Samuel Fankhauser and Cameron Hepburn

Designing carbon markets, part II: carbon markets in space

Article (Accepted version)
(Refereed)

Original citation:
Hepburn, Cameron and Fankhauser, Samuel (2010) *Designing carbon markets, part II: carbon markets in space.* Energy Policy, 38 (8). pp. 4381-4387. ISSN 0301-4215

DOI: 10.1016/j.enpol.2010.03.066

Designing Carbon Markets Part II: Carbon markets in space

Samuel Fankhauser[a] and Cameron Hepburn[b]

23 March 2010

Abstract

This paper analyses the design of carbon markets in space (i.e., geographically). It is part of a twin set of papers that, starting from first principles, ask what an optimal global carbon market would look like by around 2030. Our focus is on firm-level cap-and-trade systems, although much of what we say would also apply to government-level trading and carbon offset schemes. We examine the "first principles" of spatial design to maximise flexibility and to minimise costs, including key design issues in linking national and regional carbon markets together to create a global carbon market.

Keywords: carbon trading, environmental markets, gains from trade, EU ETS

Acknowledgements: The paper is the result of a project undertaken for the UK Office on Climate Change in the context of the Lazarowicz Review on Global Carbon Trading. We are grateful to Alex Bowen, Simon Dietz, Graham Floater, Robin Smale, Andrew Wood and two anonymous referees for their comments and feedback, We would also like to acknowledge support by the Grantham Foundation for the Protection of the Environment, as well as the Centre for Climate Change Economics and Policy, which is funded by the UK's Economic and Social Research Council (ESRC) and by Munich Re. The usual disclaimers apply.

[a] Grantham Research Institute and Centre for Climate Change Economics and Policy, London School of Economics, Houghton St, London WC2A 2AE (UK); s.fankhauser@lse.ac.uk. (Corresponding author).

[b] Grantham Research Institute, London School of Economics, and Smith School for Enterprise and the Environment, Oxford University, 75 George Street, Oxford OX1 2BQ; cameron.hepburn@economics.ox.ac.uk .

1 Introduction

Carbon markets look set to spread geographically. Currently, the world's largest carbon market is the EU Emissions Trading Scheme (EU ETS), which covers over 40% of EU carbon dioxide emissions, or about 2 $GtCO_2$. But the proposals currently contemplated by US lawmakers would create a US-wide carbon market which would be two or three times bigger than the EU ETS. Carbon trading is also contemplated in Australia, New Zealand and – more cautiously – in Japan, Canada and emerging markets like Mexico. Meanwhile, the expansion and reform of the Clean Development Mechanism (CDM) — the world's largest baseline-and-credit system — is a key aspect of the international negotiations for a new international agreement post-21012. Various other options to support carbon finance flows from developed to developing countries are being actively discussed, including sectoral crediting mechanisms which would deliver credits for emission reductions from entire sectors, along with ironing out the wrinkles in programmatic CDM which would permit credits to be granted for programmes that aggregate many small emission reducing activities, and so on (Vivid Economics, 2008; Michaelowa et al., 2008).

As the world embarks on expanding the coverage of carbon markets globally, this is a good moment to recap the economic case for carbon trading and review market design options. This paper is part of a twin set of papers addressing what a global carbon market might look like by around 2030, assessing design features relevant to both space (this paper) and time (the companion paper).

Behind the expansion of carbon markets is the recognition that any meaningful climate change policy has to put a price on carbon (Stern 2007), which ideally would eventually be roughly equivalent across nations. This is a fundamental, if fairly basic, lesson from environmental economics and the theory of externalities (Baumol and Oates, 1988; Cropper and Oates, 1992). Environmental economics also tells us that there are several ways of putting a price on carbon, including taxes, permits and any number of hybrid instruments. Different national jurisdictions may adopt different approaches, but what matters is that greenhouse gas emissions are priced to reflect their marginal social costs.

Under idealised textbook assumptions, carbon trading and carbon taxes (and hybrids of the two) are essentially equivalent, but in real world situations with imperfect information, transaction costs and external shocks, there are important differences (Hepburn, 2006).[1] The

[1] The key reference on taxes versus permits remains Weitzman (1974). Hoel and Karp (2001) and Newell and Pizer (2003) have extended the Weitzman result to stock pollutants such as CO_2, where

policy preference for carbon trading over carbon taxes in recent years is not driven by these economic differences, however, but by political economy considerations. Trading systems are easier to implement politically (Hepburn, 2006, 2007).

The choice between taxes and permits (or allowance-based systems) is not strict, and hybrid instruments that blend price-based and quantity-based features, are discussed in the companion paper (Fankhauser and Hepburn 2010). For instance, the slope of the supply curve of an allowance to emit is an issue of policy design. It is only one of many design choices policy makers have to make, of course. In designing a carbon market, other policy issues include:

- The allocation of allowances creates economic rents and therefore matters enormously to the political viability of any system (Fischer et al. 1998, Bucher et al. 2007). In many cases allocation may also influence the efficiency of the system (Stavins, 1995; Hepburn et al., 2006)
- The interaction of carbon markets with other instruments is critical for climate policy, because carbon markets will be supplemented by other instruments. While the simple theory of externalities indicates that only one instrument is needed to internalise one externality, in the climate change context several exernalities in addition to the greenhouse gas externality are relevant, including externalities relating to innovation and R&D. These other externalities may be addressed through separate policy levers that supplement a price of carbon. In addition, political distortions are likely to imply that attempts to internalise the carbon price are suboptimal, such that carbon prices are well-below the social cost of emissions, supporting the case for supplementary interventions to increase coverage or to lift long-term prices.
- Transaction costs matter with regard to design choice. Some systems are easier to administer than others. For instance, upstream trading systems have fewer (and more sophisticated) trading entities than, say, downstream trading between individual consumers. Another example is that baseline and credit systems, such as the Clean Development Mechanism, have inherently higher transaction costs than cap and trade systems, because asymmetric information requires costly signalling to prove additionality (Vivid Economics, 2008).

---

damage does not depend on the flow of emissions but on their accumulation in the atmosphere.

It is not the purpose of this paper to deal with all of the issues above. Rather we focus on a key issue that makes carbon markets a cost-effective instrument for emission control: the flexibility to spread emission reductions across space.

It is this "where flexibility" that allows markets to minimise compliance costs. In principle, the more "where" flexibility is built into market design, the more cost-effective a market is likely to be. However, there are factors that may counsel against full liberalisation of markets across space. For example, different levels of ambition in different jurisdictions may prevent the linking of regional markets. The complement to flexibility across space, and equally important, is flexibility to spread emissions across time - or "when" flexibility. We consider question of temporal design in the companion paper (Fankhauser and Hepburn 2010).

An important issue considered by this paper and the companion paper is volatility in the carbon price, which is a relevant factor in determining the ease with which large-scale projects to reduce emissions can be financed using incentives created by carbon markets. Undue price fluctuations have been an important concern of policy makers, both upward (e.g. the call for safety valves in the US and Australian discussion) and downward (for example the recent drop in EU allowance prices and the price collapse in phase I). Linking markets is one way of reducing regulatory-induced volatility, as price volatility and market flexibility are linked. The more integrated a market is across space (and time), the less volatile prices should be, all else being equal. With deeper markets, a shock to any one region will have a smaller impact on the global carbon price than it would have had on a regional carbon price in an autarkic, smaller market. While linking to other regions also creates exposure to shocks in those other regions, overall market integration might be expected to reduce price volatility (Jacks et al., 2009). In fact, in some cases price volatility is a direct consequence of market design and/or policy shocks, rather than being caused by natural market fluctuations.

The structure of this paper is as follows. Section 2 sets out some "first principles" of design – with a focus on "where" flexibility – that underpin the rest of the paper. Our focus is on firm-level trading systems, although much of what we say would also apply to government-level trading (e.g., AAU trading under the Kyoto Protocol). Section 3 examines the key design issues in linking national and regional carbon markets together to create a global carbon market. Section 4 concludes.

2 First principles of carbon market design – spatial issues

The cost-effectiveness of our efforts to reduce emissions will be critical to the success or failure of climate policy, for two reasons. First, the world's willingness to pay is limited; there are always many worthy claims to attention and funds. As such, achieving stabilisation of atmospheric carbon dioxide concentrations at 450-550 ppm will require that the available funds are spent wisely. Second, climate change is a significant global challenge because: (i) the costs of reducing emissions are expected to be substantial – at least 1% of GDP (Stern, 2007; IEA 2007) [2]; and (ii) those costs are a strong function of policy choices. It is thus extremely important that the world tackles mitigation in a cost-effective way.

Costs are reduced by allowing flexibility about where (and also when) emissions reductions occur. Integrated assessment modellers have long recognised this. For instance, in 1996 the Stanford Energy Modeling Forum noted that the cost of the then Berlin Mandate (the process that resulted in the Kyoto Protocol) could be reduced to a fraction of the total by introducing spatial and temporal flexibility (Richels et al. 1996; Manne and Richels, 1996; see Figure 1). This conclusion has proven robust to specific models and particular policies (e.g. Vrolijk and Grubb, 1999), as indeed would be expected. A recent example is the work by Edmonds et al. (2008) on the cost of delaying developing country participation in the global deal. Indeed, under certain plausible conditions it is theoretically inevitable that providing more options reduces costs.[3]

This insight on the value of "where" flexibility is significant. It suggests that, *ceteris parabus,* our ambition should be a "global" carbon market. In practice, there are various caveats and constraints on implementing such a market. Nevertheless, something approximating a global carbon market might be created by "linking" different national and regional trading systems. Linking markets not only increases "where" flexibility, it also increases liquidity, because there are more willing buyers and sellers, which reduces the costs of trading. In contrast, fragmented and unconnected national carbon trading systems would be less liquid, or "thinner", with concomitantly higher costs of reducing emissions.[4]

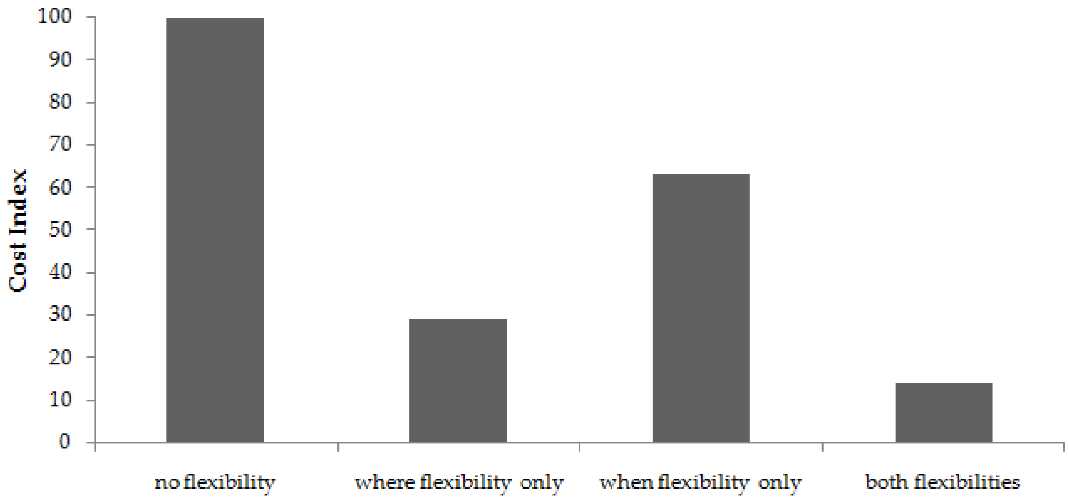
---

[2] Of course, it is expected that these costs will be hugely outweighed by the benefits from mitigating climate change (Stern, 2007).

[3] For a study of the relationship between choice and welfare, see Irons and Hepburn (2007).

[4] The new Carbon Reduction Commitment in the United Kingdom may suffer from problems of limited

Figure 1 Cost reductions from allowing "where" and "when" flexibility



Source: Richels et al (1996)

Political and economic constraints will likely prevent a perfectly global carbon market from emerging. But some of these constraints are not particular to carbon markets. For instance, the "global markets" for oil, wheat and gold are in fact complex trading systems where location, quality and time matter. Carbon will most likely be the same, and it would be surprising if there were a single, globally uniform carbon price.

In particular, there may be constraints in linking up systems because of (Flachsland et al. 2009):[5]

(i) inherent differences in the traded good. For instance, "forest carbon" from afforestation or reforestation schemes raises questions of permanence (Eliasch 2008). Aviation emissions involve complex scientific issues of radiative forcing at altitude, and various other sectors, including agriculture for instance, involve the conversion of other greenhouse gases into carbon dioxide equivalents;

(ii) excessive cost differences. While the point of emissions trading is to maximise "gains from trade" (section 3.1), political considerations demand that transfers are not "too large". For instance, one of the controversies surrounding HFC projects under the CDM was the amount of economic rent generated (Wara 2007, Hepburn,

---

liquidity (Defra, 2008).

[5] Jotzo and Betz (2009), Sterk and Kruger (2009) and Tuerk et al (2009) analyse concrete impediments to linking in from specific cap-and-trade proposals.

2007). Rightly or wrongly, the carbon market was seen as too expensive a way to phase out HFCs, compared to regulation, given the marginal costs of abatement were in principle extremely low; and

(iii) policy differences, primarily due to differences in the level of ambition of different systems. Differences in ambition manifest themselves in different carbon price levels that are deemed unacceptable.

Next we turn to design features that can overcome some of these limitations to “where” flexibility.

3 Spatial design options

The first principles of carbon market design point to a theoretical ideal of a global market with full "where" flexibility. Given the geographical distribution of low-cost mitigation opportunities (McKinsey 2009), only a global market will ensure full cost-efficiency.

A truly global carbon market with uniform rules and a global regulatory regime is unlikely to emerge for many years. However, a system of connected and coordinated regional markets can be an alternative that provides similar efficiency gains. Even established global markets like that for oil, wheat or coal are systems of separate but highly integrated regional markets with distinct local supply and demand dynamics. The most likely way in which a global carbon market will emerge is through increasingly closer links between regional trading systems.

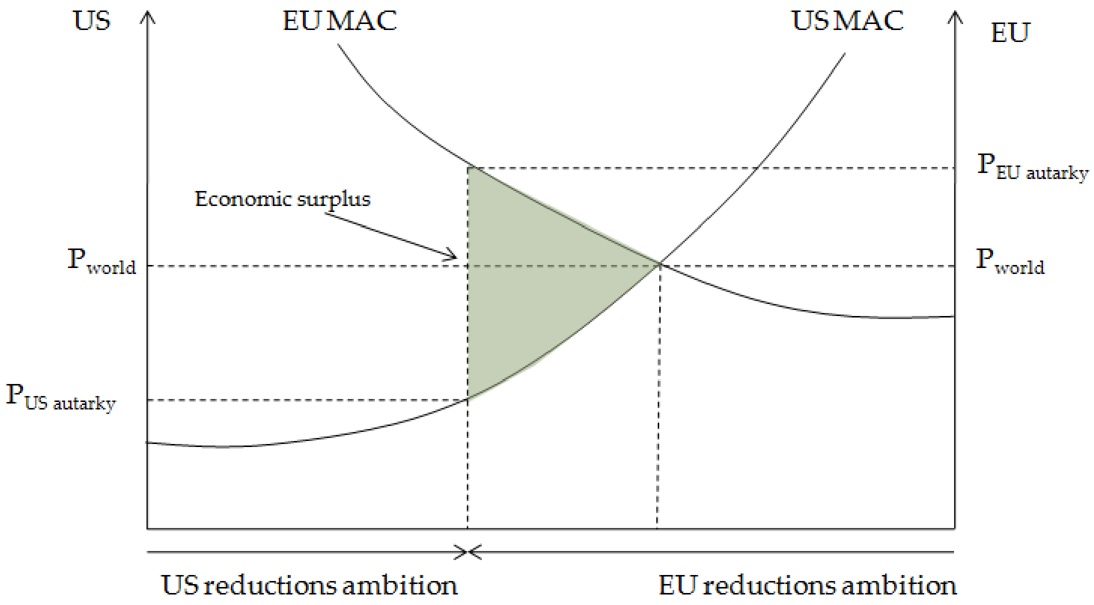
Linked markets will create trading opportunities, financial flows and "rents", or gains from trade (section 3.1). Linking regional markets requires a certain level of coordination and the alignment of policy objectives between the systems. Perhaps the most important objective upon which agreement is required is the range of acceptable carbon prices, as prices in linked systems will invariably converge through arbitrage. That is, there has to be an *equivalence of ambition* between systems (section 3.2). There is also a need for coordination on market rules such as allowance allocation, the treatment of offsets and quality standards, e.g. in terms of monitoring (section 3.3). The more integrated a market is, the lower are concerns about carbon leakage and the loss of competitiveness. If markets are insufficiently linked or "unilateral", a key concern for market design is how to address leakage and competitiveness issues (section 3.4).

3.1 The gains from trade

A key feature of integrated markets – and in fact the source of the efficiency gains – is that it allows the arbitrage of price differentials until there is a uniform price across the system.

Figure 2 shows this effect schematically. Emission reductions in the first country (in our hypothetical example, the US) are measured from left to right, those of the second country (the EU) are measured from right to left. The width of the graph denotes the combined abatement effort. Before markets are linked, different autarky prices prevail in each system. Once the two markets are linked we will observe a net flow of allowances from the low-price system (the US in this example) to the high-price system (the EU) until there is a uniform price. Higher marginal abatement costs in the EU means that EU firms find it optimal to purchase allowances from US firms instead of reducing emissions at home.

Figure 2 Hypothetical gains from linking US and EU trading systems



The activity generates economic benefits in the size of the shaded area: High-cost abatement in the EU is replaced with cheaper abatement in the US. At the firm level, EU firms benefit from reduced costs of compliance, and US firms profit from selling their excess allowances at higher prices than they would achieve in the domestic US system. The size of the gains from trade depends upon the shape of the marginal abatement cost curves of the trading regions, and the respective ambition of the two systems.

In the unlikely even that the linking systems are identical in ambition, such that carbon prices are identical in autarky, then there are no immediate gains from trade. However, even in such a case there are benefits from increased liquidity. Furthermore, Figure 2 only presents a static analysis; in reality the location of the marginal abatement costs will shift as new technologies are discovered, and indeed as the market price of other key commodities (such as coal and gas) move. These dynamic movements imply that even systems of roughly equivalent ambition would have wide discrepancies in prices unless they were linked together.

3.2 Equivalence of ambition

Because linking equalises carbon prices, a precondition for linking markets is that policy makers in both systems have similar levels of "ambition", or expectations about the carbon price. The equilibrium price P_{world} in Figure 2 has to be within an acceptable range for both jurisdictions.

This seems obvious but is in fact the main stumbling block in linking up markets. European policy makers more or less explicitly aspire to a high-price system that ultimately supports technologies like Carbon Capture and Storage (e.g., UK Committee on Climate Change 2009). In much of the rest of the world, most notably the US, the concern is more about avoiding price spikes. As long as levels of ambition are not aligned regional markets will not be linked for political reasons, and if they were linked they create political problems and would function badly.

Imagine a linked up system such as that in Figure 2 where regulators in both systems have the ability to intervene in the market. The following undesirable scenario could occur. In the low-price system, a safety valve or other mechanism might be triggered as arbitrage pushes the price up to the equilibrium level (for example, through the issuance of additional allowances or increased offset limits). In the meantime, the high-price regulator might seek to support the price by withdrawing allowances or imposing an auction reserve price above P_{world}. The two sets of action will cancel each other out (unless one regulator has more market power than the other). In the process they will increase the flow of allowances from the low-price to the high-price system. Market intervention exacerbates the ex-ante differences. The low-price system becomes even more low-price (in terms of the autarky price) as the level of ambition is scaled down, and the reverse happens in the high-price system.

A second issue is the acceptance of the financial transfers and trade flows that integration will bring. They are depicted graphically in Figure 3. The low-cost system (in our example, the US) can expect carbon market revenues from the high-cost system (in our example, the EU) in the magnitude of the shaded rectangle. Depending on the shape of the abatement cost curves and the levels of domestic ambition, cross-border flows may be significant relative to overall trading volumes. For example, in 2008 UK firms participating in the EU ETS were 24% over their allowed cap and had to buy a net 50 million allowances from firms in other countries. German firms were 21% short and had to import 84 million allowances. [6] Combined, these transactions were worth in excess of €2.5 billion.

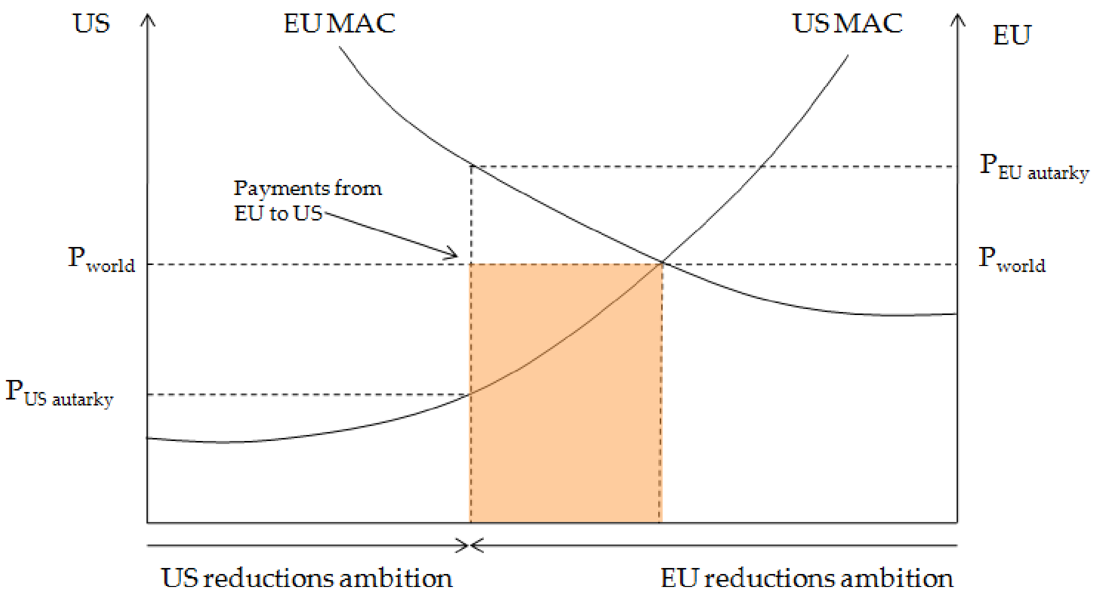
This is a small sum relative to overall trade flows. The UK imports goods and services worth over €500 billion each year. Nevertheless, the size and direction of trade flows is likely to matter when systems are linked up, and particularly when they are caused by differences in the level of ambition (a policy choice), rather than abatement costs (a technical-economic

[6] Data from http://communities.thomsonreuters.com/Carbon/. A fraction of the shortfall may also have been borrowed from the 2009 allowance pool (see section 4.1).

issue). Few policy makers will be willing to reward low levels of ambition in other countries with additional financial flows from carbon market arbitrage.

A likely compromise that is more palatable politically, at least in the short-term, may be indirect linking. This can be achieved if two parallel trading systems are linked to a third market. The most likely conduit is the international offset market, that is the CDM or eventually a more broader sector crediting scheme (Lazerowicz 2009).

Figure 3 Hypothetical payments from EU firms to US firms



3.3 Compatibility of system design

Linking trading systems requires a minimum level of coordination on market design or the combined markets will not function properly. We have already seen the impact of differing price policies (price support vs. safety valves) in the previous section. It is not the only area where coordination will be necessary (Sterk et al., 2009).

One major area where consistency across systems is crucial in the longer term is allowance allocation. In isolated markets (and in the early stages of a system) allowances tend to be issued for free, particularly to installations that are subject to international competition. The belief is that this can help to mitigate negative impacts on competitiveness. We will discuss the merits of this approach in the next section. Whatever they may be, they fall away once the competition is also capped under a linked emissions trading system and therefore subject to the same carbon price. In that case free allocation becomes a form of state aid that gives its recipients a competitive advantage over rivals that have to purchase their allowances. To avoid market distortions, linking up regional systems has to go hand-in-hand with an alignment in allocation rules.

This is the reason why allocation rules within the EU ETS are coordinated at EU rather than national level. As a consequence, differences are small (although there are some). The only sector where there are substantial differences in allocation rules is electric power, where some Central European power producers will enjoy softer auctioning rules than their Western peers in phase III of the system. However, the derogation is temporary and there is relatively little cross-border electricity trading in Europe so the competitiveness effect is small.

Another area where coordination across systems is important is the treatment of carbon offsets, such as certified emission reductions from the CDM. There has to be alignment both in terms of the quality (environmental integrity) and the quantity of offsets permitted into a system. Most cap and trade systems limit the number of offset credits that can be imported into the system. The current version of the Australian Carbon Pollution Reduction Scheme is a notable exception (Government of Australia, 2008). Different systems also impose varying degrees of quality requirements. The EU ETS, for example, does not recognise forestry credits. Once systems are linked any such differences disappear de facto. Credits may enter the market through the national system with the most permissive rules, where they can be swapped into freely tradable allowances.

3.4 Competitiveness issues

One of the main questions in designing a unilateral cap-and-trade system is how to prevent carbon leakage and the loss of international competitiveness. The two issues are linked. Leakage and competitiveness are the environmental and economic side of the same coin.

Firms facing higher production costs due to carbon regulation are at a disadvantage in the international market and will lose market share to competitors with less stringent carbon constraints. Multinational firms may choose to relocate production to avoid carbon regulations. In either case, emissions and economic activity move away from the regulated space to less-strictly regulated regions. Even if this does not happen, mitigation action in the regulated market could lead to a fall in the demand of high-carbon fuels like coal, whose price will drop as a consequence. This will in turn stimulate demand (and reduce the cost base) outside the regulated market. The result is again carbon leakage and a loss in competitiveness.

The problem is most acute between regulated and unregulated markets but it applies similarly to regions with different carbon prices and different levels of ambition. Most studies suggest that competitiveness issues are restricted to a small number of sectors (Carbon Trust 2008). Nevertheless it is an important concern.

Competitive issues become smaller the wider and more integrated the carbon market becomes as an increasing share of a sector is covered by equivalent regulation. Linking is therefore the first-best-choice of resolving competitiveness problems and preventing leakage.

If linking is not possible the next best solution is to create a level playing field in those sectors where international competition is particularly strong and the problem thus most acute. In some cases, it may be feasible to create a fully-fledged sector-level trading system. International shipping is one sector where this is contemplated. In other cases it may help to impose similar regulatory requirements on firms inside a trading system (through a carbon price) and outside the system (through equivalent regulation). Sector agreements are contemplated, for example, in steel. However, they are difficult to set up because production processes and national circumstances differ, which makes it hard to define meaningful technical benchmarks.[7] Other problems arise, including the challenge of creating incentive for participation by companies in non-regulated regions, and ensuring compliance and enforcement.

The favourite instrument to address competitiveness issues, at least in the EU, has so far been the free allocation of allowances to installations that are subject to international competition.[8] From an economic point of view, the effectiveness of this measure is uncertain. Free allocation does not change the value of allowances and should therefore not affect the behaviour of firms at the margin. An allowance has the same opportunity cost whether it has to be purchased on the market or was received for free. Free allocation may make a difference, though in the presence of transaction costs or firm-internal dynamics. Relocating factories is costly, particularly if unions and local stakeholders are involved, and may affect a firm's standing in the home market. Perhaps demonstrating profitability (however achieved) is sufficient for managers to keep an installation open. However, such short-term arguments become less convincing once a trading system has been operational for a few years.

---

[7] Vivid Economics (2008) and Michaelowa et al. (2008) provide a discussion of sectoral trading approaches.

[8] Free allocation is also a way to obtain buy-in from industry and to compensate stranded assets created through abrupt regulatory change. In political economy terms this is a key reason why cap-and-trade systems are easier to implement than a carbon tax.

The final alternative to deal with competitiveness problems is border tax adjustments. This option is discussed for example by Brewer (2004) and Ismer and Neuhoff (2007).

4 Conclusion

There are compelling reasons to establish a long-term ambition for a global carbon market. We have defined the 'global carbon market' not in the sense of a globally administered and regulated trading regime, but in the sense of a mosaic of regional and national markets that are linked and whose level of ambition is consistent with the overarching aims of climate change policy. National or regional carbon markets may be linked directly (presumably with import limits) or indirectly through common products like CERs or forest offsets that are accepted in all systems.

The current flurry of national and regional initiatives to set up carbon markets is a welcome opportunity for experimentation and innovation, allowing the opportunity to explore different designs. But there is also a risk that the results will create incompatibilities that limit the potential for linking and result in a fragmented global market in which the benefits of "where" flexibility are not fully explored.

There is merit in experimentation and learning. The concept of emissions trading is not new (Dales, 1968), and nor is the practice of emissions trading, but carbon markets on the scale, ambition and planetary importance of those currently emerging have never been seen before. We do not yet have all the answers on how these carbon markets should be designed and implemented. For example, the experience with phase I of the EU ETS has resulted in important lessons on auctioning, banking and information release that have now been incorporated in the design of subsequent systems. Experience with RGGI has also been enlightening. Continued innovation generates valuable lessons.

However, the right balance has to be found between experimentation and the need to make systems compatible so that they can eventually be linked up. The gains from trade (section 3.1) from linking are potentially enormous, even if the linked systems have identical estimated ambition (and hence carbon price) *ex ante*.

Design features that may generate political or economic obstacles to linking include: differences of ambition, treatment of free allocation vs auctioning, price management policies (including price ceilings, price floors, allowance reserves, auction reserve prices), rules on borrowing, and treatment of offsets. Design differences along these dimensions contribute to increased economic issues, design problems or political concerns about financial flows from one system to the other.

However, few of them constitute an insurmountable obstacle to linking developed country systems and advancing towards an overall long-run objective of establishing a global carbon market to reduce emissions. While there are factors discussed in this paper that counsel against full liberalisation of markets across space, taking advantage of "where" flexibility (and "when" flexibility, see Fankhauser and Hepburn 2010) is critical to minimising the costs of mitigating emissions and responding to climate change.

References

American Clean Energy and Security Act of 2009: 111th Congress, 1st Session, Discussion draft, 31 March 2009.

Baumol, W. J. and Oates, W. E., (1988), *The Theory of Environmental Policy*. Cambridge University Press, 2nd edition.

Brewer, T. L. (2004), 'The WTO and the Kyoto Protocol: Interaction Issues', *Climate Policy*, 4, 3-12.

Buchner, B,. D. Ellerman and C. Carraro (2007): *Allocation in the European Emissions Trading Scheme: rights, rents and fairness*, Cambridge: CUP.

Capoor, K. and Ambrosi, P. (2009), *State and Trends of the Carbon Market 2009,* World Bank, Washington DC.

Carbon Trust (2008), *EU ETS Impact on Profitability and Trade: A Sector-by-Sector Assessment*, www.carbontrust.co.uk.

Committee on Climate Change (2009). *Meeting Carbon Budgets. The Need for A Step Change. Progress Report to Parliament*, London, October.

Cropper, M. L. and Oates, W. E. (1992), 'Environmental Economics: A Survey', *Journal of Economic Literature*, 30:2, 675–740.

Dales, J.H. (1968), *Pollution, Property and Prices*. Toronto: University of Toronto Press.

Defra (2008), *Implementation proposals for the Carbon Reduction Commitment (formerly the Energy Performance Commitment): Review of Consultation Responses*, London: Department for Environment, Food and Rural Affairs, March.

Edmonds, J. Clarke, L., Lurz, J. and Wise M. (2008), 'Stabilizing CO2 concentrations with incomplete international cooperation', *Climate Policy*, 8:4, 355-376.

Eliasch, J. (2008), *Climate Change. Financing Global Forests*. *The Eliasch Review*, London: Earthscan.

European Commission (2009), *Towards a Comprehensive Climate Change Agreement in*

Copenhagen, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2009) 39 (final), Brussels.

European Commission (2001), *Proposal for a Directive of the European Parliament and of the Council Establishing a Framework for Greenhouse Gas Emissions Trading Within the European Community and Amending Council Directive 96/61/EC*, Explanatory Memorandum. COM (2001) 581, Brussels, 23.10.2001, 5.

European Commission (2008), Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the community. Brussels, 23 January 2008. COM (2008) 16 final.

Fankhauser, S. and C. Hepburn (2010). "Designing Carbon Markets Part I: Carbon Markets In Time", in: *Energy Policy*, forthcoming.

Fischer, C., S. Kerr and M. Toman (1998): "Using Emissions Trading to Regulate U.S. Greenhouse Gas Emissions: An Overview of Policy Design and Implementation Issues", in: *National Tax Journal* 51: 453-464.

Flachsland, C. Marschinski, R. and Edenhofer, O. (2009). 'To link or not to link: Benefits and disadvantages of linking cap-and-trade schemes', *Climate Policy* 9: 358-372.

Government of Australia (2008), *Carbon Pollution Reduction Scheme: Australia's Low Pollution Future*, White Paper, December.

Hepburn, C., Grubb, M., Neuhoff, K., Matthes, F. and Tse, M. (2006), 'Auctioning of EU ETS Phase II allowances: how and why?' *Climate Policy*, 6:1, 135-158.

Hepburn, C. (2007) 'Carbon trading: a review of the Kyoto mechanisms', *Annual Review of Environment and Resources*, 32, 375-393.

Hepburn, C. (2009), 'International carbon finance and the Clean Development Mechanism', in Helm D. and Hepburn C. (eds) *The Economics and Politics of Climate Change*, Oxford: Oxford University Press, chapter 20.

Hoel, M. and Karp, L. S. (2001), 'Taxes and Quotas for a Stock Pollutant with Multiplicative

Uncertainty'. *Journal of Public Economics*, 82, 91-114.

International Energy Agency (2007), *World Energy Outlook 2007*. Paris, France: International Energy Agency.

Irons, B. and Hepburn, C. (2007) 'Regret theory and the tyranny of choice', *Economic Record*, 83:261, 191-203.

Ismer, R. and Neuhoff, K. (2007), 'Border tax adjustment: a feasible way to support stringent emission trading', *European Journal of Law and Economics*, 24:2, 137-164.

Jacks, D. S., O'Rourke, K.H. and Williamson, J. G. (2009), 'Commodity price volatility and world market integration since 1700', NBER Working Paper No. 14748, February.

Jotzo, F. and Betz, R. (2009). 'Australia's Emissions Trading Scheme: Opoortunities and Obstacles for Linking', *Climate Policy* 9: 402-414.

Lazerowicz, M. (2009). *Global Carbon Trading. A Framework for Reducing Emissions*., London: TSO.

Mace, M.J., Millar, I., Schwarte, C., Anderson, J., Broekhoff, D., Bradley, R., Bowyer, C., Heilmayr, R., (2008), 'Analysis of legal and organisational issues arising in linking the EU Emissions Trading Scheme to other existing and emerging emissions trading schemes'. London, Brussels, Washington, DC: *Foundation for International Environmental Law and Development*, Institute for European Environmental Policy, World Resources Institute.

Manne A. S. and Richels R. G. (1996), 'The Berlin Mandate: The Costs of Meeting Post-2000 Targets and Timetables' *Energy Policy* 24:3, 205-210.

McKibbin, W. J. and Wilcoxen, P. J. (2002), 'The role of economics in climate change policy', *Journal of Economic Perspectives*, 16:2, 107-129.

McKibbin, W. J. and Wilcoxen, P. J. (2004), 'Estimates of the costs of Kyoto: Marrakesh versus the McKibbin-Wilcoxen blueprint', *Energy Policy*, 32, 467-479.

McKinsey (2009), 'Pathways to a low-carbon economy. Version 2 of the Global Greenhouse Gas Abatement Cost Curve.' London: McKinsey & Company.

Michaelowa, A., Hayashi, D., Jung, M., Müller, N., Bode, S., Castro, P., Dransfeld, B., and

Höhne, N. (2008), *A review of the current state and options for reform of the CDM*, Report for UK Department of Environment, Food and Rural Affairs, July.

Newell, R.G. and Pizer, W.A. (2003), 'Regulating Stock Externalities under Uncertainty', *Journal of Environmental Economics and Management*, 45:2, 416–432.

Richels, R., Edmonds, J., Gruenspecht, H. and T. Wigley (1996), 'The Berlin Mandate: The Design of Cost-Effective Mitigation Strategies', in N. Nakicenovic, W.D. Nordhaus, R. Richels and F.L. Toth (eds.), *Climate Change: Integrating Science, Economics and Policy*, IIASA CP-96-1, International Institute for Applied Systems Analysis, Austria, 229-248.

Stavins, R. N. (1995), 'Transaction Costs and Tradeable Permits', *Journal of Environmental Economics and Management*, 29, 133-148.

Sterk, W. and Kruger, J. (2009). 'Establishing a Transatlantic Carbon Market', *Climate Policy* 9: 389-401.

Sterk, W., Mehling, M. and Tuerk, A. (2009), 'Prospects of linking EU and US Emissions Trading Schemes: Comparing the Western Climate Initiative, the Waxman-Markey and the Lieberman-Warner Proposals', *Climate Strategies*, April.

Stern, N. (2007). *The Economics of Climate Change. The Stern Review*. Cambridge: CUP.

Stern N. H., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., et al. (2007), *Stern Review:* The Economics of Climate Change, Cambridge University Press, Cambridge, UK.

Tuerk, A., Mehling, M., Flachsland, C. and Sterk, W. (2009), Linking Carbon Markets: Concepts, Case Studies and Pathways', *Climate Policy* 9: 341-357.

Vivid Economics (2008), *Peer Review: Reform of the Clean Development Mechanism*, Report for UK Department of Environment, Food and Rural Affairs, August.

Vrolijk C. and Grubb M. (1999), 'Quantifying flexibility in combating climate change: modelling the implications of flexibility mechanisms in the climate change negotiations', *International Journal of Environment and Pollution*, 11(4), 495-524.

Wara, M. (2007). "Is the global carbon market working?", in: *Nature* 445: 595 – 596.

Weitzman, M. L. (1974), 'Prices vs. Quantities', *Review of Economic Studies*, 41(4), 477-491.