Economics and climate change

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This lecture looks at economic aspects of the challenge of global warming. It is our own technological, scientific and economic success that is causing the problem – so many of our activities rely on energy from burning fossil fuels. How to escape this reliance and replace fossil fuels with alternative sources of energy? Can we save ourselves (and future generations) by reducing consumption? What regulatory measures will produce the necessary changes with the least social and economic cost?

And how big should these changes be? For example: should we stop insisting on economic growth as the key goal of economic policy? All these are clearly questions for economists, among others. Over the last century, economic management has become the central task of government and economics has positioned itself as chief among the sciences advising government. But it has been very slow to respond to the challenge of climate change. Over the last twenty years, as climate scientists have been speaking with growing alarm of the dangers facing us, economists in general have continued to debate whether and when we should start to take action to avert it. One honourable exception: William Nordhaus (Nobel Prize for Economics, 2018).

(Why do neither the Economics nor the Politics Departments at Warwick have a full time member of staff who lists the economics and politics of climate change as a principal academic interest? Climate change is the greatest threat to humanity since the Black Death – shouldn't the university be taking it more seriously?)

What contribution can economics make to understanding the challenges of climate change? Here are three areas.

1. Game Theory
2. Externalities
3. Cost benefit analysis and the discount rate.

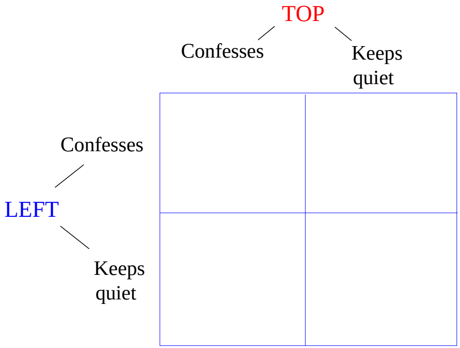
1. Game Theory

Game theory models the behaviour of competing individuals by assuming they are rationally seeking to maximise a payoff, often financial. In the following example they seek to minimise a prison term.

Example – The Prisoner's Dilemma

The *Prisoner's Dilemma* is a famous example in Game Theory, designed to show that when two individuals compete, each seeking to maximise his own profit, the outcome may be far from optimal.

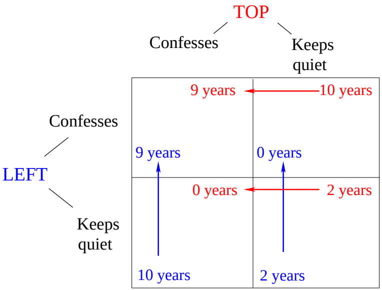
Two burglars, Top and Left, rob a house and are arrested. They are interrogated separately. Each has 2 options, to confess or to keep quiet, so four outcomes are possible.



To secure a confession, the authorities threaten the following jail terms:

		TOP: Confesses	TOP: Keeps quiet
LEFT	Confesses	TOP: 9 years; LEFT: 9 years	TOP: 10 years; LEFT: 0 years
LEFT	Keeps quiet	TOP: 0 years; LEFT: 10 years	TOP: 2 years; LEFT: 2 years

What do the prisoners do? What are their incentives?



Top reasons, correctly, as follows: Left will either confess or keep quiet. If Left confesses [top two squares in the table], I get 10 years if I keep quiet, and 9 if I confess. So, better I should confess. On the other hand, if Left keeps quiet [bottom two rows of the table] then I get 2 years if I keep quiet, and 0 years if I confess. So, again, better I should confess. *Whatever Left does, Top does better to confess*. The same applies the other way round. So both Top and Left confess, and both end up with 9 years in jail, instead of the 2 years they would have got if they'd both kept quiet. The important conclusion from this is that *by each one pursuing his own selfish advantage, both have ended up much worse off than if they had been more trusting and altruistic*.

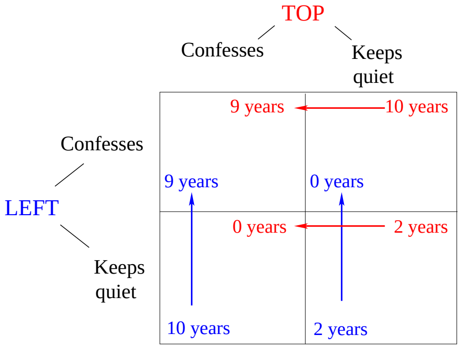
Nash Equilibrium

In a competitive game, players have to choose a strategy; these choices determine the outcome.

A set of strategies (one for each player) is a **Nash Equilibrium** if once they are adopted, no player can improve his outcome *by changing only his own strategy.*

So a Nash equilibrium is best for everyone?

Not necessarily. In the prisoner's dilemma, **L: Confess, T: Confess** is a Nash equilibrium. "The rational player follows the arrows."



Of course, if the prisoners were climate activists instead of criminals, another kind of rationality might intervene: we imagine they would show more solidarity and more trust than these two. But this artificial example shows that a Nash equilibrium, which, for better or worse is where we generally end up, may be very far from optimal.

Like all mathematics, Game Theory takes complicated situations and abstracts: simplifies, throws away detail – to reveal underlying structures. We can then see the same structures appearing in many different contexts. For us, the following instance of the prisoner's dilemma is probably the most interesting.

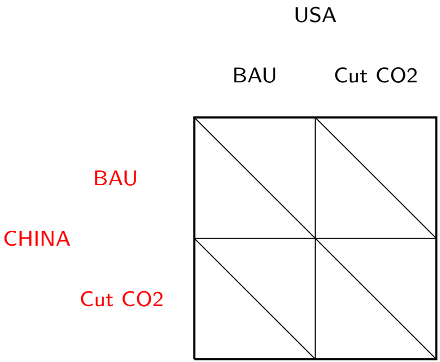
The Polluter's Dilemma

Exactly the same structure as in the prisoner's dilemma can be seen in the context of climate change. We can re-cast the prisoner' dilemma as the *Polluter's Dilemma*, with two new protagonists, this time called China and the USA. In the following diagrams, we schematically illustrate the annual growth rates that two imagined competing economies might achieve, depending on whether they continue Business As Usual, BAU, or Cut their CO2 emissions.

The Polluter's Dilemma

		USA	
		BAU	Cut CO_2
CHINA	BAU		
	Cut CO_2		

The Polluter's Dilemma



The Polluter's Dilemma

		USA	
		BAU	Cut CO_2
CHINA	BAU	Result for USA Result for China	Result for USA Result for China
	Cut CO_2	Result for USA Result for China	Result for USA Result for China

The Polluter's Dilemma

		USA	
		BAU	Cut CO2
CHINA	BAU		
	Cut CO2		4% / 4%

The Polluter's Dilemma

USA

CHINA		BAU	Cut CO2
	BAU		0% / 6%
	Cut CO2		4% / 4%

The Polluter's Dilemma

CHINA \ USA	BAU	Cut CO2
BAU		USA: 0%, CHINA: 6%
Cut CO2	USA: 6%, CHINA: 0%	USA: 4%, CHINA: 4%

The Polluter's Dilemma

		USA	
		BAU	Cut CO_2
CHINA	BAU	2% / 2%	6% / 0%
	Cut CO_2	0% / 6%	4% / 4%

As before, whatever China does, the USA does better by continuing BAU, and vice versa. So both countries end up with poorer growth rates than if they had cooperated by reducing emissions – and with rampaging climate change, as we are seeing today.

More realistic numbers

There is no need for the table to be symmetrical. The structure is rather robust. Here we give the two countries different numbers, but the incentives remain the same.

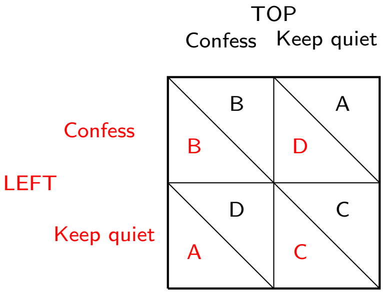
		USA	
		BAU	Cut CO2
CHINA	BAU	4% / 2%	10% / 0%
	Cut CO2	2% / 5%	8% / 3%

And as before, the likely outcome is to everyone's disadvantage.

Exercises

Here are some exercises for you to better understand the prisoner's dilemma.

1. Imagine you are the police chief responsible for fixing the prison terms with which you hope to obtain confessions from the two burglars. You have to choose the lengths of four prison terms – the four distinct numbers labelled A, B, C, D in the following diagram.



What relation must these four numbers bear to one another, in order to induce both prisoners to confess?

2. The same structure as in the Prisoner's Dilemma applies in yet another context. To explain it, we change our terminology: instead of " keeps quiet" or "confesses", as in the original Prisoner's Dilemma, we say "cooperates" or "defects".

Two companies, Giant plc and Huge plc, compete, selling the same product. If they cooperate with one another, they can both sell at a high price and make large profits. But if one defects by undercutting the other, it will sell more, and do better than its competitor. Can you make up plausible levels of profit in the following table so that the outcome, as in the Prisoner's Dilemma, is a "sub-optimal Nash Equilibrium"?

		Huge plc	
		Defect	Cooperate
Giant plc	Defect		
	Cooperate		

(Cooperating is called "forming a cartel" in this context, and is against the law. Companies may not communicate their pricing intentions to one another. This means the incentives operate just as in the prisoner's dilemma, in this case to the advantage of the public.)

End of Exercises

How do players arrive at a Nash equilibrium?

Not necessarily through rational evaluation of the available strategies.

Players in repeated games may reach a Nash equilibrium through trial and error – or just plain error – and it may be hard to escape from. Evolutionary Game Theory studies how this occurs – and how ‘players’ (societies, species, political parties, competing companies . . .) can sometimes avoid falling into a damaging Nash equilibrium, for example by evolving altruism.

Sub-optimal Nash equilibria in Public Goods games

Key idea: players reap the benefits of their actions for themselves, but share the costs among many . . . "Keep the gain, share the pain".

1. "Tragedy of the Commons"

Villagers graze their animals on shared common land. If I graze my animals,

Benefit (all to me): My animals grow fat

Cost (shared among all): Depletion of pasture

Outcome (if there is no restraint): Overgrazing and loss of shared resource.

2. Downward wages spiral

Companies compete by downsizing and lowering the wages of their employees.

Benefit (all to company which lowers wages): We reduce production costs, leading to lower prices, higher market share and greater profits

Costs (shared among all companies) Workers' purchasing power is reduced; (but my company suffers only a small part of the resulting loss of business).

So it is in each company's individual interest to downsize.

Outcome (if there is no restraint): All companies do the same, leading to economic downturn in which all suffer. "Restraint" could be minimum wage, or Trades Union.

3. The Diner's Dilemma, or, How we ate the world

Six friends dine together in a restaurant, agreeing to share the bill equally, but making their choices individually. There are two options:

Quite expensive meal, costing e and yielding pleasure p

Very expensive meal, costing E and yielding pleasure P

Which to choose? Suppose $E > P > p > e$

So if paying alone, I would choose the smaller meal.

When we split the bill, if I choose the bigger meal, the bill increases by $E - e$, so the extra cost *to me* is $(E - e)/6$.

So if

$$P > e + (E - e)/6$$

I choose the bigger meal.

The same incentives apply to all the diners. We all choose the more expensive meal. We all choose a meal that we would have preferred not to have to pay for. As soon as we leave the restaurant we regret it!

All of these model games are highly simplified versions of real situations, and the behaviour of real people will deviate from the behaviour the models predict in all sorts of ways. Some will be more generous, trusting, determined, etc., and some less. But the theory is that in aggregate, these deviations will cancel out, and thus the model games do give us some information about large scale behaviour. That is why they are useful in economics.

What do they tell us about climate change?

The lesson of public goods games applies in two aspects. First, in the use of fossil fuels: the user gains all the energy they generate, but shares the cost, in terms of CO2 emissions, with everyone else in the world. So there is an incentive to pollute.

Second: the model applies in reverse, to efforts to reduce emissions: their cost is borne by the country which puts them into practice, but the benefit is shared across the world. Crudely: for every dollar that China spends on emissions reductions, it gets 18 cents worth of benefit, as it has 18% of the world's population. But for every dollar that the UK spends, it gets 1 cent's worth of benefit. "Keep the pain, share the gain".

If nations allow these incentives to dominate their policy-making, the world will fail to deal with the challenge of climate change. This is the "tragedy of national horizons".

If we insist on "America First" or "India First", we may remain stuck in a sub-optimal Nash equilibrium. Negotiation and trust will be indispensable if we want to leave it.

2. Externalities

Climate change is the greatest market failure the world has ever seen. (*Stern Report,*, Executive Summary, page viii).

An externality is a cost, or benefit, from a transaction, which is borne, or gained, by someone who is not a party to the transaction. Thus, although these costs and benefits may be significant, they will not enter into the accounting which determines whether to carry out the transactions.

Examples

1. A company selling take-away food in plastic wraps benefits from not having to do the washing up. Instead, it exports the cost to the municipality which clears the resulting litter from the streets. The cost of clearing the litter is not paid by the restaurant or its clients, except as a tax paid by everyone for municipal services. “Privatise the gain, share the pain”.
2. Parents who vaccinate their children help unvaccinated children by reducing the spread of infection, at no cost to the latter. ”Privatise the pain, share the gain”. The unvaccinated children and their parents are “free riders”, benefiting from the efforts and risks of others.
3. Bees kept to produce honey will pollinate crops and fruits in nearby fields and orchards. This too is a beneficial externality.
4. The example that concerns us here: pollution by industry or mines, affecting people in the locality, or all over the world in the case of carbon emissions.

Economists view all externalities as “inefficiencies”. If the cost of the polluting from industry or fast food outlet were borne by the polluters, they would pollute less. If the value of the good which is given for free (herd immunity or crop pollination) were paid to its producer, more of the good would be produced.

There are several standard procedures for dealing with this inefficiency.

1. Regulation to limit the activity giving rise to negative externalities.
2. Changes to the accounting procedures to "internalise the externality" – to make the polluter pay.
3. When a negative externality affects a small group – for example, noise pollution from a factory – it may be possible for polluter and victim to agree compensation. Sometimes this comes about through a lawsuits brought by the victims; these can lead to settlements which remove the price advantage to the polluter. This has happened with tobacco: cancer victims have won enormous sums from manufacturers in compensation for their smoking-induced cancer, as have the victims of asbestosis. This approach is favoured by libertarian economists, since it by-passes the state.

In the case of climate change, direct negotiation between the polluters and the totality of the victims is impossible: some (most?) of the victims have not yet been born, and others are not in a position to hire a lawyer. Even so, this approach has some supporters, and some possibilities of success in specified cases where the damage is concentrated. If warming leads to the end of winter sports industry in the Alps, the bankrupted businesses would perhaps have a strong enough case to sue e.g. ExxonMobil. The same may be the case for island nations at risk of sinking beneath the rising seas. James Hansen has written recently urging lawsuits of this kind as a means of preventing environmental catastrophe – see links on *Climate Change in the News* (via GD305 Moodle page).

Lawsuits aside, the two other approaches, regulation and "internalisation of the externalities" both involve strong centralised action by government, and indeed, coordination between governments. Is it a coincidence that just as climate change becomes a pressing problem requiring government action, powerful political currents in the US have developed the philosophy that, in the words of Ronald Reagan, it is government itself that is the problem? It certainly seems unfortunate.

Three forms of government action to reduce emissions: carbon taxes, emissions trading schemes and regulation. Which is best? One of the lessons of 20th century economic history: top-down regulation rarely works – businesses know their own needs and abilities better than governments do.
Jean Tirole, in Economics for the Common Good:

> *Take two companies, each of which emits two tons of carbon, and assume we want to reduce their total combined pollution from four tons to two. Suppose the first company has a cleanup cost of $1,000 per ton, while the second company's cost is $10 per ton. A "fair" policy might consist of requiring each company to reduce its pollution by half, thus "equitably" distributing the effort made and generating a total cleanup cost of $1,010. Obviously, efficiency requires that the second company should eliminate its two tons of emissions, at a total cost of $20, and that the first should not do anything, thus saving society $1,100-$20=$990 in comparison with the top down policy.*

Government regulation is needed to encourage companies to reduce their emissions, but government should leave the detailed decisions about who reduces by how much to the companies themselves, so that they can do so at minimal cost.

Angel Gurria, president of the OECD, in a speech on climate change on November 1st 2017, makes a similar point:

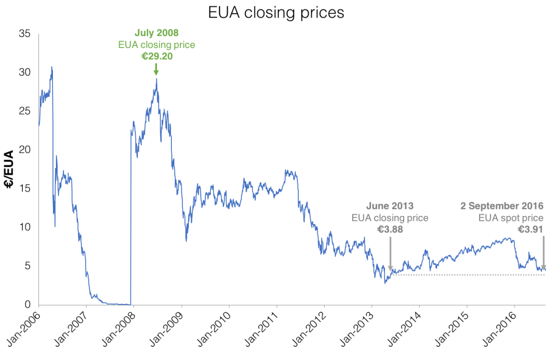
> *NDC's result in different marginal costs of mitigation across countries. The economic efficiency of Paris would be significantly improved if the international community could establish a process of convergence of carbon prices across countries. That would halve the cost of achieving the stated targets.*

https://www.youtube.com/watch?v=wI227Dgt6pE

This, supposedly, is what a Carbon Tax, and Emissions Trading Schemes (Cap and Trade), can do. Whether they work sufficiently well in practice is still the subject of disagreement. The ETS introduced in the US to limit sulphur emissions by power stations (to combat acid rain) has apparently been effective (https://www.epa.gov/airmarkets/acid-rain-program): from 1990 to 2015, SO2 emissions emissions decreased by 86% and NOx by 79%.

In the case of the European ETS, the price of permits has suffered several collapses; in May 2017 it was $4.40/tonne of carbon. Since then it has increased, reaching $20/tonne in August this year. But still not a significant stimulus to de-carbonise. From same speech of Angel Gurria:

> *The Europeans have tried four times to get the ETS [working] and they still cannot get to double digits [...] Put a big fat tax! Why don't they do it? Because politicians don't like the word Tax. They think it's a four letter word. So they go to these ETS's which don't work, [...] either because the economy didn't grow as fast, or because they emitted too many permits ...".*



Source: https://sandbag.org.uk/2016/09/02/eu-carbon-price-falls-below-e4-2/

The price is subject to constant political lobbying by countries trying to protect their fossil fuel producers. The volatility of prices discourages long term investment; low prices encourage the wrong kind of investment, leaving the economy locked in to high carbon power generation.

(Sweden instituted a carbon tax in 1991. The general rate of taxation is now 120 Euros/tonne. Its economy has not collapsed. Why not? How has it integrated the carbon tax with the rest of its tax régime?)

How likely is it that a carbon tax will be agreed among the parties to the UNFCCC? Who makes the decision in each country? It is a decision for politicians, but one which is very hard to make: a forced compromise between incompatible demands from scientists and businesses.

In 1998 the Chancellor in the incoming Labour Government, Gordon Brown, handed over control of interest rates to the Bank of England, to guarantee that they would be set according to economic rather than political factors. Can a similar argument be made, that the decision on the level of carbon tax should be taken out of the hands of politicians and handed over to a committee, say of scientists, economists and business leaders, not subject to perverse electoral incentives?

3. Cost-benefit analyses and the discount rate

Economists try to locate the point of compromise on the basis of cost-benefit analyses. These compare the costs of action – in financing new technology, in reduced revenues from phasing out fossil fuels, etc – with the costs of inaction – damage to the economy from climate change. The difficulties of doing this are compounded both by the uncertainty in climate science, and by the fact that some of the damage will take place in the distant future. Here lies one of the greatest areas of disagreement between economists.

In all cost-benefit analyses, future costs and benefits are discounted – negative compound interest is applied to their future value in order to determine their present value. The interest rate is called the discount rate.

There are different justifications, and hence argument over the rate itself:

- "Rather than spending now, we could invest, let the money grow, then spend larger amount later. So the discount rate should be (at least) current rate of return on capital."
- Pure time preference: "We would rather worry about tomorrow's problems tomorrow".
- "In 100 years, people will be richer. Why spend today's poor peoples' money to look after tomorrow's richer people?" (Nigel Lawson)
- Some unforseeable event may change everything, in which case the money spent will go to waste.

Example: to prevent £100 worth of damage today, we would pay up to £99. We are less willing to spend today to prevent £100 worth of damage next year. How much less? This is the discount rate. If willing to spend only £90, the discount rate is 10%. To prevent £100 damage in two years time, we would spend 90% of 90% of £100, i.e. £81. (this is compounding).

In his *Report*, Stern used an average discount rate of 1.4%. This means that to avert £100 of damage in 10 years time we should spend £87 now. The 1.4% discount rate turns £100 into £87 over 10 years through compounding: repeating the multiplication as many times as there are years. A discount rate of 1.4% means that each year we multiply by 1 - $(\frac{1.4}{100}) = 0.986$. Then

$$\underbrace{0.986 \times 0.986 \times \ldots \times 0.986}_{\text{ten times}} = 0.87$$

Stern was criticised by some other economists, especially from the US, for his low discount rate. William Nordhaus, using his DICE (Dynamic Integrated Climate Economy) model, argued it should be 5.5%. (The DICE model apparently predicted 10% drop in world GDP at 6 degrees warming.)

Over 10 years, 5.5% would turn £100 into about £56 - not so far from Stern's £87. But over climate policy timescales, the difference becomes dramatic. Over 85 years, Stern's 1.4% turns £100 into £30; Nordhaus's 5.5% turns it into 81p.

Stern's *Report* contains a long and technical discussion of the discount rate (or discount factor) on pages 42-52, from which it is hard to extract a pithy quote. However, (*op cit*, p. 47)

> *If the ethical judgement were that future generations count very little regardless of their consumption level then investments with mainly long-run pay-offs would not be favoured. In other words, if you care little about future generations you will care little about climate change. As we have argued, that is not a position which has much foundation in ethics and which many would find unacceptable.*

(op cit, p. 47). Nigel Lawson, former Chancellor of the Exchequer, in "An Appeal to Reason – a Cool Look at Global Warming":

> *[. . .] it has been demonstrated that with a higher, more normal discount rate, the argument for radical action over global warming now, on conventional cost-benefit calculations, collapses completely.*

See especially Chapter 7 of his book for a clear exposition of the conservative position on the discount rate.

At the root, there is a philosophical disagreement between "welfare economists" such as Stern, and others, like Lawson, but predominantly from the US, who argued that Stern was imposing moral value judgements rather than just doing economics. They believe that the discount rate should be determined by current economic indicators, including e.g. the rate of return on capital, because these measure how society places value on the future, and it's not up to economists or governments to tell society it is wrong.

Richard Tol, Professor of Economics, University of Sussex, "IPCC report shows Stern inflated climate change costs", http://theconversation.com/ipcc-report-shows-stern-inflated-climate-change-costs-25160):

> *Stern's argument for a low discount rate is a paternalistic one. People's value judgements are wrong, according to the Stern Review, and the government has the right to overrule them. Stern puts himself in the position of a colonial ruler, governing the savages against their will – but in their own interest, of course.*

Here Tol attempts to undermine the case for welfare economics with brutal language rather than with reasoned argument. But the game theory sketched at the start of the lecture, and the experience of the last 30 years, suggests that indeed, people guided by their own self interest, or even, less egotistically, by their perceived national interest, may act in a way which is contrary to those interests. It is not necessary to view one's fellow citizens, or oneself, as a savage, to believe that some guidance is appropriate.

Martin Weitzman (Professor of Economics at Harvard), in the European University Institute, Fiesole, in 2015: (worth watching: https://www.youtube.com/watch?v=pmtpKPEVSPU)

> *If you take a discount rate of 6% or 7%, which corresponds to the rate of return on capital and stock markets over long terms, the social cost of carbon, if you calculate it according to US methodology, it comes out to about $1; if you take a 1% discount rate, the social cost of carbon is something like $600 or $700. Depending on what discount rate you choose, you can get almost any answer.*

Given this level of uncertainty and disagreement, of what use are economists' cost-benefit analyses? How should governments make decisions? They should not pretend that their decisions are value-free!