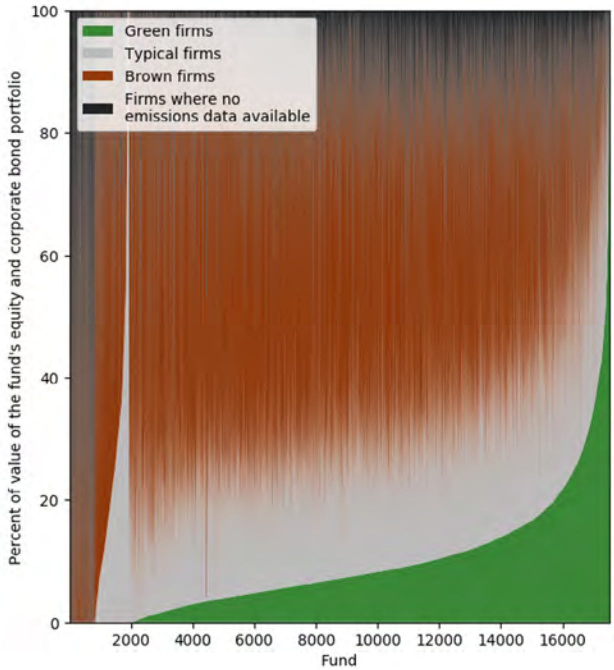
A) Firm-level emission intensities within and across climate policy relevant sectors in the euro area (x-axis: scope 1,2, and 3 emissions in tonnes of CO2 equivalents per million US dollar revenue; y-axis: NACE 1 sector



Source: Urgentem.

Note: Only firms directly reporting emissions are considered (approximately 3,000 European firms).

B) Share of EU fund portfolios by 'green' firms compared with that of 'high-emitting' firms



Sources: Morningstar, Refinitiv, and ESMA.

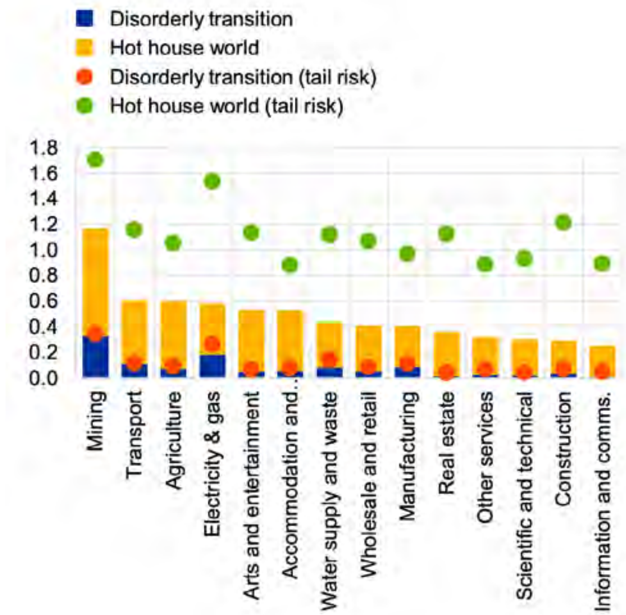
Notes: Percentage share of each individual fund's equity and corporate bond portfolio (vertical axis) that is allocated to firms classified according to their portfolio emissions: firms with emissions that are below the 33rd percentile for the data sample ('Green firms'); firms with emissions greater than or equal to the 67th percentile ('High-emitting firms'); firms with emissions that fall between these two groups ('Typical firms'); and also firms for which no emissions information is available. The horizontal axis denotes individual funds, sorted according to the percentage share of exposures to green firms in the portfolio (from lowest to highest share).

LONG-HORIZON SCENARIO ANALYSIS CAN SHED LIGHT ON FINANCIAL SYSTEM LOSSES RESULTING FROM CLIMATE CHANGE

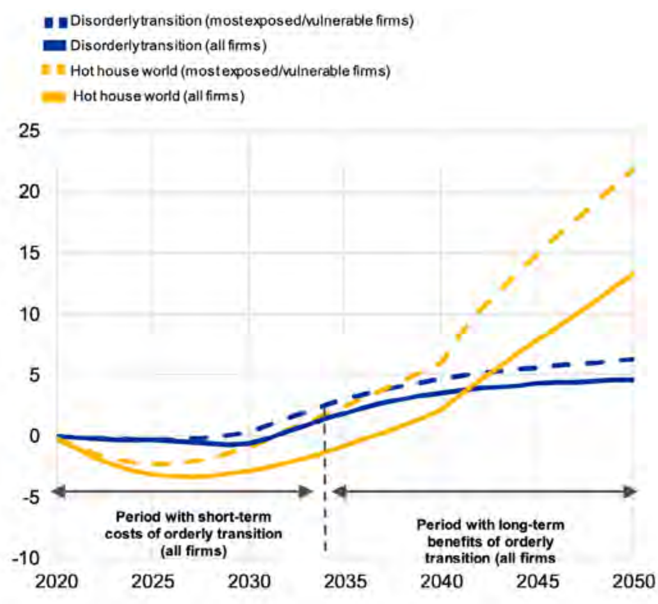
This granular vulnerability mapping can be used to gain insights on the prospective evolution of losses in the financial system as global warming gains further momentum. While a rise in temperatures accompanying carbon emissions appears inexorable (IPCC 2018), its pace and scale will be determined by the timeliness, stringency, and effectiveness of remedial action (NGFS 2020). This strong path dependence is borne out by climate scenario analysis, suggesting financial stability costs accrue over time from insufficiently orderly policy and effective technologies to limit global temperature rises.

FIGURE 3 PROBABILITY OF FIRM DEFAULTS UNDER THE ECB'S TOP-DOWN STRESS TEST (PERCENTAGES)

A) Across sectors



B) Across time



Source: ECB.

Notes: Differences in firms' default probabilities under the two adverse scenarios with respect to the orderly transition scenario, by sector and group of firms (mean firms and firms mostly exposed to physical risk). Top panel: The bars represent the median changes in default probabilities over the next 30 years; the dots report the changes in default probabilities when considering the firms that are most exposed to physical risk (95th percentile based on firms' physical risk score). Bottom panel: solid line is median across all firms in the sample, dashed line is the average of most exposed/vulnerable firms in the sample.

- A mapping of Network for Greening the Financial System (NGFS) scenarios to 55 economic sectors and numerous regions suggests that credit and market risk could cumulate from a failure to effectively counteract global warming. Notwithstanding uncertainties around methodologies analysing such long dated horizons, scenarios indicate that physical risk losses – particularly for high-emitting firms – would become dominant in around 15 years in the event of an insufficiently orderly climate transition, with falls of up to 20% in global GDP by the end of the century should mitigation prove to be insufficient or ineffective.

- First-order direct losses appear manageable for European financial system, but are concentrated, and possibly at risk of amplifying features.
  - EU banking sector credit risk losses under adverse climate scenarios could amount to 1.60-1.75% of risk-weighted assets over a 30-year timeframe. Such a magnitude, around half that of adverse scenarios in conventional macroeconomic stress test exercises (albeit with a far shorter horizon), would be concentrated the electricity and real estate sectors.
  - EU insurance sector market risk revaluation losses taking into account production plans of firms over the next 15 years are only 5% on average – but could be material in key climate-sensitive sectors such as oil, gas, and vehicles.
  - Uneven EU investment fund exposures could also lead to large losses from direct exposures of up to 14% in the next 15 years, despite limited direct aggregate asset write down risk of only 1.2% in holdings of around €4.8 trillion in equity and corporate bond exposures.

FURTHER MEASUREMENT AND MODELLING REFINEMENTS WOULD ENHANCE FOUNDATIONS OF EVIDENCE-BASED POLICY

Notwithstanding continued progress in measuring and modelling climate-related risk, much remains to be done. The ECB and ESRB will further invest in broadening and firming up analysis in the coming year. On the side of data, the heterogeneity of climate-related disclosures among firms and financial institutions implies that the granular and country-level results will be subject to refinements as progress is made in addressing data gaps and obtaining more complete climate-relevant reporting (see ESRB–ECB 2021b for a detailed exposition on data advances, and remaining challenges). On the side of modelling, the incorporation of higher-order amplifying aspects, including assumptions on dynamic balance sheet adjustments as well as sharper aspects related to so-called dual materiality impacts of bank lending impacts on climate outcomes, will help to obtain a clearer financial stability view beyond direct impacts (see Altunbaş et al. 2021 for estimates of bank credit to polluting firms, as well as De Haas and Popov 2018 on the role of finance in reducing pollution).

While still subject to many uncertainties, advances already in empirical understanding of risks provides valuable evidence, laying the groundwork to support nascent macroprudential policy considerations, in an increasingly heated policy debate.

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CHAPTER 26

Global pricing of carbon-transition risk[1]

Patrick Bolton, Marcin Kacperczyk
Columbia University and CEPR; Imperial College London Business School and CEPR

A company's carbon-transition risk – associated with curbing carbon emissions within a relatively short period of time – is proportional to the size and growth rate of the company's carbon emissions. This column asks whether companies with different carbon emissions have different stock returns. The total level of a company's CO2 emissions and the year-by-year growth in emissions significantly affect its stock returns in most geographic areas of the world. The increasing cost of equity for companies with higher emissions can be a form of carbon pricing by investors seeking compensation for carbon-transition risk.

How are firms affected by the rising calls worldwide to combat climate change? How are they affected by increasingly stringent policies aimed at curbing carbon emissions? How are they affected by technological advances and growing market shares of renewable energy?

Many sceptical commentators believe that the rise of the responsible investment movement is mostly a public-relations exercise, with little material impact on firms' cost of capital (e.g. Aswani et al. 2021). If this is true, we would expect to see little difference in the valuation of companies exposed to carbon-transition risk relative to other similar companies that are less exposed to this risk.

By carbon-transition risk, we mean the risks associated with the requirement to significantly, and maybe suddenly, curb carbon emissions within a relatively short period of time (one or two decades, if the company is required to align itself with the net-zero commitments of the countries in which it operates). The size of this risk for a company is proportional to the size of its carbon (and other greenhouse gas) emissions, and to the rate of growth of these emissions.

We undertake a broad exploration of this question, asking whether companies similar in all observable respects except for their carbon emissions have different stock returns, and if so, what the source of this difference is – exposure to policy risk, technological risk, competition from renewable energy risk, investor pressure, or reputation risk (Bolton and Kacperczyk 2020).

1 This column first appeared on VoxEU 24 March 2021 https://voxeu.org/article/global-pricing-carbon-transition-risk

We take a (forward-looking) financial market perspective to evaluate the economic importance investors attach to carbon-transition risk globally, by looking at the stock returns of more than 14,000 publicly listed companies in 77 countries with different degrees of exposure to this risk over the sample period 2005 to 2018.

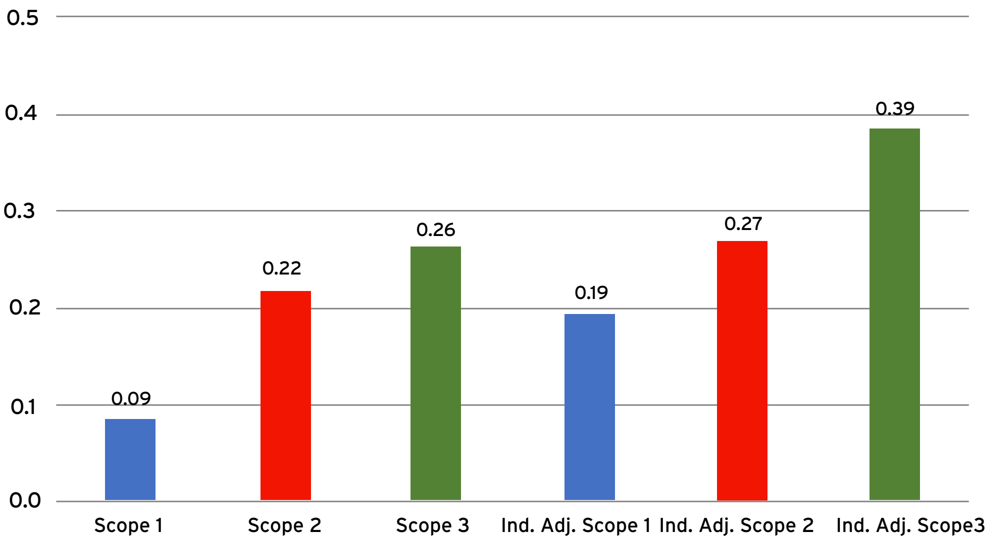
From an individual firm's perspective, transition risk captures the uncertain rate of adjustment towards carbon neutrality. From an investors' perspective, the risk also embodies the evolving beliefs about the transition to a greener economy. Transition risk is the result of a wide range of shocks, including changes in climate policy, reputational impacts, shifts in market preferences and norms, and technological innovation.

Indeed, investors in companies that supply fossil fuel energy, and investors in companies that rely on this energy for their operations, are increasingly exposed to risk with respect to policies seeking to curb carbon emissions and to technological risk from alternative, more and more affordable renewable energy.

Using firm-level carbon emission and financial data, we quantify the carbon premium – that is, the return that compensates investors for taking on this carbon-transition risk, other things being equal. If carbon-transition risk is ignored by investors, one would expect to see no significant correlation between stock returns and the level of the company's CO_2 emissions (once one controls for other relevant firm characteristics). Yet, we find that carbon emissions positively and significantly affect stock returns in most geographic areas of the world, as Figures 1 and 2, with some of our main findings, illustrate. The first three columns indicate the size of the carbon premium (the higher cost of capital, or expected returns, of firms with higher carbon emissions as compensation to shareholders for their greater exposure to carbon transition risk) for respectively direct (Scope 1 and 2) and indirect upstream (Scope 3) emissions that are one standard deviation above the average level of emissions of firms, other things equal across all industries. The second three columns indicate the size of the carbon premium within a given industry (when we add industry fixed effects).

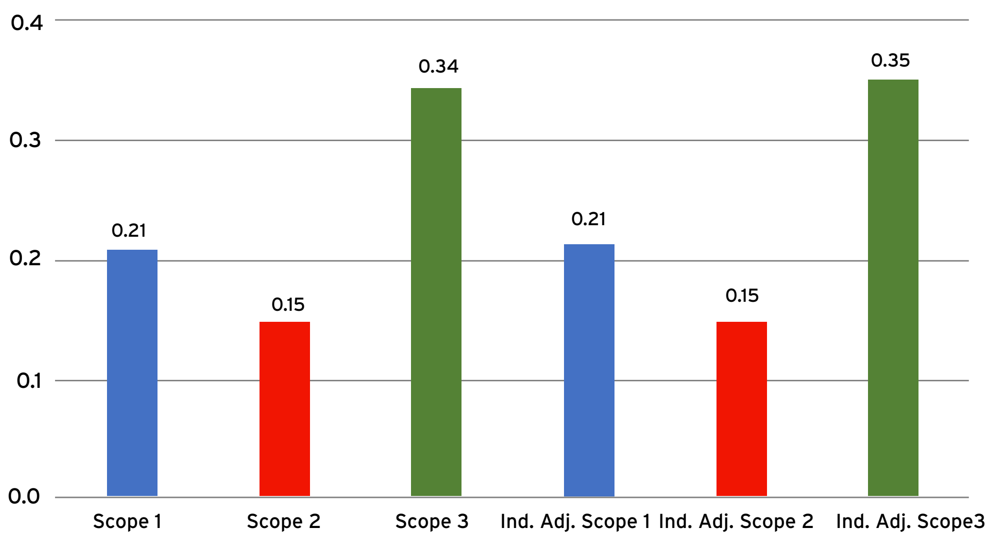
The dependent variable in Figure 1 is the average monthly stock returns of firms, a good predictor of future expected monthly returns. The main explanatory variables of interest are the logs of the total size of Scope 1, Scope 2 (both measures of direct emissions), and Scope 3 (upstream indirect) carbon emissions, all measured in units of tons of CO_2 emitted in a year. We add key firm characteristics and fixed effects as controls to make sure that we are comparing apples to apples. Each column bar represents the difference in stock returns between firms with emissions measures that are respectively one standard deviation above the average and firms with average emissions. The first three bars do not adjust for differences in emissions across industries, and the last three bars do adjust for such differences. We find that a firm that experiences an increase in its log emission levels, offers a return premium to investors. This premium is both highly statistically significant and economically sizeable, with the economic magnitudes ranging between 2 to 4 percentage points per year.

FIGURE 1 CARBON PREMIA TO CO2 EMISSION LEVELS



Interestingly, what matters is both the total level of CO2 emissions produced by companies as well as their year-by-year growth in emissions, as is shown in Figure 2.

FIGURE 2 CARBON PREMIA TO YEAR-BY-YEAR GROWTH IN CO2 EMISSIONS



The main explanatory variable of interest in Figure 2 is S1CHG, S2CHG, and S3CHG, respectively the yearly percentage growth in Scope 1, 2, and 3 emissions.

The emissions-level measure in Figure 1 can be understood as a long-term risk projection, given that emissions are highly persistent, while the growth measure in Figure 2 is a short-term projection of the risk.

Note that we do not find any relation between stock returns and emission intensity (the ratio of total emissions to sales). As we explain in our paper, this is not surprising, given that the true measure of transition risk is the level and growth rate of emissions, not emission intensity. As Ben Ratner, senior director at the Environmental Defense Fund, eloquently stated: "Meeting the goals of the Paris Agreement requires an energy transformation that slashes absolute emissions, not piecemeal intensity targets backed by spotty methane data and reporting" (McCormick et al. 2020).

We further explore which factors carbon premia are associated with across countries, industries, and firms, and discover several interesting patterns. The first surprising result is that the level of economic development does not explain cross-country variations in the carbon premium. However, several other country characteristics matter.

Both 'voice' (how democratic political institutions are) and 'rule of law' significantly affect the carbon premium associated with changes in emissions. More democratic countries with stronger rule of law tend to have lower carbon premia, other things being equal. One possible interpretation of this result is that in these countries, pressure from green public opinion has already resulted in significant tightening of carbon-emissions regulations, so that the transition risk going forward is lower. In support of this interpretation, we also find that the carbon premium is lower in countries with a higher share of renewable energy, and higher in countries with larger oil, gas, and coal extracting sectors.

We further find that firms located in countries with tighter domestic (but not international) climate policies exhibit a higher long-term return premium. Surprisingly, firms in countries that have been exposed to greater damages from climate disasters (floods, wildfires, droughts, etc.) do not show a markedly different carbon premium associated with the level of direct emissions.

Given that climate change has become a salient issue for investors only recently, we also explore how the carbon premium around the world has changed in recent years. We do this by comparing the estimated premia for the two years leading up to the Paris Agreement and following the agreement. Several striking results emerge from this analysis.

First, when we pool all countries together, we find that there was no significant premium before the Paris Agreement, but a highly significant and large premium in the years following the agreement. This general result is consistent with the view that investors have only recently become aware of the urgency of climate change.

When we break down the change in the carbon premium around the Paris Agreement by continent, we find that the premium is insignificant in North America before and after Paris, has declined in Europe, but, astonishingly, has sharply risen in Asia. In effect, Asia is entirely responsible for the rise in the global carbon premium around the Paris Agreement.

Overall, our analysis paints a nuanced picture of the pricing of carbon-transition risk around the world. The pricing is uneven across countries but widespread in North America, Asia, and Europe. The pricing is also rising, with a significant increase post–Paris Agreement in 2015.

Our study is relevant for the debates around carbon taxation. Carbon taxes have been touted as the policy solution for mitigating climate change. Yet, in practice, (global) carbon taxation has met significant political opposition. In light of this reality, our study suggests an alternative complementary approach via financial markets. The increasing cost of equity for companies with higher emissions can be viewed as another form of carbon pricing by investors seeking compensation for carbon-transition risk.

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Marcin Kacperczyk is a Professor of Finance at the Imperial College London Business School. He is also a Research Fellow at the Centre for Economic Policy and Research. In addition, he serves as an Associate Editor of Financial Management, Management Science, Review of Financial Studies and Review of Finance, and is a former Research Fellow of the National Bureau of Economic Research.

Professor Kacperczyk's research focuses mostly on financial markets, financial intermediation, and asset management. His latest work analyses the effects of unconventional monetary policy on asset management industry and corporate sector. He has also written on a broad range of topics such as social norms, short-term debt markets, performance evaluation, labour unions, insider trading, income inequality, and portfolio choice. He has analysed various effects of informed trading in finance.

His articles have appeared in *Econometrica*, *Journal of Finance*, *Journal of Financial Economics*, *Quarterly Journal of Economics*, *Review of Finance*, *Review of Financial Studies*, as well as non-academic outlets such as *Bloomberg*, *Financial Times*, *Forbes*, *New York Times*, *Wall Street Journal*, and *Business Week*. He has spoken about research on CNBC, CNN, and *Bloomberg*. He currently holds two highly prestigious research grants: European Research Council Consolidator Grant and Marie Curie Integration Grant.

Professor Kacperczyk has been teaching at Imperial College since 2013. Previously he has been appointed at the University of British Columbia Sauder School of Business and New York University Stern School of Business. He obtained a Ph.D. in finance from the Ross School of Business at the University of Michigan. He has received two student awards for Excellence in Teaching as well as two Faculty Excellence Awards from Imperial College.

CHAPTER 27

Barriers to net-zero: How firms can make or break the green transition[1]

Ralph De Haas, Ralf Martin, Mirabelle Muûls, Helena Schweiger
EBRD and CEPR; Imperial College Business School; Imperial College Business School; EBRD

Many countries are striving for net-zero carbon emissions by 2050, requiring massive investments over the next decades. But many companies, especially smaller ones, will not be able or willing to invest in cleaner technologies. This column explores how organisational constraints can hold back the green transition of firms in less-developed economies. The findings reveal how financial crises can slow down the decarbonisation of economic production and caution against excessive optimism about the potential green benefits of the current economic slowdown, which – like any recession – has led to temporary reductions in emissions.

In the absence of technologies to remove carbon dioxide from the biosphere, mitigating climate change requires a drastic reduction of carbon emissions (Pacala and Socolow 2004). This is particularly challenging for less-developed economies, which will be the source of nearly all growth in energy demand and greenhouse gas emissions over the next three decades (Wolfram et al. 2012). It is these poorest parts of the world that are therefore in most urgent need of investments in new technologies to reduce the carbon intensity of industrial production (Aiginger 2020).

In recent work, we explore how organisational constraints can hold back the green transition in less-developed economies (De Haas et al. 2021). To do so, we combine granular data on more than 11,000 firms across 22 European emerging markets. We first show that firms differ widely in both their ability to access external funding and in the quality of their green management practices (Martin et al. 2012). We then explore whether firms with better access to credit and those with stronger green management invest more to reduce their environmental and climate footprint. We also assess to what extent these investments indeed help firms to cut greenhouse gas emissions.

An initial analysis confirms that credit constraints correlate negatively with green investments, whereas green-management quality correlates positively with such investments. Correlation does of course not imply causation, and it is clear that past green

1 This column first appeared on VoxEU 19 March 2021 https://voxeu.org/article/how-firms-can-make-or-break-green-transition

investments may influence green management practices or credit constraints – rather than the other way around. To allow for a causal interpretation, we follow a two-pronged instrumental-variables approach.

First, we exploit spatial variation in credit constraints across towns and cities. The supply of bank credit tightened significantly in emerging Europe after the global financial crisis and in particular after the 2011 regulatory stress tests by the European Banking Authority (Gropp et al. 2019). The deleveraging varied greatly across banks and therefore across localities, depending on which banks operate branches where. Using data on the network of bank branches[2] combined with bank balance sheet information, we construct local proxies for credit tightness in the direct vicinity of firms.

Second, we assume that management practices are at least partly determined by knowledge diffusion that varies from area to area. We expect, and indeed find, that managers who themselves experience extreme weather events, or are informed about such events in their region, are more likely to be concerned about climate change and the environment. They will therefore be more amenable to green management practices. Hence, exposure to weather events becomes an exogenous driver we can use to explore the causal effect of management practices on green investments.

This instrumental-variables approach confirms our earlier results: both credit constraints and green management significantly affect the likelihood of green investments (Figure 1). Credit constraints hinder most types of green investment, particularly those that require higher investment amounts, such as machinery and vehicle upgrades; improved heating, cooling or lighting; and green energy generation on site.

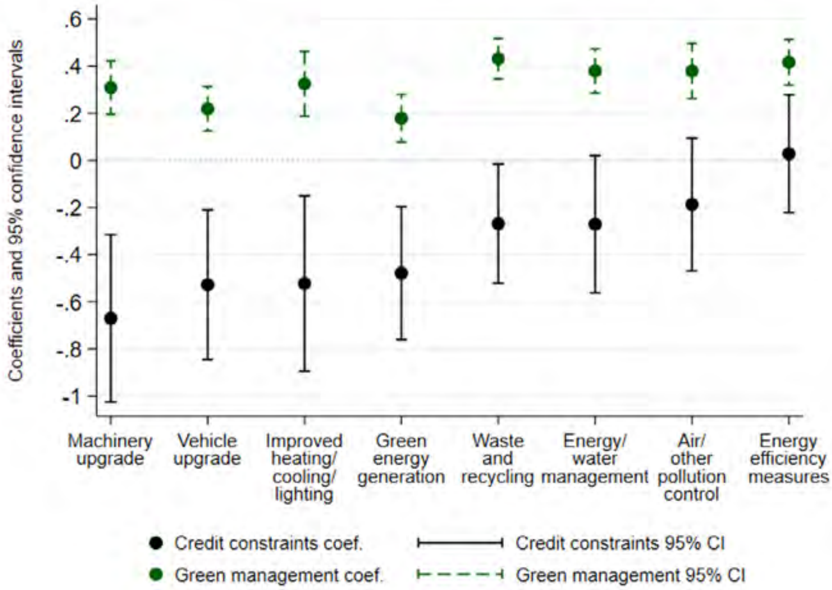
They do not significantly reduce the likelihood of investing in air and other pollution control or energy efficiency measures, potentially due to the 'low-hanging fruit' nature of such investments. Firms with good green management practices, on the other hand, are more likely to invest in all types of green investment, with the effect larger for those more typically thought of as green: waste and recycling; energy or water management; air and other pollution controls; and energy efficiency measures.

If credit constraints and weak green management prevent firms from undertaking at least some green investment projects, then one might expect that, perhaps with a lag, they can also hamper firms' ability to reduce their emissions of air pollutants. To investigate this, we use the European Pollutant Release and Transfer Register[3], which contains data on air pollutant emissions of a large number of Eastern European industrial facilities.

2 European Bank for Reconstruction and Development Banking Environment and Performance Survey (https://www.ebrd.com/what-we-do/economics/data/banking-environment-and-performance-survey.html).

3 European Environment Agency, European Pollutant Release and Transfer Register (https://prtr.eea.europa.eu/).

FIGURE 1 FIRM-LEVEL CREDIT CONSTRAINTS, GREEN MANAGEMENT, AND GREEN INVESTMENTS



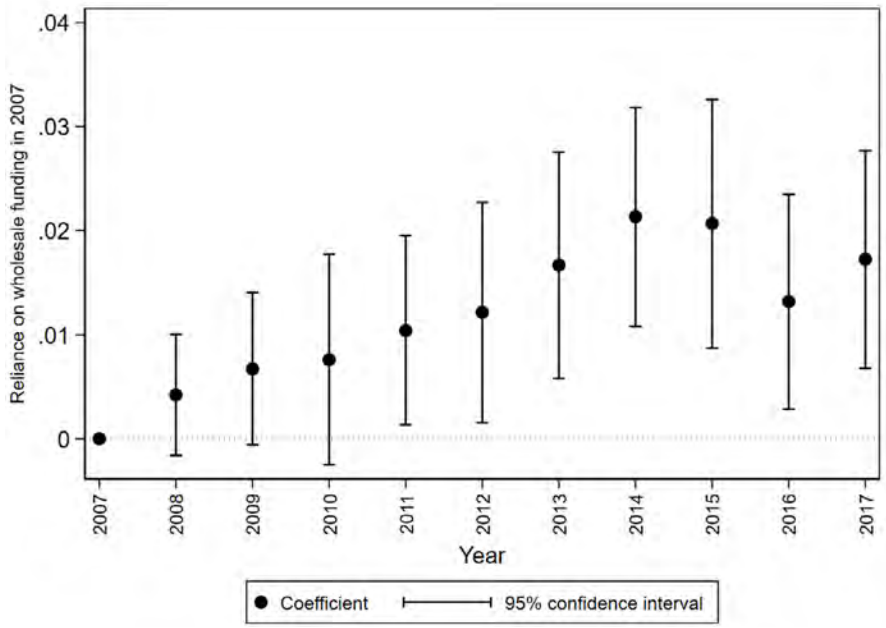
Source: EBRD-WBG-EIB Enterprise Surveys, EBRD Banking Environment and Performance Survey, BvD Orbis, European Severe Weather Database, and authors' calculations.

Notes: This figure summarises the estimates of the relation between, on the one hand, firm-level credit constraints and the quality of green management and, on the other hand, firm-level green investments. Whiskers represent 95% confidence intervals

Our estimates indicate that although there was an overall reduction in carbon emissions and air pollutants between 2007 and 2017, this decline was smaller in localities where banks had to deleverage more in the wake of the global financial crisis and where, as a result, firms were more likely to be credit constrained. The effects are increasingly strong from 2011 onwards, signalling the potential lag between investment and its effect on emissions (Figure 2).

To conclude, our results reveal how financial crises can slow down the decarbonisation of economic production and demand caution against excessive optimism about the potential green benefits of the current economic slowdown, which – like any recession (De Haas and Popov 2018) – has led to temporary reductions in emissions. Such short-term reductions might come at the cost of longer-term increases in emissions if they are associated with more severe credit-market frictions that delay or prevent green investment.

FIGURE 2 LOCAL CREDIT SHOCKS AND FACILITY-LEVEL AIR POLLUTION (2007-17)



Source: E-PRTR, EBRD Banking Environment and Performance Survey, BvD Orbis and authors' calculations.

Notes: This figure summarises the coefficient estimates of difference-in-difference regression to explain the impact of locality-level credit constraints on total air pollution (log kg) at the level of industrial facilities. Reliance on wholesale funding of all bank branches located in a circle with a 15km radius around the industrial facility, or, in the case of multi-facility firms, the parent company. The dots represent coefficient estimates of an interaction term between the reliance on wholesale funding in 2007 and individual year dummies during 2007-17.

While our analysis lends support to policy measures that ease access to bank credit specifically for green investments, it also suggests that this might just be one element of a broader policy mix to stimulate such investments. Governments and development banks should also consider measures that could strengthen green management practices. This may include requirements to measure and report environmental impact or credit lines that are contingent on the adoption of better green management practices by firms.

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CHAPTER 28

Mandatory corporate carbon disclosures and the path to net zero[1]

Patrick Bolton, Stefan Reichelstein, Marcin Kacperczyk, Christian Leuz, Gaizka Ormazabal, Dirk Schoenmaker

Columbia University, Imperial College London, and CEPR; University of Mannheim, Stanford University, and CEPR; Imperial College London and CEPR; University of Chicago, Booth School of Business; IESE Business School; Erasmus University Rotterdam and CEPR

The overwhelming majority of publicly listed companies around the world still do not disclose their carbon emissions, and even fewer privately held companies do so. This column introduces a new CEPR Policy Insight in which the authors argue that mandatory carbon disclosures can make an elementary but essential contribution to the global drive towards a net zero economy, and recommend a mandate for the governments represented at COP26 to adopt.

The pathway to a global economy with net zero carbon emissions is narrowing by the day and its success depends on a universal and ambitious drive to eliminate or capture carbon emissions by governments, corporations, financial institutions, and households. The drive to reduce, and ultimately eliminate, carbon emissions begins with the mundane tasks of annual measuring and reporting. However, despite significant progress in the methodology for measuring and reporting corporate carbon emissions, the overwhelming majority of publicly listed companies around the world still do not disclose their carbon emissions, and even fewer privately held companies do so. Also, as pointed out in a recent article in The Economist, the current voluntary disclosures lack a coherent measurement and reporting framework: "Firms disclose reams of irrelevant puffery, while often failing to reveal the few things that matter. Ideally, an asset manager would be able to work out the carbon footprint of their portfolio and how it may change over time. But many firms failed to disclose their emissions rigorously and often the measures made public by individual firms overlap, leading to double-counting when you add them all up" (The Economist 2021).

1 This column first appeared on VoxEU.org 4 October 2021 https://voxeu.org/article/mandatory-corporate-carbon-disclosures-and-path-net-zero

In anticipation of the upcoming COP26, in a new CEPR Policy Insight we argue that mandatory carbon disclosures can make an elementary but essential contribution to the global drive towards a net zero economy (Bolton et al. 2021). Such mandates can deliver much of what policymakers and asset managers need to manage carbon transition risk, and perhaps more importantly, to accelerate the pace of future carbon emission reductions. We argue that such carbon disclosure mandates ought to be simple and straightforward, and that the reported information be verifiable. A common methodology to measure and report greenhouse gas emissions has been established through the International Greenhouse Gas Protocol. This protocol envisions firms measuring their carbon footprints by including all direct (scope 1) and indirect (scope 2 and 3) emissions. The latter comprise the upstream emissions associated with a firm's operations and the entire supply chain of production inputs, as well as downstream emissions associated with the use of products sold by the firm. Our recommendation entails a mandate for reporting direct emissions.

Several important initiatives to promote the reporting of carbon emissions have already been underway for the past few years. Under the leadership of Mark Carney and Michael Bloomberg, the Financial Stability Board has established the Taskforce on Climate-related Financial Disclosures (TCFD) to consult institutional investors and companies on how to effectively report firm-level climate-risk exposures. Another initiative is the Sustainability Accounting Standards Board (SASB), which has a broader aim of defining industry-specific standards to guide the disclosure of environmental, social, and governance (ESG) metrics. The International Financial Reporting Standards Foundation (IFRS) is in the process of creating the International Sustainability Standards Board (ISSB), which will be charged with defining globally consistent and comparable sustainability reporting standards. In a significant step, this effort has received the backing of the International Organization of Securities Commissions (IOSCO).

Setting comprehensive reporting standards is a complex and time-consuming process, especially when it comes to environmental data. Yet, time is running out and metrics such as direct carbon emissions are relatively straightforward. Data providers such as the Carbon Disclosure Project (CDP) or Trucost have already developed significant expertise in collecting and estimating greenhouse gas (GHG) emissions. Furthermore, firms in carbon-intensive industries currently already report their direct emissions in order to comply with existing carbon pricing regimes in select jurisdictions. It will therefore be possible to mandate systematic corporate reporting of these emissions without having to wait for a global and comprehensive consensus to emerge around the sustainability reporting standards defined by the ISSB or other standard setting initiatives. To be sure, there appears to be a broad consensus among economists on the usefulness and effects of requiring companies to report their direct carbon emissions according to a recent poll.

We recommend that governments represented at COP26 adopt the following corporate carbon disclosure mandate:

Publicly listed firms are to report their global greenhouse gas emissions for the past calendar year in their annual reports. Private firms beyond a certain minimum size are to report their global greenhouse gas emissions for the past calendar year to a national registry in the country in which the firm is headquartered.

- Corporate GHG emissions are expressed in tons of CO_2 equivalents, where the aggregation weights for greenhouse gases other than CO_2 are determined according to current IPCC guidelines.
- Corporate GHG emissions comprise direct (scope 1) emissions from all installations and operating assets that the company (or its subsidiaries), have a majority interest in.
- In addition to the above measure of gross direct carbon emissions (GDE), we support the reporting of corporate net direct carbon emissions (NDE), provided that GDE and NDE are reported separately. The NDE metric should only allow the subtraction from GDE of those carbon offsets that the firm, or its subsidiaries, have removed and sequestered durably from the atmosphere in the past year. Durability requires a reasonably high degree of confidence that the captured CO_2 will not be released back into the atmosphere for at least 100 years.
- In future years, firms should be required to report not only their GDE and NDE figures for the most recent calendar year, but also the trajectory of past GHG emissions, beginning with the year in which the reporting mandate went into effect.

Mandated disclosures of essential financial information are the bedrock on which capital markets are founded. Given the urgency of the climate crisis, carbon emissions information about is becoming increasingly important. A requirement for both publicly listed and private companies to report their carbon emissions will be an elementary but essential first step in gauging the progress that individual corporations are making towards the net zero goal. It should be noted that some jurisdictions, including the UK, have already implemented substantial parts of our recommended reporting mandate.

We recognise that a carbon reporting mandate is unlikely to solve the climate crisis on its own. Nevertheless, there is research-based evidence that a mere reporting requirement on past emissions will spur companies to accelerate their emissions reductions as they anticipate the publicity of future emissions reporting. Furthermore, numerous global corporations have recently issued voluntary targets (milestones) on their anticipated paths towards net zero. We expect that some firms will supplement their mandatory reports of annual direct emissions with additional voluntary disclosures. Over time, the combination of such mandatory and voluntary disclosures will provide more transparency about a firm's actual achievement of earlier reduction targets.

The Montreal Protocol, established in 1987 to regulate the substances that deplete the ozone layer, provides a powerful illustration for how the international community can quickly push forward on an agreement to implement comprehensive mandatory emission reporting. Under this protocol, 24 governments quickly agreed to phase out chlorofluorocarbons (CFCs) by the year 2000, thereby initiating a long-term recovery of the ozone layer.

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PART V

GREEN MONEY: CLIMATE CHANGE AND CENTRAL BANKS

CHAPTER 29

Greening monetary policy[1]

Dirk Schoenmaker
Rotterdam School of Management, Erasmus University, Bruegel, and CEPR

The ECB's market-neutral approach to monetary policy undermines the general aim of the EU to achieve a low-carbon economy. The column argues that steering the allocation of the Eurosystem's assets and collateral towards low-carbon sectors would reduce the cost of capital for these sectors relative to high-carbon sectors. A modest titling approach could accelerate a transition to a low-carbon economy, and could be implemented without interfering with the priority of price stability.

Central banks traditionally take a long-term perspective on economic and financial developments. Through monetary policy they play an important role in the economy, and their mandate to ensure financial stability means they have an important role in the financial system too.

As part of this commitment, central banks have begun to examine the impact of climate-related risks on the stability of the financial system (Carney 2015). In monetary interventions, central banks have a long-standing policy of market neutrality, but there is evidence that the market has a bias towards carbon-intensive companies, and so monetary policy cannot be climate neutral (Matikainen et al. 2017). Doing nothing to meet this challenge is a decision that undermines the general policy of the EU to achieve a low-carbon economy.

In a recent paper (Schoenmaker 2019), I propose steering the allocation of the Eurosystem's assets and collateral towards low-carbon sectors, which would reduce the cost of capital for these sectors relative to high-carbon sectors. A modest tilting approach could reduce carbon emissions in their portfolio by 44% and lower the cost of capital of low-carbon companies by four basis points. This can be done without interfering with the transmission mechanism of monetary policy. Price stability, the primary objective, should remain the priority of the Eurosystem.

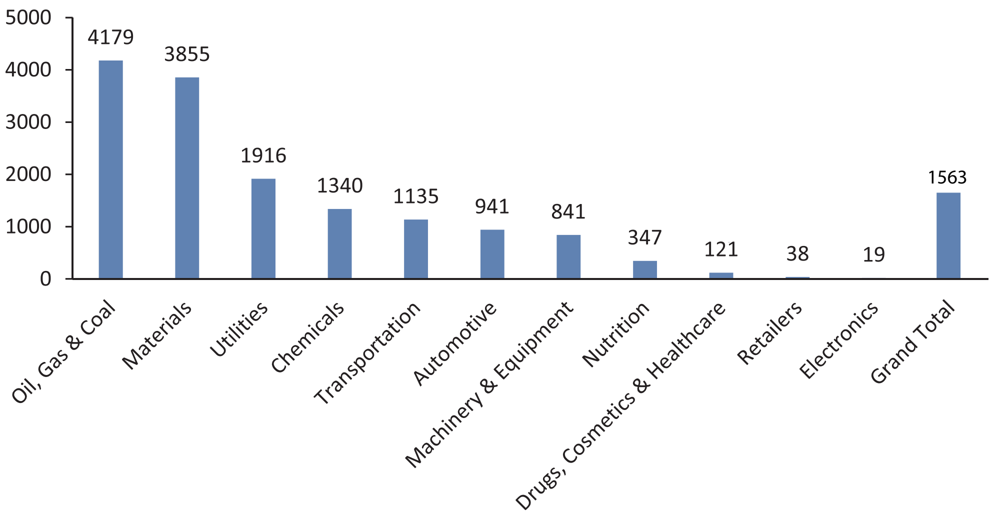
1 This column first appeared on VoxEU 17 April 2019 https://voxeu.org/article/greening-monetary-policy

CARBON-INTENSIVE ASSETS

Carbon-intensive companies – such as fossil-fuel companies, utilities, car manufacturers and airlines – are typically capital-intensive. Market indices for equities and corporate bonds are therefore overweight in high-carbon assets. Figure 1 summarises the average carbon intensity, defined as carbon emissions divided by sales, of industrial sectors in Europe.

As we might expect, the oil, gas, and coal sector has the highest carbon intensity followed by the materials sector (metal producers and construction), utilities, chemicals, transportation (airlines), and automotive (carmakers). The lopsided distribution of carbon intensity shows that carbon emissions are concentrated in a few sectors.

FIGURE 1 AVERAGE CARBON INTENSITY BY INDUSTRY (EMISSIONS IN TONNES OF CO2 DIVIDED BY SALES IN MILLIONS OF EUROS)



Note: Scope 1, 2 and 3 emissions are included for the 60 largest corporations in the euro area.

Source: Schoenmaker (2019).

In its monetary policy, the ECB – like any other central bank – follows a market-neutral approach in order to avoid market distortions. This means that it buys a proportion of the available corporate bonds in the market. This market-neutral approach leads to the Eurosystem's private-sector asset and collateral base being relatively carbon-intensive too (Matikainen et al. 2017).

Investment in high-carbon companies reinforces the long-term lock-in of carbon in production processes and infrastructure. We can conclude that the ECB's market-neutral approach undermines the broader policy of the EU to achieve a low-carbon economy.

Now that central banks have started to examine the impact of climate-related risks on the stability of the financial system (Carney 2015). Why not address the carbon intensity of assets and collateral in central banks' monetary policy operations as well?

LEGAL MANDATE

First, the legal mandate of central banks must allow the 'greening' of monetary policy. The primary responsibility of central banks is to maintain price stability, with a secondary responsibility to support economic growth. Interestingly, the EU applies a broad definition of economic growth. Article 3(3) of the Treaty on European Union says that:

> "The Union shall establish an internal market. It shall work for the sustainable development of Europe based on balanced economic growth and price stability ... and a high level of protection and improvement of the quality of the environment."

This broad definition of sustainable economic growth could provide a legal basis for greening monetary policy.

The ECB can only pursue its secondary objectives as long as they do not conflict with its first objective. The proposed tilting approach would not lead to undue interference with price stability. As everyone is a stakeholder in the environment and the climate (Schoenmaker and Schramade 2019), the ECB could contribute to the climate agenda without getting into political discussions.

There is thus a need for political space for the ECB to avoid central bankers making policy decisions. As climate policy is a top priority of European policy on a consistent basis, the ECB can contribute to this secondary objective using its asset and collateral framework of monetary policy operations. The European Commission and Council have repeatedly stated their aim to combat climate change by reducing carbon emissions. European Parliament members have also asked questions to the ECB president about the ECB's lack of carbon policies (see, for example, Draghi 2018).

GREENING MONETARY POLICY OPERATIONS

I propose a tilting approach to steer the Eurosystem's assets and collateral towards low-carbon companies (Schoenmaker 2019). The Eurosystem manages about €2.6 trillion of assets in its Asset Purchase Programme, which includes corporate and bank bonds in addition to government bonds.[2] In its monetary policy operations, the Eurosystem provides funds to banks in exchange for collateral, which currently amounts to €1.6 trillion. A haircut is applied to the value of collateral, reflecting the credit risk.

To avoid disruptions to the transmission of its monetary policy to the economy, the Eurosystem should remain active in the entire market. The basic idea of tilting is to buy relatively more low-carbon assets (for example, a 50% overallocation) and fewer high-carbon assets (in this case, it would be a 50% underallocation). The Eurosystem can then apply a higher haircut to high-carbon assets. Calculations show that such a tilting approach could reduce carbon emissions in the Eurosystem's corporate and bank bond portfolio by 44%.

Applying a higher haircut to high-carbon assets also makes them less attractive, reducing their liquidity. Early estimates indicate that this haircut could result in a higher cost of capital for high-carbon companies relative to low-carbon companies of four basis points.

ACCELERATING THE TRANSITION

A low-carbon allocation policy would reduce the financing cost of low-carbon companies, fostering low-carbon production. The higher cost of capital incentivises high-carbon companies to reform their production process using low-carbon technologies, because this will save on financing costs.

A low-carbon allocation policy in the Eurosystem's asset and collateral framework would therefore contribute to the EU's policy of accelerating the transition to a low-carbon economy. To avoid political interference, it is important that the Eurosystem remains fully independent in the choice and design of its allocation policies.

This allocation policy can and must be designed so it does not affect the effective implementation of monetary policy. Price stability is, and should remain, the top priority of the Eurosystem.

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2 While the carbon intensity of corporate bonds can be assessed directly, it is more difficult for bank bonds. The look-through approach can be applied, whereby the underlying beneficiary instead of the intermediating bank is assessed. For bank bonds, the carbon intensity of a bank's total loan portfolio should be evaluated.

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CHAPTER 30

Central banks and climate change[1]

Markus K Brunnermeier, Jean-Pierre Landau
Princeton University and CEPR; Sciences Po, Harvard Kennedy

Central banks have been called on to contribute to fighting climate change. This column presents a framework for thinking about the issue and identifies some major trade-offs and choices. It argues that climate should be a major part of risk assessments and that capital ratios could be used in a proactive way by applying favourable regimes to 'green' loans and investments. It also suggests that central banks may want to take several climate change-related aspects into account when designing and implementing monetary policies. However, the central bank should retain absolute discretion to interrupt any action if its first-priority objective – price stability – were to be compromised.

Fighting climate change had become the major priority of public policy in a great number of countries, and central banks have been called to contribute. Some have shown an inclination to internalise climate change in their policy objectives and frameworks. Others are more reluctant. In this column, we present a framework to think about the issue and identify some major trade-offs and choices.

An essential distinction must be introduced from the start between the two responsibilities that central banks undertake in most countries: the supervision, regulation, and oversight of financial institutions' activities; and the implementation of monetary policy.

CENTRAL BANKS, REGULATION, AND OVERSIGHT OF FINANCIAL ACTIVITIES

One can think of a spectrum of interventions on climate change, some of them uncontroversial, others more innovative or intrusive.

Internalising climate risks in financial supervision

This seems an obvious obligation. Climate should be a major part of financial risk assessments. Stress tests and, in the euro area, the Internal Capital Adequacy Assessment Process (ICAAP) should have a climate component. Climate scenarios should be conducted in parallel (or as complements) to macroeconomic scenarios, as the climate has

1 This column first appeared on VoxEU 15 January 2020 https://voxeu.org/article/central-banks-and-climate-change

an obvious impact on the valuation of long-term assets and liabilities. Climate sensitivity analyses should systematically be conducted and updated for the portfolios of insurance companies, institutional investors, and asset managers.

A subtle distinction must be introduced, however, between three categories:

- The risks stemming directly *from climate events* (for instance, mining, farming or some industrial activities may become impossible in some areas and existing assets must be depreciated accordingly)
- The future impact of *existing climate policies* that must be assessed and priced accordingly
- The impact of *future climate policies* that have not yet been decided. For instance, should a carbon tax (or some equivalent measure) be implemented, some oil reserves would become 'stranded' and exposures by financial intermediaries should record some impairment. It is economically logical that institutions be stress-tested against that possibility. It is also financially sound that institutions be asked to protect against it. However, it may be operationally awkward for supervisors to assess the probability of policies that have been enshrined in international agreements (the Paris Agreement, for instance) but not enacted by the legislator.

  Interestingly there is a feedback effect. If private institutions provision for the impact of future climate policies, they will be more resilient when measures are taken. In turn, increased preparation in the private sector may make it easier and politically more feasible to adopt the necessary policies.

Using of prudential ratios (capital requirements) to direct financing towards sustainable investments

Most capital ratios under Basel III regime are 'risk weighted' – they vary with the estimated riskiness of loans and assets held by banks. It would be relatively straightforward to expand the concept and definition of riskiness to take climate risks into account. Again, there is a graduation of possible regimes depending on the kind of risks that would be considered: existing and materialised climate risks or future possible climate risks; impairments resulting from existing policies of future possible policies.

Capital ratios could also be used in a more proactive way by applying favourable regimes to loans and investments deemed 'green' by supervisors. While operationally easy to implement, such regimes would confront central banks with a triple challenge:

- Green investments may be intrinsically riskier and would, per se, require higher capital buffers.

- How would the 'green' characterisation be defined and by whom? Are regulators equipped to make such a determination?

- Using prudential ratios to influence the allocation of credit would mark a shift toward more 'directed credit' policies. Those policies were abandoned in most advanced economies several decades ago but are practised in many emerging economies. Again, the question would arise as to whether central banks are equipped to implement such policies. The central banks might become subject to severe lobbying pressure from various interest groups.

None of these challenges is insurmountable, but they would need to be addressed ex ante and the proper institutional and governance arrangements put into place.

Creating and increasing incentives to 'green finance'

- While the concept of green finance is widely utilised, it remains largely undefined in terms of instruments and legislation. At this stage, in addition to specific regulatory incentives, central banks could pursue two general and distinct objectives:

  - Encourage the development of long-term project finance as most of the difficulties attached to financing the energy transitions are common to all long-term risky projects

  - Push governments and parliaments to take clear and predictable measures. Uncertainty on future policies – more than the lack of financing – is the main factor inhibiting investment in climate change. Once those uncertainties are removed, investors will be able to take full advantage of existing low interest rates and easy financial conditions.

CENTRAL BANKS, MONETARY POLICY, AND CLIMATE CHANGE

This section outlines a problematic rather than prescribing specific orientations.

It is obvious that the link between climate change and monetary policy is looser and less well-defined than with financial stability and supervision. One major difficulty is the difference in horizons. The conventional wisdom on monetary policy is that it has no impact on long-term growth; its influence is mostly felt on a 1.5 to 2.5 years horizon. By contrast, climate change is all about the long term; effects and policies materialise and matter over several decades.

Impact of climate risk on macroeconomy

This being said, central banks may want to take several climate change-related aspects into account when designing and implementing monetary policies:

- First, they should incorporate climate risks in their assessment of potential growth and output as well as the *natural* equilibrium interest rate (r*).
- Second, even in the short run, the climate can have an impact if it leads to an *increased frequency* of extreme weather events. Those events are 'negative supply shocks' with inverse effects on output and prices. They very much complicate the conduct of monetary policy. Some small and medium-sized emerging economies may be especially exposed and adjust their policy frameworks accordingly.

Monetary instruments

The big question, however, is whether central banks can use their monetary instruments to actively promote the fight against climate change (Honohan 2019). Over the last decade, central banks have significantly expanded their balance sheets, often by a factor of five or ten. In many countries, those balance sheets are now commensurate to the size of the national economy. With such an imprint on the economy and financial markets, central banks could take a more proactive approach to financing the climate transition.

Two possibilities come to mind, both without significant changes to the current operational framework:

- Reorient their asset purchases towards 'green' securities
- Modulate haircuts applied to different kinds of collateral used in refinancing operations, thus creating an incentive to detain some and offload others.

Some reflections in light of Musgrave's categorisation

Should central banks take that route? This may be the most sensitive and difficult question. In this column, we simply present some reflections – first at a general level, and then applied to particular central banks.

Generally speaking, it is useful to refer to the classical Musgrave distinction between the three functions of public economic policies: allocation (of resources), *redistribution* (of incomes) and *stabilisation* (Musgrave 1939).

In countries in which central banks are subordinate to the government and do not enjoy any independence, a clear assignment of the various policy functions is less relevant. This is especially true if the government-directed credit is part of the economic model, as in the case of China for example.

In democratic societies, decisions on allocating resources and redistributing incomes are taken by elected bodies. Obviously, policies relating to climate change belong to that category. Independent central banks are non-elected 'agents' of the society; they have a well-specified *mandate to stabilise the economy.* It can be argued that central banks would be going beyond their mandate if they were to tweak their instruments of monetary policy to allocate resources and direct credit. This seems to be the position taken by the Federal Reserve. Chairman Powell stated recently that "[c]limate change is an important issue but not principally for the Fed".

The situation may be more complex for the ECB. Compared to the US Federal Reserve, its mandate is both more hierarchical – with price stability as a priority objective – and more complex. The Treaty states that "… without prejudice to the objective of price stability", the Euro system shall also "support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union". These include "full employment" and "balanced economic growth".

To the extent that price stability is not compromised, and fighting climate change is a major (recently reaffirmed and emphasised) priority of the EU, the question arises as to whether the ECB can use some of its available instruments to also pursue a climate change objective. This is certainly a point made by many climate activists.

However, this immediately raises further questions. Governments in various countries pursue many policies. Is it legitimate for the central bank to pick and freely select its preferred secondary objective? Or should it defer to elected bodies if the policy aims at allocating public resources, as seems normal in a representative democracy.

The trade-off is real and difficult. If the central bank were to assess the situation itself and contemplate actions, its legitimacy would be challenged (Tucker 2018). In addition, it would expose itself to various political pressures. One other hand, if it requests some formal guidance by elected bodies (e.g. the parliament), it risks fuelling the perception that it has lost its independence. There might be subtle ways and procedures to navigate between those risks, but the dangers are real and would justify a great caution. Under all circumstances, the central bank should keep the absolute discretion to interrupt any action or programme if its first-priority objective – price stability – were to be compromised.

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CHAPTER 31

Carbon taxation and inflation: Evidence from Europe and Canada[1]

Maximilian Konradt, Beatrice Weder di Mauro
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Model-based studies on the effect of carbon taxation point to sizeable inflationary effects. This column uses evidence from Canada and Europe over the past three decades to show that carbon taxes changed relative prices but did not increase the overall price level. Instead, they were slightly deflationary. In the case of British Columbia, the driver may have been a fall in household income depressing the prices of non-energy goods, which more than offset rising energy prices. The income compression was most pronounced among the richest households, suggesting that the redistribution scheme achieved its intended aim of favouring low-income households.

Recently the CEO of Black Rock, Larry Fink, made headlines by predicting that climate policies could lead to a large inflation shock.[2] This is of first order importance for all central banks, in particular in light of the ECBs' new strategy focus on climate risks. Will a secular increase in the price of carbon (and carbon equivalents) put upward pressure on the price level? How large is this effect likely to be? How much does this effect depend on the reaction of monetary policy? Should central banks take such risks into account in their strategies?

Modelling studies on the effect of carbon taxation point to sizeable effects on inflation, based on the assumption that higher energy prices are largely passed on to consumers and the central bank follows a Taylor rule. For instance, McKibbin et al. (2014) consider a US$15 carbon tax implemented in the US and find that it causes a rise in inflation of 0.8% during the first year of the policy. In practice, the effect of a carbon tax on inflation will depend on many factors, including the tax rate, coverage, and incidence, as well as the fiscal and monetary policy responses.

In a new study (Konradt and Weder di Mauro 2021), we use the experience of three decades of carbon taxation in Canada and Europe to explore the effect empirically.

1 This column first appeared on VoxEU 29 July 2021 https://voxeu.org/article/carbon-taxation-and-inflation
2 See https://www.bloomberg.com/news/articles/2021-06-18/the-climate-change-fight-is-adding-to-the-global-inflation-scare

We find that carbon taxes do not have to be inflationary, and may even be deflationary. Our evidence suggests that the increase in energy prices was more than offset by a fall in the prices of services and other non-tradables. Our results are consistent across Canadian provinces and European countries, and survive various robustness checks. At least in case of British Columbia, a contraction in household incomes and expenditures, in particular among the richer households, could explain the deflationary effect.

OUR FINDINGS

a) Deflationary effects

Our analysis builds on two separate empirical methods, the synthetic control method (Abadie et al. 2010), and local projections (Jordà 2005) to identify the effects on the consumer price index (CPI) and its components on the intensive margin, as well as the extensive margin.

Following Metcalf and Stock (2020), we consider a $40 carbon tax implementation that remains flat over time and accrues on 30% of total GHG emissions. We estimate dynamic impulse responses based on three provincial carbon taxes in Canada and 15 national carbon taxes in Europe, respectively.

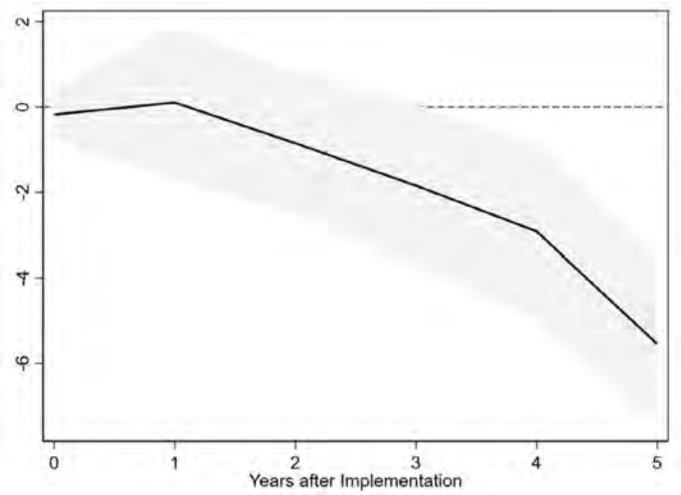
Figure 1 plots the cumulative impulse response (assuming a parallel trends assumption) for the Canadian (Panel A) and European sample (Panel B), including country (or province) and year fixed effects. The shaded grey bounds denote 95% confidence bands.

The impulse response of CPI in Canadian provinces following a carbon tax implementation is economically sizeable and statistically significant. Five years removed, CPI falls by a total of 6 points following the enactment of a $40 tax on 30% of GHG emissions. For European countries we estimate a contemporaneous negative response of about −0.5 index points, which is statistically significant at the 5% confidence level. In the following years, the impulse response trends upwards. After five years, the estimates point to a small, negative cumulative effect on CPI, which is, however, not statistically significant.

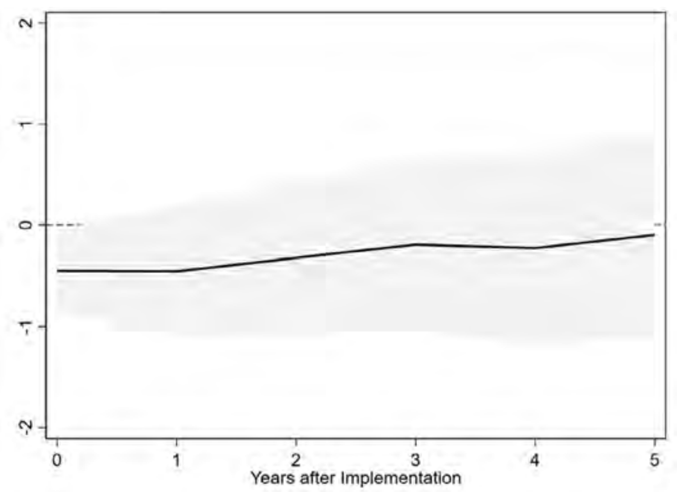
Next, we check whether relative (final) prices for energy versus other goods changed in response to the tax enactments, as intended. On this front, carbon taxes seem to have 'worked'. In most cases, energy prices rose in the period after carbon taxes were implemented (compared to a synthetic control group). At the same time, prices of other components of the CPI basket, mostly non-tradables, fell. Again, this result holds for both Canadian and European jurisdictions.

FIGURE 1 CUMULATIVE IMPULSE RESPONSES OF CPI

Canada



Europe



Note: This figure shows the cumulative impulse response of CPI to a $40 carbon tax with 30% emission coverage, estimated for Canada (panel A) and Europe (panel B), respectively. Shaded grey bounds show 95% confidence bands.

Our main finding that carbon taxes do not lead to an inflationary response is remarkably robust. For Europe, it holds for early as well as late carbon tax adopters, although the deflationary effect is smaller for the latter group. Moreover, the result is robust for countries with 'high' carbon taxes. The finding also overwhelmingly holds across jurisdictions that manage their own monetary policy and those that do not (provinces in Canada or countries in the euro area). Finally, deflationary effects also dominate regardless of whether or not countries are 'recycling' carbon tax revenues.

We cannot fully control for other factors driving our results. Most of the carbon taxes in our sample were implemented during the Great Moderation or secular stagnation decades. However, these forces would apply equally to the non-carbon tax jurisdictions, which are in our control group. The same is true for the various financial crisis in the last three decades.

b) Falling household income and expenditure in British Columbia, mostly among the rich

Finally, we turn to the macroeconomic and distributional effects of the carbon taxes in Canada in order to understand what is driving our muted price responses. One hypothesis is that carbon taxes put downward pressure on wages (consistent with Yamazaki 2017) and aggregate income. Lower real income could lead households to cut expenditure and consume fewer goods and services at the margin, akin to a negative demand shock.

We also explore heterogeneous effects on households across the income distribution. With the experience of the 'yellow vest' movement in France in mind, our suspicion was that the carbon tax may have been regressive, reducing the incomes and expenditures of the poorest the most.

Our results suggest that following the carbon tax introduction, (real) household income and consumption expenditure fell in British Columbia compared to the rest of Canada. Along the lines of prior studies (e.g. Metcalf 2019), we find no negative effect of the carbon tax on GDP. We illustrate the effect graphically in Figure 2 by comparing households of different income in British Columbia to a plausible counterfactual (synthetic control).

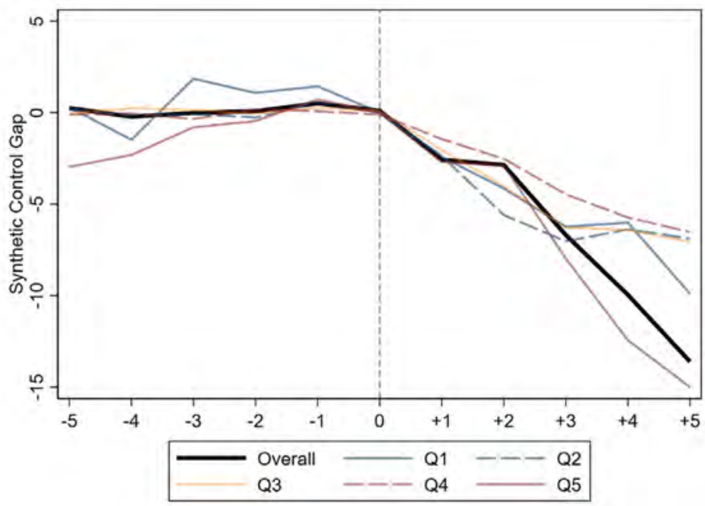
Panel A highlights the fall in household income on average (dark solid line) and across income groups (coloured lines) in British Columbia after the introduction of the tax. After five years, the cumulative difference of average real household income in British Columbia is 10 percentage points below that of the counterfactual economy.

The same pattern holds for household expenditures (panel B) and is most pronounced for high-income households (red line). By contrast, the lowest income group increased expenditures following the taxation, potentially related to the progressive redistribution scheme in British Columbia.

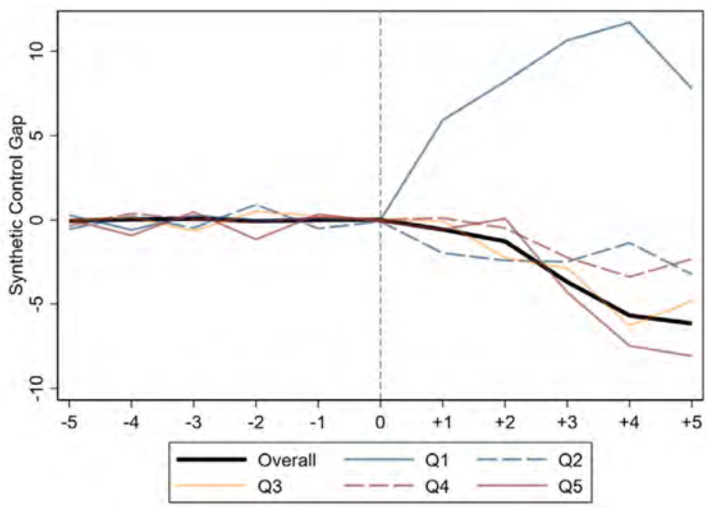
In addition to the income channel, we find some support that the tax, through permanently higher energy prices, put downward pressure on the net present value of real estate and energy-intensive durable goods. Both the price of shelter and passenger vehicles fell in British Columbia after the enactment of the tax.

FIGURE 2 INCOME AND EXPENDITURE, SYNTHETIC CONTROL GAP

Income



Consumption expenditure



Note: This figure shows the synthetic control gap for household income (panel A) and household consumption expenditure (panel B). All series are in real terms and were smoothed using a symmetric moving average. Solid dark line is the total response, coloured lines correspond to the 5 different income quintiles (Q1: bottom, Q5: top).

CONCLUSIONS: NO ANGST

Our initial intuition was in line with that of Larry Finks; we expected to find a positive effect of carbon taxes on inflation and mostly wondered about its size. Our findings, instead, point the other way. In both Canada and Europe, the evidence suggests that introducing carbon taxes had deflationary, rather than inflationary, effects. We explored several possible avenues to explain these findings. The most promising candidate explanation is that the carbon taxes may have reduced household income and expenditures, thus depressing non-energy prices.

Even though our analysis provides no support for an inflationary effect, deflation is equally undesirable and central banks still have to pay close attention to carbon pricing and taxation. Moreover, the absent reaction of monetary policy in most jurisdictions that introduced carbon taxes might have contributed to the deflationary outcome in the first place. No doubt, further research will be needed to draw the broader implications of carbon price shocks for optimal monetary policy responses.

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CHAPTER 32

Climate change and central banks: Introducing the expectations channel[1]

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Climate change has emerged as a major challenge for central banks, although its extent and the immediate consequences are highly uncertain. This column uses a survey of over 10,000 US consumers to show that irrespective of when and how climate change actually plays out, what matters for monetary policy is how people expect it to play out. Central bankers ignore the expectations channel of climate change at their peril.

Climate change has emerged as a major challenge for central banks. On the one hand, there is a debate about appropriate actions of central banks to limit climate change. In this regard, the ECB has taken a leading role, recognising that the "urgency of this topic… requires all policymakers to explore their roles in tackling this challenge" (Schnabel 2021) and noting that while "we are not in the driving seat", this "does not mean that we can simply ignore climate change, or that we do not play a role in combating it" (Lagarde 2021). On the other hand, it is widely accepted that climate change matters for monetary policy, at least to the extent that it gives rise to financial stability risks (Brunnermeier and Landau 2020).

MEASURING EXPECTATIONS ABOUT THE NEAR-TERM ECONOMIC IMPACT OF CLIMATE CHANGE

Against the background of these far-reaching and fundamental considerations, we show in a new paper that climate change represents a much more direct and immediate challenge for monetary policy (Dietrich et al. 2021). Our point of departure is the fact that irrespective of when and how climate change actually plays out, what matters for monetary policy is how people expect it to play out. After all, expectations feed back into economically relevant decisions today and these decisions matter for monetary policy.

1 This column first appeared on VoxEU 22 March 2021 https://voxeu.org/article/climate-change-and-central-banks-expectations-channel

We solicited these expectations through a representative survey of US consumers. Specifically, our data come from a larger, nationally representative daily survey of consumers sponsored by the Federal Reserve Bank of Cleveland. We asked more than 10,000 respondents how they expect climate change to impact the economy in the near term, that is, over the next 12 months. Specifically, we asked them about (1) the impact of climate change on GDP growth, (2) likely damages caused by climate change to economic activity and (3) the probability of larger, climate-change related disasters (causing damages of as much as 5% of GDP). We also obtained information on respondents' socioeconomic background and checked their ability to compute probabilities.

Three main results on the effect of climate emerge, summarised in Table 1. The top panel of the table pertains to all respondents while the bottom panel summarises statistics for those respondents with high numerical ability. There are no systematic differences across the two panels. First, the expected impact of climate change on GDP growth is approximately zero across respondents. Second, the average for climate change-related damages over the next 12 months is 1.5% of GDP (we asked respondents to assign probabilities to five brackets ranging from zero damages to damages of 5%). Our third question zooms in on large disasters and asks respondents to state the probability of such a large disaster. Here we find quite high values: the median response is 12% across all respondents, and 15% for respondents with high numerical ability.

TABLE 1

All Respondents	Mean	Median	Std. Dev.	N
Growth Impact	0.16 pp	0.00 pp	1.24 pp	4344
Disaster Costs	1.51%	1.50%	0.81%	3228
Disaster Probability	23.08%	12.00%	23.76%	3223
High Numerical Ability Respondents	**Mean**	**Median**	**Std.Dev.**	**N**
Growth Impact	0.11 pp	0.00 pp	1.18 pp	157
Disaster Costs	1.51%	1.50%	0.69%	151
Disaster Probability	20.38%	15.00%	19.13%	363

Notes: statistics are weighted using survey weights as well as Huber-robust weights. High numerical ability respondents answer a question on probabilities with an error margin of at most 2 percentage points.

SALIENCE EFFECTS

There are various possibilities for why the perceived probability of disaster is so high, and in fact much higher than what historical data suggest. For instance, respondents may think we have been lucky in the past, just like in the case of 'peso problems' - in the relatively short sample under consideration, adverse events may have simply materialised less often than what the objective probability would imply. Alternatively, natural disasters due to climate change may be much more frequent in the future because we may have reached so-called 'tipping points'. Yet another possibility is that we are picking up a salient 'Greta effect' – people overestimate the risk of natural disasters because of a media focus on climate change, consistent with research that has documented how media focus can be an independent source of business cycle fluctuations (Chahrour et al. 2020).

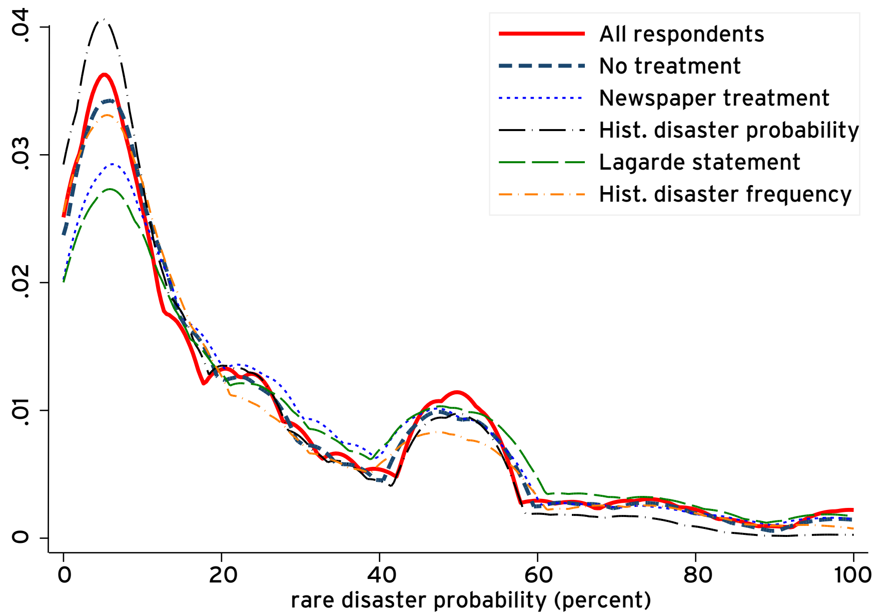
In support of this last possibility, we find in the survey that respondents that are not exposed to media at all report a significantly lower estimate of the probability of natural disasters. Moreover, we formally complement our survey analysis with several information treatments: a 'newspaper treatment', which shows respondents sections of a USA Today newspaper article on the 2020 wildfire and hurricane season; a 'Lagarde treatment', which is a recent statement by ECB President Lagarde on the importance of climate change for the ECB's monetary policy; and two treatments that provide respondents with information about the frequency and extent of large disasters in the past.

These treatments have a sizeable impact on the answers of the survey respondents. In Figure 1, we show the distribution of responses to the third question (on the probability of rare disaster within the next 12 months). The red solid line is the distribution across all respondents (median: 12%). The newspaper and the Lagarde treatment, shown by the blue-dotted and the green-dashed lines in the top panel, respectively, stand out in the way they shift the mass of the distribution to right – people who receive information about these disasters think they are more likely to happen.

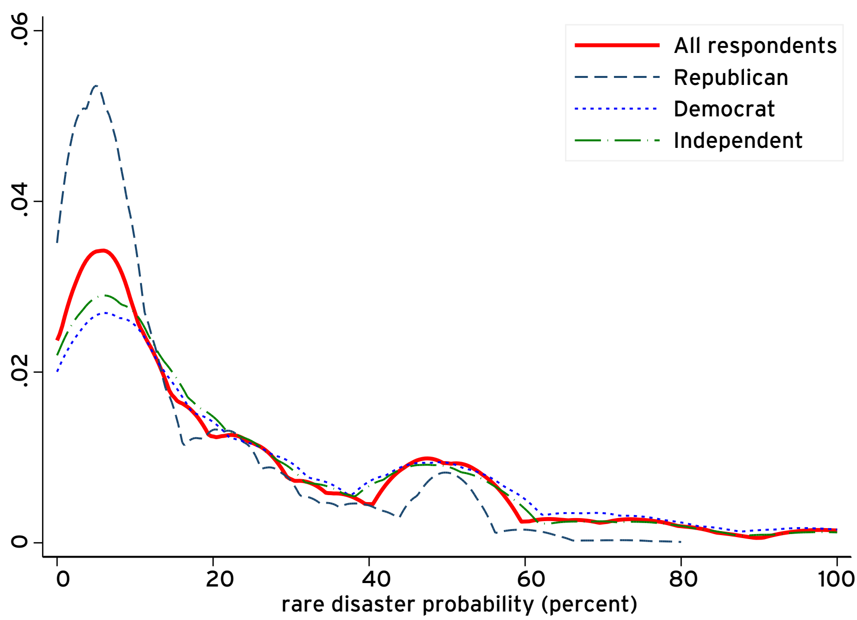
In addition, we correlate the responses with other covariates and detect very plausible patterns. For instance, personal experiences of disasters raise the perceived probability of disasters. Likewise, we find that Republicans assign smaller probabilities to large climate change-related disasters; the opposite holds for Democrats and independent voters (see the bottom panel of Figure 1). The tenor of our findings here is that expectations of climate change-related disasters in the near future are very high and vary in a meaningful way with a number of socioeconomic characteristics. More importantly still, we find that reported expectations are also quite sensitive to new information.

FIGURE 1

a) Disaster probability distribution: Info treatments



B Disaster probability distribution: Political affiliation



IMPLICATIONS FOR MONETARY POLICY

Expectations about climate change-related disasters are 'bad news' about the future and induce a contraction of current expenditures according to theory – an instance of 'Keynesian supply shocks' (Guerrieri et al. 2020). We establish this formally in a New Keynesian model. The model is due to Fernández-Villaverde and Levintal (2018) and features rare disasters, but also nests the textbook version of the New Keynesian model for which we establish a number of closed form results. In particular, we show that the natural rate of interest declines in response to expected disasters, both with the probability and the size of natural disasters. Monetary policy plays a key role in shaping the adjustment of the economy to these disaster expectations. In the basic model there are no supply-side effects of disaster expectations as such, and monetary policy may fully stabilise the economy at potential if it adjusts the policy rate in sync with the natural rate of interest.

TABLE 2

	Baseline	High p	Low p	Low $\bar{\mu}$
Disaster probability p	12%	**20%**	**10%**	12%
Mean disaster size $\bar{\mu}$	0.05	0.05	0.05	**0.025**
Natural rate of interest r^n	-0.64pp	-1.04pp	-0.53pp	-0.30pp
Output gap tilde y	-0.20pp	-0.32pp	-0.17pp	-0.10pp
Inflation pi	-0.29pp	-0.47pp	-0.24pp	-0.12pp
Nominal interest rate i	-0.66pp	-1.08pp	-0.56pp	-0.29pp
Rental rate of capital R^K	0.17pp	0.29pp	0.14pp	0.08pp
Outout Y	-2.03%	-3.34%	-1.70%	-0.98%
Consumption C	-1.56%	-2.58%	-1.30%	-0.75%
Investment X	-5.27%	-8.66%	-4.40%	-2.53%
Capital K	-5.28%	-8.71%	-4.42%	-2.54%
Labour N	-0.56%	-0.86%	-0.44%	-0.25%

Notes: The table gives simulation results for different disaster calibrations. Numbers represent deviations from the no disaster steady state.

We calibrate the full model to capture key results of our survey and solve it numerically. Table 2 summarises the effect of disaster expectations on key variables under the baseline scenario according to which a disaster is expected to occur with a 12% probability. It reduces productivity and destroys a fraction of the capital stock such that output declines by 5% on impact. What matters in our analysis, however, are expectations of the disaster, not the disaster itself.

These expectations reduce the natural rate by about 65 basis points. This is a sizeable effect and may put central banks in a difficult position, notably if policy rates are low to begin with – if monetary policy is unable or unwilling to lower policy rates, a large recession might ensue. For our baseline scenario we assume a conventional Taylor-type interest rate rule which ensures that the demand contraction remains fairly contained – the output gap and inflation decline by about 0.2 and 0.3 percentage points, respectively. Yet disaster expectations also lower potential output because the expected damages to the capital stock in the event of a disaster reduce investment significantly.

AND FINALLY… A PARADOX OF COMMUNICATION

In sum, climate change represents a major challenge for central banks and central banks have started to confront this challenge in various ways – not least by communicating frequently about the issue. This is certainly laudable. But there is a risk that the immediate implications of climate change – namely, those that operate through the expectations channel – are going unnoticed because of an undue focus on how to battle climate change, a task central banks are perhaps not particularly well-equipped to deal with. What's more, there may even be a paradox of communication inherent to central bank activity. To the extent that central bankers engage in the debate, they may themselves contribute to the media focus and salience of climate change. This contribution, in turn, may exacerbate adverse expectations about future climate-change related disasters. In this way, by trying to tackle a major global challenge upfront, central banks actually make their tasks harder today – because interest rates are low and further reductions in the natural rate are hard to accommodate.

Authors' note: The views stated in this column are those of the authors and are not necessarily those of the Federal Reserve Bank of Cleveland or the Board of Governors of the Federal Reserve System.

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CHAPTER 33

The ECB's green agenda[1]

Ethan Ilzetzki, Jason Jia

London School of Economics and CEPR; University of Chicago

Debates have emerged recently on central banks' role in mitigating climate change, or at least on increasing their awareness of their environmental impact. The February 2021 CfM-CEPR survey asked members of its European panel of experts about measures the ECB could take to address the environmental impact of its bond-purchasing policies. The majority of the panel supports active measures to use the ECB's bond-purchasing programme to either exclude industries with negative environmental impact or bias its portfolio towards green investments. An additional 30% of the panel believes that the ECB should rebalance its portfolio to correct its current bias in favour of polluting industries. However, a majority also believes it would be inappropriate to change the ECB's mandate to reflect green objectives.

Concerns about climate change have been central to the economic policy discussion in recent decades, with increasing urgency. More recently, debates have emerged on central banks' role in mitigating climate change, or on increasing their awareness of their environmental impact (Brunnermeier and Landau 2020). The February 2021 CfM-CEPR survey asked members of its European panel of experts about measures the ECB could take to address the environmental impact of its bond-purchasing policies, in light of some suggestions that the bonds the central bank purchases overweigh industries that have negative environmental impact. The panel was also asked whether it would consider changing the ECB's mandate to contain environmental targets.

CONCERNS ABOUT THE ECB'S ENVIRONMENTAL IMPACT

The ECB has been on the forefront of thinking among central banks and climate policy is a central "work stream" of the Bank's monetary policy review this year.[2]

The ECB's existing policy states that environmental externalities are best tackled by taxation, but that there is still potential scope for monetary policy to factor environmental concerns into its policy considerations. The ECB has already been doing so, having purchased green bonds under its asset purchase programmes, amounting to 3.5% of its

1 This column first appeared on VoxEU 10 March 2021 https://voxeu.org/article/ecb-s-green-agenda
2 https://www.ecb.europa.eu/home/search/review/html/workstreams.en.html

portfolio (before the Covid-19 pandemic). The ECB's annual report from 2019 states that "all authorities need to reflect on the appropriate response to climate change and related risks in their own area of competence" (ECB 2020).

The main argument for central bank action in this regard has been that the central bank's actions are not 'market neutral'. That is, the types of bonds typically purchased through central banks' quantitative easing policies tend to be from larger firms that do more environmental harm on average than does the average firm. In this regard, the quantitative easing may be an implicit subsidy for fossil fuel and other 'brown' industries.

In a recent lecture at the 2021 American Economic Association meetings, Monika Piazzesi presented work in progress (Piazzesi et al. 2021) that shows that the ECB's bond portfolio is significantly different from the universe of outstanding bonds in the market and overweighs industries that are heavier in emissions (manufacturing, utilities, and transport), as these industries issue more bonds than do other sectors. She argues that the ECB should restore market neutrality by consciously tilting its portfolio towards green industries. Paul De Grawe goes further[3] and argues that the ECB could actively tilt its portfolio towards green bonds and do so without stoking inflation.

Ferrair and Nispi Landi (2020) model a temporary green quantitative easing (QE) in a DSGE model and concur that this policy could be effective in mitigating emissions, but this requires imperfect substitutability between bonds of 'green' and 'brown' firms (an assumption also made in Piazzesi et al.'s analysis). Further, they find that green QE can only have a small positive impact on the environment because it cannot affect the stock of atmospheric carbon, only the flow of emissions.

In recent speeches, ECB President Lagarde has supported this view[4], arguing that "we have to ask ourselves as to whether market neutrality should be the actual principle that drives our monetary policy portfolio management". Isabel Schnabel, an ECB executive board member, goes beyond market neutrality and argues for excluding bonds from the Bank's portfolio that are inconsistent with the EU's target to be carbon-neutral by 2050. President of the Bank de France, François Villeroy de Galhau, also supports this idea[5], calling for "decarbonising the ECB's balance sheet in a pragmatic, gradual and targeted manner for all corporate assets, whether they are held on the central bank's balance sheet or taken as collateral".

Other central bankers are less supportive of this shift. Jens Weidmann, president of the Bundesbank, wrote in the *Financial Times* that "it is not up to us to correct market distortions and political actions or omissions"[6], adding that "the market price of carbon" is an issue for governments to address — not central banks." Otmar Issing, the Bank's former chief economist has written that "[c]entral bankers who would assume responsibility

3 https://www.socialeurope.eu/green-money-without-inflation
4 https://www.ft.com/content/495cc894-04c1-4637-841b-bf141e420e15
5 https://www.bloomberg.com/news/articles/2021-02-11/ecb-s-villeroy-proposes-climate-leap-for-corporate-bond-program
6 https://www.bundesbank.de/en/press/contributions/central-banks-cannot-solve-climate-change-on-their-own--851320

for tackling climate change are acting out of pretention, and could well undermine the very independence upon which their institutions rely. Central banks were not made independent so that they could extend their own mandates. And where environmental issues are among their secondary objectives, central banks should warn against exaggerated expectations regarding their contribution. Making themselves publicly accountable beyond their limited capability in this field must lead to disappointment and undermine their reputation."[7]

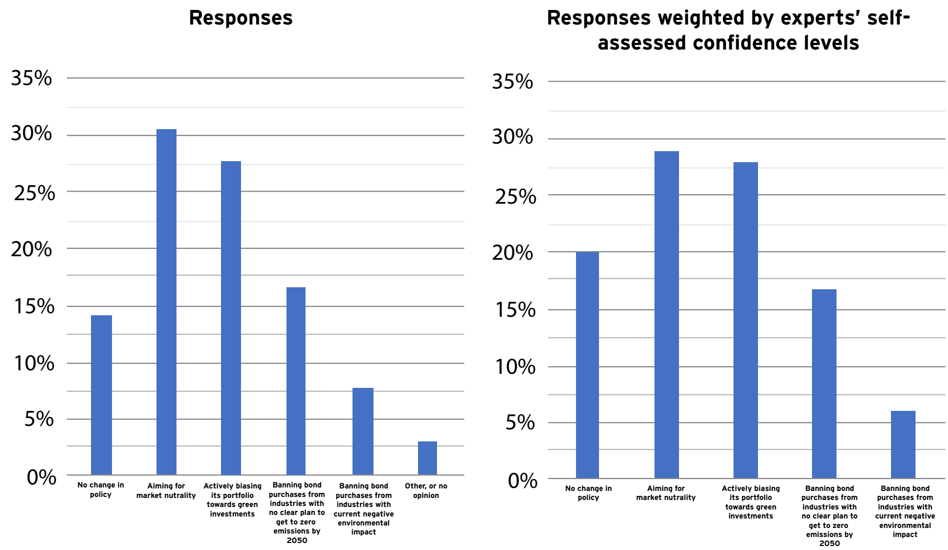
There are also reasons to be sceptical whether a change in the ECB's portfolio will have much more than a symbolic effect on a transition to climate neutrality. Hassler et al. (2020) predict that reducing the price (and thus the financing costs) of green technologies alone is not an effective substitute for emission pricing. This is because green and brown technologies are not sufficiently substitutable for lower priced green technologies to 'outcompete' brown ones.

Beyond market neutrality, climate change itself may have important implications for price stability. As Volker Wieland pointed out in his 2020 presentation to the ECB Forum on Central Banking[8], increased energy prices due to CO_2 pricing may lead inflationary pressures and have a negative impact on growth, as in a traditional cost push (see also Garnadt et al. 2020.) These factors may affect the type of policies the ECB needs to pursue to fulfil its targets of medium-term price stability while attempting to ensure full employment.

In this month's survey, members of the CfM-CEPR European panel of experts were asked about their views on policies that have been proposed to address the environmental impact of the ECB's bond-purchasing programme.

7 https://www.project-syndicate.org/commentary/central-banks-no-to-green-monetary-policy-by-otmar-issing-2019-11?barrier=accesspaylog
8 https://www.ecb.europa.eu/pub/conferences/shared/pdf/20201111_ECB_Forum/presentation_Wieland.pdf

QUESTION 1 WHICH OF THE FOLLOWING ACTIONS IS THE MOST ADVISABLE APPROACH FOR THE EUROPEAN CENTRAL BANK TO ADDRESS THE ENVIRONMENTAL IMPACT OF ITS BOND-PURCHASING POLICIES?



Thirty-six panellists responded to this question. More than half the panellists supported some active measures to use the ECB's balance sheet to support climate objectives (biasing the portfolio to green industries, banning purchases of bonds of firms who currently have a negative environmental impact, or of those who have no plan to improve by 2050). An additional 30% of the panel supports aiming for market neutrality – this was also the single most popular answer. A minority of 14% rejected any change in policy regarding climate change. The minority view was strongly held – this was the group that expressed most confidence in its response.

Supporters of ECB action suggested that the ECB should help mitigate climate change and is able to do so even within its current remit. Robert Kollmann (Université Libre de Bruxelles) opined that "[s]aving the environment and stopping climate change is an existential challenge for humanity. All countries and all institutions, including the ECB, must contribute to this goal." Ramon Marimon (European University Institute and UPF-Barcelona GSE) suggested that "the ECB may well take into account that some firms have a (well documented) negative environmental externality and stop purchasing their bonds." Alexander Ludwig (Goethe University) sought to dismiss concerns regarding central bank independence, positing that ECB action "does not undermine independence of the central bank, as it only refers to making its portfolio selection problem consistent with EU policy".

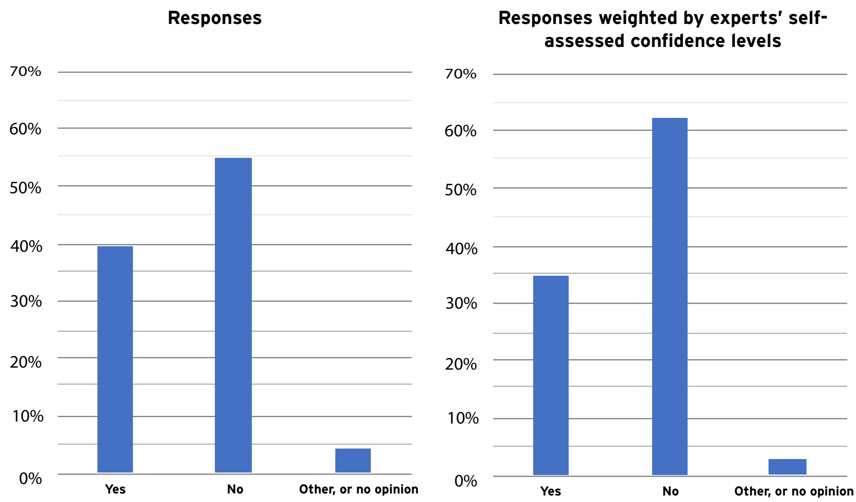
The panellists' comments paint more consensus, and more middle ground, than there may seem at first glance. In fact, many supporters of an active ECB approach on climate change had substantial caveats in their support for ECB action. The respondents' most notable reservations regard the effectiveness of 'green' monetary policy. Costas Milas

(University of Liverpool), who supported an active bias of the ECB's portfolio towards green investments, pointed out that "there appears to be some inherent contradiction in the whole debate. Indeed, the ECB's QE programme by definition will be short lived. So it appears rather futile for the ECB to support green technology now (or at least in the short run) only to 'pull the green plug' later on when QE is abandoned." David Miles (Imperial College London), who supported market neutrality, also questioned the exact role of monetary policy in achieving environmental objectives: "The best way to address environmental issues is by setting an appropriate price for carbon which reflects the cost of the externalities. Using monetary policy seems like fourth best as a policy and unlikely to do much good." John Van Reenen (London School of Economics) echoed this sentiment: "Monetary authority can only have a marginal impact on climate change. [The] main issue is raising carbon price, subsidising green innovation and better regulation."

Concerns regarding the political implications of such a move were also raised. Patrick Minford (Cardiff Business School) remarked that "it is important that monetary policy is independent of politics". Sir Charles Bean (London School of Economics) elaborated on the political sensitivities underlying this issue: "I would be more than happy to see the ECB (and other central banks) skew their operations to foster the greening of the economy and to meet climate objectives. But the initiative to do this should in the first instance come from the appropriate political authorities. Central banks should only stray beyond their mandates if they have the support of the political authorities, as otherwise they lack the necessary democratic legitimacy."

Furthermore, respondents discussed the potential negative impacts of market-neutral policy. John Hassler (IIES, Stockholm University), advocating for no change in policy, opined that "[o]ne might argue that a neutral stance with respect to temporary purchases and sales of different types of assets is reasonable. However, I think the proponents of green monetary policy are after a more permanent money financing of investments in green projects." Regarding the reduction of bold holdings in polluting industries, he raised the point that "the fossil industry that is most vulnerable to emission prices is coal power, but the stock market value of this industry is almost gone already, in both [the] EU and the US." He further argued that "financial stability is also threatened if a green bubble is building up", and that "the most effective way to reduce financial risk is to make sure risky assets are held by risk tolerant agents, e.g. pension funds rather than banks. Policies that might lead to a more concentrated ownership of fossil assets could therefore be a risk to financial stability."

QUESTION 2 WOULD YOU SUPPORT CHANGING THE ECB'S MANDATE TO INCORPORATE THE EU'S TARGET OF CARBON NEUTRALITY BY 2050, IF SUCH A CHANGE IS DEEMED LEGALLY NECESSARY TO ADOPT YOUR PREFERRED APPROACH?



Forty members of the panel responded to this question. Although most panellists supported taking some action in the first question, only a minority is willing to go so far as to change the ECB's mandate for this objective.

One panellist who does support changing the ECB's mandate is Wendy Carlin (University College London), who voiced her support unambiguously: "If such a change is necessary, then the mandate should change. Climate change is non-negotiable."

However, many more panellists who supported climate action in the first question would not go so far as to support a change in mandate in the second. Ricardo Reis (London School of Economics), who supports a move to market neutrality, pointed out that current research is unclear on what constitutes an effective 'green mandate' for central banks: "I think incorporating carbon targets for central banks may eventually be a good idea. But I'm not sure how I would do it right now in an effective way, given what I know of research in the area." Agnès Bénassy-Quéré (University Paris 1 and Paris School of Economics), who supports a ban on bond purchases from industries with no clear plan to get to zero emissions by 2050, raises a different concern regarding the role of central banks: "Carbon neutrality is an objective for governments, not for central banks. The latter should draw the consequences of such policies for price stability and financial stability." Ramon Marimon, who also supports banning non-green bond purchases, directly attacked the slippery slope argument that could arise from a change in mandate: "Then we should also incorporate an unemployment target (e.g. not to purchase bonds of firms that fire workers), a health industry target, you name it. This is not, and should not be, the job of the ECB or any independent central bank."

Finally, panellists who were unsupportive of a change in ECB policy were naturally opposed to changing its mandate for this purpose. Volker Wieland (Goethe University Frankfurt and IMFS) argued that environmental goals can (and should) be achieved without changing the mandate and by use of other policy means: "Achieving carbon neutrality of the EU economy by 2050 and achieving price stability in the euro area in the medium are two completely different objectives that require deploying different policy tools and can be achieved independently of each other." John Hassler laid out a similar line of reasoning: "The key tool for climate policy is the EU ETS. Additional tools need to be used for dealing with, e.g., distributional consequences of climate policy and climate change. Also here, monetary policy is not the right tool and ECB not the right institution to deal with these issues."

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CHAPTER 34

Climate change and central banks: The case for violating neutrality[1]

Luke Bartholomew, Paul Diggle
abrdn

Central banks are increasingly considering their role in meeting climate objectives. Often, they justify this by arguing that climate considerations directly impact on their primary objectives of price and financial stability. This column argues that a stronger case is that the urgency of climate risks is such that standard neutrality-based objections to central bank involvement in economic allocation are obviated. Indeed, neutrality-based arguments look especially weak when it is realised that neutrality is essentially impossible for central banks to achieve.

Climate change is a defining challenge for politicians, policymakers, and financial markets, and it is beholden on each of those to think deeply about the role they can play in limiting the global temperature rise. As the ECB's strategic review amply demonstrates, central banks are among those institutions increasingly considering their role in meeting climate objectives (ECB 2021).

But central banks are unelected, technocratic institutions, operating within strict legal frameworks whose primary task is typically price stability. Any involvement in climate policy must therefore have a sound basis, grounded in the mandate handed to them by elected politicians (Tucker 2019).

MOTIVATING CENTRAL BANK ACTION ON CLIMATE CHANGE WITHIN EXISTING MANDATES

Therefore, one justification typically given for central banks to involve themselves in climate policy is that such considerations already fall within existing mandates (Schnabel 2021). Climate change and associated policy responses may impact inflation through its impact on economic activity and very large swings in certain relative prices. Moreover, climate change has implications for financial stability if banks are highly exposed to assets whose value is compromised by physical and transition risks, or if financial markets are failing to price certain climate scenarios (Löyttyniemi 2019).

1 This column first appeared on VoxEU 12 August 2021 https://voxeu.org/article/climate-change-and-central-banks-case-violating-neutrality

But these justifications are not without objections. The impact from climate change on inflation is likely to be felt over much longer horizons than central banks operate over – what Carney (2015) has called the tragedy of the horizon. And it is not obvious that central banks will always possess superior knowledge relative to the private sector on how assets should be valued in light of climate risks.

A MORE FUNDAMENTAL JUSTIFICATION

Instead, we argue that the most robust case for central bank involvement in climate change is more fundamentally because the central bank can do some good in furthering a policy priority of government and a challenge of critical importance to the entire polity (Bartholomew and Diggle 2021). The pressing urgency of climate risks means that all public policy levers should be employed in the pursuit of meeting government climate objectives. Or at the very least, central banks should not be acting in a way that pushes against government objectives in this area.

For a central bank like the ECB, which has a secondary mandate that "without prejudice to the objective of price stability, the ECB shall support the general economic principles and objectives of the Union" (one of which is tackling climate change), this falls within existing mandates. To ensure democratic transparency and accountability, central banks with narrower mandates require legal changes or clarifications before they can pursue policy along these lines, as for example has happened with the Bank of England. Indeed, ultimately elected politicians could add an explicit climate mandate to a central bank's objectives, overcoming objections of technocratic overreach in one fell swoop.

Climate policy is different in this regard from arenas like industrial policy or reducing inequality, which are sometimes added to the long list of things central banks could do, for two reasons. First, climate change is potentially existential – the future survival of the polity itself may be at stake. This is why mobilising central banks to fund total war efforts is a legitimate use of monetary policy, but industrial policy or inequality, for all their importance, are not. And second, central banks do actually have some potentially quite effective tools in the fight against climate change, in a way they do not in other arenas.

'GREEN MONETARY POLICY' WOULD VIOLATE CENTRAL BANK NEUTRALITY

However, this argument typically runs into the objection that it violates the standard commitment to central bank neutrality. Neutrality in this context means the central bank setting policy to affect the aggregate variables of the macroeconomy – nominal growth and employment – rather than to affect the microeconomic considerations of precisely in which sectors or regions economic activity occurs, including whether activity should occur in 'green' or 'brown' sectors. There are indeed several reasons why neutrality is typically an attractive property of central bank behaviour.

First, as long as market failures are limited, decisions about how and where production occurs are generally best made by the private sector. Efficiency is best served by allowing market mechanisms to allocate resources within a macroeconomic context consistent with full employment.

Second, if the public sector does involve itself in questions of microeconomic allocation, perhaps because of market inefficiencies or considerations like equity or economic geography, in a democratic society this is the responsibility of an elected government rather than technocrats.

Third, to the extent to which the central bank starts to involve itself in some allocative issues, it might find itself under pressure from the government to intervene in ever more areas of the economy. This pressure could see the gradual politicisation of the central bank, which may undermine confidence in price stability.

These kinds of considerations would seem to lean quite heavily against central bank involvement in climate issues, because the entire point of central bank involvement would be to make certain kinds of economic activity face a systematically higher cost of capital (i.e. 'brown' industries) and other kinds of activity face a systematically lower cost of capital (i.e. 'green' industries). This seems clearly to be microeconomic credit allocation policy and so a violation of neutrality.

BUT 'UNCONVENTIONAL' MONETARY POLICY ALREADY VIOLATES NEUTRALITY

However, it is hard to see how the full suite of post-crisis tools employed by central banks is neutral in this way. Purchases of government bonds, investment grade credits, and high yield credit; providing liquidity on generous terms; and use of negative rates all impact the economy through quite different channels. For example, buying corporate bonds tends to help those firms who issue bonds, while enhanced liquidity provision helps banks. So the very use of these tools seems to be non-neutral in that they impact some sectors more than others.

And it is not just the tools themselves, but the way they are employed together which is also non-neutral. Monetary tools can be substitutes for one another at the margin – using this particular tool more means this other tool needs to be used slightly less to achieve the same macroeconomic objective. Slightly more asset purchases might mean slightly less use of highly negative interest rates or slightly less liquidity provision. Because those tools work through different sectors of the economy, using more of one tool and less of another will have different impacts on different sectors, and hence violate neutrality.

None of this is to say that there is anything wrong with the many new tools introduced by central banks after the financial crisis. The point is just that they were not neutral. Indeed as Schoenmaker (2019) notes, ECB policy is already non-neutral in the sense that its policies tend to systematically bias support towards carbon-intensive activities.

'STRONG FORM' NEUTRALITY IS UNACHIEVABLE, AND 'WEAK FORM' NEUTRALITY IS RIGHTLY VIOLATED WHEN EXISTENTIAL QUESTIONS ARE AT STAKE

It is therefore helpful to distinguish between two concepts of neutrality: strong and weak form neutrality. Strong form neutrality is where central bank actions have no impact on microeconomic allocation within the context of a particular constellation of macroeconomic aggregates. Weak form neutrality is where central bank action impacts microeconomic allocation but this is an unintended and perhaps unavoidable consequence of pursuing optimal policy for the macroeconomy.

So while corporate QE is non-neutral, it is non-neutral in a rather different way to skewing purchases of corporate QE towards 'green' companies to deliberately influence microeconomic outcomes. In other words, corporate QE violates strong neutrality, but not weak neutrality, while green QE violates both forms.

However, the point still stands that once we accept that strong form neutrality is impossible, the questions stops being about whether this or that policy is strictly neutral and whether the violation of neutrality is justified. And it seems perfectly plausible that even intended violations of neutrality could be justified so long as they were consistent with the broader democratic commitments of the society in which the central bank operates, and are welfare enhancing. This is especially so if continuing with policy as normal, under the pretence that this is somehow consistent with weak form neutrality, is actively biasing policy against achieving governmental climate objectives.

So in those societies that choose to give mandates to central banks to help pursue climate objectives, deliberate violations of neutrality to aid the green transition would be justifiable because of the extreme welfare consequences at stake.

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PART VI

GREEN POLITICAL ECONOMY AND GLOBAL DISTRIBUTIONAL ISSUES

CHAPTER 35

Why cap-and-trade should (and does) have appeal to politicians[1]

Robert Stavins, Robert Hahn

Harvard Kennedy School; University of Manchester

Are cap-and-trade schemes working? This column presents a summary of eight existing schemes arguing that half meet the independence property whereby the initial allocation of property rights does not affect the environmental or social outcome and the scheme is cost-effective. This success is a contrast with other policy proposals where political bargaining reduces the effectiveness and drives up cost.

Economists have long recognised that both price and quantity mechanisms, such as emissions taxes and cap-and-trades systems, can be cost-effective ways of improving environmental quality (Pigou 1920 and Dales 1968). The politics of the two approaches is a different matter.

The political appeal of cap-and-trade can be explained, in part, by the fact that politicians can fiddle with the initial distribution of property rights (the permits or allowances) without affecting the final equilibrium (in the sense of not affecting the environmental performance or aggregate cost). Furthermore, under certain conditions, the final equilibrium will represent a least cost solution to the problem of achieving a given environmental target (Montgomery 1972) – something that may surely be desirable from the standpoint of allocating resources more efficiently. The Montgomery result is closely related to an idea presented in Coase (1960), where he shows that under certain conditions, the initial distribution of property rights between the generator or recipient of an externality does not matter for achieving an efficient result.

Because of its potential political importance, we have decided to examine a version of what we call the "independence property" for cap-and-trade (Hahn and Stavins 2010). A cap-and-trade system is said to satisfy the independence property if the final equilibrium is both cost-effective and does not vary with the initial distribution of allowances (i.e., property rights).

1 This column first appeared on VoxEU 13 April 2010 https://voxeu.org/article/why-cap-and-trade-should-and-does-have-appeal-politicians

THEORY: WHAT CAN GO WRONG, IN PRINCIPLE

Markets don't always work perfectly and environmental markets are no exception. We investigated a number of ways in which these markets might violate the independence property. One obvious way is if a firm or group of firms had market power in the allowance market. A related way is if a firm had market power in both a product market and the allowance market. In such cases, the initial distribution of allowances will frequently affect the final distribution of allowances in the allowance market, and the cost-effective allocation of allowances may not be achieved. A dominant firm or group of firms may find it in their interest to offer too few or too many allowances for sale in the allowance market (relative to the cost minimising solution), depending on their initial allocation (Hahn 1984).

The independence property also may be violated when there are transaction costs associated with trading. Such costs can arise from bargaining, monitoring and enforcement, and search. Stavins (1995) shows that when marginal transaction costs are not constant, this can lead to a violation of the independence property.

Another factor that can affect the final distribution of allowances is uncertainty. In particular, uncertainty regarding future allowance prices can lead to violation of the independence property under two conditions: risk aversion on the part of regulated firms, and limits to transferability of allowances (transaction costs). The consequences are that firms with small initial allocations would be expected to tend to over-invest in abatement technology in order to hedge against possible high future allowance prices, and firms with large initial allocations would tend to under-invest in abatement technology in order to hedge against possible low future allowance prices (Badlursson and von dehr Fehr 2004).

If firms are not cost minimisers, then the final allocation of allowances can be tied to the initial allocation of allowances. There are a variety of potential sources of such non-cost-minimising behaviour. An interesting case is that of government-to-government trading. The international emissions quota regime established under Article 17 of the Kyoto Protocol allows trades in national targets ("assigned amounts") among nations. There is no reason to assume that nations are simple cost-minimisers, or even if they sought to be, that they would have the necessary information regarding their national abatement costs to carry out cost-effective international exchanges.

Behavioural economics provides several potential explanations for other sorts of non-cost-minimising behaviour. For example, the endowment effect describes situations in which firms or individuals "overvalue" items already in their possession (Thaler 1980 and Kahneman et al. 1990). If the firms granted emissions allowances tend to value them more highly than other firms simply because they happen to hold them, then fewer transactions will occur than would otherwise be predicted by market forces. If firms initially endowed with permits tend not to sell them, independence will not hold.

The way regulators treat different allowance trades will also affect the market. If firms receive different regulatory treatment, then initial allocations of allowances can affect equilibrium allocations, performance, and cost. State-level regulation of electricity producers, such as rate-of-return regulation, can discourage or even prevent firms from cost-minimising with respect to emissions (Hahn and Noll 1983 and Oates and Strassman 1984). In addition, regulators may discourage trading, due to concerns about local pollution (Fullerton et al. 1997). Finally, if a cap-and-trade system is interstate, then jurisdictions may be regulated differently. In all of these cases, the equilibrium allocation will not be independent of the initial allocation, and the outcome will not be cost-effective.

THE REAL WORLD: THINGS ACTUALLY LOOK PRETTY GOOD

Market imperfections are present in most real-world markets. For example, in most markets, there are transactions costs in bringing buyers and sellers together. The question is whether these market imperfections turn out to be important in terms of leading to significant violations of the independence property. We have examined eight past and present cap-and-trade systems.

TABLE 1 SUMMARY OF EMPIRICAL FINDINGS REGARDING INDEPENDENCE PROPERTY

Cap-and-Trade System	Indirect Evidence of Possible Permit Market Distortions	Support for Independence Property
Lead Trading	Transaction Costs	Medium
CFC Trading under Montreal Protocol	Market Power	Medium
SO2 Allowance Trading	Transaction Costs, Differential Regulatory Treatment, Uncertainty	Low at the outset Subsequently high
RECLAIM	Transaction Costs, Uncertainty	High*
Eastern Ozone Transport NOX Markets	Market Power, Uncertainty, Non-Cost-Minimising Behaviour	High
EU ETS	Uncertainty?	High*
Kyoto Protocol Article 17	Transaction Costs, Market Power, Non-Cost-Minimising Behaviour	Low
Regional Greenhouse Gas Initiative	Uncertainty?	Unknown

Note *Partly based on statistical tests. Only those applications of cap-and-trade considered in the text are included.

We have reviewed both indirect (circumstantial) evidence regarding the presence and importance of various factors in past and present cap-and-trade systems, as well as direct (statistical) evidence of the violation of the independence property in these systems. Looking at eight past and present cap-and-trade systems (Table 1), we find that support for the independence property is strong in half of the systems, and moderate in two others.

CONCLUSIONS

The independence property is of great relevance to the practical development of policy, because it allows equity and efficiency concerns to be separated. In particular, a government can set an overall cap of pollutant emissions (that is, a pollution-reduction goal), and leave it up to a legislature to construct a constituency in support of the program by allocating shares of the allowances to various interests, such as sectors and geographic regions, without affecting either the environmental performance of the system or its aggregate social costs.

Because of the importance of this property, we considered the conditions under which it is more or less likely to hold – both in theory and in practice. We find that in theory, a number of factors can lead to the independence property being violated. These are: particular types of transaction costs in cap-and-trade markets; significant market power in the allowance market; uncertainty regarding the future price of allowances; non-cost-minimising behaviour by firms; and specific kinds of regulatory treatment of participants in a cap-and-trade market.

Of course, the fact that these factors can lead to violation of the independence property does not mean that in practice they do so in quantitatively significant ways. We find that, in practice, there is support for the independence property in some, but not all cap-and-trade applications.

The fact that the independence property is broadly validated provides support for the efficacy of past political judgments regarding constituency-building through legislatures' allowance allocations in cap-and-trade systems. Repeatedly, governments have set the overall emissions cap and then left it up to the political process to allocate the available number of allowances among sources to build support for an initiative without reducing the system's environmental performance or driving up its cost. This success with environmental cap-and-trade systems should be contrasted with many other public policy proposals for which the normal course of events is that the political bargaining that is necessary to develop support reduces the effectiveness of the policy or drives up its overall costs.

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CHAPTER 36

Migration's response to increasing temperatures[1]

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Climate change can affect agricultural productivity and the incentives of people to remain in rural areas. This column looks at the effects of warming trends on rural-urban and international migration. In middle-income economies, higher temperatures increased emigration rates to urban areas and to other countries. In very poor countries, however, higher temperatures reduced the probability of emigration to cities or to other countries, consistent with the presence of liquidity constraints.

CLIMATE CHANGE AND RELATED MIGRATION

The Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5), which is the most comprehensive and relevant analysis of climate change, concludes that hundreds of millions of people will be affected by climate change. Its consequences will be felt directly and indirectly via resource availability and population movements, spreading consequences across the globe.

For this reason, the EU's foreign and security policies, as well as official publications and strategies, have devoted increasing attention to climate-related factors. For instance, the joint report by Javier Solana and the European Commission defines climate change as a 'threat' multiplier, as it could be responsible for political and security risks affecting European interests (European Council 2008). Environmentally induced migration is quoted among the various threats identified in the report. According to the Council Conclusions on EU Climate Diplomacy, adopted in June 2011, climate change is a global environmental and development challenge with significant implications related to security and migratory pressures (European Council 2011).

The idea that climate-related migration could generate repercussions for European security is related to the possibility of large inflows of people from the areas adversely affected by climate change. Predictions of these flows, however, are extremely imprecise

1 This column first appeared on VoxEU 14 November 2015 https://voxeu.org/article/migration-s-response-increasing-temperatures

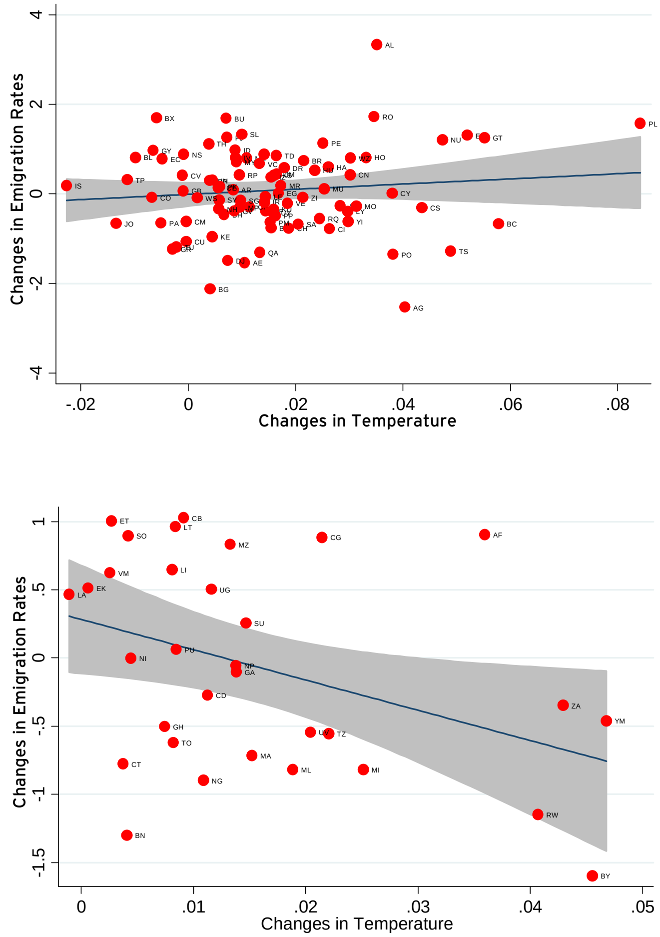
and based on a very wide range of hypotheses. The number of predicted migrants range wildly from 25 million to one billion over the next 40 years (IOM 2009). Vulnerability to climate change in poor countries, while certainly increasing the incentive to migrate, does not necessarily imply that migration will occur. Climate change, by decreasing the available resources, may constrain the ability to emigrate, and some vulnerable individuals may find themselves less mobile and less likely to migrate (Barrett 2008, Cattaneo and Massetti 2015, Gray and Mueller 2012, Foresight 2011).

NEW RESEARCH

In a recent paper (Cattaneo and Peri 2015), we tackle the connection between increasing temperatures and migration by analysing the effect of differential warming trends across countries on the probability of migrating out of the country or migrating from rural to urban areas. A crucial insight is that by impoverishing rural populations and worsening their income perspectives, long-term warming affects migration in different ways, depending on the initial income of those rural populations. A decline in agricultural productivity, causing a decline in rural income, seems to have a depressing effect on the possibility of emigrating in extremely poor countries where individuals live on subsistence income. Lower income worsens their liquidity constraint, implying that potential migrants have a reduced ability to pay for migration costs and to afford travel and relocation costs. In this case, global warming may trap rural populations in local poverty. In contrast, in countries where individuals are not extremely poor, a decline in agricultural income strengthens the incentives to migrate to cities or abroad. Decreasing agricultural productivity may encourage a mechanism that ultimately leads to economic success of migrants, benefitting their country of origin and shifting people out of agriculture into urban environments.

Figure 1 provides correlations that corroborate this insight. The figure plots long-term changes (between 1960 and 2000) in temperature (horizontal axis) against long-term changes in emigration rates for poor countries (Panel 2) and for middle-income countries (Panel 1). The difference in the relationship between the two groups of countries is clear. Middle-income countries show a (small) positive correlation while poor countries show a negative correlation between temperature and emigration rate changes.

FIGURE 1 CHANGE IN EMIGRATION RATES AND IN AVERAGE TEMPERATURE



Note: The graphs plot on the horizontal axis the natural logarithm of the average temperatures between 2000 and 1981 minus the natural logarithm of the average temperatures between 1960 and 1980. On the vertical axis we represent the natural logarithm of the average emigration rates between 1990 and 2000 minus the average emigration rates between 1970 and 1980.

THE DIFFERENCE BETWEEN MIDDLE-INCOME AND POOR COUNTRIES

In the empirical analysis we pursue more systematically the two effects presented in Figure 1. Using decade changes between 1960 and 2000 for 116 countries, ranging from very poor to middle income, we perform a regression analysis that controls for country effects, decade effects, and several other geographic variables and allows for a different impact of temperature on emigration and urbanisation rates in poor and middle-income countries.

- We find that increasing temperatures are associated with lower emigration and urbanisation rates in very poor countries.

- In contrast, in middle-income countries they are associated with positive changes in emigration and urbanisation rates.

The incentive effect driven by lower agricultural productivity prevails in middle-income countries, and rural population is driven to cities, speeding the country's structural transformation and ultimately increasing income per person. In poor countries, the worsening of the liquidity constraint due to lower agricultural productivity prevails, and urbanisation and emigration are slowed.

- We find consistently that emigration in middle-income countries induced by higher temperatures is associated with growth in GDP per person.
- The slowing of emigration and urbanisation associated with climate warming in poor countries is associated with lower average GDP per person.

This connection between temperatures and GDP growth was first pointed out by Dell and Olkien (2012). Our study provides an important channel to explain it.

Urbanisation and industrialisation are crucial mechanisms for GDP growth. For countries with intermediate levels of income per person, warming can push towards these gains. However, for countries where agricultural productivity is so low as to trap rural populations at subsistence levels, warming may instead slow economic transformation. These effects could contribute to divergence of income between poor and middle-income countries.

WHERE DO PEOPLE MIGRATE TO IN RESPONSE TO WARMING?

Does warming produce large scale movements of individuals from middle-income countries in Africa, Asia, and Latin America to rich countries in Europe and North America? Or does it produce more local migrations in the regions?

- We find that growing temperatures are mainly associated with emigration to non-OECD destinations that are close to the countries of origin (especially those within a 1,000km radius).
- Emigration to OECD (i.e. rich) countries does not seem affected.

This result is consistent with the idea that climate-driven emigration is associated with a worsening of local opportunities and migrants move where they have better chances of finding a job given their current constraints. This 'push' factor (decreased rural income) increases migration to similar economies rather than to OECD economies. On the other hand, the migration-reducing effect for poor countries (due to worsening opportunities) affects both types of destination, as potential emigrants become less likely to leave the country altogether. Combining the effect on poor and middle-income countries, it appears that increases in average temperatures may actually decrease overall emigration to OECD countries. Middle-income countries are not more likely to experience emigration towards those destinations, while poor countries experience a reduction in emigration rates altogether. These findings suggest that climate change is unlikely to be the driver of large migrations to Europe as the impact on poor countries seems negative and climate-related migrations seem more local.

MIGRATION AND NATURAL DISASTERS

Climate change is also expected to bring an intensification of extreme weather events. For this reason, we tested whether temperature anomalies and natural disasters such as droughts, floods, and storms influence emigration rates in middle-income and poor countries. We find that long-run emigration rates in poor or middle income countries are not significantly affected by the occurrence of these events. It is likely that natural disasters drive different types of migration, more akin to local mobility and temporary. Given their relatively rare occurrence and temporary nature in the considered period, extreme weather episodes did not affect significantly long-run rural-urban and international migration.

CONCLUSIONS

In this column we have focused on the potential impact of growing average temperatures on rural-urban and international migration. We found that in very poor countries, warming implies less emigration. Rural populations may be stuck in deeper poverty with fewer resources to migrate. In contrast, in countries where income is not as low, lower agricultural productivity increases the incentives to migrate, producing higher emigration rates. Through these different responses temperature changes may contribute to a divergence of income and opportunities between very poor and middle-income countries. Finally, a future of increased migrations to Europe or to the US driven by global warming is not a scenario supported by our analysis.

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CHAPTER 37

Carbon and inequality: From Kyoto to Paris[1]

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The COP21 conference faces a severe problem when it comes to funding climate adaptation in developing countries. This column examines novel strategies to increase the funding. The strategies are based on high individual carbon emitters wherever they are in the world, rather than according to the responsibilities of high-emitting countries. To this end, a global distribution of individual income and CO2e emissions is constructed.

The 21st United Nations Climate Change Conference is being held in Paris. One key issue to be debated relates to the financing of climate adaptation in developing countries, i.e. how to finance investments in infrastructure and human capital to make societies more resilient to the impacts of climate change. Climate adaptation is currently under-funded: the needs range from €100bn to €300bn a year according to the United Nations (UNEP 2014), but less than €10bn is currently dedicated to climate adaptation funds (OECD 2015).

Our new study (Chancel and Piketty 2015) examines novel strategies to increase the volume of funding for climate adaptation in developing countries. In these strategies, efforts are determined according to the emissions of high individual carbon emitters wherever they are in the world, rather than according to the responsibilities of high-emitting countries. In order to do so, we construct a global distribution of individual income and CO2e emissions (CO2 and other Green House Gases).

OUR METHODOLOGY

Our methodology is based on the pioneering work of Chakravarty et al. (2009), further refined along three lines: we aim at better representing top individual incomes and emitters; we focus on consumption-based emissions to better represent responsibilities associated to climate change (for example, CO2e emissions due to the production in China of smartphones used in Europe are attributed to Europeans, not to Chinese); and we also provide dynamic estimates ranging from the Kyoto Protocol in 1998 to 2013.

1 This column first appeared on VoxEU 1 December 2015 https://voxeu.org/article/carbon-and-inequality-kyoto-paris

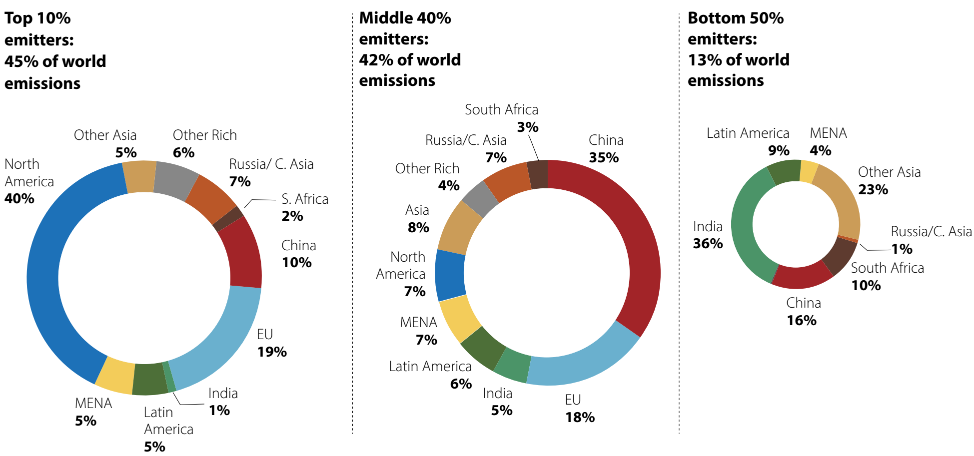
We start by reconstructing a global distribution of income, using data from Lakner and Milanovic (2015), obtained from income and consumption surveys. One issue with survey data is that it often misrepresents top incomes. We follow Anand and Segal (2014) and combine Lakner-Milanovic estimates with fiscal data from the World Top Income Database (WTID 2015) in order better represent inequality at the top of the distribution. In effect, we regress existing top 1% income shares (from fiscal sources) on decile shares (from survey sources) so as to predict top income shares in countries without fiscal data. We stress that our estimates should not be seen as definitive values for the world income distribution, but as a first attempt to combine global income distributions with top incomes data.

We then attribute CO2e emissions to each income group using consumption-based CO2e data provided by Peters and Andrew (2015). For each country, we use a simple income-CO2e elasticity model and allocate national CO2e emissions to income groups assuming different income-CO2e elasticity values. We use a central value of 0.9 as suggested by a review of country-level income-CO2e elasticity studies.

TRENDS IN THE GLOBAL DISTRIBUTION OF CARBON EMISSIONS (1998-2013)

Our results show that global CO2e emissions inequalities between individuals decreased from the Kyoto Climate Protocol in 1998 to 2013, due to the rise of top and mid-income groups in developing countries and the relative stagnation of incomes and emissions of the majority of the population in industrialised economies. Income and CO2e emissions inequalities, however, increased within countries over the period. Global CO2e emissions remain highly concentrated today: the top 10% emitters contribute to 45% of global emissions, while the bottom 50% contribute to 13% of global emissions. The top 10% emitters live on all continents, with one third of them from emerging countries (Figure 1).

FIGURE 1 BREAKDOWN OF TOP 10, MIDDLE 40 AND BOTTOM 50% CO2e EMITTERS



Note: Among the top 10% global emitters, 40% of CO2e emissions are due to US citizens, 20% to the EU and 10% from

China.

Source: Chancel and Piketty (2015).

Such results are moderately sensitive to elasticity choices we make (Table 1). Higher within-country elasticities imply higher global CO2e concentrations: assuming an elasticity of 0.7 within countries, the top 10% of global emitters are responsible for 40% of total emissions. The figure rises up to over 50% with an elasticity of 1.1. We also provide in our online data files (available here) a scenario in which elasticities vary across countries. In all cases, the top 1% world emitters (about 70 million individuals out of 7 billion) pollute approximately as much as the bottom 50% world emitters (3.5 billion individuals out of 7 billion).

TABLE 1 CO2e CONCENTRATIONS FOR DIFFERENT ELASTICITY VALUES

Year	elast	top1	top5	top10	mid40	bot50	bot10
2013	0.9	13.8	31.5	45.2	41.8	13.0	1.2
2013	0.7	9.9	26.6	40.0	44.8	15.3	1.5
2013	1.1	19.0	38.0	51.3	38.0	10.7	0.9

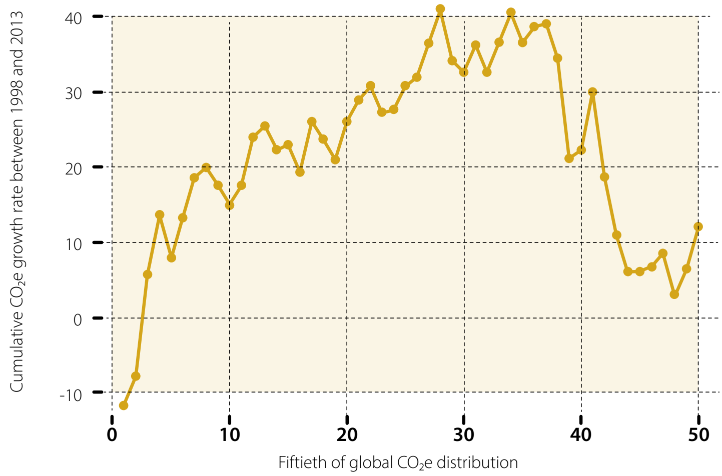
Note: Assuming an income-CO2e elasticity of 1.1 within countries, the top 1% emitters are responsible for 19% of global emissions in 2013.

Source: Chancel and Piketty (2015).

Our estimations show that the top 1% richest Americans, Luxemburgers, Singaporeans, and Saudi Arabians are the highest individual emitters in the world, with annual per capita emissions above 200tCO2e. At the other end of the pyramid of emitters lie the lowest income groups of Honduras, Mozambique, Rwanda and Malawi, with emissions 2,000 times lower, at around 0.1tCO2e per person per year. In the middle of the world distribution of emitters (between 6 and 7tCO2e per year) lie groups such as the top 1% richest Tanzanians, the Chinese 7th income decile, the French 2nd income decile and the 3rd German income decile.

Middle and upper classes of emerging countries increased their CO2e emissions more than any other group within the past 15 years, with cumulated per capita growth rates over 30%, about twice the world average (17%) and much higher than growth rates for the majority of the population in industrialised countries. This led to a reduction in the global dispersion of CO2e emissions – especially between the middle of the income distribution and the top (Figure 2). However, the inequality of CO2e emissions increased between the bottom of the distribution and the middle. While these trends, if continued, are positive from an income point of view (emergence of a global middle class), they constitute a real challenge for future global CO2e emissions levels.

FIGURE 2 HOW DID CO2E EMISSIONS GROW FROM KYOTO TO PARIS FOR DIFFERENT GROUPS OF EMITTERS?

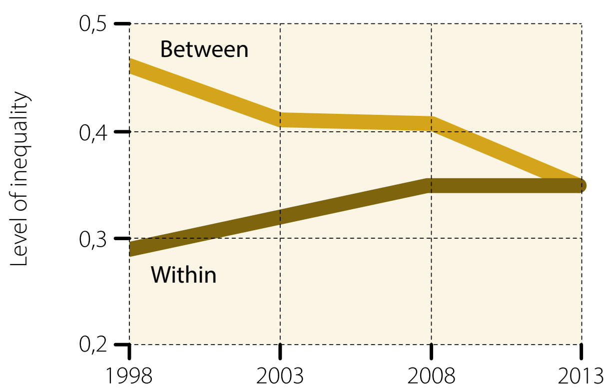


Note: the group representing the 2% lowest CO2e emitters in the world, saw its per capita CO2e emissions level decrease by 12% between 1998 and 2013.

Source: Chancel and Piketty (2015).

Our estimates also show that within-country inequality in CO2e emissions matters more and more in explaining the global dispersion of CO2e emissions. In 1998, one third of global CO2e emissions inequality was accounted for by inequality within countries. Today, within-country inequality makes up 50% of the global dispersion of CO2e emissions (Figure 3). It is then crucial to focus on high individual emitters rather than high-emitting countries.

FIGURE 3 WORLD CO2E EMISSIONS INEQUALITIES: WITHIN AND BETWEEN COUNTRY IMPORTANCE



Note: in 2008, the within-country component of the Theil index was of 0.35 and the between-country component of 0.40, i.e. between-country inequalities contributed to 53% of total inequalities - as measured by the Theil index.

Source: Chancel and Piketty (2015).

PROSPECTS FOR AN EQUITABLE ADAPTATION FUND

The new geography of global emitters calls for climate action in all countries. While developed and developing countries already engaged in mitigation efforts, contributions to climate adaptation funds remain almost entirely financed by developed nations, and for the most part by Europe (with more than half total contributions). If it is necessary to increase the volume of adaptation finance from developed countries, our study shows that upper income groups of emerging countries, who benefited from income growth and resulting CO2e emissions growth over the past decades, could also participate in such funds. With the contributions of South Korea, Mexico or Columbia to the Green Climate Fund, emerging and developing countries are committing to finance adaptation and broke the standard developed-developing countries divide which prevailed so far. However, their contributions remain symbolic at this stage (less than 1% of all global adaptation funds) and the equity logic behind adaptation funding remains unclear.

The study suggests novel strategies to increase global climate adaptation funding, in which individual CO2e emissions are the basis for contributions. In order to better align these contributions to the new distribution of high emitters, we first examine the implications of a global progressive carbon tax to raise €150 billion required annually for climate adaptation (Table 2). In Strategy 1, all emitters above world average emissions (i.e. all individuals emitting more than 6.2t per year) contribute to the scheme in proportion to their emissions in excess of this threshold. North Americans would contribute to 36% of the fund, versus 20% for Europeans and 15% for China. In Strategy 2, the effort is shared by all top 10% emitters in the world (i.e. all individuals emitting more than 2.3 times world average emissions), again in proportion to their emissions in excess of this threshold. North Americans would then pay 46% of the tax, versus 16% for Europeans and 12% for China. In Strategy 3, the effort is shared by all top 1% emitters in the world (i.e. all individuals emitting more than 9.1 times world average emissions). North Americans would then contribute to 57% of efforts, versus 15% for Europeans and 6% for China. In these strategies, the share of Europe would decrease in proportion, but increase in absolute terms. In Strategy 3, the most favourable to Europeans, the volume of finance coming from Europe would reach €23 billion, about four times its current contributions.

TABLE 2 WHO SHOULD CONTRIBUTE TO CLIMATE ADAPTATION FUNDS?

Regions	Effort sharing according to all emissions (flat carbon tax)(%)	Progressive carbon tax strategies			Effort sharing according to a global tax on air tickets (%)
		Strategy 1	Strategy 2	Strategy 3	
		Effort sharing among all emitters above world average (%)	Effort sharing among top 10% emitters (above 2.3x world average)(%)	Effort sharing among top 1% emitters (above 9.1x world average)(%)	
North America	21.2	35.7	46.2	57.3	29.1
EU	16.4	20.0	15.6	14.8	21.9
China	21.5	15.1	11.6	5.7	13.6
Russia/C. Asia	6.0	6.6	6.3	6.1	2.8
Other Rich	4.6	5.8	4.5	3.8	3.8
Middle East/N.A.	5.8	5.4	5.5	6.6	5.7
Latin America	5.9	4.3	4.1	1.9	7.0
India	7.2	1.0	0.7	0.0	2.9
Other Asia	8.3	4.7	4.1	2.7	12.1
S.S. Africa	3.1	1.5	1.5	1.1	1.1
World	100	100	100	100	100

Note: North Americans represent 46.2% of global emissions released by individuals who emit 2.3 times more than the global average. Individuals who emit more than 2.3 times average emissions (14.3 tCO2e per year) belong to the top 10% emitters.

Source: Chancel and Piketty (2015).

We also discuss possible implementations via country-level carbon and income taxes or via a generalised progressive tax on air tickets to finance the adaptation fund. A tax on air tickets has already been implemented in a handful of countries and is currently used to finance development programmes. Taxing all business class tickets in the world at a rate of €180 and all economy class tickets at a rate of €20 would yield €150 billion required for climate adaptation every year. This latter solution might be easier to implement but less well targeted at top emitters.

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CHAPTER 38

Making carbon pricing work for citizens[1]

David Klenert, Cameron Hepburn

European Commission; Smith School, University of Oxford

Political acceptability is the biggest challenge to implementing ambitious carbon pricing schemes. This column argues that behavioural economics and political science provide new insights into the acceptability of carbon pricing which suggest that successful reforms are more likely when the revenues are recycled through lump-sum dividends to citizens. There is no 'one size fits all' solution, however, and revenue recycling strategies should account for different social and political contexts and will most likely be mixed in real-world carbon pricing schemes.

Carbon pricing is widely understood to be an indispensable tool for meeting the goals of the Paris Agreement to mitigate climate change. Success stories like that of Sweden, which currently has the highest carbon price in the world at US$139 (World Bank 2018), demonstrate that it is indeed possible to make carbon pricing work. While the Swedish economy grew by 60% since the introduction of the Swedish carbon tax in 1991, carbon emissions decreased by 25% (World Bank 2016). However, less than 20% of current global greenhouse gas emissions are covered by a carbon price, and most prices are below the $40-80 per tonne of CO_2 (tCO_2) range necessary to achieve the goals pledged under the Paris Agreement (Stiglitz and Stern 2017).

How can more ambitious carbon pricing policies be introduced? First of all, we need to realise that garnering greater political acceptability is the primary challenge for policymakers. Most economic advice on the design of carbon pricing reforms focuses on questions of efficiency and equity: How might the policy affect GDP growth? What are the policy's projected distributional effects? Of course, efficiency and distributional impacts are crucial determinants of public acceptability. However, traditional economic lessons are of little importance if the carbon pricing reform cannot be implemented for political reasons.

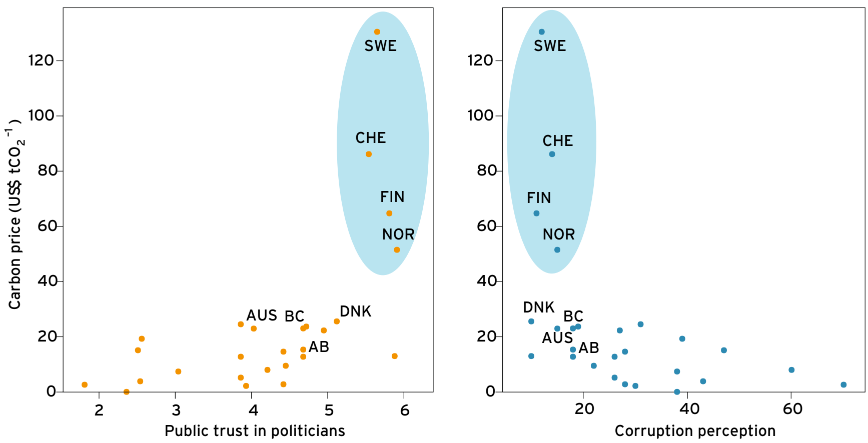
In a new article (Klenert et al. 2018), we suggest how the design of carbon pricing reforms could be tweaked to enhance their acceptability to the general public, building on recent insights from behavioural and political sciences, which go beyond traditional lessons

1 This column first appeared on VoxEU 31 July 2018 https://voxeu.org/article/making-carbon-pricing-work-citizens

on equity and efficiency. Global carbon pricing revenues are already substantial, at $33 billion in 2017 (World Bank 2018), and are likely to increase in the future. How they are used thus plays a major role in the public perception of carbon pricing.

Lessons from behavioural economics and political science point to ways of recycling carbon pricing revenues that enhance political acceptability to citizens. Factors related to public perception, such as the salience of benefits, cultural world views or general trust in politicians, help explain why some carbon pricing schemes are currently (un)popular and contribute to ideas on how carbon pricing could be made more attractive to the public.

FIGURE 1 CARBON PRICES, PUBLIC TRUST AND PERCEIVED CORRUPTION



Note: All carbon prices are for 2016, except for Australia's data, which is for 2012.

WHAT MAKES CARBON PRICING (UN)POPULAR?

Four major effects emerge from behavioural science regarding the acceptability of carbon pricing reforms.

- First, the willingness to pay for climate change mitigation is largely a function of political, economic, and cultural **world views**. Triggering 'solution aversion' – the tendency for citizens to be more sceptical of environmental problems if the policy solution challenges or contradicts underlying ideological predispositions – has to be avoided.
- Second, citizens tend to ignore or **doubt the corrective ('Pigouvian') effect** of carbon pricing, but may be mollified if revenue is earmarked for a specific purpose such as green spending or transfers to disadvantaged households.

- Third, the **labelling** of the carbon price may alter perceptions of its desirability. Something as plain as re-labelling a carbon price as a 'CO2levy', as done in Switzerland and Alberta, or speaking of 'fee and dividend', could circumvent solution aversion and make the measure more acceptable to citizens.

- Fourth, increasing the **salience of the benefits** derived from a carbon-pricing reform enhances acceptability, so that visible revenue recycling may be advisable. Some recycling methods, such as transfers to households or public investment, might be more visible to the public than tax cuts, for instance.

Political science yields two main insights regarding carbon pricing.

- First, ambitious carbon pricing is often correlated with **high political trust** and **low corruption levels** (see Figure 1).

Cross-national studies indicate that countries with greater public distrust of politicians and perceived corruption persistently have weaker climate policies and higher greenhouse gas emissions (Baranzini et al. 2014, Rafaty 2018). This is exemplified by Finland, Norway, Sweden and Switzerland, which all exhibit high levels of trust and have carbon prices above $40/tCO2. If trust is low, revenue should thus be recycled using a transparent, trust-boosting strategy to enhance its acceptability.

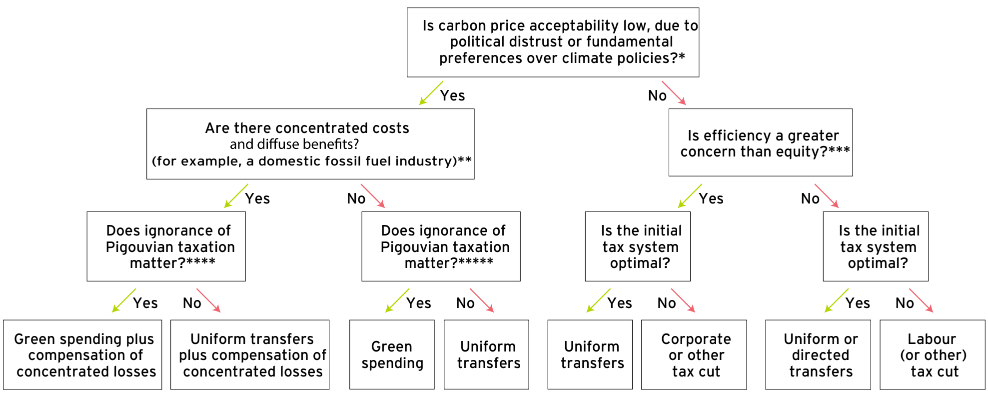
- Second, a policy reform is more likely to be successful if its costs are diffused and the benefits are concentrated.

The challenge with carbon pricing is that it tends to have diffuse benefits and concentrated costs, such that the scattered beneficiaries of the policy are less likely to support it in the political process than carbon-intensive companies are to oppose it. Success may be more likely if **the benefits of carbon pricing reform are concentrated** on constituencies who will actively support the policy's passage and preservation. Additionally, carbon pricing schemes are more likely to survive successive partisan changes in government if they benefit constituencies across the political spectrum.

WHICH DESIGN STRATEGIES ENHANCE THE POLITICAL ACCEPTABILITY OF A CARBON TAX REFORM?

Apart from careful labelling, making sure that the benefits are salient, avoiding solution-aversion and ensuring transparency and clear communication, the acceptability of a carbon tax reform can be enhanced by adapting the revenue recycling strategy to the socioeconomic context (see Figure 2). While recycling revenue as lump-sum dividends addresses most behavioural and political constraints on carbon pricing, other recycling methods such as green spending, targeted transfers or tax cuts can be more appropriate. If citizens question the mitigation impact of Pigouvian pricing, for example, increasing green spending might convince them of the policy reform. Earmarking the revenue to address specific salient problems such as underfunded pension schemes or crumbling infrastructure could also enhance the acceptability of a carbon pricing reform. Inequality concerns should be addressed by directed or lump-sum transfers, which would predominantly benefit poor households as they receive more in transfers than they spend on carbon taxes. If efficiency is a major concern, using the revenue to reduce other distortionary taxes is the preferred option. Budget-neutral strategies such as uniform transfers or tax cuts are more appropriate in contexts of prevalent centre-right world views, low-trust governments and tax aversion.

FIGURE 2 DECISION TREE. THERE IS NO 'ONE SIZE FITS ALL' TO MAKE CARBON PRICING POLITICALLY ACCEPTABLE – A CARBON PRICING REFORM HAS TO BE ADJUSTED TO THE SOCIOECONOMIC CONTEXT



Notes: *Lessons regarding political trust and political, economic and cultural world views apply; **lessons regarding the salience of revenue recycling and the creation of politically powerful beneficiaries apply; ***from here on and below traditional public economics lessons apply; ****lessons on citizens' ignorance of the corrective ('Pigouvian') effect of carbon pricing apply.

WHAT CAN BE LEARNED FROM REAL-WORLD CARBON PRICING SCHEMES?

In reality we observe mixed recycling strategies (see Figure 3 for an overview of recycling strategies in different carbon tax schemes). However, successful carbon pricing initiatives have designed their revenue recycling in accordance with at least some of the presented political and behavioural effects.

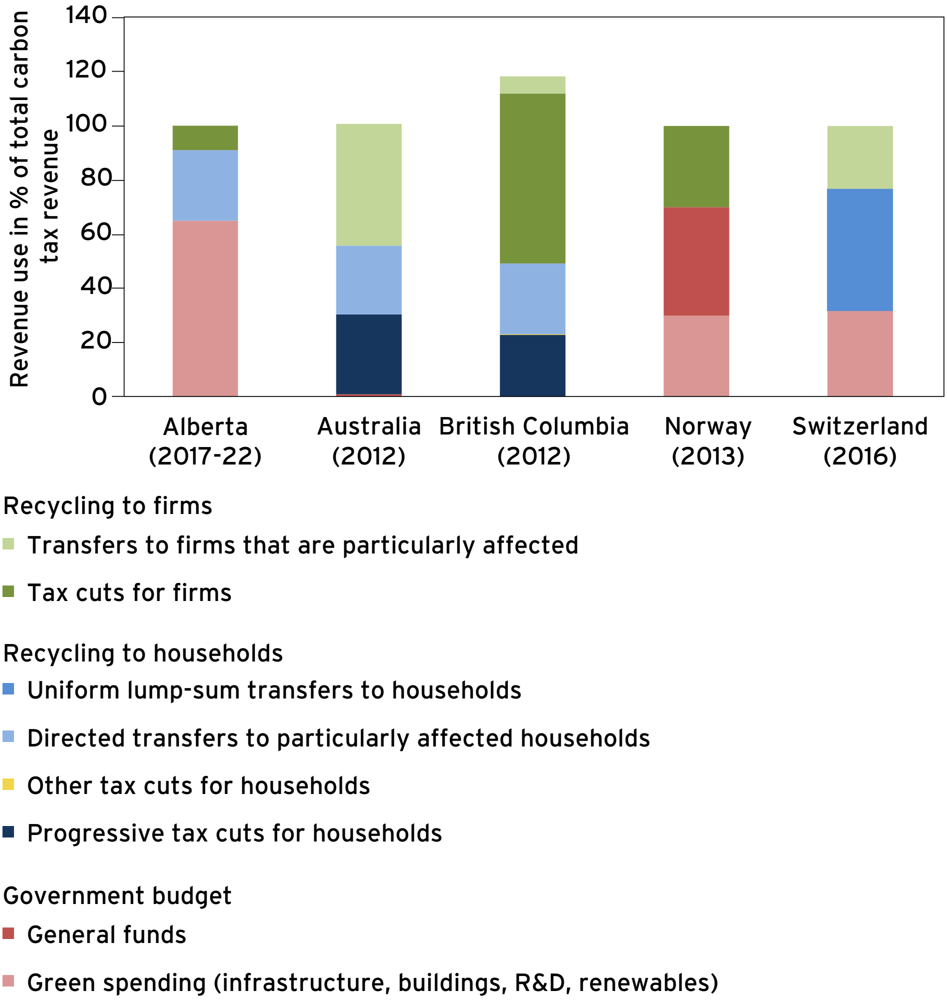
The success story of Sweden's world-leading carbon tax may partly be owed to extensive public dialogue and social deliberation which may have reinforced political trust and transparency prior to the fiscal reform that introduced carbon taxation.

The revenues of Alberta's successful 'carbon levy' are split between green spending and compensation for those who are disproportionately affected by carbon pricing, thereby illustrating lessons on labelling and the ignorance of Pigouvian pricing.

British Columbia, where all carbon tax revenues go to households and firms, has created strong constituencies in favour of carbon pricing. Backed by both an environmentally aware electorate base and the business community, the centre-right government was able to design a carbon tax reform that enjoys broad political acceptance.

The Australian carbon pricing scheme provides a cautionary tale. Introduced in 2012, the recycling strategy was designed 'by the book', taking into account insights on equity and efficiency. However, the carbon price was abolished in 2014, demonstrating that a carbon price design that meets equity and efficiency goals alone is not sufficient, while politics and political communication are of crucial importance.

FIGURE 3 REVENUE RECYCLING IN REAL-WORLD CARBON TAX SCHEMES



Note: The spending in British Columbia exceeds 100% since the region committed to additional spending.

MAKING CARBON PRICING WORK – ACCEPTABILITY FIRST, EFFICIENCY AND EQUITY SECOND

In light of the current carbon pricing gap, economic lessons on efficiency and equity are subsidiary to the primary challenge of garnering greater political acceptability. Designing revenue recycling mechanisms with an eye on political and behavioural insights and in accordance with the socioeconomic context can help make carbon pricing work for citizens and thus a political success.

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CHAPTER 39

Climate migration frightens… climate poverty is frightening![1]

Michał Burzynski, Christoph Deuster, Frédéric Docquier, Jaime de Melo
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There has been much discourse on how long-term climate change will affect human mobility over the course of the 21st century. This column estimates the long-term welfare and mobility responses to climate change. Depending on the scenario, climate change will force between 210 and 320 million people to move, mostly within their own countries. Massive international flows of climate refugees are unlikely, except under generalised and persistent conflicts. The poorest economies will be hardest hit, thus increasing global inequality and extreme poverty.

Over the 21st century, climate change will manifest itself through anthropogenic temperature changes, sea-level rise, and increased frequency/intensity of extreme weather events and natural disasters. Damages from climate change are expected to vary across and within countries according to proximity of seas and oceans, land topology, industry structure, and initial temperature levels. Developing countries that have contributed the least to climate change will be the most adversely affected, and migratory pressures – both internal and international – will presumably be strongest in the poorest countries of the world (Dell et al. 2014).

Modelling and predicting migration responses to long-term climate change is a challenging task. Beyond uncertainty about expected climate change, climate variables closely interact with other economic and political drivers of migration. In addition, mobility decisions are context-specific and are influenced by many factors that vary across regions and countries – such as country size, level of economic development, political situation, migrants' networks, or cultural characteristics.

And last but not least, the predicted effects of climate change have barely started to materialise. Existing literature has mostly looked at the mobility responses to fast-onset climate shocks, like weather anomalies, storms, hurricanes, torrential rains,

1 This column first appeared on VoxEU 10 December 2019 https://voxeu.org/article/climate-migration-frightens-climate-poverty-frightening

floods, landslides, and so on. Because slow-onset climate effects like global warming, desertification and sea-level rise have only started, evidence on their implications for long-term migration is much more controversial.

In a recent paper (Burzynski et al. 2019), we investigate the long-term effects of climate change on intra-regional (rural or urban), inter-regional (rural to urban), and international migration, as well as on global inequality and extreme poverty. We carry out simulations for virtually all developing countries and the OECD countries. South–South migration – often between contiguous countries affected by similar long-term climate trends – is ignored.

MODELLING DIRECT AND INDIRECT EFFECTS OF CLIMATE CHANGE

Instead of extrapolating empirical estimates of reduced-form migration responses to weather shocks, we use a structural model of the world economy that formalises the income and mobility responses to climate-related changes in space liveability, and economic and health variables. The model distinguishes between forced displacement and voluntary migration. It accounts for the interplay between different forms of migration at various spatial scales, as well as for the high degree of heterogeneity in migratory behaviour between people of different places of origin (rich versus poor countries, rural versus urban regions, flooded versus unflooded areas), and levels of education.

The model is used to predict the joint effects of changing temperature and sea level on income distribution and individual decisions about fertility, education, and mobility. Mitigation policies are not considered; climate change scenarios are exogenous to human decisions or reflect the outcome of mitigation policies that are not captured in the model.

The parameters of the model – reflecting technological disparities between spatial units as well as all legal and private mobility costs – are calibrated to exactly match international mobility and urbanisation data from the last 30 years. The 'backcast' exercises conducted with this type of model demonstrate that it accurately fits past migration trends and generates sensible projections. The calibrated model is simulated over three periods of 30 years each (2010–2040, 2040–2070, and 2070–2100) under three main climate scenarios:

- **Benchmark**: Constant temperature and sea level. Most likely unattainable, this scenario serves as a reference for comparisons.
- **Intermediate**: +2.1°C in global temperature with +1.1m sea-level rise over the century. This corresponds to the median scenario from the World Bank. The bulk of changes in the sea level is expected to take place during the first half of the century.
- **Maximalist**: +4.1°C in global temperature with +1.3m sea-level rise over the century.

CLIMATE DAMAGE FUNCTIONS

Four climate damage functions are considered. Two relate to slow-onset mechanisms that are easier to anticipate and are more likely to induce adaptation strategies such as crop switching and migration. We also include two additional mechanisms related to the greater frequency of fast-onset climate shocks, which are more difficult to estimate and/or are more uncertain.

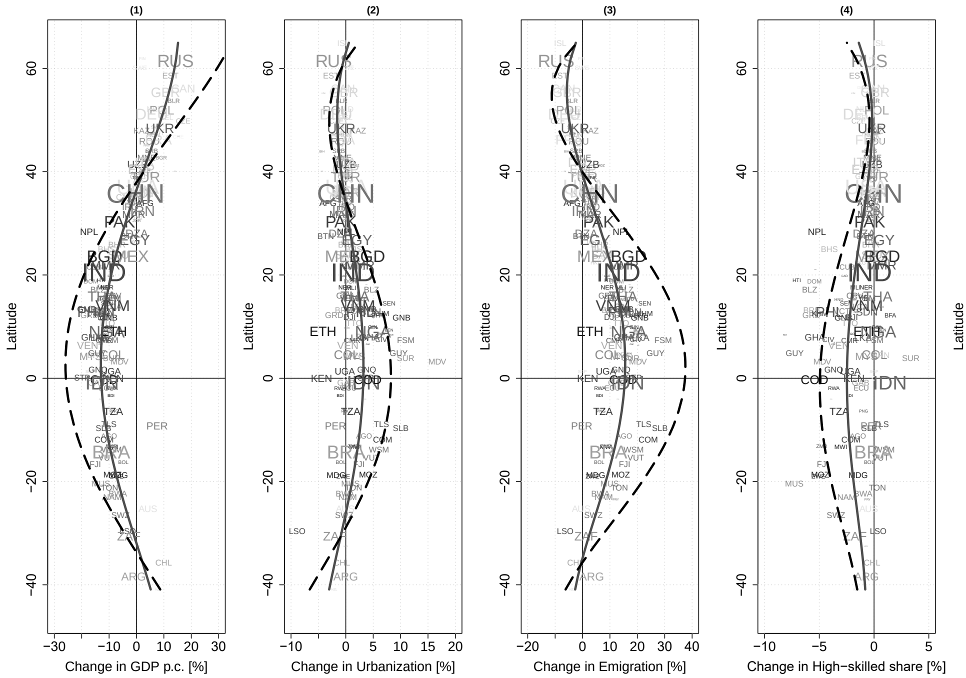
- First, we account for **changes in total factor productivity driven by long-term variations in mean temperature** (Desmet and Rossi-Hansberg 2015, Shayegh 2017). For countries close to the equator, agricultural productivity will decrease by 20–25% over the century if the temperature increases by 2.1°C; non-agricultural productivity will decrease by 10%. The effect will be 2.5-times greater if temperature increases by 4.1°C. In contrast, productivity will be positively impacted in countries above the 35th parallel.
- Second, we model **forced displacements driven by the uniform rise in the sea level.** Combining NASA estimates with our population forecasts, we predict that about 80 million adults will be forcibly displaced by the middle of the century if the sea level increases by 1.1 metres, a scenario that is consistent with a +2.1°C change in temperature (Desmet et al. 2018). About 100 million adults will be forced to move if the sea level increases by 1.3 metres, which is consistent with a +4.1°C change in temperature.
- Third, we model the **expected income losses induced by natural disasters and by the productivity and health effects of extreme heat waves** (Burke et al. 2015b). Those losses are calibrated using cross-sectional data on the US states.

Another set of explorative results accounts for climate-driven conflicts over resources.

CLIMATE CHANGE WILL INCREASE GLOBAL INEQUALITY AND EXTREME POVERTY

In Figure 1, we report the relative differences in 2100 between the intermediate (+2.1°C and +1.1 metres) and benchmark scenarios (no climate change). Focusing on the intermediate scenario, climate change will reduce income per worker by 15% in countries close to the equator and will increase it by 10% at higher latitudes. Hence, the income gap between the richest and poorest countries will increase by 25% over the course of the 21st century. Climate change increases the share of the world population living with less than 2% of the worldwide mean level of income by 0.5 percentage points.

FIGURE 1 MACROECONOMIC RESPONSES BY LATITUDE (2100)



Notes: The font size of country labels is proportional to the log of population; the font lightens as level of GDP per worker rises (i.e. poor countries are labelled in dark characters). The third-degree polynomial trends in solid grey lines represent the mean difference between the intermediate and benchmark scenarios as a function of latitude. Conversely, the polynomial trends in dashed black lines represent the mean difference between the maximalist (+4.1°C and +1.3 metres) and benchmark scenarios.

The second panel in Figure 1 illustrates changes in urbanisation, which attenuates the total factor productivity shocks because the average level of labour productivity is greater in non-agriculture than in agriculture. The third panel shows the rise in international emigration. Finally, the fourth panel shows how urbanisation and international migration affect human capital accumulation.

Although urbanisation increases access to education in poor countries, rising international emigration reduces human capital accumulation in developing countries. The reason is that high-skilled people face smaller migration costs, which implies that international emigration is of the brain-drain type.

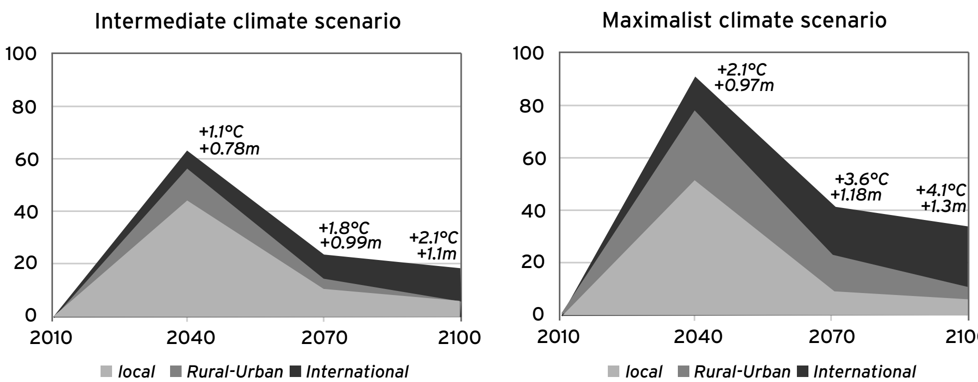
As temperatures and sea level continue to rise, the economic prosperity of dozens of millions is under threat. Under the maximalist scenario, the macroeconomic effects will be twice as large, and the share of the population below the poverty line will increase by five percentage points.

CLIMATE MIGRANTS WILL MOSTLY RELOCATE WITHIN THEIR COUNTRY

Comparing climate scenarios to the benchmark, Figure 2 gives the number of climate migrants predicted for the 21st century for each 30-year window. We suppose that migration laws and policies do not change from those of the current period, and we first ignore climate-related conflicts.

Combining slow-onset and fast-onset mechanisms, climate change will lead to displacements from vulnerable to more viable locations in their country or abroad (Rigaud et al. 2018). Over the century, this will induce movement of 105 million adults in the intermediate scenario to 162 million adults in the maximalist, translating to about 210 to 320 million people with accompanying children.

FIGURE 2 NUMBER AND TYPE OF CLIMATE MIGRANTS (MILLION PER 30-YEAR WINDOW)



In the intermediate scenario, 58% (maximalist scenario: 41%) are local movements within the region of birth (from flooded to non-flooded areas), 16% (maximalist: 26%) are interregional (from agriculture to non-agriculture), and 26% (maximalist: 33%) international to the OECD countries. This represents 27.7 million (maximalist: 56.1 million) international adult migrants over the century. On average, this means that the stock of climate immigrants to OECD countries increases by 9 million (maximalist: 17 million) per period.

Figure 2 also reveals that the brunt of climate change impact is in the first half of the century. By the year 2040, only 10% (maximalist: 14%) of climate migrants will leave their country. Hence, compared to other drivers of migration pressure – such as population growth differentials and the rise in educational attainment – climate change will induce limited effects on the share of international migrants to high-income countries. It will increase the immigrant share in total population by 0.4 percentage points (maximalist: 0.9 percentage points) in the US and in Europe, while demographic imbalances and the rise of education should increase migration pressure by seven to nine percentage points.

Considering additional climate variants, our model clearly suggests that forced displacements due to sea-level rise will be mostly local, while inter-regional and international mobility responses will be overwhelmingly governed by the total factor productivity responses to temperature change.

ADDED INTERNATIONAL MIGRATION PRESSURE FROM CLIMATE-RELATED CONFLICTS

In contexts of high political and social instability, climate change could contribute to the onset and propagation of conflicts, which would produce additional waves of forced displacements. While the literature on climate and conflicts shows mixed results, Burke et al. (2015b) and Abel et al. (2019) argue that climate change's effect on conflict occurrence is particularly relevant for countries undergoing political transformation or poverty crises.

Building on these studies, we consider a pessimistic scenario with a climate-related persistent conflict in seven Western Asian countries (i.e. experiencing widespread political instability), and in ten countries with significant levels of poverty (i.e. experiencing social instability). Starting from the intermediate climate scenario, this scenario almost triples the international migration response, adding 45 million international adult migrants over the 21st century (i.e. 15 million per 30-year period). The long-run share of international migrants in the world population increases by 0.5 percentage points.

Hence, international migration responses become larger when accounting for generalised and persistent conflicts over resources. Security and humanitarian policy measures are needed to avoid climate-related humanitarian crises and additional waves of forced displacements.

CONCLUDING REMARKS

Climate change is sometimes perceived as a trigger of mass emigration from developing to developed countries. This is because low-latitude countries in general, and their rural population in particular, will likely be the most adversely affected. Considering plausible climate scenarios, we predict forced and voluntary movements of 210 to 320 million climate migrants over the 21st century.

However, disentangling the spatial structure of these mobility responses suggests that, depending on the climate scenario, around two-thirds or three-quarters of these migrants will relocate internally, leaving about 28 to 56 million international migrants over the century. In poor countries and regions, long-haul migration to OECD destinations is a costly adaptation strategy of last resort. In addition, the minority of cross-border migrants is positively selected along education levels, which implies that international climate migration reinforces the adverse impact of climate change.

Overall, our study suggests that massive international flows of climate refugees are unlikely, except under generalised and persistent conflicts over resources. On the contrary, climate change will most likely increase global inequality and extreme poverty. This is the real threat to all of us.

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CHAPTER 40

Unequal gains: Assessing the aggregate and spatial economic impact of global warming[1]

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The effects of climate change are heterogenous across space. While some regions will be significantly negatively impacted, others may benefit from warmer temperatures. This column uses an integrated assessment model with rich spatial data that looks at interactions between regions to show how the effects of global warming on production and migration are large, worrying, and unequal. Policies such as carbon taxes are effective delaying tools, but prevention of global warming will require greater and more localised policies.

Climate change is affecting, and will affect, the economic geography of the world in significant ways, from warmer climates that can disrupt production patterns and the quality of life across regions, to sea level-rise and the resulting flooding of coastal cities. These effects are, evidently, highly heterogenous across space. Warming negatively affects locations that are already uncomfortably warm, while it can potentially benefit some of the coldest places; flooding only affects coastal areas. This large spatial heterogeneity in the impact of climate change implies that, in order to understand and predict its overall economic cost, we need to understand its local economic impact and the redistribution of resources that it will generate across regions.

Most integrated assessment models (IAMs) used in the climate literature focus on the dynamic implications of climate change, but abstract from spatial heterogeneity and its implications (e.g. Nordhaus 2017, IPCC 2013). When they do include regions, there are only a few of them and the interactions of economic agents across space are extremely limited. As such, these models do not incorporate the impact that changes in the distribution of economic activity will have on the fortunes of particular locations, or the implications that these changes will have on aggregate effects.

1 This column first appeared on VoxEU 2 March 2021 https://voxeu.org/article/assessing-aggregate-and-spatial-economic-impact-global-warming

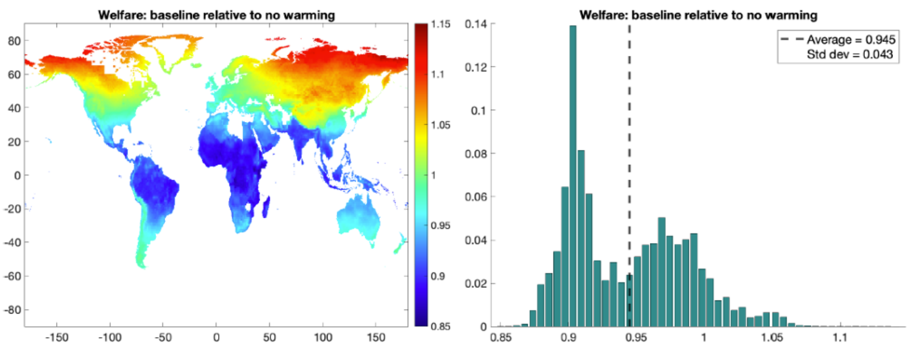
In a recent paper (Cruz and Rossi-Hansberg 2021), we propose an IAM that incorporates high spatial resolution as well as a rich set of interactions between regions (the core of our model is based on the dynamic-spatial model of Desmet et al. 2018). Agents that are impacted by warmer temperatures adapt by moving, trading, altered fertility decisions, and, in the case of firms, by investing in alternative locations that benefit from (or are less impacted by) higher temperatures. Of course, it is important to recognise and incorporate that these forms of adaptation are costly, and therefore that agents use them only when their benefits exceed their costs. Ultimately, in a world in which climate change has many regions that lose but also some that gain, these spatial adaptation costs are an essential part of the effective cost of this phenomenon. Costless adaptation results in no cost, or even net benefits, of climate change, and impossible adaptation implies costs that are unrealistically high. As is almost always the case, reality is somewhere in between. The role of geographically detailed IAMs is to determine these costs somewhat more precisely. Any serious evaluation of policy requires us to do so.

A central component of the quantification of our model is the estimation of the effect of temperature on the fundamental amenities that make a location a desirable place to live, and the fundamental productivity that makes a location a good place to produce. Of course, part of the characteristics of a location as a place of residence or production is endogenous to the people that live there, the level of economic activity, and other endogenous components. Hence, it is important to first obtain 'fundamental' levels of these local amenities and productivities. We do so by matching the model to four cross-sections of the G-Econ data at the 1°x1° level. That is, we first obtain the local fundamentals and migration costs that make the model match exactly local population and income levels, as well as changes in population over time. With these measures in hand, we estimate the effect of temperature on these fundamental amenities and productivities in a flexible way that allows the semi-elasticity to depend on the level of temperature. We control for local natural features or regional fixed effects, as well as sub-national trends. The results are intuitive. A 1°C increase in temperature in the warmest places in the world lowers amenities by 5% and productivity by 15%. The effect is commensurate, but with opposite sign, for the coldest places. Although we are successful in measuring significant effects of increases in temperature in the regions with extreme climate, our estimates also showcase large uncertainty about the level of these damage functions. This uncertainty translates directly into uncertainty about the aggregate impact of global warming. Once we incorporate clean and fossil energy sources and a carbon cycle, the 95% confidence interval of the impact that global warming will have on economic outcomes by 2200 goes from 0% to 20%. In contrast, the spatial distribution of local impacts is fairly stable across damage function levels.

The effects of global warming on the spatial distribution of economic activity are large and worrying. As illustrated in Figure 1, while welfare in our baseline scenario can increase by as much as 15% in some regions of Canada and Siberia, areas in Central and South America (except for parts of Argentina and Chile), Central Africa, India, and South East

Asia can suffer losses of between 10% and 15%. The distribution of the losses associated with global warming is bimodal both for welfare and for the present discounted value of real GDP. The losers are today's poorest locations. Today's richest regions are only marginally affected in our baseline.

FIGURE 1 SPATIAL IMPACT ON WELFARE OF CLIMATE CHANGE



This unequal distribution of effects is not only unfair, given that the source of this phenomenon are global carbon emissions, but embeds large migrations of people and innovation to the North. Indeed, our findings show that migration, and to a lesser extent investment in local technological improvements, are important adaptation mechanisms. Trade, in contrast, is less relevant. This is natural, as trade declines rapidly with distance and temperature changes are highly spatially correlated. Of course, if climate change affects local sectoral specialisation, an effect that we abstract from in this study, it can play a larger role (see Desmet and Rossi-Hansberg 2015, Nath 2020, and Conte et al. 2020 for papers that incorporate this mechanism).

As for policy, the role of carbon taxes or clean energy subsidies is also governed by spatial heterogeneity and adaptation mechanisms across locations. Carbon taxes, for example, improve many of the regions most affected by global warming and have the potential of lowering temperatures significantly over hundreds of years. However, absent other innovations in abatement technologies, they mostly delay – rather than eliminate – the use of carbon. The reason is that fossil fuel extraction costs are convex in the amount of carbon that has been exploited in the world. Thus, if a global carbon tax leads to less fossil fuel use today, it also implies a lower carbon price in the future. The implication is that carbon taxes 'flatten' the temperature curve, but do not eliminate the long-run temperature changes that arise from the ultimate depletion of carbon resources on Earth. The resulting gains from the policy are, therefore, relatively small. Delaying carbon emissions with carbon taxes is much more useful when an abatement technology, 'a cure', is forthcoming.

The large heterogenous impacts of climate change across regions is a first-order characteristic of one of the most important phenomena faced by humankind. It's time to incorporate it fully in the set of models and tools that are used to predict the economic effects of climate change and make the appropriate policy recommendations.

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CHAPTER 41

The joint effect of private and public environmental regulation on emissions[1]

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The adoption of environmentally friendly production methods matters to both firms and policymakers, as both are concerned with reducing the emissions of greenhouse gases and pollutants. This column studies the effect on emissions of environmental protection provisions in EU free trade agreements, as well as that of private ISO-14001 environmental certifications. Environmental protection provisions in EU trade agreements are associated with lower levels of sulphur dioxide and nitrogen oxide emissions, while ISO-14001 certifications are associated with lower levels of greenhouse gas emissions. For carbon dioxide, ISO-14001 certifications matter only for members of trade agreements with environmental protection provisions, suggesting the existence of complementarities between private and public environmental regulation.

Reducing emissions of greenhouse gases and air pollutants is a key issue on the agenda of both public regulators and private firms. On the one side, firms seek to adopt more environmentally friendly production methods to fill institutional voids, to become more efficient in the use of energy and resources, or simply to signal their socially responsible behaviour to customers and policymakers (Darnall et al. 2008, Baek 2017).

On the other side, policymakers have been led by environmental concerns to introduce elements of environmental protection regulation not only in their domestic legislation, but also in various international instruments, such as multilateral conventions and, more recently, bilateral trade agreements (Lechner 2016).

The effectiveness of private (voluntary) environmental regulations in reducing emissions has been contested (Boiral et al. 2018). Certifications such as the ISO-14001 can induce firms to make substantial investments and train personnel to reduce their environmental impact (Potoski and Prakash 2013). However, firms have also been observed to vary their level of compliance with the standards' requirements depending on the likelihood of monitoring and expected sanctions (Christmann and Taylor 2006).

1 This column first appeared on VoxEU 3 January 2021 https://voxeu.org/article/joint-effect-private-and-public-environmental-regulation-emissions

The success of public environmental regulation, especially when involving trade agreements, is also not free of criticism. The EU has often used its commercial power to 'export' its regulatory model to third countries, by making preferential access to EU markets conditional on compliance with non-trade objectives such as environmental protection (Borchert et al. 2020). Countries that have signed up for environmental protection provisions in their bilateral trade agreement with the EU include Canada, Chile, Colombia, Croatia, Mexico, Peru, Singapore, South Africa, South Korea, and Vietnam. Yet, the trade and sustainable development chapters in EU trade agreements have been often considered to lack necessary vigour because they do not have enforcement mechanisms that can be adopted in case of violations.

COMPLEMENTARITIES BETWEEN PUBLIC AND PRIVATE REGULATION

With production being increasingly internationalised and many multinational enterprises' headquarters based in large, green-conscious markets such as the EU, there is scope to consider the role of complementarities that might arise between private and public environmental regulations.

Tighter public regulations can complement private standards such as the ISo-14001 by making companies more aware of the potential resource efficiencies and innovations from minimising waste and pollution. Such regulations can help level the playing field by reducing opportunistic behaviour (Porter and Van der Linde 1995). Trade agreements with environmental protection provisions could improve the enforceability of private ISO-14001 standards; they could enhance the effect of the standards on the environment through reduced levels of pollution.

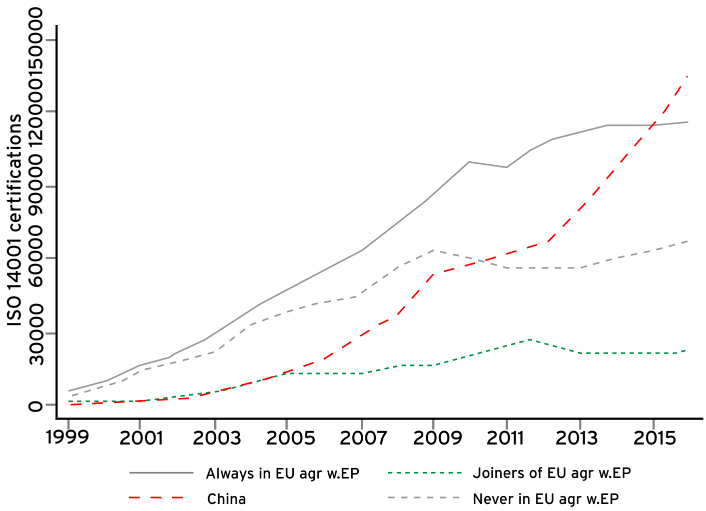
ISO standards can also help push trade agreements to include environmental protection provisions. The EU's economic weight could in fact act indirectly through the so-called 'Brussels effect' (Sinopoli and Purnhargen 2016). This effect works through the intermediation of EU firms which serve as de facto inspectors of their subcontractors in third countries. The EU firms make sure that the subcontractors satisfy a range of product and process standards to be part of EU-based value chains (Héritier et al 2009).

In a recent paper (Di Ubaldo et al. 2019), we investigate the extent to which environmental protection provisions in EU trade agreements affect emissions of greenhouse gases and air pollutants, and whether their effect is complementary to that of private ISO 14001 certifications.

We exploit a dataset with information on the number of ISO-14001 certifications (from the ISO survey), emissions (from the Environmental Performance Index report), and the 'environmental content' of EU free trade agreements (Lechner 2016), for 147 countries over the 1999–2014 period.

Figure 1 shows the uptake of ISO-14001 certifications over time by groups of countries which, from 1999 onwards, were always members of EU agreements with environmental protection provisions (e.g. EU members, north-African countries), entered such agreements (e.g. member of European Partnership Agreements, Canada, Chile), never entered EU agreements (e.g. India, Russia and the USA), and China, the country with the largest number of certifications. The growth of ISO-14001 certifications was rapid but uneven.

FIGURE 1 ISO-14001 CERTIFICATIONS AND MEMBERS OF EU AGREEMENTS WITH ENVIRONMENTAL PROTECTION PROVISIONS



Note: EP = environmental protection.

Source: Authors' elaboration on data from ISO survey and Lechner 2016.

Countries always in EU free trade agreements with environmental protection provisions kept increasing the number of ISO-14001 certifications over time and so did China, at an even faster rate. In countries that never entered EU free trade agreements, the growth of ISO-14001 certifications seems to have plateaued post-2009. Joiners of EU free trade agreements find themselves in the middle, exhibiting a modest growth of ISO certifications throughout the period under analysis.

We exploit a dynamic panel setting to estimate the impact of ISO-14001 certifications, EU agreements with environmental protection provisions, as well as their interaction, on the level of emissions of greenhouse gases and pollutants. The results paint a somewhat more complicated picture than might be expected.

Membership in EU trade agreements with environmental protection provisions is associated with lower emissions of harmful pollutants, sulphur dioxide and nitrogen oxide. In comparison, ISO-14001 certifications are strongly associated with lower emissions of carbon dioxide and methane, which account for approximately 90% of all greenhouse gases.

For carbon dioxide, we find evidence of an interaction effect of ISO-14001 with EU trade agreements: the negative impact of the certifications on emissions is driven by the subsample of members of EU agreements with environmental protection provisions, with no effect of ISO-14001 for countries not part of such agreements. By themselves, EU agreements are found to have no impact on carbon-dioxide emissions.

CONCLUSION

The challenges of global warming and climate change require a coordinated effort by a variety of stakeholders, including businesses and governments. Emissions of air pollutants and greenhouse gases contribute to global warming and climate change and will increasingly adversely affect human health and sustainable development (Kolk and Pinkse 2008).

We find that ISO-14001 certifications interact with an element of public environmental regulation, i.e. the environmental protection provisions in EU free trade agreements, in reducing emissions of carbon dioxide. While public and private regulation by themselves appear to affect different kinds of emissions, the complementarity emerging for carbon-dioxide emissions suggests a potential avenue for further coordinated efforts to reduce emissions.

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CHAPTER 42

Trade to adapt: Changing specialisation to cope with climate change[1]

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Trade restrictions are often invoked as a way to stem climate change. Although international transportation is an important source of carbon emissions, this view is incomplete. Using a dynamic spatial growth model, this column argues that trade can be a powerful mechanism to adapt to rising temperatures. The interaction of climate change, productivity, and migration decisions gives rise to significant global changes in populations and sectoral specialisations. On aggregate, rising temperatures are predicted to lower real GDP per capita by 6% and welfare by 15% by the year 2200.

In discussing trade policy in the context of climate change, some people are quick to argue that trade might have to be restricted. After all, trade involves transportation, and unfortunately, transportation is an important source of carbon emissions. In addition, there is growing support for carbon border adjustments, a tariff on carbon-intensive imports (e.g. Elliot et al. 2010, Mehling et al. 2019, Farrokhi and Lashkaripour 2020, Kortum and Weisbach 2020).

Yet, by facilitating locations to switch specialisation, trade may also be a powerful way to mitigate the negative economic effects of global warming. The underlying logic of this claim is straightforward. The impact of rising temperatures depends both on location (e.g. southern Canada or equatorial Africa) and occupation (e.g. farmer or service worker). As such, climate change can be thought of as a shock to comparative advantage. Faced with such a shock, locations are bound to respond by changing their specialisation patterns.

Needless to say, the strength of trade as an adaptation mechanism to climate change depends on the ease of switching production across sectors. Moving out of farming may not be so helpful if the rest of the economy suffers from low productivity. And if trade is costly, goods have to be sourced locally, limiting the scope of switching to other activities. If adaptation through changing specialisation is difficult, we may see a rise in migration instead.

1 This column first appeared on VoxEU 4 May 2021 https://voxeu.org/article/changing-specialisation-cope-climate-change

To assess the role of trade, specialisation, and migration in responding to climate change, in Conte et al. (2020) we develop a high-resolution, two-sector dynamic model of the globe with costly trade and migration. The model includes both the effect of temperature on productivity and the effect of production on emissions, the carbon stock, and rising temperatures. After discretising the world into 64,000 one degree by one degree grid cells, we simulate the model forward for several centuries. Our assessment assumes fossil-fuel-intensive economic growth, consistent with a 1,200 gigatons of carbon (GTC) increase in the stock of carbon and a 3.7°C increase in global temperature by the end of the 21st century. This corresponds to the so-called Representative Concentration Pathway (RCP) 8.5 used by the Intergovernmental Panel on Climate Change (IPCC).

THE GEOGRAPHY OF SECTORAL SPECIALISATION

Global warming does not dramatically change the spatial distribution of the population. Today's most densely populated regions, such as western Europe, India, and eastern China, continue to be the frontrunners 200 years from now. But there are obviously winners and losers: northern latitudes gain at the expense of the Arabian Peninsula, northern India, western Australia, northern Africa, Brazil, and Central America (see Figure 1).

Agricultural production becomes geographically more concentrated over time, but its location changes dramatically because of rising temperatures (see Figure 2). By the year 2200, if there were no climate change, South America, sub-Saharan Africa, India, eastern China, and eastern Europe would become the world's breadbaskets. In contrast, with global warming, Canada, Russia, and Central Asia will become the world's most prominent agricultural producers. These regions have high fundamental productivity in agriculture, but in today's world suffer from a large productivity penalty because of their cold temperatures. As the globe warms up, they emerge as major players in agriculture.

FIGURE 1 CLIMATE-INDUCED LOG DIFFERENCE IN POPULATION IN THE YEAR 2200

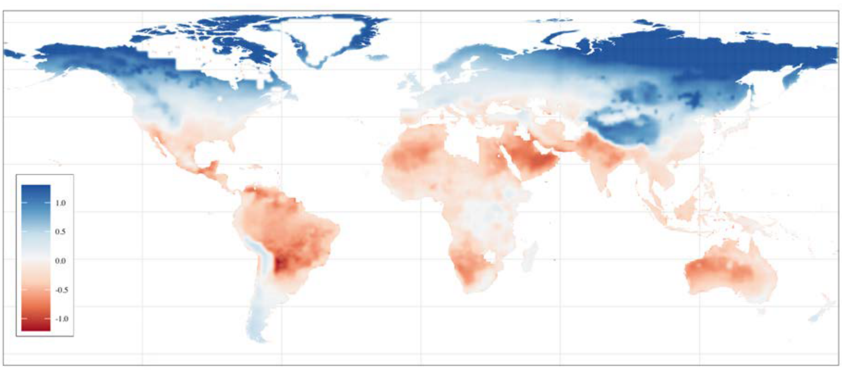
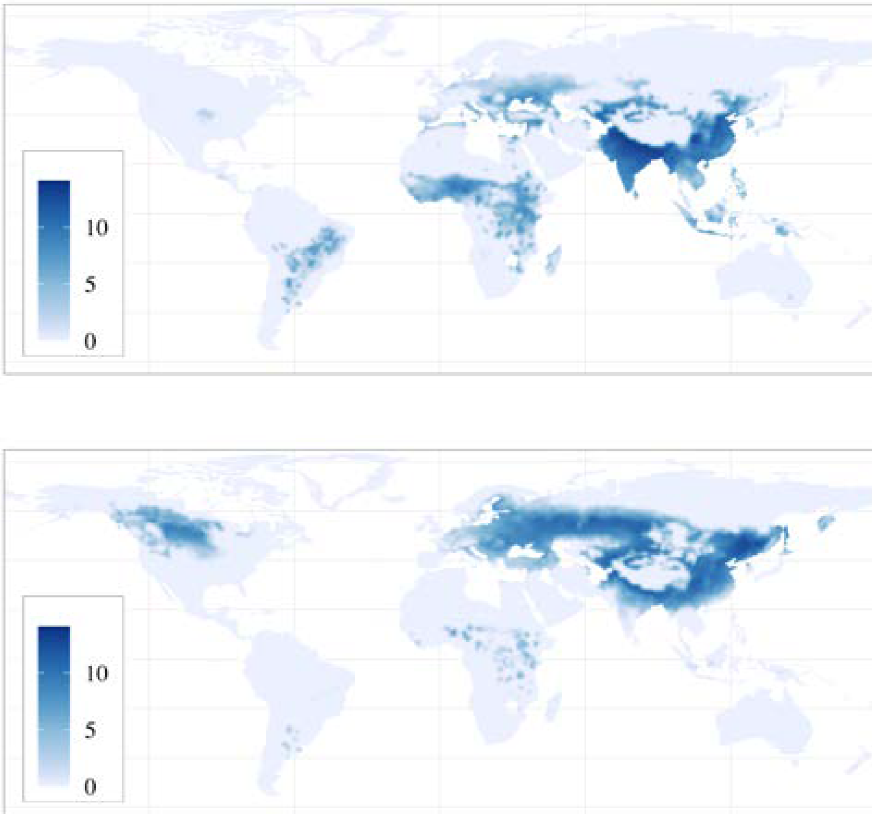


FIGURE 2 AGRICULTURAL OUTPUT IN THE YEAR 2200 WITHOUT CLIMATE CHANGE (TOP) AND WITH CLIMATE CHANGE (BOTTOM)



What happens to the equatorial regions of South America and sub-Saharan Africa that become inhospitable to agriculture? Although they move into non-agricultural activities, they fail to thrive. Unfortunately, their original productivity in non-agriculture is not high. In addition, though less sensitive to temperature, non-agricultural production is most productive in temperate zones. While trade provides them some respite, they still fall behind.

AGGREGATE EFFECTS

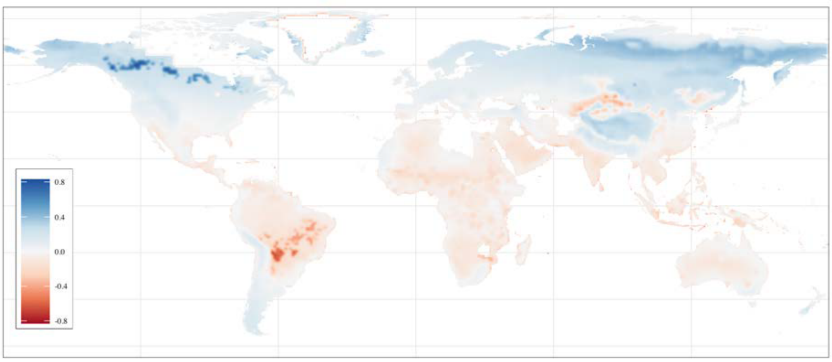
At the level of the global economy, rising temperatures are predicted to lower real GDP per capita by 6% by the year 2200. The negative impact on welfare is 15%, two and a half times larger. The greater welfare penalty stems from global warming benefitting locations at more polar latitudes, where natural amenities tend to be worse. In Cruz and Rossi-Hansberg (2021), where higher temperatures improve amenities at northern latitudes, the welfare losses are less extreme and commensurate with the effects on real GDP.

Maybe surprisingly, climate change enhances global productivity growth in agriculture, despite farming being sensitive to temperature. By shifting agriculture to regions with relatively high fundamental productivity, climate change is a net positive for agricultural productivity. Global employment in agriculture also declines due to climate change. This occurs because agriculture relocates from regions where labour is abundant, such as India, to regions where land is abundant, such as Russia.

TRADE AND CLIMATE CHANGE

When trade costs are higher, climate change leads to more relocation from regions close to the equator to northern latitudes (see Figure 3). This suggests that trade and migration are substitutes in their response to climate shocks. If the scope of trade to act as an adjustment mechanism to climate change is hampered because of higher costs, migration becomes a more attractive adjustment mechanism. That is, if people in sub-Saharan Africa and Latin America cannot sufficiently switch to other sectors because trade is too expensive and agricultural products need to be locally sourced, then climate change will incentivise them to pack their bags and move to more northern latitudes.

FIGURE 3 CLIMATE-INDUCED LOG DIFFERENCE IN POPULATION WITH TRADE COSTS 50% HIGHER MINUS CLIMATE-INDUCED LOG DIFFERENCE IN POPULATION WITH TRADE COSTS 50% LOWER THAN BASELINE (YEAR 2200)



In the aggregate, how do trade costs affect the climate-induced losses in real GDP per capita? There are two opposing forces at work. On the one hand, when trade costs are higher, there is less scope to respond and adapt by changing sectoral specialisation. This makes the world more vulnerable to climate change. On the other hand, when trade costs are higher, climate change incentivises people to move to temperate zones that in the long run end up being less affected by rising temperatures. This makes the world less vulnerable to climate change. Our model predicts the latter effect initially dominating the former, with the relationship eventually reverting.

While trade has certainly some direct negative effects on emissions, our work suggests that we should think of climate change as a shock to comparative (and sometimes absolute) advantage. The possibility of responding to this shock by either shifting specialisation patterns or by migrating are bound to be first-order adaptation mechanisms.

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His research specialises in international trade, regional and urban economics, as well as growth and organizational economics. He has published extensively in all the major journals in economics. In 2007, he received the prestigious Alfred Sloan Research Fellowship and in 2010, he received the August Lösch Prize and the Geoffrey Hewings Award. He is an elected fellow of the Econometric Society since 2017 and won the Robert E. Lucas Jr. Prize in 2019.

CHAPTER 43

Air pollution policy should focus on the most vulnerable people, not just the most polluted places[1]

Tatyana Deryugina, Nolan Miller, David Molitor, Julian Reif
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Policies aimed at reducing the harmful effects of air pollution on human health typically focus on improving air quality in polluted areas. This column suggests a shift in focus from targeting the most polluted places to serving the most vulnerable people. Basing air quality regulations on pollution levels may be less valuable than reducing air pollution in regions with vulnerable populations. Programmes that reduce poverty or improve access to health care may also lessen the recipients' susceptibility to acute pollution exposure.

A large number of studies have documented the fact that acute air pollution exposure harms human health, even in places where ambient pollution levels are generally low (e.g. Ward 2015, Knittel et al. 2016, Schlenker and Walker 2016, Deryugina et al. 2019). Growing understanding of such harms suggests that further reducing air pollution would substantially improve human health and well-being.

The traditional regulatory approach to improving air quality targets regions with high levels of air pollution. For example, the US Clean Air Act requires "non-attainment" areas that fail to meet minimum air quality standards to take action to reduce pollution, and to achieve "attainment" status as soon as possible. Little is known about the distributional characteristics of the environmental benefits and environmental costs from such an approach, as the work of Hsiang et al. (2018) underscores. Moreover, our understanding of the economics of such policies is changing. For example, research by Bento et al. (2014) found that existing policies are progressive, contradicting the long-held, conventional wisdom that poor communities bear a disproportionate cost of complying with the provisions of the Clean Air Act. It is also not known whether there are alternative targeting approaches that would deliver superior outcomes.

Enhancing our understanding of the distribution of policy benefits and costs is crucial for designing superior environmental regulations.

1 This column first appeared on VoxEU 13 January 2021 https://voxeu.org/article/air-pollution-policy-should-focus-most-vulnerable-people-not-just-most-polluted-places

CONSIDERING A NEW APPROACH

With this in mind, we explore an alternative approach to mitigating harm from air pollution exposure – namely, targeting areas for air quality improvement based on population vulnerability rather than on air pollution levels alone. If places with the populations that are the most vulnerable to pollution are also the places with the worst air quality, then targeting pollution regulations at high-pollution areas is sensible. However, if vulnerable populations tend to live in less polluted areas, then current pollution regulations could be adapted to achieve greater improvements in health. This approach of focusing on vulnerability also highlights an additional avenue for reducing pollution harms – environmental policies could be designed to directly reduce vulnerability to pollution through, for example, improvements in health care infrastructure or healthy behaviours (e.g. diet and exercise), which could reduce the harms of pollution even in the absence of improved air quality.

We examine this issue in the context of a particularly vulnerable population: The US elderly. Specifically, we consider the vulnerability to air pollution among people in the continental US between the ages of 65 and 100 who were enrolled in Medicare, the federal health insurance programme for the elderly. Nearly all (97%) of the over-65 age group in the US are enrolled in the programme.

We look specifically at the mortality risks posed by fine particulate matter (PM2.5) – a mixture of very small particles that are less than 2.5 micrometres in diameter, or about 30 times smaller than the width of a human hair. PM2.5 is generated by burning fuel, such as in power plants and vehicles. It can be carried for hundreds of miles from emission sources and is small enough to be breathed deeply into the lungs. Numerous epidemiological studies have documented a positive correlation between exposure to particulate matter and mortality, especially from cardiovascular disease.

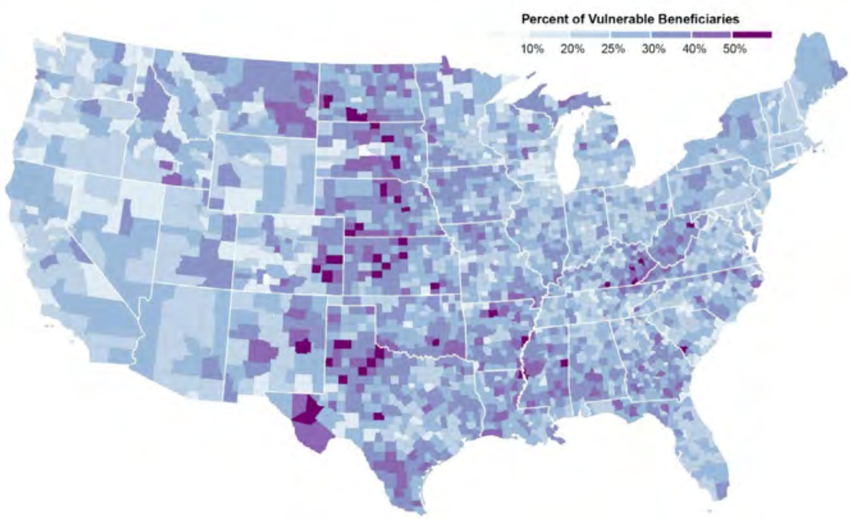
Using detailed information for nearly 15 million US residents aged 65 and over, we examine regional and individual characteristics that may affect vulnerability. Following the methodology of Deryugina et al. (2019), we use machine learning to create a vulnerability index for each individual and explore the geographic, health, and socioeconomic correlates of vulnerability to air pollution exposure.

WIDE VARIATION IN PATTERN OF VULNERABILITY

We find that vulnerability to PM2.5 among the elderly varies widely across US states and counties as well as across ZIP codes within counties. The highest proportions of vulnerable individuals live in a region that forms something of an L-shape across the continental US, extending south from the Dakotas to Texas and then east along the Gulf Coast States (Figure 1). Large shares of vulnerable elderly also live in eastern Kentucky and West Virginia. The West Coast states have the lowest fraction of vulnerable elderly.

We also find substantial divergence between the geography of vulnerable elderly and the geography of elevated PM2.5 levels. The maps in Figures 1 and 2 illustrate differences in the location of counties that have the highest proportion of vulnerable elderly in the population (Figure 1) and counties that have the highest levels of PM2.5 (Figure 2). A statistical analysis of these patterns reveals that, while average PM2.5 levels are positively related to the prevalence of an array of adverse health conditions, average vulnerability and average PM2.5 levels are negatively related.

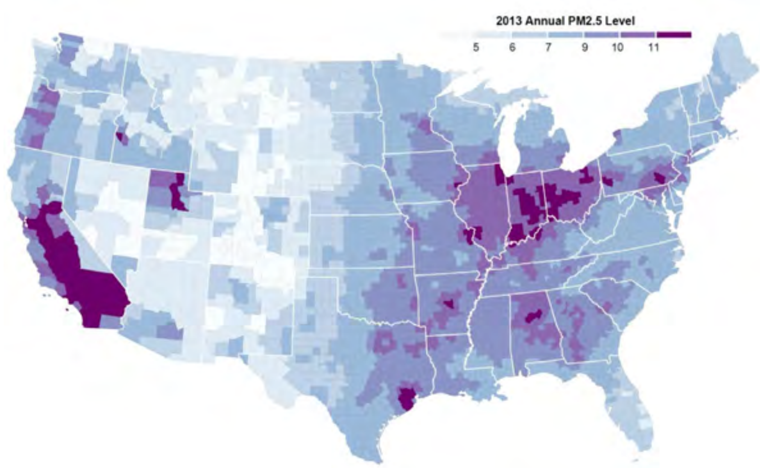
FIGURE 1 PERCENT OF VULNERABLE BENEFICIARIES



Note: The map shows the fraction of Medicare beneficiaries in each county who were vulnerable to acute PM2.5 exposure (i.e. were in the top 25% of the acute PM2.5 vulnerability index) in 2013.

Source: Deryugina et al. (2020)

FIGURE 2 ANNUAL PM2.5 LEVELS



Note: The map shows county-level annual PM2.5 levels in 2013. The PM2.5 measure is provided by the US Centers for Disease Control and Prevention National Environmental Public Health Tracking Network, and was created using air pollution monitor data, where available, and modelled estimates for days or counties that do not have monitor data.

Source: Deryugina et. al (2020)

If we consider the total number of vulnerable individuals rather than their share of the population, we obtain a positive correlation between vulnerability and PM 2.5 levels. However, the correlation is far from perfect, implying that targeting the most polluted counties would neglect many vulnerable elderly compared to policies that targeted areas based on vulnerability.

The finding that less-polluted counties tend to have a higher share of vulnerable beneficiaries is notable. There are many possible explanations for this relationship, and our analysis does not isolate the causal effect of average pollution levels on vulnerability. Areas that are less polluted may also have superior medical care facilities that attract frail elderly residents; or those who are vulnerable to air pollution may take care to avoid polluted areas. Indeed, the work of Banzhaf et al. (2019) reviews numerous studies documenting residential sorting on the basis of air pollution. Alternatively, the relationship could be coincidental, with both pollution and vulnerability determined indirectly by population preferences. Regardless of the underlying mechanism, these patterns suggest that there is a trade-off between targeting areas with a high share of vulnerable individuals and targeting areas with high levels of air pollution.

CHARACTERISTICS LINKED TO VULNERABILITY

Areas with higher proportions of vulnerable individuals are poorer and less urban. They have a higher prevalence of obesity and smoking, higher overall elderly mortality rates, and a lower prevalence of exercise. They also have hotter climates, as measured by the annual number of cooling-degree days. Similar patterns emerge when we consider the total number of vulnerable individuals in a county rather than their share of the population.

Our work also finds, unsurprisingly, that those most vulnerable to pollution have poor health overall. They are more likely to have chronic conditions, such as Alzheimer's disease or related dementia, chronic obstructive pulmonary diseases (COPD), lung cancer, chronic kidney disease, and congestive heart failure. They use and spend more on health care than those who are less vulnerable.

Although more research is needed to establish causality, these correlations suggest that it is possible to reduce vulnerability to pollution without necessarily reducing pollution levels. For example, programs that target poverty or improve access to health care may also reduce the recipients' vulnerability to acute pollution exposure. Because pollution levels in the US are already low, and further reductions may be increasingly costly, policies that target vulnerability to air pollution rather than air pollution itself may be more cost-effective.

RETHINKING POLICY APPROACHES

Our study has several limitations. We emphasise that the relationships we document between pollution vulnerability and geographic, health, and socioeconomic characteristics are correlational, not causal. Our work examines just one population group (the elderly). Although substantial evidence shows that elderly people are particularly vulnerable to air pollution, research by Chay and Greenstone (2003) and Knittel et al. (2016) has documented significant effects of air pollution on infant mortality, even in developed countries.

Nevertheless, our work suggests that reducing air pollution in the most polluted areas may be less beneficial than expected because these areas do not necessarily contain the greatest number of vulnerable individuals who stand to benefit from such reductions. Our results cast doubt on the presumption that it is optimal to regulate pollution by targeting pollution-reduction efforts based solely on a region's baseline pollution level. Emphasising high-pollution areas may fail to direct resources to where the benefit is highest. Moreover, the substantial variation in vulnerability within counties suggests that broad, geographically defined approaches are imprecisely targeted. Our findings suggest that additional attention should be paid to policies that account for local populations' socioeconomic characteristics such as income, education, and health; local amenities such as hospital quality and capacity; and local environmental characteristics.

Our results also suggest that regulatory policies that operate only by reducing air pollution exposure are inefficient. Policies should include a focus on interventions that reduce overall vulnerability to pollution exposure, whether or not they reduce pollution levels. For example, regulations may be able to cost-effectively reduce vulnerability by improving health care infrastructure, reducing heat exposure, or promoting population health.

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CHAPTER 44

Design of climate change policies needs to internalise political realities[1]

Davide Furceri, Michael Ganslmeier, Jonathan D. Ostry

International Monetary Fund; University Oxford; International Monetary Fund and CEPR

The call for stricter climate change policies is gaining momentum in many countries. But despite rising public awareness, there could be political obstacles to adopting the measures needed to combat climate change. This column argues that policy design and timing are critical to overcoming political costs to climate mitigation policies, as is the need to provide effective social insurance policies. An implication is that political realities may often dictate the need to sacrifice some efficiency in climate mitigation policies in order to secure political buy-in.

There are few issues that have sparked more attention across the globe than how to avoid the environmental and human catastrophe that climate change is inflicting on our planet. There has been unprecedented advocacy to pursue far-reaching climate changes policies (CCPs). But even in the wake of massive public protests and an ambitious agenda since the 2015 Paris Agreement, the hesitancy of politicians is remarkable.

From a theoretical perspective, there are two key factors that may provide an explanation for the slow reform progress on environmental issues. On the one hand, passing far-reaching CCPs often comes with distributional consequences: since CCPs limit economic activity in specific industries, the costs tend to be concentrated on a few stakeholders, while the benefits from climate protection are distributed widely across the entire population (Stokes 2016, Tvinnereim and Iversflaten 2016). On the other hand, pricing the externalities of carbon emission would affect primary products (energy, fuel, etc.) – which loom large in the budgets of poor households (Metcalf 2009, Habla and Roeder 2017, Goulder et al. 2019).

In our analysis (Furceri et al. 2021), we aim to assess the relevance of these hypotheses. To do so, we combine indicators of environmental policy stringency (EPS) from the OECD (Botta and Koźluk 2014) with measures of popular support for government in 31 countries between 2001 and 2015. The EPS database provides detailed sub-indices of environmental legislation across energy sources and instruments and coverage spans a large number of countries and years. In total, the countries in our sample are responsible for 43% of

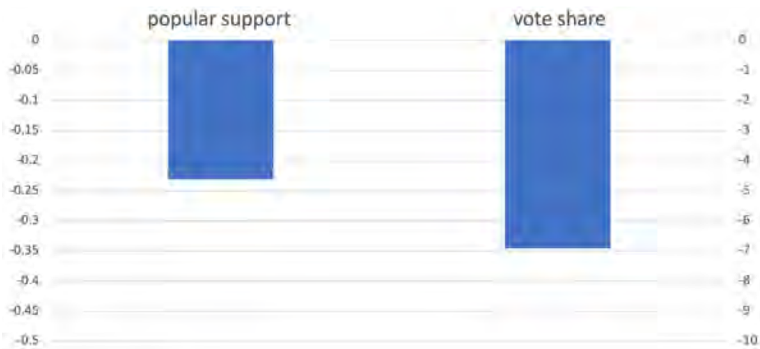
1 This column first appeared on VoxEU 7 September 2021 https://voxeu.org/article/design-climate-change-policies-needs-internalise-political-realities

global carbon emissions (Muntean et al. 2018). As our main dependent variable, we use a poll-based indicator of the popularity of governments constructed by the International Country Risk Guide (ICRG 2020).

CLIMATE CHANGE POLICIES MAY INCUR POLITICAL COSTS

CCPs seemingly do engender statistically significant political costs. A government moving from the first to the third quartile of the EPS distribution will experience – on average – a 10% decline in popular support (Figure 1). The effect is equivalent to a decline in vote share of about 11.17% during election years. These results are robust to various sensitivity checks. In addition, we use an instrumental variable (IV) approach to estimate the causal effect of CCPs on popular support for a government. Our instrument interacts a time-varying global term capturing 'pressure' for climate change policies (the occurrence of global extreme weather events) and a country-specific term capturing the vulnerability of a country to climate change (such as the length of its coastline which gauges vulnerability to rising sea levels).

FIGURE 1 THE EFFECT OF CLIMATE CHANGE POLICIES (CHANGE) ON GOVERNMENTAL POPULAR SUPPORT (LEFT AXIS) AND VOTE SHARE IN ELECTION YEARS (RIGHT AXIS)



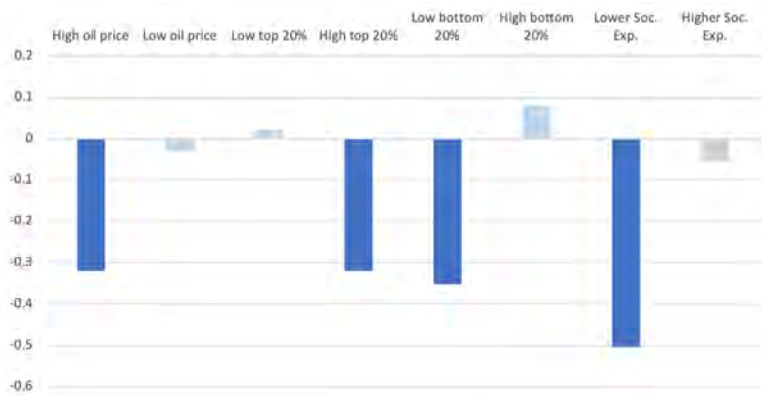
Note: A coefficient of -0.2 is equivalent to a 10% decline in popular support from an increase in EPS from the 1st to the 3rd quartile of the EPS distribution. Both coefficients are statistically significant (at least) at the 10% level.

STRATEGIC TIMING AND COMPLEMENTARY SOCIAL INSURANCE MITIGATE THE POLITICAL COSTS OF CCPS

Policy design – in terms of timing and complementary reforms – can mitigate the political costs of CCPs. First, governments can build support for advancing mitigation policies in times of low oil and gasoline prices, since electorates suffer less from higher carbon prices when energy is cheap (Figure 2). Indeed, as our results show, the effect of changes in EPS is only significant when oil and/or gasoline prices are at high levels, but indistinguishable from zero otherwise. Second, economies with a large industrial base reliant on dirty-energy (coal) inputs are more challenged in building support for mitigation and suffer greater political costs when adopting such measures (Figure 2). Diversifying the industrial base ex ante may reduce political opposition to CCPs.

Third, the distributional consequences of CCPs loom large in determining political feasibility. When inequality – measured by the (pre- or post-tax) GINI or different percentiles along the income distribution – is high, the effect of CCPs on popular support is substantial (Figure 2). On the other hand, we do not find a significant cost when inequality is low. Our results show that taking complementary measures in terms of social insurance provision may succeed in limiting the political backlash against CCPs (Figure 2). The dividend from greater protection against labour market risks underscores the importance of active labour market policies and/or unemployment benefits as essential complementary policies to CCPs. Internalising the distributional side-effects of CCPs seems critical in developing politically achievable strategies for averting climate change.

FIGURE 2 LOW OIL PRICES AND EXPANDING SOCIAL INSURANCE CAN MITIGATE THE POLITICAL COSTS OF CLIMATE CHANGE POLICIES

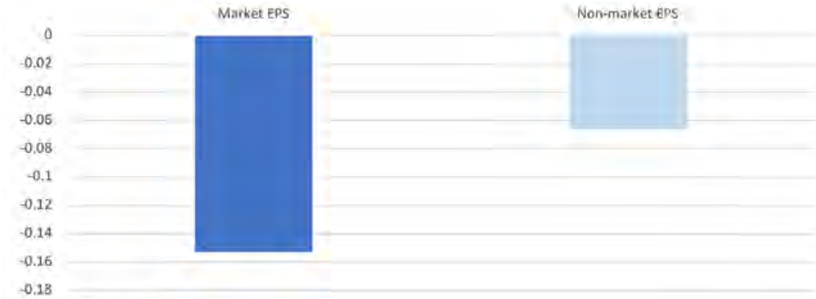


Notes: A coefficient of -0.2 is equivalent to a 10% decline in popular support from an increase in EPS from the 1st to the 3rd quartile of the EPS distribution. Bars denote the effect of climate change policies (change) interacted with different mediating factors on governmental popular support. Dark (light) blue indicates that effects are (not) statistically significant at the 10% level.

EMISSION LIMITS ARE POLITICALLY MORE FEASIBLE THAN CARBON TAXES

We also find large heterogeneity of political costs across different policy instruments. Our findings indicate that market-based measures such as taxation led to significant decreases in governmental support (Figure 3). However, we do not find significant costs when governments use non-market-based measures such as emission limits. This finding strikes us as central as it underscores that non-market-based measures could be an important alternative that is politically viable – despite lower efficacy of non-market measures in reducing carbon emissions compared to tax-based instruments.

FIGURE 3 ONLY MARKET-BASED CLIMATE CHANGE POLICIES LEAD TO A DECLINE IN POPULAR SUPPORT FOR THE GOVERNMENT



Notes: Bars denote the effect of climate change policies (change) of different instruments on governmental popular support. A coefficient of -0.2 is equivalent to a 10% decline in popular support from an increase in EPS from the 1st to the 3rd quartile of the EPS distribution. Dark (light) blue indicates that effects are (not) statistically significant at the 10% level.

THREE LESSONS TO ESCAPE THE POLITICAL DILEMMA OF INACTION

Climate change will remain the defining global challenge for decades to come. As with all policies that generate winners and losers, environmental legislation requires political support to be viable. Rational governments will continue to hesitate as long as political damage is palpable. Our research identifies key lessons to overcome this political dilemma and use the current crisis as an opportunity to advance low-carbon and climate-resilient economic growth. First, adopting stricter environmental policies in times of low oil prices can help to underpin popular support for mitigation. Second, providing social insurance for those adversely affected by climate mitigation can help to give those who are vulnerable to the transition to a greener economy the wherewithal to bounce back, and thus give governments the political backing to advance a greener policy agenda. Finally, adopting non-market-based measures such as emission limits or feebates can be a politically viable alternative to market-based emissions pricing, provided that they come with a transparent analysis of the costs and benefits.

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CHAPTER 45

Debt, natural disasters, and special drawing rights: A modest proposal[1]

Avinash Persaud
Gresham College

For the countries on the frontline in the war against climate change, there is a nasty nexus between climate change and debt. The cost of environmental damage, the loss of revenues from a natural disaster, and the high price of building back better all contribute to higher debt. This column proposes three ways to break this climate-debt nexus: (1) redistribute special drawing rights using a new classification of vulnerability; (2) incorporate natural disaster clauses into multilateral development banks' lending arrangements; and (3) use the unused special drawing rights of the world's strongest countries to recapitalise regional development banks to finance resilience in the vulnerable countries without adding to their debt.

The Trump administration's denial of climate change slowed down international progress at a critical juncture. But not all failure to act can be laid at the door of one country. The international community as a whole abandoned the commitment to cap the increase in the average global temperature to 1.5°C (Intergovernmental Panel on Climate Change 2018). One critical reason is that while all of humanity will be affected by climate change, the initial impact is highly differentiated.

Many see climate change as a future threat, not a present reality. Meanwhile, those that climate change has already hit hard are falling under the radar. Old measures of vulnerability focus on past income per capita levels. We don't need a new reason to deviate from conventions that hinge on gross national income per capita (Coyle 2014), but measures of past income per capita do not transform well onto the present likelihood of a future climate disaster that destroys lives and livelihoods. By using these old conventions, less than 15% of US overseas development assistance earmarked for climate mitigation went to those countries that are extremely vulnerable to climate change (UNDESA 2015). Neither the OECD nor IMF explicitly includes vulnerability to climate change as a priority (OECD 2015).

1 This column first appeared on VoxEU 17 March 2021 https://voxeu.org/article/debt-natural-disasters-and-special-drawing-rights

We need a new classification of vulnerability – one that is focused on the likelihood of a substantial loss and damage from climate change. Not only will this better target support to where it can make the most significant difference, but highlighting present loss and damage will help to shake the world out of a dangerous complacency. And this must be coupled with policies that are more focused on where the vulnerability lies and building resilience, some of which I describe below.

Higher temperatures will first become insufferable where it is already warm. Warming will initially benefit places that are currently cold.[2] And because of the earth's rotation, when the polar ice caps melt, sea levels will rise near the equator (Spade et al. 2013). North of the Tropic of Cancer and south of the Tropic of Capricorn, the horror of climate change is forecast, not current, and based on models and theories few understand. Consequently, the sense of urgency is not there from those who need to make a difference today.

The frontline in the war against climate change currently lies between the tropics. That is where sea levels have risen the highest, increasing temperatures do the greatest harm, and flooding, droughts, or forest fires have intensified the most. Extreme weather events caused $320 billion of losses and damage around the world in 2017, but $215 billion, or 67%, occurred in the Atlantic hurricane belt, with a country like Dominica losing 226% of GDP in a few hours (Löw 2018). Climate change is the lived reality for these places; denial is rare.

For those on the frontline, there is a nasty nexus between climate change and debt. The cost of environmental damage, the loss of revenues from a natural disaster, and the high price of building back better is a contributor to higher debt (Stiglitz and Rashid 2020). It is no surprise that the countries defined as the most environmentally vulnerable by the UN Environment Programme and others have the highest debt levels.[3]

While it would be wrong to suggest that they have no choice or policy space, these countries are caught in a vicious cycle. Climate-change vulnerable countries have been using debt to absorb the impact of external shocks and natural disasters. The role of the state as a shock absorber is particularly acute in small states. When a disaster strikes there is no place to hide – hurricanes are many times wider than most small island developing states – and the depth and absorptive capacity of the private sector in small places are thin (Acevedo et al. 2013). Debt-constrained fiscal policy severely limits investment in resilience.

2 The IPCC pointed out in its 2007 Synthesis Report, supra note 2 (p. 69), that "for increases in global average temperature of less than 1 to 3°C above 1980-1999 levels, some impacts are projected to produce market benefits in some places and sectors while, at the same time, imposing costs in other places and sectors…." There will be benefits to some crops grown where there may be improved water availability, longer frost-free periods and longer growing seasons.

3 In the Caribbean for instance, seven out of ten countries are categorised as having high or extreme environmental vulnerability have a debt-to-GDP ratio of over 60%, which is often considered a threshold for debt sustainability (Munevar 2018). See also Pratt et al. (2004).

All this leaves these countries exposed to large-scale natural disasters that put at risk their environmental, economic and social viability. This genuine risk lowers their credit rating more than high debt levels on their own would justify (Moody's 2016), increasing the cost of external financing for resilience building and narrowing the fiscal space further.[4]

We propose three ways to break the climate-debt nexus.

1. Redistributing special drawing rights using a new classification of vulnerability
First, countries that have suffered substantial loss and damage from a climate event need immediate and cheap liquidity.

The Trump administration blocked the special drawing rights (SDR) allocation last year, despite efforts by IMF Managing Director Kristalina Georgieva and other proponents. The G20 has now agreed to a new allocation of special drawing rights. While the precise scale of the new allocation has yet to be agreed upon, it is likely to be above $500 billion but below $650 billion – the total value of IMF quotas – as that would require approval from the US Congress which would delay or derail the decision.

The newly issued special drawing rights will be allocated according to IMF quotas, meaning that the entire emerging and developing world would receive less than the combined quotas of the EU, UK, and US, who do not need it. Still, $500 billion is not to be sniffed at. It is twice what was issued in 2009 and can boost reserve assets significantly, even in small developing countries.[5] But we need a mechanism that will redistribute special drawing rights from those that do not need them to those that do.

We propose that the world's strongest economies, led by the US, lend the new SDR allocation to an IMF-administered global disaster mechanism. The global disaster mechanism will provide immediate, unconditional liquidity to those countries suffering loss and damage greater than 5% of GDP on the independent declaration that a climate or natural disaster event has occurred. Today, natural disasters must include pandemics, and the global disaster mechanism should be able to refinance the additional debt incurred during COVID-19 for the countries impacted by more than 5% of GDP (Djankov and Panizza 2020).

Rightly or wrongly, creditors will feel more comfortable with the special drawing rights being managed by an IMF trust. Lending could be capped at a particular multiple of IMF quotas and on floating money market rates with no fixed repayment period. Currently, middle-income countries that are extremely vulnerable to climate change have limited access to concessional financing like the Rapid Credit Facility, and even the less concessionary Rapid Financing Instrument limits funding to only 60% of the quota. This

4 Munevar (2018) describes this interplay well.
5 Commentators in countries with continuous access to international capital markets think that special drawing rights are meaningless, but as I have seen first-hand, they play an important role in the reserves and borrowing capacity of many developing countries.

is woefully mismatched to the potential scale of a climate disaster. The global disaster mechanism would be more fit for purpose: targeted to vulnerability, fast, substantial, cheap, and unconditional.

2. Innovation in lending instruments by the multilateral development banks

At times like these, the private sector pulls in its horns and the only ones with an appetite to lend are the multilateral development banks (MDBs). And while the MDBs think of themselves as highly innovative, borrowers are not always so convinced. One fast way MDBs can provide needed liquidity in a crisis is by writing natural disaster clauses in their lending arrangements.

Barbados is now the world's largest issuer of sovereign bonds with natural disaster clauses. The external bonds have been trading with these clauses for over a year without signs of any 'cost'. (We understand, however, that natural disaster clauses probably improve the credit quality of a sovereign-issued instrument in a way that would not translate to an MDB.)

Under the Barbados version of these clauses, when an independent agency makes the declaration of a natural disaster, there is an immediate two-year suspension of debt servicing. The maturity of the instrument is then automatically extended for two years. In Barbados's case, this allows 7% of GDP to be redirected to relief and reconstruction costs. The Barbados clauses inserted in 2019 did not include pandemics. We have learned that these clauses should be written more generally to cover other unforeseen disasters while ensuring that the definition is only to cover rare, 'external' events.

3. Financing resilience in the world's most vulnerable countries without adding to their debt

Before a disaster, and hopefully lessening its impact, countries need financing to build resilience. But most don't have space for more public debt (Ocampo 2021).

The world's strongest countries, led by the US, should use their unused special drawing rights to recapitalise regional development banks, with the new capital going towards resilience-building projects in the private sector, where the debt sits on the private sector's balance sheet. These may include public–private partnerships where, for instance, in return for the state playing a convening role, organising and requiring all utilities to underground lines together in the same conduit, the private sector will share the costs amongst themselves.

Maturities of this lending must be commensurate with the long-term returns of these projects. We suggest a definition of a climate-vulnerable country as one facing a high probability that they will suffer a climate event that leads to a loss and damage of greater than 5% of GDP within the next five years.

While these three proposals require no new budgeted resources from the world's strongest economies, they offer substantially more emergency liquidity and will build targeted resilience without adding onerously to already high debt levels. They may help to loosen the dangerous nexus between climate and debt.

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CENTRE FOR ECONOMIC POLICY RESEARCH

Concerns surrounding climate change have heightened considerably in recent years, with a universal view emerging that human behaviour is accelerating global warming at an alarming rate. Left unchecked, the current trajectory could result in irreversible damage to our planet and potentially dire consequences for the millions who inhabit it.

CEPR, and economics more generally, has devoted more and more attention to understanding the short- and long-term effects of climate change on the economy, migration and inequality, all of which will affect societies worldwide. A greater research focus is now being applied to understanding the costs, benefits, and trade-offs of climate policies. However, as evidenced by this eBook, a comprehensive solution to combatting climate change across sectors remains elusive.

Published during the 2021 COP26 summit in Glasgow, this eBook provides a selection of solution-oriented research studies first featured on CEPR's policy platform VoxEU.org, which highlight key policy issues for governments going forward, as well as detailed analyses of the effectiveness of policies currently in place. The eBook also provides a fascinating insight into the evolution of economic research on climate change over the last decade, and most starkly highlights the shift in urgency and appreciation of this daunting threat to humanity.

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