The energy mix, carbon pricing and border carbon adjustments

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1 Introduction

Human civilisation is powered by fossil fuels. Over the past 100–200 years, the vast increases in material standards of living in the West were made possible by the efficient utilisation of energy and the dramatic falls in the cost of energy services.[1] Over the last 10–20 years, the rapid industrialisation of economies such as China and India, with corresponding increases in material living standards and reduction of poverty, have also been driven by fossil fuels and, in large part, by the dirtiest of them all – coal. These developments have been a wonderful boon for humanity, but have some very negative side effects that are already causing harm today (eg local pollution and corresponding health problems, leading to deaths from coal mining) and are storing up major problems for tomorrow, particularly in the form of future climate change impacts.

I have been asked to address the question of the 'energy mix', which I discuss directly in section 2 below. I will look at this from a global (section 2.1) and briefly from a UK (section 2.2) perspective, and from a historical point of view as well as considering some potential scenarios for the future. The data suggest that we appear to be heading into a world of significantly increased mean surface temperatures – of perhaps 3–4°C – with potentially severe consequences for the climate and water systems in large parts of the world. This is despite the best efforts over 20 years of international negotiations on climate change, since the United Nations Framework Convention on Climate Change opened for signature in 1992.[2]

In section 3 below I consider how a start to shift away from that fossil-fuel-intensive pathway might be achieved, building on joint research with Dieter Helm and Giovanni Ruta.[3] The focus in this article is on carbon pricing and border carbon adjustments, which is not to deny the importance of much greater research and development (R&D) in renewable technologies, accompanied by policies to stimulate cost-effectively the switch from dirtier to cleaner energy today. I will present a simple game-theoretic model of how a border carbon adjustment in one region could stimulate carbon prices to spread into exporting regions. Dieter, Giovanni and I advance the argument that, given the failure of other, more convivial and friendly efforts to address the problem collectively, border carbon adjustments are now worth serious consideration.

2 The energy mix

2.1 Global energy system

The global energy system is resoundingly based on fossil fuels. Figure 1 shows the world's primary energy demand in 2009, which comprised approximately 33% oil, 27% coal, 21% gas and 10% biomass, with the remaining 9% split between nuclear (6%), hydro (2%) and other renewables (1%).[4] Pondering these facts can serve as a helpful reality check to environmentalists. It is clear that, despite all the effort that has gone into supporting and building renewable technologies in recent times, this is still a very, very fossil-fuel-driven system.

Unfortunately for those seeking to shift the balance in the global energy system towards low carbon sources, there is considerable inertia and 'lock-in' in this system. Because energy sector assets, such as power stations, often have a lifetime of several decades, the major opportunity to shift the energy mix is found in those countries with growing energy demand. These countries are adding the power stations now that will still be operating in 2050 and, as discussed below, the large majority of this new capacity has been and, indeed, will be fossil-fuel powered.

Another important feature of the global energy system is that the vast majority of increases in future consumption – around or above 90% according to the IEA[5] and BP[6] – is expected from growth in non-OECD countries, as shown in Figure 1. That non-OECD economies are driving energy growth is a notable area of agreement found among almost all major projections.[7] An entire 50% of the growth in final energy consumption is expected to be driven by two countries alone – China and India.[8] In other words, what happens in China, India, Brazil and the other large non-OECD countries, will have an enormous effect on the global energy mix over the next 50 years. And it is the global energy mix over the

1 R Fouquet *Heat, Power and Light: Revolutions in Energy Services* (Edward Elgar Publications Cheltenham 2008).
2 Entered into force 21 March 1994.
3 D Helm, C Hepburn and G Ruta 'Trade, climate change and the political game theory of border carbon adjustments' (2012) 28(2) *Oxford Review of Economic Policy* (forthcoming).
4 International Energy Agency *World Energy Outlook* (OECD/IEA Paris 2011).
5 ibid.
6 BP Energy Outlook 2030 (London January 2012) available at http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/O/2012_2030_energy_outlook_booklet.pdf.
7 The existing set of energy sector forecasts may be far from reliable in other areas, however, and a backcasting exercise to test their accuracy might be very illuminating.
8 ibid.

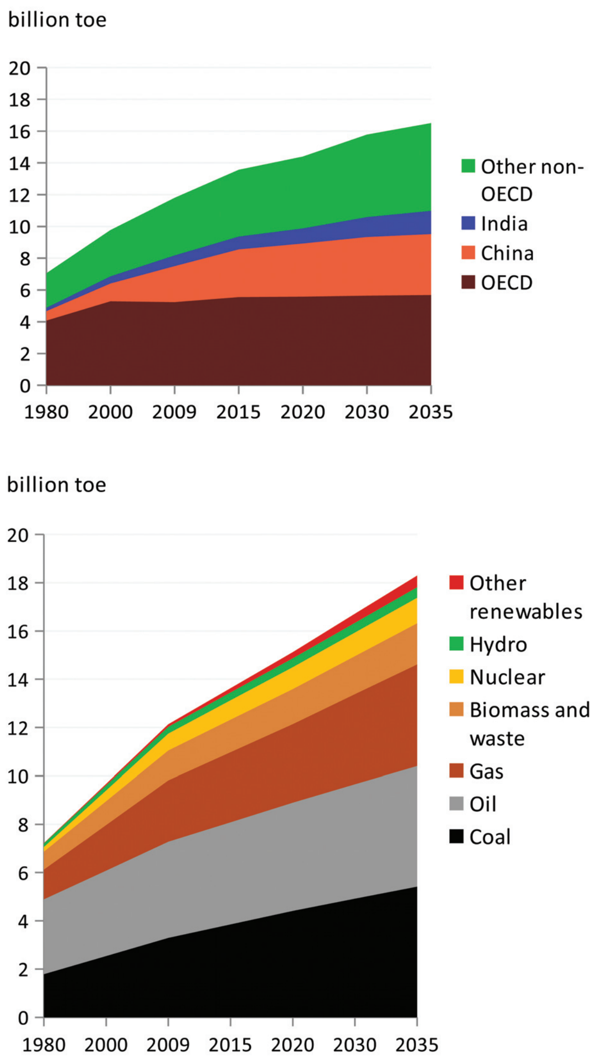

Figure 1: World primary energy demand projections (IEA (2011) New Policies Scenario)[9]

coming decades that determines, in large part, the scale of the temperature increases that will ensue, and hence the frequency and severity of extreme weather events and so on.

The other sobering thing that emerges from any cursory review of the data and projections is that, even with all of the current and projected effort and investment in renewable energy, more fossil fuel will probably be added to the global energy system than non-fossil fuel over the next couple of decades.[10] Indeed, in the first decade of the twenty-first century, almost half of the growth in global energy demand was satisfied by additional coal,[11] the dirtiest of the fossil fuels. One obvious implication is that far from reducing greenhouse gas emissions, as required to stabilise concentrations of greenhouse gases in the atmosphere, not only are emissions continuing to be pumped out into the atmosphere at a rapid rate, but business-as-usual means that substantially more, rather than less, will be emitted in the coming decades.

These data and projections can be examined from different angles. Some of these angles suggest that while it is largely bad news, it is not all bad news. For instance, examining the share of clean energy over time tells a more positive story. The share of clean energy (in the form of renewables and nuclear) is rising, while the share of the dirtiest energy sources (coal and oil) is falling. The share of gas is rising. As gas is the cleanest of the fossil fuels, in the short term this may also be contributing to reducing emissions on the assumption that it is displacing other fossil fuels, particularly coal.

So, to the extent that the share of renewable energy is on the increase, what is driving it? There are two main factors – support from policies such as feed-in tariffs in richer countries, and substantial cost-reductions in manufacturing countries. Here, China is playing an important and helpful role. It is the largest manufacturer of both wind turbines and solar panels[12] and, in addition to making the equipment at low cost, it is starting to increase renewable energy deployment domestically. For instance, China seeks to increase the proportion of non-fossil energy consumption to at least 15% by 2020.[13] Earlier in 2012, the government announced an increase of 50% in its 2015 solar capacity target (from 10 GW to 15 GW), and in August that target was further increased to 21 GW.[14] Overall, China looks set to have added several hundred gigawatts of clean capacity by 2020. This compares with total capacity of approximately 1000 GW in the US and approximately 80 GW in the UK. So there is considerable investment going into clean energy, which is good. However, at current levels of renewable energy investment, a 2°C limit on global mean temperature increases will not be met.

The aspect of the global energy mix that has been extremely important over recent years is the developments in gas, particularly unconventional gas. These have been much discussed in the popular media and indeed in various notorious films. A good place to start, in order to understand the impact of recent technological advances[15] is to examine changes in prices. Economists tend to be interested in prices because of the information they reveal, and the change in prices in less than a decade tells a remarkable story. In 2000, gas prices in the US,[16] the

9 International Energy Agency (n 4).
10 BP Energy Outlook 2030 (n 6).
11 IEA (2011) (n 4).

12 R Scotney, S Chapman, C Hepburn and J Cui 'Carbon markets and climate policy in China: China's pursuit of a clean energy future' (The Climate Institute and Climate Bridge 2012).
13 The Climate Group 'Delivering low carbon growth: a guide to China's 12th Five Year Plan' (March 2011) available at http://www.theclimategroup.org/...assets/files/China-Five-Year-Plan-EXECUTIVE-SUMMARY.pdf.
14 Reuters 'China hikes 2015 solar power target by 40 pct' (8 August 2012) available at http://in.reuters.com/article/2012/08/08/china-power-renewables-idINL4E8J80J120120808.
15 See eg H Rogers 'Shale gas – the unfolding story' (2011) 27(1) *Oxford Review of Economic Policy* 117–43.
16 The Henry Hub is a distribution hub on the natural gas pipeline system in Erath, Louisiana, owned by Sabine Pipe Line LLC. Owing to its importance, it lends its name to the pricing point for natural gas futures contracts traded on the New York Mercantile Exchange (NYMEX) and the OTC swaps traded on Intercontinental Exchange (ICE).

UK,[17] Germany and Japan and were not vastly different from one another, varying between US$3 and US$5 per MMBTU.[18] Indeed, Japanese and US prices were less than US$1 apart. Ten years later, Japanese prices have risen dramatically to around US$15, while US prices have fallen and indeed had spells below US$2 per MMBTU.

The simple reason for those low prices in the USA is the application of fracking technologies to develop reserves of unconventional shale gas.[19] While there are a range of important environmental and legal issues to manage associated with the exploitation of that resource, there is no doubt that unconventional gas has had a massive impact on the US energy market. These developments have cut greenhouse gas emissions in the US noticeably; it is one of the few, along with the financial crisis, that has delivered a real reduction in emissions. And as time passes, the LNG terminals that were being built in the US to import gas will likely be reconfigured to export the gas to Asia. This should, in due course, eventually bring high prices in Asia down somewhat. This implies that more gas will be used, displacing some coal, and switching from coal to gas is clearly one of the short-term mechanisms for reducing global greenhouse gas emissions.

Note, however, that US shale gas developments do not necessarily reduce emissions everywhere in the shorter term. For instance, shale gas discoveries in the US have led to lower US prices, as has been seen, which implies that the US is starting to use more gas, and some switching from coal to gas is taking place. This process reduces coal prices in the USA. That gives coal players an incentive to export the coal to countries with higher coal prices, and coal prices elsewhere, including in Europe, should also fall. The consequences are that new and increased coal fire burn in Europe is being witnessed and, were it not for the emissions caps in the EU ETS, a rise in emissions. This is not to deny the usefulness of the gas finds, which could potentially have global impacts, but it is a salutary reminder that in the energy system one cannot simply focus on the UK or Europe – all of these energy markets are interconnected, and becoming more so as time goes on.

So, overall, the good news is that there has been more energy from renewables and gas, both of which have an increased share of the global energy mix at the expense of coal and oil. However, importantly, the fact that the share of cleaner energy is rising is not inconsistent with the fact that the global energy system is predominantly fossil-fuelled, and that much more fossil-based energy than clean energy will be developed in the coming decades. In short, the clean energy transition is not happening anywhere near fast enough to constrain a temperature increase to 2°C. That target looks remote at this stage and, furthermore, ensuring that a 3°C increase is not exceeded is now looking challenging.

2.2 The United Kingdom

In the UK, the prospects for a shale gas revolution are less promising than in the USA,[20] and the government has been focusing on the deployment of technologies such as offshore wind to meet government carbon and renewable energy targets. The Committee on Climate Change has set out projections for the energy mix up until 2030 that would be consistent with our legally-mandated carbon budgets.[21] In the electricity sector, this involves decarbonisation to below 100 gCO_2/kWh by 2030, probably around 50 gCO_2/kWh, implying investment in 30–40 GW of low-carbon capacity from 2020–2030. While there would be some coal to gas switching up until 2020, the achievement of these very ambitious targets would be reliant upon a vast increase in low-carbon plant (nuclear, renewables and CCS) from around 15 GW today to almost 60 GW by 2030. A large part of that will be wind, both onshore and offshore, and nuclear. Delivery of these targets is quite another matter. The ongoing Electricity Market Reform[22] process contains several elements that could potentially assist in providing the long-term investment framework required by the private sector. However, tensions at the heart of this coalition government have not helped to send a clear investment signal to date.

While the UK is not unimportant, it is good to keep things in perspective. Figure 2 steps back and compares the UK's total capacity with both clean and dirty capacity today and in the future for China. China already has more clean power installed than the UK's entire electricity system, and clean energy in China may grow by around 400 GW up until 2020. In short, while UK policy is potentially important from the perspective of attracting investment, and especially so in terms of future R&D, global climate change is precisely that – global – and it is far more important to shift China's energy system onto a low-carbon path than that of the United Kingdom.

2.3 Implications of the energy mix

This broad point is no doubt already obvious to many, even if the figures are not widely known. However, I restate it here both because it helps to keep focused on the important points and because it motivates the second part of this article. What matters is *global* emissions, and Figure 3 presents data on past emissions from 1990, in

17 The National Balancing Point, commonly referred to as the NBP, is a virtual trading location for the sale and purchase and exchange of UK natural gas. It is the pricing and delivery point for the ICE (Intercontinental Exchange) natural gas futures contract. It is the most liquid gas trading point in Europe and is a major influence on the price that domestic consumers pay for their gas at home. Gas at the NBP trades in pence per therm. It is similar in concept to the Henry Hub in the United States – but differs in that it is not an actual physical location.

18 BP (n 6).

19 See Rogers (n 15).

20 ibid.

21 Committee on Climate Change 'The Fourth Carbon Budget: reducing emissions through the 2020s' (December 2010) available at http://downloads.theccc.org.uk.s3.amazonaws.com/4th%20Budget/CCC_4th-Budget_interactive.pdf. The fourth budget covers the period from 2023–27.

22 http://www.decc.gov.uk/en/content/cms/meeting_energy/markets/electricity/electricity.aspx.

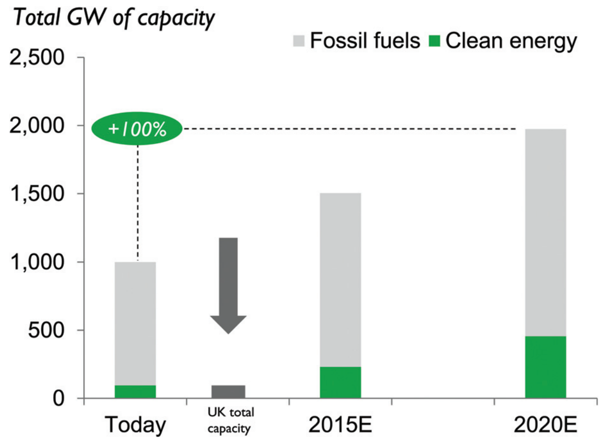

Figure 2: Current capacity and projected supply in China to 2020, compared with the UK. Copyright Climate Bridge analysis, based on the Climate Group (2011).

conjunction with an ensemble of pathways that would deliver a 50% chance of limiting warming to below 2°C.[23] The figure shows that over the decade prior to the great recession, the actual rate of global emissions accelerated.[24] Indeed, our emissions profile turned out to be worse than even the dirtiest of the scenarios by the Intergovernmental Panel on Climate Change[25] that are sometimes very loosely described as 'business-as-usual'.[26] Looking ahead, business-as-usual involves an increase in emissions that would imply implausibly rapid reductions to return to a pathway with a 50% chance of staying below 2°C. Clearly, this is not happening. Indeed, it is not likely to happen. The somewhat sad thing is that, 20 years ago, scientists were plotting charts which, in their broad shape, did not look excessively dissimilar to this one – rapid past emissions, associated with hopeful trajectories where emissions slowed, peaked and started falling. Unfortunately, a plateau is nowhere close, let alone a decline.

Parenthetically, there is a phenomenon in the social sciences and sciences called 'naive hyperbolic discounting', observed in pigeons, monkeys and humans, among others, where animals are more impatient in the short term than they think they will be in the long term. Various mathematical forms can be devised to model this sort of behaviour, and these models explain human phenomena such as addiction, procrastination and under-saving that 'rational' economic theory has difficulty explaining. For instance, humans find it attractive to consume more now and plan to compensate by saving more tomorrow,

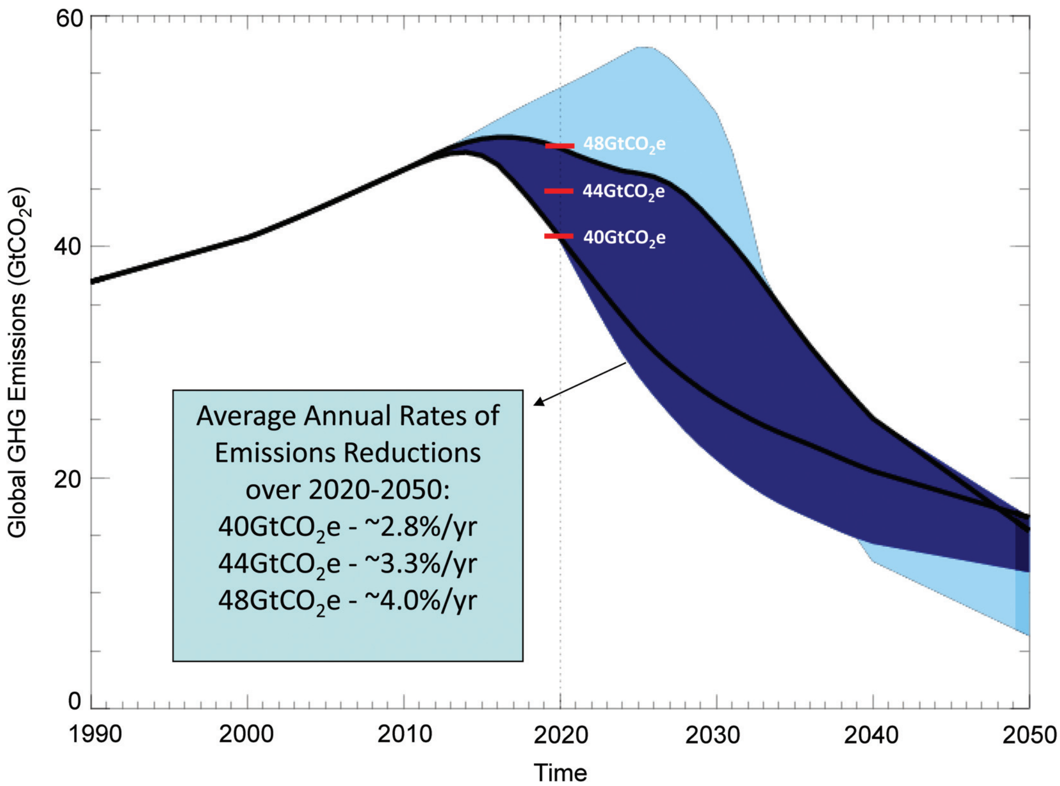

Figure 3: A business-as-usual emissions pathway, compared with a 2°C pathway[27]

23 A Bowen, N Ranger 'Mitigating climate change through reductions in greenhouse gas emissions: the science and economics of future paths for global annual emissions' Grantham/CCCEP Policy Brief No 2 (2009) available at http://www.cccep.ac.uk/Publications/Policy/Policy-docs/bowen-Ranger_MitigatingClimateChange_Dec09.pdf.

24 R Garnaut, S Howes, F Jotzo and P Sheehan 'Emissions in the platinum age: the implications of rapid development for climate change mitigation' (2008) 24 *Oxford Review of Economic Policy* 377–401.

25 IPCC 'Special report on emission scenarios: summary for policy-makers (2000) available at http://www.grida.no/climate/ipcc/emission/index.htm.

26 See also N Nakicenovic et al *Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge, UK 2000).

27 Bowen, Ranger (n 23).

but tomorrow never comes. Applying this theory to renewable resource management, as I have done with colleagues at Oxford, you find that humans may well choose to over-exploit a particular stock (eg a fishery), with a plan to reduce catch levels in the future to allow the stock to return to more healthy (and indeed economically valuable) levels, so that some happy equilibrium is reached.[28] Or, equivalently, the plan might be to emit more than really should be emitted right now and, at some point in the future, reduce emissions so that they are under control, before it is too late. Unfortunately, if the environmental system has inherently long lags, such as the climate (not to mention the lags in the capital assets and infrastructure of the energy system that is causing the problem), it can be 'too late' before anyone realises that the emissions are locked in and the effects will hit us in 30 years' time. I begin to wonder whether climate change and humanity is not just a special case of naive hyperbolic discounting.

The current trajectory is for 3–4 degrees of warming, or possibly even more. Of course, it is not all downside. There are some upsides to warming – the Arctic is opening up, creating new shipping routes, which will be good for global trade. And there is yet more oil up there to be exploited. However, I suspect that readers of this article do not need to be reminded that the earth has not experienced these sorts of temperatures for tens of millions of years[29] and that a 4°C warming would involve a dramatic change in the physical geography of the planet, including with regard to human habitability and economic activity.[30] A range of other major risks, including conflict, could result from reductions in water supply and the need to move hundreds of millions of people to habitable areas. This does not appear to me to be a set of risks that any well-run civilisation would wish to run.

So, given the continual rise in emissions and the continual addition of fossil fuels into the energy mix, one is forgiven for asking whether things could be done better and what might work. Why have existing efforts to shift the energy mix to constrain emissions not (yet) delivered? In the second part of this article I will argue that it is possible to do better. A key part of the problem is that clean technological progress and environmental research and development are not taken anywhere near seriously enough, but this is not the place to address that. The other key part of the problem is that countries and regions that are putting in place ambitious environmental policies spend too much of their time 'playing nice' with those who do not. There is a need to be more pragmatic, more evidence-based and more hard-nosed about climate change. Countries that do genuinely consider this to be one of the most serious problems of this century need to consider using their muscle to spread appropriate carbon prices around the world. And, while difficult, I will argue that this can be done.

One starting point is to shift the focus onto the consumption of embodied carbon dioxide emissions, rather than production, as my colleague and co-author Dieter Helm has persistently argued over the last five years.[31] While there would be little difference in addressing production or consumption of carbon if carbon prices were put in place globally, there are clearly no global carbon prices. In the absence of global carbon trading, one of the key points of leverage in the West is that it is the Western world that is the biggest consumer of carbon embodied in goods and services.[32] Western consumption of carbon is obviously a primary driver of its production, even if that carbon is not produced directly. If the EU were to focus its efforts on ensuring the consumption of carbon were priced, it would have a greater impact on the global system.

However, addressing carbon consumption implies ensuring that carbon prices are imposed on the embodied carbon in all goods and services, irrespective of where they are produced. This involves trade theory, and also game theory, and this is where the picture becomes really interesting.

3 Carbon pricing and border carbon adjustments

I will now explore some simple game theory that might make it easier to understand the potential impacts of a nation or region imposing a border carbon adjustment. First, a few key terms need to be explained. A border carbon adjustment (BCA) is a trade measure that includes a tariff (a tax at the border) on incoming goods based on their embodied carbon – the amount of carbon dioxide that was emitted in the production of the good. A similar form of BCA would be to require importers to purchase permits to cover their embodied carbon, in the same way as domestic producers are required to do. The amount of tax payable, or the number of permits, would reflect the amount of carbon tax already paid in the country of origin. So there would be no need for importers to pay carbon taxes or purchase carbon permits if their home country already has a reasonable emissions trading scheme in place. The net effect is that, for instance, importers of steel or cement into Europe from a country without carbon prices, would need to acquire and retire the full number of permits under the EU emissions trading scheme to cover all of the embodied emissions.

28 C Hepburn, S Duncan and A Papachristodoulou 'Behavioural economics, hyperbolic discounting and environmental policy' (2010) 46(2) *Environmental & Resource Economics* 189–206.

29 J Zachos et al 'Trends, rhythms, and aberrations in global climate 65 million years ago to present' (2001) *Science* 292 (5517) at 686–93; doi: 10.1126/science.1059412.

30 N Stern *The Economics of Climate Change: The Stern Review* (Cambridge University Press Cambridge and New York 2007).

31 D R Helm, R Smale and J Phillips 'Too good to be true? The UK's climate change record' (December 2007) available at http://www.dieterhelm.co.uk/node/656. See also Helm, Hepburn and Ruta (n 3).

32 G Atkinson, K Hamilton, G Ruta and D V D Mensbrugghe 'Trade in "virtual carbon": Empirical results and implications for policy' (2011) 21(2) *Global Environmental Change* 563–74. See also T Wiedmann 'A review of recent multi-region input-output models used for consumption-based emission and resource accounting' (2009) 69(2) *Ecological Economics* 211–22. M Jakob and R Marschinski 'Interpreting Trade-Related CO_2 Emission Transfers' (2012) *Nature Climate Change* doi:10.1038/nclimate1630.

BCAs can also potentially encompass adjustments at the border for exporters too. Export subsidies might be provided to companies selling their goods into markets without carbon prices, so that they are able to compete on equal terms with producers in other regions without carbon prices. In economic theory and trade theory, if the optimal situation (free trade coupled with appropriate carbon prices around the world) cannot be achieved, a second best outcome could be delivered by as many regions as possible imposing BCAs, incorporating both the import adjustment and the export adjustment. The starting assumption here is that the welfare losses from climate change are likely to dominate the welfare from any small reduction in international trade, and hence the focus is pragmatically upon BCAs that help spread carbon prices around the world. That said, I will concentrate on the requirements on importers to acquire and retire carbon permits, or pay a carbon tax, rather than on the provision of export subsidies to firms exporting into markets with lower carbon prices.

The next point for definition is that this argument engages in what I am calling 'political game theory', rather than the standard game theory of economics textbooks. In standard economic theory and trade theory, one finds that countries are often best placed by unilaterally reducing tariffs because, although this may hurt producers, it provides greater benefits to consumers. However, in practice unilateral tariff reductions are very rarely observed. The reasons for this are well understood and relate to our political system, the concentrated power of producers compared with diffuse and poorly organised consumers, and the fact that production may generate other externalities that politicians seek to capture. Irrespective of the reasons for the divergence of reality from economic theory, the emphasis here is on constructing a simple model that reflects what can be observed in practice. So it is a pragmatic, highly stylised model that is informed by political realities.

3.1 A simple international trade game

Figure 4 shows a simple international trade game where there are two players, Country A and Country B. The two players are trading with one another. There are no climate change concerns in this game – these will appear shortly. At this stage the trade game is just being set up. The game starts at the top, and Country B is going to play first. Country B can 'do nothing' – and continue to trade merrily with Country A – or it can decide to slap a trade restriction upon Country A. Why? Possibly a new protectionist government has come to power. Or possibly there are other reasons – this is not important.

If Country B imposes a trade restriction, Country A can either 'do nothing' in response or it can decide to retaliate with its own trade restriction. And that is the essence of the game – it is pretty simple. The pay-offs to the countries depend on which play of the game is followed. So, if Country B does nothing, this is business-as-usual with an assumed pay-off of zero. In other words, the pay-offs are relative to the pay-off achieved under business-as-usual. If Country B puts on a trade restriction and Country A does nothing, B gets a benefit of p, while A suffers a loss of q (ie a pay-off of $-q$). This is, as noted above, where this model differs from standard economic theory. The assumption is that in practice there is some real or perceived benefit from the unilateral application of a trade restriction (eg political popularity, campaign donations from a large producer, perceived benefits associated with an industrial strategy etc) and that this benefit is of size p.

If both countries put restrictions on one another, they both end up with a benefit of p and a loss of q. As, by assumption, q is greater than p, under this play of the game both countries end up worse off. So that is how the pay-offs work. It is all extremely simple, perhaps overly simple, but in my view it is a not unreasonable, stylised model of how trade negotiations work in practice.

So, now that the pay-offs have been defined, how would this simple game be played? In economics, games like this one are solved by 'backward induction' – by starting at the end and working backwards. So, consider the choice facing Country A if Country B has already imposed a trade restriction on it. What is its best choice? Country A can go to the World Trade Organization (WTO) and, under WTO law (again, extremely loosely if not comically speaking), if one country punches another country, the second country is entitled to punch the first one back. Admittedly, the process by which countries are permitted to return the punch is extremely lengthy and tedious. But it can be done eventually. And, in this little model, it turns out that punching people rewards the puncher and costs the punchee. So if Country B imposes a trade restriction on Country A, Country A finds it optimal to return the favour and impose a trade restriction on Country B.

Now, given that Country A is going to follow a strategy of retaliation, in order to work out what Country B should do a move up the game to the top is required. If Country B imposes a restriction, Country A will respond and it will end up with a pay-off of $p-q$, which is a negative number.

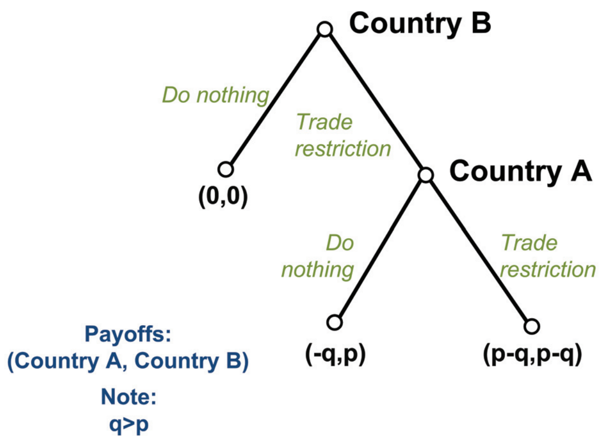

Figure 4: A simple, stylised game of international trade restrictions

Note: p represents the absolute values of the domestic gains from a trade measure imposed by a country. q represents the losses imposed on a country by a trade restriction imposed by its trading partner. Helm, Hepburn, Ruta (2012) (n 3).

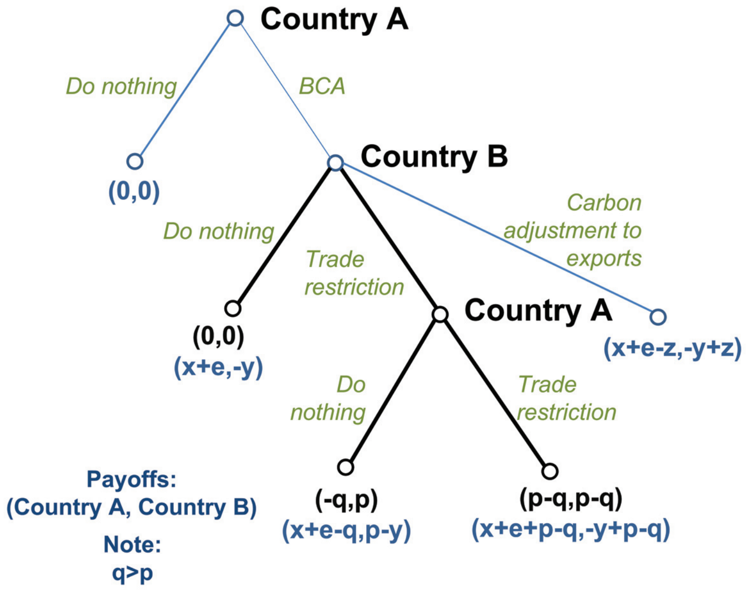

Figure 5: Simple game theory of border carbon adjustments

Note: pay-offs in black are the pay-offs of the trade sub-game (black lines). Pay-offs in blue are the pay-offs of the trade sub-game plus the BCA pay-offs. x represents the absolute value of gains to the country imposing the BCA excluding the environmental benefits. y represents the losses imposed on a trade partner by the BCA excluding the environmental benefits. e represents the environmental benefits (they are assumed to accrue only to country A). z represents net losses to Country A and gains to Country B if B imposes a carbon adjustment on exports. p represents the absolute values of the domestic gains from a trade measure imposed by a country. q represents the losses imposed on a trading partner by a trade restriction imposed by a given country. Helm, Hepburn, Ruta (2012) (n 3).

Alternatively, it can do nothing, and achieve a pay-off of zero. Zero is preferable to a negative number. So Country B does nothing, and the two keep trading merrily between each other. And, by and large, that is one of the basic aims of the WTO – to prevent trade restrictions being put in force by legally allowing retaliation if the rules are violated. This is highly simplistic, admittedly, and it fails to capture all sorts of important dimensions of the politics and economics of international trade, but for present purposes it is a useful starting point with which to carry on to consider the game theory of BCAs.

3.2 A game with border carbon adjustments

A few components now need to be added to the simple little trade model in Figure 4 so that the slightly more complicated model set out in Figure 5 is reached. The simple model from Figure 4 is in heavy black, and the new parts to the game are shown in lighter blue. In this slightly more sophisticated game, suppose that Country A seeks to have an ambitious environmental policy, with high carbon prices, while Country B is an environmental laggard with low or zero carbon prices. The possible play of the game is as follows. Country A begins, and it can either 'do nothing', or it can impose a BCA on imports from Country B to reflect the fact that Country B does not have appropriate carbon prices in place. Country B can then do one of three things. It can either 'do nothing', retaliate with its own trade restriction[33] or it can put in place a 'carbon adjustment to exports', which is to say that it imposes carbon prices (taxes or permits) on firms exporting to other countries. The idea of the latter is that if Country B puts a carbon price on its goods before they are exported, this prevents Country A from imposing the BCA. And it means that Country B collects the revenues from the carbon tax, rather than country A collecting the revenue.

If Country B retaliates with a trade restriction, then the game analysed in Figure 4 above is played. The result of that analysis was that Country B finds it preferable to 'do nothing' rather than to impose a trade restriction. So it is possible to use our analysis of Figure 4 to shortcut the analysis of the game in Figure 5 by simply asking whether, in response to a BCA, Country B is better off doing nothing or imposing a carbon adjustment to exports.

I turn now to the pay-offs in Figure 5. These are a little more complicated than in Figure 4. If, in response to a BCA, Country B imposes a carbon adjustment to exports, it gets a pay-off of $-y+z$, where y is the loss incurred by Country B as a result of Country A imposing the BCA, and z is the net benefit derived by Country B from imposing the carbon adjustment (which includes the direct revenue that it would raise and that Country A would no longer receive). If, in response to a BCA, Country B does nothing, it gets a pay-off of $-y$, which is the loss from the BCA. As it does not receive the additional benefit of z, it is clear that responding to a BCA with a carbon adjustment to exports is the optimal reaction from Country B.

Given this, the next step is to move to the top of the game in Figure 5 and assess the optimal strategy for Country A. If Country A imposes the BCA, it knows that Country B will respond with a carbon adjustment to its

33 For instance, in the current case of the dispute between the EU and others about the pricing of CO_2 emissions in the aviation sector, the Chinese have threatened retaliation in the form of not proceeding with a planned purchase of Airbus jets, discussed below.

exports. Therefore, Country A's eventual pay-off from imposing the BCA is shown at Figure 5 to be $x + e - z$, where x represents the gains to Country A from imposing the BCA (eg revenues raised, domestic interests protected) excluding the environmental benefits, e represents the environmental benefits to Country A created by the BCA, and z represents net losses to Country A and gains to Country B if Country B imposes a carbon adjustment on exports and collects the revenue at home.

In contrast, if Country A 'does nothing', it receives a pay-off of zero. So Country A should impose the BCA if $x + e - z > 0$. This inequality is likely to hold, especially if Country A cares about the environment (ie $e > 0$). The effect of Country A imposing the BCA and Country B responding with a carbon adjustment to exports, so that Country A then has to remove the BCA, is that Country B has put in a carbon price where previously there was none. The effect of this (excluding environmental concerns), captured by $x - z$, is likely to be positive for Country A, but is not necessarily positive. However, provided Country A does have concern for the environment ($e > 0$) and is not imposing the BCA solely for protectionist reasons, the inequality will hold and Country A will be better off imposing a BCA.

So my highly stylised, highly simplistic argument is that, after much consternation, threats of retaliation, legalistic disputes and so on, the core of the economic incentives behind the international trade game is that leaders in the environmental space should put these border carbon adjustments on, and then promptly remove them once the countries affected have responded with carbon export tariffs. At this stage of the discussions on the inclusion of aviation in the EU ETS, one could argue that this still appears to be a plausible outcome.

3.3 Caveats and experience to date

There are all sorts of caveats and nuances that should be applied to this analysis. For instance, one important question is whether BCAs are legal. It is not possible to say whether or not BCAs in the abstract are legal, because a ruling of the WTO Dispute Panel can be made only on a specific BCA.[34] Nevertheless, it would appear that BCAs are potentially able to be compliant with WTO rules, provided that they are designed carefully. Given that I am not a lawyer (although many of my readers will be), I merely note that the broad principles that need to be satisfied to ensure WTO compliance include the following:

- importers need to pay in the same manner as the domestic producers, so that if a domestic product is subject to a tax or a permit, then imported products are subject to the same tax or same permit requirements
- terms need to be no less favourable to importers than to domestic firms
- there needs to be an ability to appeal decisions
- there needs to be some input from the affected countries and
- if countries take comparable measures, there needs to be some kind of partial exemption.

I will leave the details of all this to others, such as UNEP and the WTO[35] and Monjon and Quirion.[36] But the key point is that BCAs have the potential to be legal, should they come in to use.

Another concern is that the imposition of BCAs will, rather than merely leading to the gradual spread of carbon prices (after various threats are made), in fact lead to a cascade of protection measures and disputes that unravels the entire trade regime. In short, the concern is that countries' actions will not follow the sort of economic incentives spelled out in the game above. This is the concern of Evenett and Vines,[37] who consider the trade regime too fragile to withstand the sort of pressure that would be created by the application of BCAs. That may be true. However, in my view, one has to balance the (low) risks of escalation of 'green protectionism' on the one hand, with the (high) risks (indeed, status quo) of a breakdown in the climate regime, and substantial economic costs from climate damages. Damage to the trade regime could also lead to substantial economic damages, but it is the climate risk that causes me greater concern.

The current dispute about the inclusion of aviation in the EU ETS from January 2012 illustrates some of these issues. This effectively imposes a carbon price on all flights *to and from* Europe, irrespective of destination or domicile of the carrier. It therefore is similar (but not identical) to a BCA. And, as one might expect, the policy has been attacked by countries including China, the US and India.

So, will there be retaliation or a carbon adjustment to exports? Retaliation has certainly been threatened. In June 2011, China threatened to prevent Hong Kong Airlines from purchasing 10 A380 aircraft from Airbus. The China Air Transport Association (CATA), which represents four of the country's biggest airlines, has announced that it will not pay for the emissions allowances. A case brought by the Air Transport Association of America in the European Court of Justice, arguing that the policy (the inclusion of aviation in the EU ETS from January 2012) was breaking international law, failed in December 2011.[38] The fight continues at the diplomatic and political levels. In February 2012, the Chinese Government banned airlines from complying with the EU scheme. However, in April 2012, China indicated that it might use revenue from a passenger tax on international flights to cut emissions from the aviation sector,[39] an indication of an interest in

34 UNEP and WTO 'Trade and climate change. A report by the United Nations Environment Programme and the World Trade Organization' (WTO Geneva 2009) available at http://www.wto.org/english/res_e/booksp_e/trade_climate_change_e.pdf.

35 ibid.

36 S Monjon, P Quirion 'How to design a border adjustment for the European Union Emissions Trading System' (2010) 38(9) *Energy Policy* 5199–207.

37 S Evenett, D Vines 'Crisis-era protectionism and the multilateral governance of trade' (2012) 28(2) *Oxford Review of Economic Policy* (forthcoming).

38 Case C–366/10 *Air Transport Association of America and Others* European Court of Justice (21 December 2011).

39 Hepburn and Müller (2010) suggested a somewhat similar policy intervention for adaptation based on the principles of responsibility and capability. See C Hepburn, B Müller 'International air travel and greenhouse gas emissions: a proposal for an adaptation levy' (2010) 33(6) *The World Economy* 830–49.

obtaining exemption on the grounds of taking 'equivalent measures'. This model suggests that other countries might similarly look for the equivalent of a 'carbon export adjustment', which will allow them to capture the revenue in-country, and claim an exemption from inclusion in the EU ETS.

4 Conclusion

A cursory analysis of the energy mix, both globally and in the UK, clearly indicates that Western economies are largely powered by fossil fuels and that this will continue to be the case for at least a few decades. The implications are that relatively little progress has been made in mitigating climate change. At the international level, attempts to reach a comprehensive and legally binding agreement continue, but even if such an agreement is eventually obtained, this will only set obligations commencing in 2020. This continuing path can, on a first approximation, still be described as being 'business as usual', involving the likelihood of 3–4°C warming, with potentially catastrophic consequences.

The level of ambition on climate change still varies dramatically from one region to another. I have argued in this article that BCAs might be a way of both levelling the economic playing field between domestic production and importers, eliminating an economic inefficiency, but also pragmatically spreading carbon prices around the world. This is not a strategy that would be associated with 'playing nice', and it is clearly too tough for some scholars to stomach, especially those in the trade community. However, the economic logic of BCAs is sound, and although there are risks in proceeding down the BCA route, there are also major risks to the climate and human civilisation in the 'do nothing' strategy. In short, this is not a 'first best' solution. But we are now so far away from 'first best' that policies resembling the 'second best' now need to be put into play.