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A global carbon market?

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Abstract This paper explores the prospects for a global carbon market as the centerpiece of any serious attempt to reach the ambitious goal for greenhouse gas (GHG) reductions set by climate scientists. My aim is to clarify the extent to which we know what policy might best support global decarbonisation. We begin by discussing what we might mean by a global carbon market and its theoretical properties. We then go on to discuss the EU Emissions Trading System experience and the recent experience with the Australian carbon tax. Next, we assess recent carbon market initiatives in the US and in China. My argument is that while establishing the amount of emissions required and dividing it up acceptably between countries requires an enormous scientific and international negotiations effort, the economic instruments to deliver the agreed targets are readily at hand.

Keywords carbon market, carbon tax, EU ETS

1 Introduction

Dealing with climate change caused by dangerous levels of man-made greenhouse gas (GHG) emissions is seen as one of the most pressing global problems currently faced. Climate scientists tell us that, in order to have a 50 %

chance of limiting the rise in global temperature to just 2 degrees (relative to 1850–1900) from 1990 levels, there needs to be a global 40%–70% cut in carbon dioxide equivalent (CO₂e) emissions¹⁾ levels by 2050 relative to 2010 (see for example Allen et al., 2009 and IPCC, 2014).²⁾ This has been translated into an approximately 80% target reduction in CO₂e for advanced countries relative to 1990³⁾. Otherwise there is a heightened risk of dangerously high levels of global temperature rises that will have difficult-to-predict impacts on the stability of the global environment.

On the face of it this looks like a very challenging situation that requires action on a scale that we have not seen so far and that seems increasingly unlikely to happen in the time frame identified. The Kyoto Protocol of 1997 led to initial agreement on action to reduce GHGs at the global level, but was only ratified by 83 countries (out of over 190), and only included quantified emissions limitation or reduction objectives for a much smaller group of industrialized countries (so called Annex 1 countries). Approximately 63% of emissions from these advanced economies are accounted for by countries that have ratified the Protocol.⁴⁾ But more than a decade since the Kyoto Protocol entered into force, annual GHG emissions have not yet started to decline.⁵⁾

The prospects for a ‘Global Deal’ (Stern, 2008) on emissions reduction seemed remote until the COP-21 conference in Paris of December 2015. At this conference the United Nations (UN) did manage to get an agreement to limit the global temperature rise to ‘well below 2°C’ between around 191 countries.⁶⁾ As of February 2018, 175 countries representing 88% of global emissions have ratified the agreement (though the US has notified its intent

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1) For simplicity, CO₂e will be referred to as ‘carbon’ throughout the rest of this paper.

2) Global GHG emissions in 1990 were 38 Gt of CO₂e, in 2010 they were 49 Gt CO₂e (IPCC 2014, p.22). A 70% cut relative to 2010, is a 60% cut relative to 1990.

3) See for example: <https://www.theccc.org.uk/2014/11/25/the-ipcc-report-and-the-uk-2050-target/>, accessed 24 November 2015.

4) http://unfccc.int/files/kyoto_protocol/status_of_ratification/application/pdf/kp_ratification.pdf

5) Annual global GHG emissions (excluding land use and forestry change) reportedly rose 0.5% in 2016 to a new record 49.3 Gt CO₂e (see Olivier et al., 2017).

6) http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

to withdraw).¹⁾ The agreement however is some way short of a global agreement to actually limit emissions because it involves unilateral voluntary commitments to action (so called Intended Nationally Determined Contributions – INDCs), which together do not collectively sum up to policies that would achieve the required reduction in emissions. The agreement does not specify mechanisms to achieve the required reduction in emissions to meet the stated temperature target but ‘recognizes the important role of providing incentives for emission reduction activities, including tools such as domestic policies and carbon pricing’ (V.137). Arguably the success of the UN in Paris was due to the fact that the agreement was focused on the final target (of a global temperature reduction) rather than anything more concrete around the mechanisms of how it was to be achieved.

Against that backdrop, this paper explores the prospects for a global carbon market as the centerpiece of any serious attempt to reach the ambitious goal for GHG reductions set by climate scientists. My aim is to clarify the extent to which we know what policy might best support global decarbonisation.

My starting point is that the policy solution to excessive emissions of GHGs is actually well established in theory and in very large scale experiments, specifically the European Union’s Emissions Trading System (EU ETS). These give some confidence that carbon emissions reduction policy based around restricting the quantity of emissions permits to the level suggested by climate scientists would be the most sensible approach to delivering the depths of emissions reductions that is required.²⁾

Indeed, we should stop giving the impression that we do not know what policy to put in place to deal with global GHG emissions. Climate science may be constantly evolving and contentious, but the economics of emissions control is not. An example of this was the recent suggestion that there needed to be a big increase in global publicly funded renewable energy research and development (RD + D) expenditure, from \$6 bn to \$15 bn per year for the next 10 years (under the ‘Global Apollo Programme’)³⁾. This type of proposal suggests that dealing with decarbonisation is still primarily a research project.

On the contrary: it is already the case that significant sums are being spent on renewable energy RD + D. In 2017 the world spent an estimated \$9.9 bn p.a. on renewable energy RD + D alone (Frankfurt School-UNEP

Centre/BNEF (2018) and has been close to this level since 2009. The IEA reports that 90% of *public* energy RD + D (out of budgets of \$17 bn) was spent on non-fossil fuel technologies in 2015⁴⁾. In the power sector, global RES investment was significantly higher than in global fossil investment in 2017 (Frankfurt School-UNEP Centre/BNEF, 2018) and has been so for the past several years. Within OECD countries the picture is even more striking with perhaps 75% of power generation investment being spent on zero carbon technologies over the period 2007–2013 (World Economic Forum and Bain Consulting, 2015). A transition in the research base and in investment is underway at least in electric power – these suggest that the technological barriers to decarbonisation are being addressed.

Instead my contention is that the way forward is that we should (simply!) implement a reasonably comprehensive set of quantity restrictions on CO₂e, building on experience with existing policies such as the EU ETS. While the path to achieving this is difficult, the economic building blocks are clear.

The paper proceeds as follows. First, I discuss what I mean by a global carbon market and its theoretical properties. Next, I discuss the EU ETS experience and the recent experience with the Australian carbon tax. I then go on to assess the evolving carbon market initiatives in the US and in China. In my conclusions, I reflect on the overall lessons from carbon pricing experience.

2 What do we mean by a global carbon market?

2.1 Why price carbon?

At the heart of a carbon market is the idea that putting a single price on CO₂e emissions regardless of their source is a good idea. Carbon pricing through a market has most value in the early stages of decarbonisation. The market can help with identifying the mix of sectors to decarbonise; the mix of existing low carbon technologies per sector; the role of demand side reduction and substitution; and with guiding consumer and climate NGO pressure. A single price of carbon is fundamentally about identification of low cost decarbonisation options within a general equilibrium (i.e., multiple interconnected markets) setting. This sort of idea is in sharp contrast to a technology-based

1) <https://cait.wri.org/source/ratification/#?lang=en&ratified=AL,DZ,AG,AR,AU,AT,BD,BB,BY,BZ,BJ,BO,BW,BR,BN,BG,BF,CM,CA,CF,CN,KM,CK,CR,DK,DJ,DM,EE,EU,FM,FJ,FI,FR,GA,GM,DE,GH,GR,GD,GN,GY,HN,HU,IS,IN,ID,IE,IL,IT,CI,JP,JO,KZ,KI,LA,LU,MG,MY,MV,ML,MT,MH,MU,MX,MC,MN,MA,NA,NR,NP,NZ,NE,NU,KP,NO,PK,PW,PS,PA,,AF,AD,AM,AZ,BH,BE,BT,BA,BI,KH,CV,TD,CL,HR,CU,CY,CZ,CD,DO,EC,EG,SV,ET,GE,GT,HT,JM,KE,LV,LS,LI,LT,MK,MW,MR,MD,ME,MM,NL,NI,NG,PG,PY,PE,PH,PL,PT,QA,CG,RS,RO,RW,KN,LC,VC,WS,ST,SA,SN,SC,SL,SG,SK,SI,SB,SO,ZA,KR,ES,LK,SD,SZ,SE,CH,SY,TJ,TH,BS,TL,TG,TO,TT,TN,TM,TV,UG,UA,AE,GB,US,UY,VU,VE,VN,ZM,ZW>, accessed 28 February 2018.

2) Indeed, one could go further and suggest that any other conceivable policy (or set of policies) seems to have no realistic prospect of adding up to a policy strong enough to reach the required cuts in GHG emissions.

3) King et al. (undated).

4) See IEA (2017a, p.56).

approach, which assumes both the efficacy of the technology and the extent to which it should be implemented. It is because at the whole economy level we are unlikely to know how best to approach decarbonisation that carbon pricing, rather than a technology driven approach, is so valuable. Putting a price on pollution is a policy that has wide support among environmental economists because it directly tackles the environmental externality involved in pollution and because it has a good track record, especially when contrasted with conventional command and control approaches based on the mandating of particular technological solutions.

Carbon markets (cap and trade schemes) and carbon taxes are the two standard ways of putting a price on carbon emissions. The major difference between these two approaches is that carbon markets set the quantity of carbon to be emitted and let the price vary in the market for emissions permits, while carbon taxes fix the price but let the quantity of emissions vary. As such, carbon markets introduce a price risk for those exposed to the spot price of permits, while carbon taxes introduce quantity risks on the climate. Carbon markets and carbon taxes share many of the same theoretical properties and can be identical in many respects (see Goulder and Schein, 2013). However as we shall see, carbon markets are emerging as the more popular form of carbon pricing globally.

Many societal stakeholders – such as large fossil fuel based energy companies and many of their larger customers – do not like carbon markets precisely because they deal so effectively with the general equilibrium issues and ensure that the overall quantity of permits is fixed no matter what the demand conditions are in the market for permits.

The ways in which they do this are that they are transparent and highlight: differences between included and non-included parties; the incidence of final costs and prices, especially to consumers; the financial flows within and between countries; the cost impact of political interventions; the lowest cost interventions, which effectively acts to restrain special interests. Thus if governments choose to enact limited carbon trading schemes, it will soon become clear what effect they are having and on whom. It is also clear when the initial quantities of permits available in the market are too few or too many by the evolution of prices, while any announcement on extension of the current trading scheme will have a verdict given on its tightness by the price reaction in the permit market.

Basically, political opposition to the use of carbon markets is based on the fact that they do work in a predictable way.

2.2 What are the characteristics of a global market?

What would a global carbon market look like? This is an interesting conceptual question. One might imagine that it

would involve a single type of emissions permit issued by a global authority and a single global monitoring and enforcement authority. The United Nations Framework Convention on Climate Change (UNFCCC) does issue Certified Emissions Reductions (CERs), which approximately have this property and in some sense already provide a global carbon price at the moment.

However, in general, global markets do not have this type of framework. Global markets are actually made up of voluntarily interconnected markets, which produce and trade broadly similar products with price arbitrage between them. The individual markets within the interconnected system have their own systems of property right definition and enforcement. A good example of this is the global market for oil. While one can clearly speak about the global price of oil and global supply and demand conditions, actually the global market is made up of a number of interconnected markets (such as West Texas Intermediate (WTI) and Brent Crude). These markets give rise to their own prices (WTI is usually cheaper than Brent, due to local market factors). The situation in global natural gas is even less integrated, with major regional markets (in the US, Europe and the Pacific Basin), but prices do to some extent move together.

For us to talk about a global market, all that needs to be true is that markets are interconnected enough for major price differences between significant regions to be arbitrated. This clearly does happen in oil and is happening to an increasing extent in natural gas. A single trading platform or integrated regional platforms (as for oil, or foreign currency) are not required, though clearly end-users can arbitrage between markets for both oil and gas because the underlying commodity can be used in any location. The parallel for a global market in carbon emissions permits is simply that individual markets recognize a permit from another market as being exercisable in their market.

The idea of a global market does not require all sectors of the economy to be exposed to global price fluctuations. Whole sectors can be exempted from such exposure, either by contractual hedging with longer-term private contracts or by government intervention. Thus even in market based energy systems, energy companies can sign long-term contracts for the supply of gas or coal which effectively reduces the exposure of their customers to spot market fluctuations in international commodity prices. This happens with carbon when the government buys renewables or nuclear power with multi-year fixed prices above the expected average long-term market price. It also happens when governments fix final (i.e. administered) prices of energy regardless of the fluctuating fossil fuel price, such as in the many oil producing countries who choose to sell oil to their domestic consumers at much less than the world market price equivalent price. By contrast developed countries with very high taxes on oil products, such as gasoline, also reduce the exposure of their

domestic customers to global oil price fluctuations. Doing this dulls the exposure of the domestic economy by reducing the demand below what it might otherwise have been.

Once a global market emerges for any commodity we might expect the degree of exposure to prices based on the global market price to increase over time. This occurs because the costs of non-alignment are likely to grow over time, especially for countries with abnormally low prices. These countries are over-consuming the commodity with the loss of export revenue (if they produce it domestically) or an increasing import bill. One might expect that internal prices might converge with international prices over time, though this process may be very slow.¹⁾

This process of convergence might also apply to global carbon pricing, with initially very different approaches to the determination of national carbon prices giving way over time to more market integration and price convergence. This would imply that even if countries started off with initially purely domestically determined carbon pricing (via, say, a carbon tax), there would be pressure to align domestic carbon prices with those emerging from large international carbon markets. Indeed, Stiglitz (2015) has recently made the case for a hybrid approach with some countries opting for cap and trade, and others going for carbon taxes, each as they see fit, as part of a global solution to GHG emissions.

An effective set of ‘global’ prices, arising from a reasonably comprehensive attempt to restrict quantities of emissions using carbon pricing instruments does not therefore imply a single global price for every tonne of GHG emissions. While a set of fully linked markets – with unrestricted trading between them – might be envisaged, this is clearly not necessary to combat climate change. A set of separate carbon markets with varying degrees of linkage²⁾, which in aggregate enforced the required global quantity of emissions cap, would be sufficient.

2.3 What would be the scale of a global carbon market?

The global oil market provides a good backdrop to thinking about a global carbon market. The basic parameters of a global carbon market are the following.

In 2016 the amount of CO₂e emissions was around 49000 m tonnes³⁾ (of which around c.70% is CO₂). Assume the long run price of CO₂e needs to be \$100 per tonne CO₂e by 2050 to be consistent with the emissions

reduction target needed. This would suggest that the market might be worth \$4900 bn per year. However this would overstate the value of the likely carbon market at any point in time. A plausible long run equilibrium might therefore be 10000 m tonnes at \$80 per tonne⁴⁾. If 10% of the value of this market were traded between regional markets (say US, China, EU etc), this would require global flows of funds equal to \$80 bn p.a. How large is this market? For comparison, the global oil market is roughly 90 million barrels per day⁵⁾. At \$100 per barrel (which might be a long run price) this adds up to \$3285 bn per year. Meanwhile looking at the potential financial flows between regional carbon markets, \$80bn is less than the current global international aid budget (which is \$145 bn p.a.)⁶⁾.

These numbers suggest that if all GHGs were part of a global carbon market, then this would be a large market but not out of all proportion to the sorts of markets that already exist at the global level.⁷⁾

2.4 Creating the global carbon market – is it possible?

There are around 190 states in the world. It would seem that reaching a global agreement on allocating the quantity of GHG emissions to each state would seem very difficult, but global emissions are highly skewed as Table 1 shows. The top 10 emitters alone, including the European Union, cover 68% of emissions.

Looking at the G20⁸⁾ + Spain (the group of leading countries who regularly meet to discuss international

Table 1 Top ten emitters of GHGs globally (exc. Land use change and forestry (LUCF)) 2016

China	26.5%
United States	13.1%
European Union	9.0%
India	7.4%
Russian Federation	4.5%
Japan	2.8%
Brazil	2.3%
Indonesia	1.9%
Canada	1.8%
Iran	1.7%
Total	71%

Source: Olivier et al., 2017, p.46.

1) Indeed the IEA (2015, pp.96–99) does discuss some evidence that global fossil fuel subsidies are beginning to decline, after adjusting for oil price effects.

2) For a discussion of linking carbon markets see Tuerk et al. (2011).

3) See Olivier et al. (2017).

4) See IPCC (2014, p.21), in the years out to 2070–2080.

5) See BP (2017).

6) See <http://www.oecd.org/dac/financing-sustainable-development/final-oda.htm>, accessed 28 February 2018.

7) While a global carbon market is similar in scale to the global oil market. It is different in other ways. Oil from different sub-markets is physically interchangeable in a way that carbon permits – as legal property rights – are not. Governments need to recognise one another’s carbon permits.

8) The G20 consists of Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States and the European Union. Spain is a permanent invitee.

affairs), this covers 85% of world GDP and 78% of world CO₂e (exc. LUCF). If we include the next 10 largest emitting countries, we get to around 85% of world CO₂e. A reasonably sized initial large carbon market, with border tax adjustment (Neuhoff and Ismer, 2007)¹⁾ would be sufficient to incentivize emergence of an increasingly global carbon market drawing in all the largest countries. How difficult would it be to get 31 countries to agree to quantitative emissions reduction targets?

The EU ETS has 31 countries participating at the moment (28 EU member states plus Iceland, Norway and Liechtenstein). Of the G21, 6 (including the EU itself) are in the EU ETS. Of the 35 OECD countries, 24 are in the EUETS. Of the rest of the world, many are in the spheres of influence of the largest 31 emitting countries. This suggests that agreeing a reasonably comprehensive agreement on quantity controls for GHGs is not primarily a problem of the complexity of the negotiations that might be involved. This is not to say that such a negotiation is straightforward – it clearly is not. The EU is clearly not a representative sample of countries in the world, but what it does exhibit very well is the power of shared interest on a number of issues to enforce agreement on a particular issue, where the majority of countries harbors a strong political position.

2.5 Carbon trading vs carbon taxes?

An important theoretical discussion in environmental economics relates to the relative efficacy of emissions trading vs emissions taxes. Should the world attempt to coordinate on quantity targets for GHG emissions or a set of reasonably consistent carbon prices (taxes)? Weitzman (1974) makes a strong case for pollution taxes, which can be illustrated by the diagram in Fig. 1. He argues that if the slope of the marginal cost of abatement curve (MC) is steeper than the slope of the marginal benefit of abatement curve (MB), then it is better to set a tax than to set quantity limits if there is uncertainty about the exact position of the MC curve. This is because the cost of mistakes in the estimation of the position of the MC curve (cost of abatement uncertainty) is lower if we get the tax level wrong than if we get the quantity level wrong, something that is illustrated by the size of the deadweight loss from the mistakes in the following diagram:

It may be questioned, however, whether this sort of argument applies well to GHGs.

The Weitzman result depends on the relative slopes of two curves, and his analysis suggests that the extreme cases where the relative cost of setting taxes is higher is more ‘likely’ than the extreme cases where the cost of setting quantities is higher. Since we do not really know where the MB curve is, and since it might involve big discontinuities in environmental damage (and hence be very steep in places), that is an argument in favor of

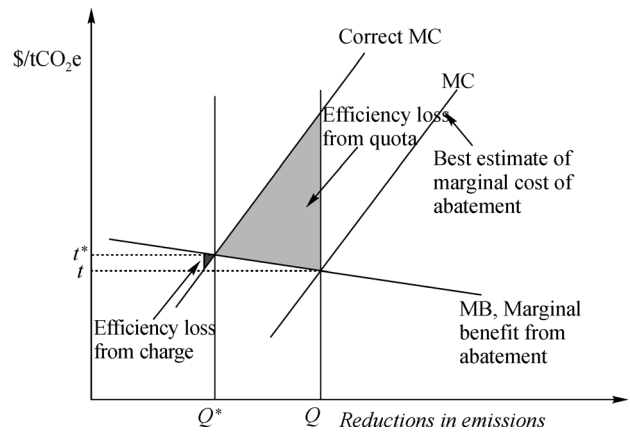


Fig. 1 Carbon taxes or carbon markets? Weitzman argument: Costs of errors setting quantities

quantity setting (see Fig. 2 where there is no efficiency loss from a quota). In reality, a lot of uncertainty exists about the marginal benefit curve (i.e. we do not know where the climate damage effects exactly kick in, or how societies will adjust if they do). This is indicated by the wildly differing estimates on the value of the social cost of carbon (see Hope and Newbery, 2008).

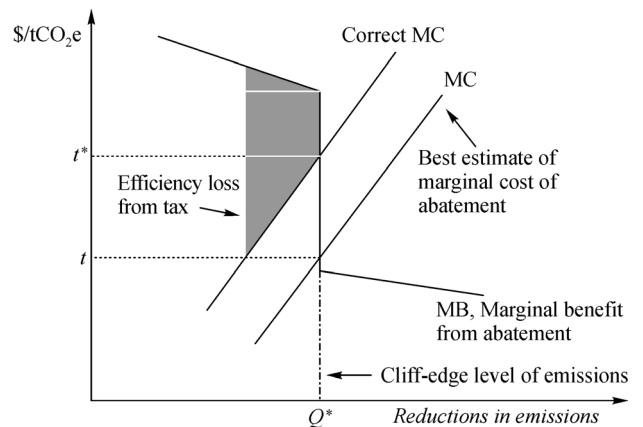


Fig. 2 The benefit of quantity setting in the presence of cliff-edge effects in emissions

It is worth pointing out that if there is no uncertainty in the MC curve, but only in the MB curve, then the cost of mistakes is the same under both quantity or price setting. Thus if the marginal cost of abatement is actually relatively well defined or lower than predicted, then it is unlikely that the mistake in quantity is worse than the mistake in price.

In practice there is no suggestion that we would ever seek to impose a single price or quantity limit for all time, as the model is set up to analyze; instead, we would look to tighten the pollution control regime over time. This significantly reduces the cost of mistakes, allowing the

1) Border tax adjustments could impose carbon tax adjustments on imports from countries that choose to remain outside the large carbon trading area.

incorporation of learning on the position of curves in the light of further information on the position of the MB and, especially, the MC curve. Thus a better representation of the situation is perhaps Fig. 3, where identifying the optimal price (in the region of the blue ball) is very difficult, given the uncertainty in both the MC and MB curves.

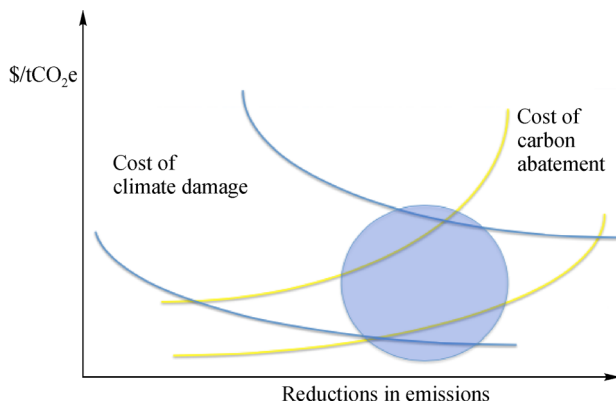


Fig. 3 A better argument? More important (and easier) to identify dangerous quantity than ‘correct’ price
Source: From Grubb and Newbery, 2008, p. 282.

Weitzman’s arguments are based on the relative dead-weight losses arising from price setting vs. quantity setting. Weitzman (2015) has recently made three additional arguments in favor of a global carbon tax over a global quantity cap. These are: That revenues are nationally collected with a tax; that negotiating one price is easier than negotiating on quantities; and that governments have an incentive to coordinate upwards on the tax, rather than try and reduce the price under a quantity cap by seeking higher quantities. It is worth addressing each of these in turn. First, revenues from auctioning permits under carbon trading can be (and indeed are in the EU ETS) collected nationally, so this is not in reality a difference. Except that under central allocation of permits, one can (additionally) use the national quantity allocation to transfer wealth to countries bearing heavier costs of adjustment, in a way that might be easier than under the direct transfer of tax receipts. Second, the complexity of negotiation point is an interesting one. This is superficially attractive, but in international tax coordination, one suspects the devil is in the detail of implementation in each country and the fact that the nominal tax rate (in US dollars?) is the same is not really the issue – it could equally well be different without any loss of difficulty of implementation. Finally, on the fact that self-enforcement on a higher tax rate is likely, I am not sure there is any evidence that countries do coordinate upwards in negotiations on taxes. The EU carbon tax

experience was that countries could not even agree to introduce the tax, let alone coordinate it upwards.

Cramton et al. (2015) make a further important conceptual point in favor of a uniform global carbon tax. Namely, that it introduces less volatility into the pricing of carbon and hence into the flow of funds that must necessarily flow between nations to achieve ambitious climate goals. Of course, this is an important argument. However it is easy to overstate the extent to which carbon prices within a cap and trade system are volatile, relative to the non-volatility of carbon taxes. Yes, prices in carbon markets are volatile in the same way as other commodities, such as oil and gas. However this is a volatility that can be managed and indeed is managed by long-term contracts, with the exposure to short run carbon prices ultimately being quite limited. Carbon taxes may not exhibit daily or monthly variability, but they can be reduced, increased or even removed by future government action (c.f. the Australian carbon tax discussed below). What is more, carbon taxes can introduce volatility into the outturn quantity of GHGs released, with consequences for climate risk.

Goulder and Schein (2013) raise the issue of whether fossil fuel producers will have different incentives under a carbon trading scheme or a carbon tax. They suggest that in the presence of a trading scheme it would be possible for oil producers to reduce supply to reduce the price of permits and hence absorb the rent created by the intended restriction in demand. This cannot happen with carbon taxation. As they point out, this result rather supposes that fossil fuel producers have the market power to act in this way in the face of falling demand. In a strong carbon policy environment it would seem to be the case that fossil fuels will be abundant and the ability of fossil fuel producers to behave strategically is likely to be undermined. The greater worry in this case is likely to be the green paradox¹⁾ where fossil fuel producers, anticipating long run oversupply of fossil fuels, are likely to increase extraction rates. In this case quantity targets are likely to be a more efficacious climate policy than carbon taxation.

There are some other types of arguments that are very important in favor of carbon trading.

First, there is the importance of consistency between the recommendations from climate science and the economic instruments employed to act on that science. Climate science can and does frame the climate problem as being about the absolute quantity of GHGs emitted (e.g. Max = c.1000 Giga Tonnes (GT) of Carbon = c.2440 GT CO₂e) if the rise of significant warming is to be contained (e.g. Allen et al., 2009). Clearly, emissions trading based on quantity limitation coordinates the economic framing and the scientific framing in a way that setting a target price for carbon emissions does not. Put another way, setting the right social cost of carbon (via a carbon tax) might give rise

1) See Sinn (2008).

to the right quantity of emissions reduction in theory, but fixing the quantity of emissions directly (as in a trading system) would be a surer way of meeting the scientifically determined target.

Second, there are important legal precedents that an international agreement on emissions reduction must work within. As we have seen with the global oil market, global markets can and do exist based on internationally respected property rights. The idea that commodities and ownership rights can be traded internationally is well established in international law. This can happen while respecting national sovereignty. Thus tradable quantities of emission permits with initial allocations of pollution rights is consistent with the current basis of property rights and trade (as the EU ETS and other international agreements to respect nationally created property rights demonstrate). By contrast, co-ordination of taxes across borders is not something that is consistent with national sovereignty, and there are no examples globally of co-ordination upwards¹⁾ of environmental or any other tax rates.²⁾

Third, there is a rather important point to do with the rebound effects of a carbon tax. It is common to argue that carbon taxes produce a double dividend, in that higher carbon (and indeed any environmental taxation) leads to reduced taxes elsewhere and hence may stimulate the economy by reducing the inefficiencies associated with conventional taxes which are leveled on earned income and are therefore distortionary of work – leisure choices.³⁾ If environmental tax revenue is then used to target benefits on lower income consumers (as was the intention in Australia) this may also stimulate the economy via the multiplier effect arising from their re-distributional effects. Both of these types of effects mean that environmental taxes may raise demand for goods and services and hence produce some offsetting rise in CO₂e emissions. Thus carbon taxes may not produce as big a reduction in aggregate emissions as expected. This is not a problem with quantity restrictions on carbon emissions, where there is no possibility of a rebound effect being at work in aggregate.

Fourth, a key advantage of carbon trading is that the price of carbon dioxide permits is pro-cyclical (i.e. when GDP growth is faster, prices are higher). This is a good way of protecting the mechanism at times when the economy is doing poorly. There are good reasons why this makes sense from a social cost benefit analysis point of

view, namely that social discount rates rise in times of recession: This is because inequality aversion goes up and hence social discount rates rise. Fixed tax rates become more burdensome and hence difficult to defend in times of recession, and more vulnerable to being reduced in a way that undermines the long-term credibility of the carbon tax mechanism.

Finally, Gollier and Tirole (2015) make an interesting set of arguments in favor of cap and trade based on the relative ease of enforcing a global carbon tax vs global quantity restrictions. Their point is that enforcing a global carbon tax would be very difficult to monitor. This is because it would be easy to turn a blind eye to enforcement of payments from particular polluters where this produced a national benefit. In addition, other taxes could easily be adjusted to mitigate the impacts of the carbon tax, in particular other taxes on fuel. This would undermine the overall quantity impact of carbon taxes.

2.6 The evidence on carbon emissions trading vs carbon taxes

The European Union spent five years in the early 1990s discussing a carbon tax at the EU level.⁴⁾ It could not agree on a carbon tax, but it did subsequently agree on introducing an emissions trading system. Other international or multi-jurisdictional systems for carbon pricing have all made use of carbon trading, notably California and Quebec under the Western Climate Initiative (WCI) and nine states in the US North-east and Mid-Atlantic under the Regional Greenhouse Gas Initiative (RGGI). Even within countries, carbon taxation has proved very difficult to enact.

This is not only about the sovereignty of governments with respect to taxation, which they expect to be able to adjust annually within the budget. It is also about the fact that tax rates are subject to periodic review, making any initial scheme vulnerable to subsequent political interference. In particular, it may be difficult to raise taxes from their initial levels in order to strengthen the price signal. Differences in the political cycle mean that it would be difficult to coordinate increases to tax rates across countries, in a way that agreements to tighten the quantities within an emissions cap may not be.⁵⁾

Energy taxation on different fuels shows wide variance within and between countries. This suggests the political

1) There are some good examples of global coordination on the reduction or elimination of tax rates (e.g. as part of the GATT free trade rounds). However co-ordinating on tax increases is quite a different story. The closest example is perhaps the EU's effort to co-ordinate VAT rates within the EU, but this is not about equalizing the VAT rates, and rather about keeping them within bands.

2) Canada is an interesting case study, where different provinces have adopted carbon taxation (e.g. British Columbia) and emissions trading (e.g. Ontario and Quebec). Recently the federal government announced a policy of moving towards pricing carbon across Canada. Provinces with emissions trading regimes need to set caps in line with their share of the national targets. Provinces with carbon taxes need to set minimum tax rates. The federal government does not propose rolling out a single carbon tax across the whole of Canada (see World Bank, 2017, p.45–46).

3) For a discussion see Smith (1998).

4) The carbon tax was proposed in 1992 and finally withdrawn in 1997. The proposed level of the tax was initially \$3 per barrel of oil (which is approximately \$7 per tonne CO₂) rising at \$1 per year to \$10 (European Commission, 1992).

5) The EU has recently agreed to tighten its carbon cap out to 2030.

difficulty of co-ordinating on taxes, given very different attitudes to energy taxation in general. This is perhaps because vested interests in many jurisdictions find it easy to keep taxes at a low level or have been able to secure substantial exemptions, due to the lack of transparency around the domestic tax setting process.

Table 2 shows the relative size of the biggest actual and planned carbon trading schemes in 2016. The coverage for all carbon trading schemes is about 9% of global GHGs, which together with carbon taxes, brings about 13% of GHGs under some form of carbon pricing. By the end of 2020, the coverage of all carbon pricing might be over 20%, of which most would be covered by emissions trading schemes (World Bank and Ecofys, 2018).

Table 2 Example Emissions Trading Scheme sizes

EU ETS	1964 mt p.a. (2015)
China pilot schemes	1115 mt p.a. (2013-14)
Korea	539 mt p.a. (2015)
California-Quebec	490 mt p.a. (2020)
Australia (initially a tax)	283 mt p.a. (2012-13)
RGGI – Eastern United States	56 mt p.a. (2017)
Switzerland	5 mt p.a. (2015)
Total	c.9% of global emissions

Source: World Bank (2014), IETA website.

The prices and the coverage of the current schemes remains low (World Bank, 2017). Prices are often very low and a long way short of the \$80 that might be necessary to actually help achieve the emissions reductions required. In the EU ETS, for instance, the price is currently (February 2018) only around \$12.34 (10.10 Euros) per tonne of CO₂; in California-Quebec it is \$15.28 per tonne of CO₂e; and in RGGI it is \$3.80 per tonne of CO₂. The global value of carbon pricing is thus around \$50 bn p.a. – a long way short of the \$800 bn envisioned above. Some carbon taxes are very high (e.g. the Swedish carbon tax is \$140 / tonne of CO₂)¹⁾, but these high prices are rare. Emissions coverage within pricing systems ranges from 20 to 85% of GHG emissions, and typically amounts to around 40%–50% (the EU ETS covers 45% of EU emissions). Normally this will include the power sector and energy intensive industry (such as steel and cement).

By contrast governments are much keener to subsidise renewables (via Feed-in-tariffs and Renewable Certificate Schemes) and fossil fuels by selling them below economic cost. In 2016 renewable subsidies were \$140 bn globally, while fossil fuel subsidies were \$260 bn (IEA, 2017b). At

the moment governments are clearly willing to spend large amounts of money subsidising energy production and use, but much less on pollution control.

However the World Bank (2017, p.22–25) has documented the progress with carbon pricing, and in particular emissions trading. As of 2017, 42 countries (and 25 sub-national territories) will have some form of carbon pricing. This has increased from 2 countries in 1990.

It is important to point out that emissions trading schemes can be combined with carbon taxes and other emissions reductions policies, if this is thought to bring additional benefits over and above a single instrument. Indeed such hybrid schemes²⁾ are popular. Emissions trading schemes can have maximum and minimum prices (e.g. RGGI has a floor price of \$2.05), making them look closer to a tax, and hence reducing price volatility. Carbon taxes can be imposed on top of or alongside emissions trading regimes (e.g. several EU ETS countries do this). This may be desirable if emissions prices are thought to be too low or if trading schemes – which may be cross jurisdictional- do not cover certain polluters.

3 Lessons from the EU ETS and the Australian Carbon Tax

3.1 The EU Emissions Trading System

The EU ETS began in January 2005 and has now been extended to 2030. It is currently (April 2018) the biggest emissions trading scheme in the world, covering 11,000 individual stationary sources of emissions in the power and industrial sectors, as well as aviation within the EU. The EU ETS has had a chequered history as the evolution of prices within the mechanism demonstrates³⁾. Prices have been as high as 30 Euros per tonne of CO₂, but are now around 10 Euros. This is partly a result of the way an emissions trading system works to minimise the cost of complying with a given quantity cap within the scheme. Lower than expected prices are a sign of success in achieving a given quantity target.

There was an initial collapse of prices toward zero in 2007 due to over allocation of quantities in the initial trading period (which were not bankable to the second period from January 2008). This primarily happened because national governments were able to set their own quantity targets within the scheme. A second price collapse occurred in 2009 following the global financial crisis, which particularly effected EU GDP and demand growth.

However the scheme has continued and has now been extended from 2020 to 2030.⁴⁾ The scheme has evolved

1) World Bank (2017).

2) See Schmalensee and Stavins (2017).

3) See for example: http://www.eea.europa.eu/data-and-maps/figures/eua-future-prices-200520132011/eua-future-prices-200520132011-eps-file/image_original, accessed 28 February 2018.

4) For a discussion of progress with the EU ETS and future directions, see Meadows et al. (2015).

and been strengthened to some extent. There is now an EU wide cap with allocation of auction shares to national governments, preventing the over allocation problem at the national level. Free allocation of permits to existing polluters, which comprised most of the permits in the early trading years, has now been replaced with residual free allocation to trade impacted sectors, with most sectors having to buy permits at auction. This reduces the problem in the power sector of double payment to polluters, who gained free allocation of valuable permits, plus the ability to increase electricity rates based on the rise in the marginal price of power due to the opportunity cost of extra permits at the marginal price setting plant.

There is a move toward linking the EU ETS with other emissions trading systems, rather than allowing the introduction of large numbers of offset reductions from CER projects. The introduction of large numbers of CERs served to keep the price down in the initial years. However, in spite of promising recent developments in the overall design of the scheme, there remains a substantial overhang of permits in the market, perhaps as much as one year's emissions, banked for future use. This serves to keep the price low into the future. The EU has decided to introduce a market stability reserve (MSR) to take some of the permits out of the market and raise the price in the short run (and potentially reduce high prices in the future), but the MSR is small in relation to the size of the overhang of permits.¹⁾

The most encouraging development spearheaded by the EU Commission (which is responsible for administering the scheme) is that, when setting the new 2030 energy and climate policy targets, carbon emission reduction is now the center piece of the policy, rather than one of three potentially conflicting policy goals. Thus the 2030 target for decarbonisation is a 40% reduction in GHG emissions (relative to 1990), i.e. a further 25% emissions reduction relative to the 2020 target in 10 years, implying a 43% reduction of ETS covered sectors relative to 2005. This is in addition to an EU-wide renewable energy (RE) target of 32%, which is subject to weaker enforcement than the current 20% target for 2020, and seems capable of being delivered by the necessary national efforts to achieve the decarbonisation target.

Similarly, the energy efficiency target of a 32.5% reduction in energy use relative to business as usual (up from 20% in 2020) is also not subject to national enforcement and is capable of being delivered by the decarbonisation target.

Ellerman et al. (2010) give an initial and broadly positive assessment of the EU ETS. They note that carbon has been priced, and while initial allocation was controversial, emissions did fall by 2%–5% in the early years

of the scheme. Moreover, the market for permits is liquid and efficient, and the negative effects on traded sectors has been small. The EU ETS remains an impressive multi-country environmental policy instrument capable of further tightening if other jurisdictions agree to also restrict their emissions, reducing the problem of carbon leakage. Boasson and Wettstad (2012) label it a good example of what they call international institutional entrepreneurship, which clearly established the EU as the leading policy maker with respect to decarbonisation.

3.2 The Australian Carbon Tax

If the EU ETS provides a broadly positive experience of carbon pricing generally and carbon emissions trading in particular, the Australian experience with carbon pricing is rather different.

The Australian Carbon Pricing Mechanism (CPM) was introduced as a carbon tax in July 2012 at AUD 23.00. It rose to AUD 24.15 (c.16 Euros) per tonne of CO₂e in 2013–2014, with a view to transitioning to a cap-and-trade scheme in July 2015. The CPM covered 60% of Australian emissions. On the face of it, this was an impressive achievement, which opened up the possibility of linking Australia with the EU ETS and other cap-and-trade schemes.

The problem was that the scheme was controversial from the outset. Unlike in Europe, where there has been a widespread consensus on the need to do something about the climate problem and cross-party political support for carbon emission reductions,²⁾ this was not the case in Australia. The Clean Energy Act 2011 passed narrowly in the legislature.³⁾ The then opposition Liberal party campaigned on a promise to abolish the CPM as one of their flagship policies. They won the election in 2013, and the tax was abolished in July 2014.

Robson (2014) offers an interesting analysis of the failure of the Australian carbon tax, suggesting that other measures (such as subsidies to renewables) might have been more effective. In particular, his analysis shows that although the government did attempt to mitigate the impact of the tax on voters by substantially recycling the revenue, this was poorly targeted and most taxpayers were worse off as a result of the combination of higher energy prices and lower non-energy tax rates. Robson highlights calculations which show the effective marginal tax rate going down for 0.56m lower income tax payers, but going up for 2.21m middle income tax payers. Overall, the fiscal impact was large, with AUD 27.7 bn (c. \$20 bn USD) of taxes being raised over four years, of which only AUD 15.3bn was returned to households, with the government fiscal position actually worsening after taking into account the free

1) See http://ec.europa.eu/clima/policies/ets/reform/index_en.htm Accessed 24 November 2015.

2) In the UK the Climate Change Act 2008 passed its final vote in the House of Commons 463-3.

3) 36-32 in the Senate, see <http://www.rsc.org/chemistryworld/News/2011/November/14111101.asp> Accessed 24 November 2015.

allocation of permits and other measures undertaken.

The failure of the Australian carbon tax highlights once again that taxes are clearly not superior to cap-and-trade as a way of reducing price volatility, given that the key to policy certainty is the political sustainability of any pricing scheme and the basic economics were not affected by the lack of daily volatility in carbon prices.¹⁾ As Robson points out, the initial price of carbon was quite high, especially relative to the wholesale price of electricity. Introducing the carbon tax produced a sharp spike in wholesale electricity prices (of around 20%, at a time when prices were rising), which could have been avoided if the tax had been introduced at a lower level initially.

4 Signs of progress in the United States and China

4.1 Progress under the Clean Air Act in the United States?

The US already has a number of regional carbon trading schemes. Indeed, as of early 2018, no less than 10 US states are already participating in regional carbon trading. All of these schemes cover the power sector and have been the result of state-level initiatives.

The US Congress failed to ratify the Kyoto Protocol of 1997 and hence has not signed up to emissions reductions targets as part of the UNFCCC process so far. The EU, by contrast, did ratify the Kyoto Protocol, and the EU ETS is a major part of its policy response. National carbon trading proposals have been presented in Congress, but so far have not progressed. These include, for instance, the Lieberman-McCain Bill in the Senate in 2003, and the Waxman-Markey Bill in the House of Representatives in 2009.²⁾ Both of these bills proposed a reasonably comprehensive carbon market, covering 85% of CO₂e emissions, including the power sector, industry and transportation.

However, another potential route to a federal carbon market was pursued, with the support of President Obama, under existing legislation around the Clean Air Act, which is administered by the Environmental Protection Agency (EPA) (see Palmer, 2014).

In 2007, the EPA established its authority to regulate GHGs under the Clean Air Act, when the Supreme Court ruled in its favor in a case between it and the US State of Massachusetts. In 2009, the EPA established that GHGs were an ‘Endangerment’ to public health and that GHGs did ‘Cause or Contribute’ to negative environmental

impacts. These rulings established that the EPA was free to regulate GHGs at the national level. In 2010, the EPA reached a settlement between various state and environmental petitioners who were demanding that the EPA take action on GHGs from power plants.³⁾

The EPA then established a three-part plan for reducing GHG emissions. This consisted of improvements to mobile source standards, construction permitting and stationary sources. The mobile source standards (5% per year to 2025), involve moving the vehicle fleet average fuel efficiency to 35.5 miles per gallon (mpg) in 2016 to 54.5 mpg in 2025. The construction permitting sees improvements to the energy efficiency of new buildings, to be implemented by the states. And finally, the introduction of performance standards for new and existing electricity generators. This covers around 32% of current emissions. The first two approaches were set out in 2011, and the third, known as the EPA Clean Power Plan, was set out in 2014.

The EPA’s approach involved setting out conditions where a carbon market might emerge as the cheapest way to meet the emission standards it has set (Environmental Protection Agency 2014, 2015). To that end, the EPA took a number of technology building blocks to arrive at a Best System of Emission Reduction (BSER) standard for each state out to 2030. These technology building blocks suggested actions that each US state could take with respect to its existing fossil fuel plant fleet. The final BSER standards were arrived at by combining: An improvement in the heat rate of coal fired power plants; an increase in the utilization of natural gas power plants; and increased use of zero carbon renewables. The Final Rule published in October 2015 showed projected power plant emissions reductions of 32% by 2030, relative to 2005 (Environmental Protection Agency, 2015, p.64924).

At the state level, the BSER translated into proposed state level goals for adjusted MWh-weighted-average pounds of CO₂ per Net MWh covering all Affected Fossil Fuel-Fired units. Because the existing mix of fossil fuel power plants is different the state level goals varied by state (see some examples in Table 3).

Under the policy each state was to submit a plan for compliance. State level plans were to be presented to the EPA by 2016 (with the possibility of a two-year extension) with the compliance period due to begin in 2022. The states were free to pursue multiple pathways to compliance using a CO₂ per unit of MWh (rate-based) or a total emissions (mass-based) standard. They could comply, for

1) ³³ This is not to say that taxes cannot be stable or indeed increasing. British Columbia has had a successful carbon tax experience (see Elgie and McClay, 2013). The tax has been increased from CAD 10 in 2008 to CAD 30 in 2012 per tonne of CO₂. However, the tax has not been linked with other jurisdictions (unlike Canada’s provincial emission trading schemes), significantly falls on otherwise gasoline (which is not as highly taxed in Canada as in Europe) and is significantly about raising revenue. By contrast the UK’s carbon tax on fossil fuels for electricity generation (carbon price floor) was initially due to rise from its currently level of £18 per tonne of CO₂, but has been capped at this level.

2) The Waxman-Markey Bill (the proposed US Clean Energy and Security Act 2009) actually passed 219-212 in the House of Representatives, but failed to progress in the Senate.

3) The Settlement is available at: http://www.eenews.net/assets/2010/12/23/document_gw_02.pdf Accessed 03 December 2015.

Table 3 Final State Goals for selected States (lbs CO₂ per MWh- rate-based standard)

State	Interim Goal (2022–2029)	Final Goal 2030
Montana	1534	1305
Kentucky	1509	1286
Illinois	1456	1245
Ohio	1383	1190
Pennsylvania	1258	1095
Texas	1188	1042
New York	1025	918
California	907	828
Idaho	832	771

Source: Environmental Protection Agency (2015, p.64824).

instance, through emissions trading with other states. Thus states could participate in multi-state plan in order to achieve their emissions reduction goals.

A key feature of the EPA's impact assessment of their Clean Power Plan was that there is substantial net present value in the social cost benefit assessment of their plan. Most interestingly half (or more) of the benefits arise from associated reductions in other types of pollutants (produced with the CO₂) that directly impact on local and regional health within the United States. Total compliance costs are estimated to \$5–9 billion p.a.. Table 4 shows the detail for rate-based scheme. Mass-based schemes are estimated to have lower compliance costs (\$3bn p.a. less in 2030) and lower air pollution health co-benefits, but similar net benefits. This is partly because mass-based schemes can benefit from (cheaper) demand reduction measures. Existing state carbon trading regimes are consistent with a mass-based approach.

The Clean Power Plan (CPP) formed a key part of the US's INDC submitted to COP-21 and lies behind the US's ratification of the Paris Agreement.¹⁾ The EPA's plan was however subject to legal and political challenge, modification and delay.²⁾

Unfortunately, President Trump has decided to withdraw the US from the Paris Agreement³⁾ and consistent with this the EPA proposed, in October 2017, to repeal the CPP.⁴⁾ As of February 2018, repeal seems likely. However the CPP still provides a blueprint for executive action on climate change and is in line with previous attempts to introduce a

national carbon market in the US.

4.2 Chinese progress with carbon trading

China is now the world's biggest emitter of GHGs (26.5% in 2016) and has been making significant progress with its carbon policy.⁵⁾

The National Development and Reform Commission (NDRC)⁶⁾(2013) has stated that China's climate change-related goals for 2020 include the following: Reducing CO₂ per unit of GDP by 40%–45% relative to 2005, and increasing the ratio of non-fossil energy to the consumption of primary energy to 15%. Its previous Five Year Plan (12th FYP 2011–2015) goals were: to reduce CO₂ per unit of GDP by 17% relative to the end of the end of FYP 11, and to reduce national energy consumption per unit of GDP by 16% relative to the end of FYP 11. During the 12th FYP, seven local pilot carbon trading schemes have been established, following approval from the NDRC in October 2011, and the intention is to move to a national carbon market by 2017. These goals have been recently reaffirmed under the 13th FYP for 2016–2020 that seeks to reduce CO₂ per unit of GDP by 18% and to reduce national energy consumption per unit of GDP by 15% (relative to end 2015). China has also ratified the Paris Agreement and committed to reduce CO₂ per unit of GDP by 60%–65% by 2030 (relative to 2005) under its submitted INDC.

The characteristics of the 7 pilot carbon trading schemes are indicated in Table 5. They all cover the electric power sector and other heavy industry. For the initial pilot period 2013-2015 emissions were capped at the same annual level for Shenzhen, Shanghai, Beijing and Tianjin, and capped at levels requiring a decrease of 4.13% p.a. for Chongqing, and allowing moderate increases in Guangdong and Hubei (Xiong et al., 2015). The coverage of sectors varies from 4 sectors in Guangdong to 26 sectors in Shanghai (though all cover electric power) (Zhang, 2015).

Table 5 indicates that these are large pilots, though the number of covered entities is small. Zhang (2015) reports that there has been a high level of compliance with the scheme in the first year and that there have been some emissions reductions, though the pattern of trading in the markets indicates that covered entities are waiting to the end of the compliance window to buy permits rather than trying to minimise the cost throughout the trading period. However, the experience to date shows that the idea of carbon pricing can work in China.

1) See US Government (2015), INDC Submission, at: <http://www4.unfccc.int/Submissions/INDC/Published%20Documents/United%20States%20of%20America/1/U.S.%20Cover%20Note%20INDC%20and%20Accompanying%20Information.pdf>

2) See Carson and Kreilis (2015).

3) The withdrawal was announced on 1 June 2017.

4) See <https://www.epa.gov/energy-independence>, accessed 28 February 2018.

5) Indeed the US and China have made a joint Presidential announcement about their carbon trading plans. See <https://www.whitehouse.gov/the-press-office/2015/09/25/us-china-joint-presidential-statement-climate-change>, accessed 03 December 2015.

6) The NDRC is a cabinet level department responsible for state economic development planning and for guiding the restructuring of the Chinese economy.

Table 4 Summary of Estimated Monetized Benefits, Compliance Costs and Net Benefits for the Proposed Guidelines in 2030 (billions of 2011\$)

	Rate-Based Plan 3% discount rate
<i>Climate Benefits</i>	20
<i>Air pollution health co-benefits</i>	14–34
<i>Total compliance costs</i>	8.4
Net Benefits (with climate benefits at 3% discount rate)	26–45

Source: Environmental Protection Agency (2015, p.64680).

In December 2017 the NDRC announced the intention to start a national carbon market.¹⁾ The market will initially include just the power sector, but the intention is to extend this over time to more industries. The initial coverage will be around 3500 mt CO₂ (75% bigger than the EUETS) and around one third of China's total GHGs. Implementing the market will be a challenge (and explains the expected delays) given its scale and the relative inexperience in China with trading emissions allowances.

Air pollution remains a major political issue in China, which may drive emissions reduction. The health co-benefits of reduced coal use (by heavy industry) in China remain very large (around 10% of GDP from excess mortality)²⁾ and suggest additional momentum behind emissions reduction that might not be present in other countries. China has also re-embarked on power market reform aimed at reducing electricity prices (which are very high for Chinese industry relative to the United States) following the publication of the No.9 Document of March 2015.³⁾ This should drive rationalisation of the Chinese coal industry and reduced investment in new coal fired generation more likely. The Chinese power sector is responsible for around 7% of global CO₂e emissions.

Table 5 Key characteristics of the Chinese Emissions Trading Pilots

	Shenzhen	Shanghai	Beijing	Hubei	Guangdong	Tianjin	Chongqing
<i>Start of operation</i>	2013	2013	2013	2014	2013	2013	2014
<i>Carbon intensity target 2011-2015</i>	-21%	-21%	-18%	-17%	-19.5%	-19%	-17%
<i>Threshold</i>	> 20000 t CO ₂	> 20000 t CO ₂	> 20000 t CO ₂	> 60000 t CO ₂	> 20000 t CO ₂	> 20000 t CO ₂	> 20000 t CO ₂
<i>Initial Year Allowances</i>	33mt	160mt	50mt	324mt	388mt	160mt	125mt
<i>Entities covered</i>	635	191	490	138	242	114	184
<i>Emissions covered</i>	38%	50%	50%	35%	42%	60%	35-40%
<i>Offsets</i>	10%	5%	5%	10%	10%	10%	8%
<i>Free initial allocation</i>	c.95%	100%	c.95%	c.90%	c.97%	100%	100%
<i>Penalties</i>	3X market price	10-100k CNY	3-5X market price	3X market price	3X market price	NA	2X market price

Source: World Bank 2014, p.122; Xiong et al., 2015, p.2511, 2513; Zhang, 2015.

5 Conclusions

The idea of using the market to deliver carbon reductions is a potent one relative to the alternatives (notably regulatory controls through technology and performance standards, or incentives for low carbon technologies through subsidies and price supports). Carbon emissions permit trading is a globally popular form of carbon pricing. A global carbon market is highly desirable as a low cost way of delivering emissions reduction: Indeed a reasonably comprehensive set of carbon markets should be the economic center-piece of any quantity based target for global GHG emissions, especially in the early stages toward deep cuts in global emissions.

We are still a long way from trading carbon in significant volumes across borders, but once again, there are encouraging signs that this is happening. The EU ETS has achieved transboundary trading of carbon in a wide geographic area. This scheme is capable of being linked globally and has helped create a significant market for CDM CERs from developing countries. Carbon does thus have an opportunity cost in many countries as a result of the EU ETS.

Australia provides a cautionary tale on the steady progress of carbon pricing mechanisms. Clearly, distributional issues need to be addressed within countries, as do the substantial leakage issues associated with the potential impact on traded sectors. However, have been encouraging signs in both the US and China on the potential future direction of carbon markets within those countries.

There is still a long way to go before we see emergence of anything like a comprehensive system for pricing of carbon externalities, built on large national or regional schemes. There is still considerable doubt as to whether the piecemeal actions of individual governments with respect

1) See Emily Feng, 'China moves towards launch of carbon trading scheme', *Financial Times*, 19 December 2017.

2) The Global Commission on the Economy and Climate (2014, Chapter 4, p.13).

3) See: Deepening Reform of the Power Sector, China State Council, Document #9, March 21, 2015, accessed at <http://www.ne21.com/news/show-64821.html>.

to emissions (as represented by the current set of INDCs) will ever add up to the necessary amount of emissions reductions that climate science claims to be necessary.¹⁾ While establishing the amount of emissions required and dividing it up acceptably between countries requires an enormous scientific and international negotiations effort, the economic instruments to deliver the agreed targets are readily at hand.

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1) The current public commitments made in the INDCs submitted ahead of COP-21 in Paris (as of October 2015) of governments to reduce GHGs by 2030 fall well short of what the IPCC (2014) are calling for, see Boyd et al. (2015).

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