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REPORT

HOT AIR

THE CARBON PRICE FLOOR IN THE UK

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CONTENTS

EXECUTIVE SUMMARY

The UK government is introducing a floor price for carbon – to be known as carbon price support (CPS). It will be levied as an additional tax on the carbon content of fuels used for power generation in the UK, and calibrated to supplement the price of carbon set in the EU Emissions Trading Scheme (EU ETS).

A floor price in cap-and-trade schemes is widely supported in the literature. If the cost of reducing emissions is much lower than expected, a floor price can mean the number of permits is reduced – an adjustment that increases economic efficiency. It can also provide investors with greater certainty, lowering the cost of finance.

However, the particular design of the UK proposal could mean these benefits are not captured. Three questions need to be asked.

First, will it save carbon? It introduces a floor for only part of the system, the UK; and imposes it through an additional tax rather than reserve prices at auction. Therefore the floor price has no impact on the total number of permits: every ton of carbon that is priced out of the UK will be emitted elsewhere in Europe.

Second, will it provide investor certainty? It is designed to do so, but the mechanism itself is uncertain, relying on an annual vote in Parliament as part of each year's Finance Bill.

Investors have many reasons to doubt the longevity of this policy, including precedent, incentives, and the fact that governments will feel most pressure to weaken the policy at times when it is most important.

If the policy is not seen as credible, modelling commissioned by the government suggests it could do more harm than good, reducing investment in renewables and reducing security of supply.

The most promising solution is for government to underwrite the tax-inclusive carbon price with a carbon price support guarantee (CPSG). This would not expose the government to market risk, would have no cost if the government delivered on the policy as promised, and would allow the benefits of investor certainty to be realised.

Third, what might be the unintended consequences?

A UK-only floor price, because it creates two prices within the EU ETS, creates economic waste. Using a simple model of the cost of reducing greenhouse gas emissions from the UK power sector and the rest of Europe, this waste is estimated at £92 million in 2020. If this year is typical, the net present value of the waste created by the policy could be approximately £1 billion.

By increasing the costs of electricity, the policy is expected to cause 30,000–60,000 more households to fall into fuel poverty in 2013, increasing to 50,000–90,000 per year in 2020.

By increasing the supply of carbon permits in the rest of Europe (from reducing the supply in the UK), the policy will also affect the carbon price in the rest of Europe. The expected value is estimated to fall by eight per cent in 2020, and up to an additional 18 per cent reduction when business-as-usual (BAU) emissions are lower than forecast. If the carbon price in the rest of Europe is expected to be lower and more variable, low-carbon investments are likely to be less attractive.

By reducing the price of carbon permits in the rest of Europe, the policy will also cause European governments to lose money, and European emitters to save money. This transfer is estimated at £1.3 billion in 2020. If the figure for other years is equivalent, the net present value in 2011 of the reduction in auction revenue over the period of the policy would be £17 billion.

The most comprehensive solution to the problems with the UK proposal is to enact the carbon price floor at a European level, not a national level. This would provide more investor certainty across the continent, allow the quantity of permits to adjust, and prevent the unintended consequences mentioned above. It would accord with the strong finding in the literature that such hybrid regimes are more efficient than a pure cap and trade.

If, however, the UK does implement a unilateral floor price, then setting the level low, to minimise unintended consequences, and introducing a carbon price support guarantee, to secure the benefits of greater certainty, offer the best combination of outcomes.

1. BACKGROUND

The UK government has spotted an important problem: investors in low-carbon power need more certainty than current policy provides. The current price of carbon, set in the market through the European Emissions Trading Scheme, is said to be too low and too uncertain for the long-term decisions that need to be made.

In response, the government has introduced a measure to underpin the carbon price, by taxing fossil fuels used for power generation in the UK. At the moment, the Climate Change Levy levies a tax on electricity and other energy provided to non-domestic users, but any fossil fuels used to produce the electricity are exempt to prevent double counting. This exemption will be removed.

High-carbon fuels such as coal will have a high tax, while lower carbon fuels such as natural gas will have a proportionately lower tax, so that the tax on fuel would in effect be a tax on carbon. Its precise level would be adjusted in response to the market price of EU ETS allowances (EUAs, equal to one tonne of CO_2), with the intention that the EUA price plus tax, or 'tax-inclusive carbon price', would reach a specified minimum in each year.

In effect, the new policy introduces a floor on the tax-inclusive price of carbon-facing UK power generators. If the market price is expected to be above the floor, the tax would be zero; if the market price is well below the floor, the tax would make up the difference.

After being trailed in the manifesto from the Conservative Party (2010: 16), the Treasury launched a consultation on 16 December 2010 (HM Treasury 2010), looking at different levels from 2013 and 2020.

In March, the rates were confirmed, as part of the Budget introduced by George Osborne. The carbon price floor will start at around £16 per tonne of carbon dioxide from 1 April 2013, meaning that the carbon price support, or Climate Change Levy, will be equivalent to £4.94 per tonne of carbon dioxide. The price floor will increase in a straight line to £30 per tonne in 2020, and, according to the consultation, are intended to rise to £70 per tonne in 2030.

The rationale for the change is that this would introduce a higher carbon price, and more certainty for low-carbon investors, encouraging the transition to low carbon.

Three questions, however, have not been adequately addressed by the government documents, and are explored by this paper:

- How much carbon would be saved?
- How much certainty would actually be created for investors?
- What might be the unintended consequences?

2. FLOOR AND CEILING PRICES IN CAP-AND-TRADE REGIMES

The economic literature strongly suggests that cap-and-trade schemes like the EU ETS can benefit from a floor price, either alone or in combination with a ceiling price.

As Weitzman (1974) pointed out, any pollution control such as a cap-and-trade scheme, limiting quantities, or a carbon tax, affecting prices, has to be set before the regulator knows the true costs and benefits of controlling pollution. The regulator may wish to set marginal benefits of carbon abatement equal to marginal costs, but after decisions are taken unpredictable events such as a deep recession, or unexpectedly cheap carbon abatement, will change the calculation. The question then becomes how to minimise the costs of what turn out to have been errors in setting the price or quantity level.

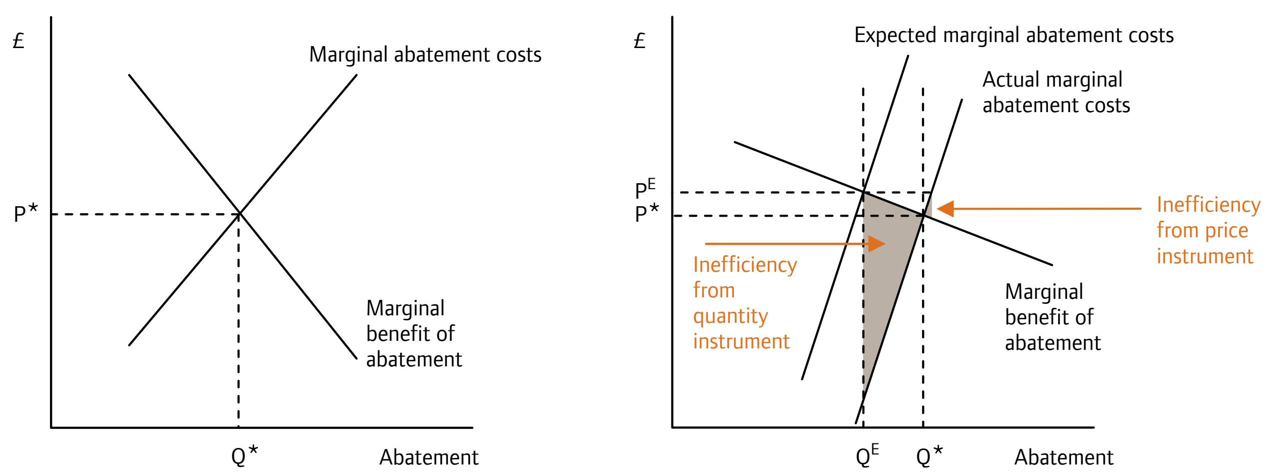
If the marginal benefits curve is steep, then the consequences of having the wrong price level are high: it is better to set the quantities, and let the market set the price in response to changing circumstances and information. On the other hand, if the marginal cost curve is steep, the consequences of having the wrong *quantity* are high: it is better to set a tax, and let the market decide on the quantity.

With climate change, the marginal benefits curve of carbon abatement is relatively flat: each additional tonne in any one year has an impact relatively similar to the tonne before. Therefore, climate change is generally seen as a case when a tax would be more efficient (see for example Pizer and Newell 2003).

This is illustrated in Figure 2.1. Under perfect foresight, as in 2.1A, both a price and a quantity instrument produce the efficient level of abatement Q*, and a carbon price or tax of P*.

If, however, the marginal abatement function is lower than expected, as in 2.1B, then the difference can be clearly seen. If the incorrect quantity, Q^E, is set in a cap-and-trade scheme, then the inefficiency is the large shaded area to the left. If the incorrect carbon tax is set, P^E, then the inefficiency is the shaded area to the right – and much smaller.

Figure 2.1
Prices versus quantities



Political reasons may mean a quantity control is chosen instead, and in this case, floor and ceiling prices can help to import some of the certainty about cost that is the advantage of taxes, in return for less certainty about the quantity of emissions. Introducing a floor tends to mean removing permits from the market when the price falls to the specified level, either by a government buy-back or by having a reserve price at auction; introducing a ceiling price, on the other hand, tends to mean introducing additional permits onto the market if the ceiling is reached. The burden of adjustment to circumstances is therefore shared by both the price and the quantity side.

On climate change, Pizer (2003) showed the impact on expected costs that can come from combining price and quantity measures. He used a modified version of the DICE integrated assessment model to look at the optimal policy over a 100-year period. The cost of achieving the Kyoto Protocol goal of limiting emissions to slightly below 1990 emission levels from 2010 onwards was cut dramatically by combining the quantity restriction with a buy-out, or ceiling price. Even with a tax as high as US$250 per tonne carbon, the expected cost was cut in half. Looking just at the year 2010, a buy-out price of £100 per tonne carbon had less than a one-in-four chance of being triggered, but cut the expected welfare cost of the policy by a factor of ten.

The importance of this price control being symmetrical, rather than just a ceiling at the top, was analysed by Burtraw et al (2009). As they point out, 'in virtually every case when an incentive-based form of regulation like emissions cap and trade has been used, costs have been overestimated rather than underestimated prior to the regulation taking effect'.

Indeed, we can compare the current marginal costs with the government's expectations. In 2009, conducting benefit-cost analysis of the EU commitment to reduce greenhouse gas emissions by 20 per cent by 2020, the DECC carbon price model suggested an average price forecast of €32 for the period 2008–2020, in 2008 prices (DECC 2009b: 66). Sensitivity analysis for different fuel prices suggested a range of €18 to €63 per tonne. This may still turn out to be right – but the current price is only around €16.

Burtraw et al (2009) also calculated an approximate welfare effect of over-estimating abatement costs. Looking at the SO_2 cap under Title IV of the 1990 Clean Air Act Amendments, and assuming legislators intended to equilibrate marginal costs and damages, they calculate that a floor price protecting against the prospect that actual costs would be substantially lower than expected would have improved economic welfare by US$1.5 billion to US$8.25 billion per year in each year since 1995 (2004 prices).

On this basis, introducing a floor price so that the quantity of EUAs can adjust to very low prices, through some reserve price at auction or similar approach, may produce significant welfare gains.

The second perspective on floor prices is at the level of the firm or investor, rather than social costs and benefits. By reducing uncertainty about allowance prices, it reduces the risk profile of investments – and so makes the cost of finance cheaper. This is particularly important given the long time horizon of energy investments, and the capital-intensive nature of low-carbon sources such as renewables and nuclear. With around £200 billion needed in energy investments over the next decade (Ofgem 2009), small differences in finance cost quickly add up.

Fell and Morgenstern (2009) used a stochastic dynamic representative firm model in which the firm chooses emissions paths under various regulatory regimes, in an effort to minimize abatement costs. They found that price collars and safety valves reduced expected abatement costs by as much as 18 and 17 percent, respectively, relative to a cap-and-trade system with no banking and borrowing.

Similarly, Laing and Grubb (2010) modelled returns to investment in different projects with and without a floor price. They built a multi-period model, with initial investment in the first period, larger investment in the second period, and each investment starts reducing emissions in the period after the decision is taken. The model included three sources of uncertainty: emissions level without abatement, operating costs of new technology, and the level of abatement from the initial investment. The use of price floors reduced the distribution of returns and increased the average return over a standard cap-and-trade scheme in the range of US$1 to US$59 million net present value, for a firm the size of EON.

Not surprisingly, these arguments have led many to call for a floor price. In the United States, the Waxman-Markey Bill that attempted to introduce a cap-and-trade regime included a reserve auction price of US$10 in 2012, rising by five per cent plus inflation each year (HR 2454: §791(d)). In the specific context of the current EU ETS, experts gave testimony to the House of Commons Environmental Audit Committee (2010) on the advantages of a floor price.

A floor price, then, has much to commend it. The UK policy, however, is not quite as straightforward.

3. TEST 1: WILL IT SAVE CARBON?

In the theoretical arguments, outlined above, a floor price can lead to extra carbon savings: if the marginal cost of abatement is sufficiently low, the number of permits available for auction is reduced. People whose primary motivations are to tackle climate change, or to maintain economic efficiency, should therefore be in favour.

However, the proposed policy differs from the models in two key respects, leading to different conclusions. First, it introduces a floor for only part of the system, that is, in the UK; and second, it is imposed through an additional tax rather than reserve prices at auction. The floor price has no impact on the total number of permits in the system.

As a result, this policy would have *no* direct effect on emissions reaching the atmosphere. A high price in the UK means fewer emissions within the country; the extra permits would remain on the market. The price in the rest of Europe would fall until demand there rises to equal supply. Exactly the same number would be available, by auctioning or other means, whether the tax is high or zero, and instead of coming from Britain, emissions come from the rest of Europe.

The government's policy is like squeezing a balloon, ignoring the fact that it will simply bulge elsewhere.

The first message for greens, and the government, is to be clear about this conclusion.

On the one hand, the government knows that the working of the EU ETS means no actual emissions would be prevented from reaching the atmosphere by this policy. The consultation document (HM Treasury 2010: 34) says that 'the introduction of a UK carbon price support mechanism for those electricity generating plants whose emissions are covered by the EU ETS would not directly impact on the government's ability to meet its carbon budgets', which takes the EU ETS into account.

Elsewhere, though, the emphasis has been on the UK's separate targets under the Climate Change Act. Justine Greening, the Treasury Minister who launched the consultation, described it in her statement to Parliament as 'achieving the UK's energy and climate policy objectives' (Hansard: 16 December 2010: Column 113WS). The official impact assessment said that not to introduce the floor price would 'put at risk the government's ability to meet UK emission targets' (HM Treasury 2010: 50). The Treasury website, announcing the consultation, said that without reform 'the UK may fail to meet its legally binding targets'.[1] While this may be true, it is important to be clear that the UK would be meeting climate change targets in a way that has zero direct effect on emissions.

Casual readers could also be forgiven for construing a mistaken impression from the government's impact assessment. The benefit-cost analysis includes carbon savings with a net present value of £4.9 billion, £7.2 billion, and £12.5 billion under the different choices of floor price (HM Treasury 2010: 33). This is a legitimate assessment of the benefits for the UK, as fewer permits would have to be purchased. Following Treasury and DECC guidance (2010), EUAs are valued at the government's central estimates of the traded price in the relevant year, and discounted at 3.5 per cent a year to give a net present value. It would be a mistake, however, to see these as environmental rather than financial benefits: there are no carbon savings in the sense of direct reductions in emissions.

1 http://www.hm-treasury.gov.uk/consult_carbon_price_support.htm

No direct impact on greenhouse gas emissions does not in itself mean the policy is a mistake, if it leads to reductions in the long term, analysed below, or reductions in investment costs, analysed in the next section.

Are there long-term savings?

The number of permits in the EU ETS is fixed until 2020, and the floor price will have no effect on emissions during this period. But perhaps, through investment decisions, the UK's floor price could eventually lead to an emissions reduction.

This could be the case under an interim solution argument. A Europe-wide floor price is preferable, but it would take time to win support and come into effect, and in the meantime investment decisions are being made in the UK that will have consequences well beyond 2020. A UK-only floor price could therefore be an interim solution, to be replaced as soon as possible by one across the EU ETS. When the cap comes to be set in future periods, it could take account of the low-carbon investment already made in Britain.

There is no evidence that the government is following this strategy. The impact assessment describes the two options as being either a detailed description of this policy, or '2. Do nothing'. The Conservative Manifesto describes the policy as being this specific change to the Climate Change Levy, without any reference to European action (Conservative Party 2010: 31). The Coalition agreement states 'We will introduce a floor price for carbon, and make efforts to persuade the EU to move towards full auctioning of ETS permits', without reference to any other desired changes in EU policy (HM Government 2010: 16). The government has argued for raising the level of European ambition from a 20 per cent cut to a 30 per cent cut, and this would raise the market price of EUAs; it would not, though, provide investor certainty, or make the UK-only policy any less an example of squeezing a balloon.

Further, according to the modelling by Redpoint Energy, it is not clear that an interim use of the carbon price support would be advisable. Under their assumptions, a CPS from 2013 leads the market to produce new nuclear power only after 2022, and carbon capture and storage (CCS) being fully retrofit onto the demonstration plants only after 2025 (Redpoint Energy 2010: 54). Other elements of the government's proposals, such as the contract for difference for low-carbon generation, do lead to earlier investments, so it is not clear what the CPS adds.

It is hard to see, then, the benefits of the CPS in terms of reduced emissions. The question remains as to whether there are advantages from reducing the costs of investment. This is explored in the next section.

4. TEST 2: WILL IT STRENGTHEN INVESTOR CONFIDENCE?

The primary intention of the policy, as the first sentence of the consultation makes clear, is to 'reduce revenue uncertainty and improve the economics for investment in low-carbon generation' (HM Treasury 2010: 5). More certainty means a lower cost of capital, and a cheaper transition to a low-carbon economy.

On the basis of more uncertainty leading to cheaper finance, the government suggests the policy as a whole has a positive net present value for the UK. But a policy to reduce uncertainty must itself be certain, and four factors may cause investors to doubt the existing carbon price floor.

First, there are incentives for government to renege on the deal: once investors have made irreversible decisions in low-carbon generation, a future government could weaken the carbon price support, and so reduce energy costs for consumers.

Second, a tax mechanism, as proposed for the CPS, is particularly susceptible to this problem of 'time-inconsistent preferences'. It would require annual votes in Parliament, as part of each year's Finance Bill.

Table 4.1
Strategies to improve policy credibility

		Credibility		
		Low	Medium	High
Flexibility	Low		Pre-determined decisions For example, the number of allowances in the EU ETS is set in advance	Contracted decisions For example, the annual rate of increase in payments under the feed-in tariff
	High	Pre-announced decisions For example, fuel duty escalator	Externally-advised decisions For example, Committee on Climate Change advice on the level of the UK carbon budgets	Delegated decisions For example, Monetary Policy Committee of the Bank of England; Ofgem

The experience of similar attempts to commit to future tax rises does not inspire confidence. In the same budget that the Chancellor introduced the carbon price support, he ended an existing multi-year tax plan: the increase in fuel duty of 1p above inflation, due to take place every year 2010–13. It lasted only one year. The original fuel price escalator, introduced by the Major government in 1993, was abandoned by the Blair government, under pressure from protesting lorry drivers, after six years. To have an effect the carbon price support must be continued, from government to government, not for one year or six years but more than 20 years.

Long-term credibility is not a new problem in public policy, and various mechanisms have been developed to strengthen the ability of government to commit (see Helm et al 2005). Unlike those illustrated in Table 4.1, the tax mechanism is neither embedded in a legally binding framework, nor strengthened through arms-length implementation.

The third issue that may cause investors to doubt the CPS is the price level it is set at. The government consulted on targets of £20, £30 or £40 in 2020, and £70 in 2030, before announcing the target of £30 in 2020. Market expectations of the EUA price, however, are substantially below this.

Approximate long-term market expectations can be derived from the current price and the interest rate. The ability to bank and borrow in the EU ETS, and the ETS Directive's commitment to a post 2020 phase 4, means the price of EUAs should be expected to act like any other non-renewable resource: buyers and sellers will time their decisions to maximise net present value, meaning, in equilibrium, the expected price of EUAs should rise at the rate of interest – the condition known as the Hotelling Rule (see Weitzman 2003).[2]

The relevant interest rate depends on the amount of perceived risk, but a rate high enough to achieve the government price targets is implausible. For the EUA price to grow from its current level of around £12.50 to £30, over nine years, would require an interest rate of 10.2 per cent per year. To grow from £30 to £70 in the subsequent decade would require an annual rate of 8.8 per cent. A more realistic level, say, five per cent, reveals market expectations of a price of £19 in 2020 and £32 in 2030.

Even taking account of the fact that market participants may be behaving inefficiently, or perhaps discounting the long-term viability of the EU ETS, there is no indication that the European-wide market foresees EUA prices at anything like the levels assumed for the carbon price floor in the government's scenarios in 2030.

As a result, for this policy to be credible, investors must believe that the government will make very large market interventions.

The fourth cause of doubt is that, if prices do deviate from their expected levels, the most important decisions will need to be taken at the most difficult times to make them.

Generally the EU ETS price will be lowest when the EU economy is weak and so the supplementary carbon price support will be needed to top it up to the floor price. It is at precisely these moments, however, that a large increase in the carbon price support may be most politically difficult. Supporters of cap and trade or quantity-based approaches to carbon pricing have pointed out that during the recession of 2008 it would have been very hard for governments to maintain high carbon taxes. Under the government's proposed hybrid EUA plus tax approach, there would be pressure to reduce carbon price support levels.

Consequences of a lack of credibility

The central purpose of the policy, as the subtitle of the consultation document makes clear, is 'certainty for low-carbon investment' (HM Treasury 2010). If this fails to be achieved, and investors continue to discount the carbon price in investment spreadsheets and for credit control committees, what is the effect?

Modelling conducted for the government on its carbon floor policy included a sensitivity test of low credibility, which assumed investors' future view of carbon prices would revert to the prevailing EUA price beyond a five-year horizon (Redpoint Energy 2010). It suggested that carbon price support, without policy credibility, would lead to:

- no reduction in financing costs
- no extra investment in nuclear generation
- *reduced* investment in renewables
- *reduced* security of supply in the long term.

2 An equivalent finding can be derived from the cost of carry, given zero storage costs, no dividends, and minimal convenience yields.

In other words, a CPS without credibility would be likely to be not merely costly and ineffective, but costly and counterproductive. Given the weakness of the policy's credibility, this may well be a more likely set of outcomes than the ones suggested in the government's official consultation.

Potential solutions

Solutions to similar dilemmas in other policy realms, shown in Table 4.1, suggest some ways in which this credibility problem might be resolved. Each can be evaluated against its impact on credibility, its cost-effectiveness, and the avoidance of unintended consequences.

Option 1: Delegation or external advice

A suitable body, such as the Committee on Climate Change (CCC), an expert group that advises the government on the level of carbon budgets, or the Office of Budget Responsibility, could be used to provide external credibility.

In the case of interest rates, decisions are fully delegated to the independent Monetary Policy Committee of the Bank of England. A similar arrangement would be unprecedented for tax policy, and would likely raise strenuous objections from the Treasury.

A more moderate solution could be to ask the CCC to provide advice on the appropriate level of the CPS before each budget. This would be similar to the process for the UK's national carbon budgets, which are proposed by the CCC, then introduced by the Secretary of State via statutory instrument.

The advantage of such a move would be that with minimal cost, the decision becomes more clearly a technical rather than a political decision. It would make it more obvious when the government was deviating from its planned path of carbon prices, and, perhaps, increase the political consequences of doing so. Credibility would thus be slightly improved.

It is unlikely the impact would be large, though. The political cost of ignoring CCC advice is limited by the fact that they are not widely known by the public, they are relatively new, and could offer little counterweight to public clamour for a reduction in energy prices.

Worse, expecting more from the CCC's authority than it is able to deliver could mean that its main recommendations, about the level of the carbon budgets, would also be ignored by the government. The level of carbon budgets is a far more important and wide-ranging decision than the CPS, and it would be unwise to put it at risk.

Option 2: Contractual certainty on the EUA price

Instead of implementing the floor price through annual decisions about tax rates, suggestions have been made that it should be through a contract for difference (CfD) on the price of carbon.

Under a CfD on the carbon price, investors would receive a payment equal to the difference between the EUA price and the carbon floor price. For example, if the floor price was set at £20 and the EUA price was £18, investors would receive £2. No payment would be made if the EUA price stayed above the floor price.

The use of a CfD for electricity prices, rather than carbon, is a core proposal in the government's energy market reforms (DECC 2010a).

Embedded within a contract, the commitment would have full credibility. The negative consequences of the low credibility scenario, as modelled by Redpoint Energy, would be avoided. A CfD approach could also be implemented by the 2013 start date of the current proposals.

However, the substantial drawback is cost: the Exchequer would be assuming full risk of low carbon prices. These liabilities could turn out to be zero, or very large, depending on how low the carbon price falls, but an approximate expected cost is given by the price of option contracts.

A 'put option' in carbon gives the buyer the right to sell an EUA for a specified price (the 'strike price') during a specified period of time. If they choose, at the time they exercise the option and sell the EUA, they can also buy one at the current market price – so that their net gain is the difference between the market price and the strike price: exactly as with a CfD. The price of a put option is therefore the same as the expected value of the CfD, and takes account of the expected asset price, its variability, the interest rate, and other factors.[3]

Given current market prices, a CfD for a floor price of £30 would mean the government assuming a liability worth £700 million for 2013, its first year of operation, and £900 million for 2014,[4] and more in every subsequent year to 2030. Futures contracts beyond 2014 are not quoted, but the price can be expected to continue rising as both the floor price (or strike price) and the level of uncertainty increase towards 2030. Taking the 2014 figure as a strong underestimate, the value for every year to 2030 would be £6 billion, £7 billion, and £9 billion for floor prices of £20/£30/£40 per tonne in 2020.[5]

To put this into context, the heavy underestimate of a £7 billion liability is approximately the cost of installing a smart meter in every home by 2020 (DECC 2009a: 71). Again, this is the ex-ante value, and the true pay-out by the Treasury could be multiples higher than this, or zero.

Some might argue that the floor price should be designed to provide insurance against unexpectedly low carbon prices, and so be set at a level below rather than above the expected future price. This would reduce the cost, but the value of the liability would still be large. If the floor price is set to be £2 below the expected (futures) price in each year, the value of the liability is still £300-£400 million for each of 2013 and 2014, and more than £3 billion for the period of the policy.

A CfD on the carbon price, then, offers full certainty for investors, but unacceptable cost to the Exchequer.

Option 3: Contractual certainty through a CPS guarantee
A third possibility exists: a CfD not on the EUA price, but on EUAs plus the carbon price support – what might be termed a Carbon Price Support Guarantee (CPSG).

For example, illustrated in Figure 4.1, the scheduled tax-inclusive carbon price for 2020 might be £30 per tonne of CO_2, as suggested in the consultation document.

3 See any finance textbook for definition of Black-Scholes model.

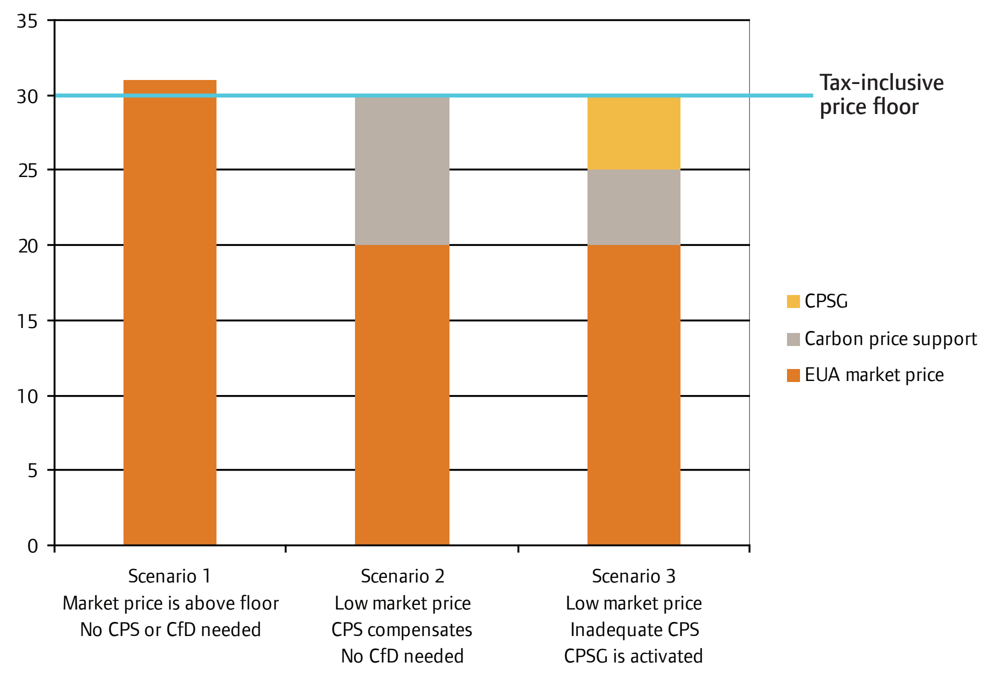
4 Based on option prices for £1 above the futures price for December 2013, with linear annual growth from that level to £30 tax-inclusive price in 2020; and covering 9.9% of the EU ETS, representing the UK power sector. Prices quoted on ECX, 3 February 2011.

5 Based on 3.7 MT reduction in EUAs each year, in line with falling EU ETS cap.

If the market price in the EU ETS was equivalent to £31, the floor would be satisfied, the carbon price support would be zero, and the guarantee would be met without any cost. If, however, the market price was £20 and carbon price support was only £5, the guarantee would oblige the Treasury to pay the remaining £5 per tonne to all owners who exercised the CPSG.

Unlike in the case of a CfD on carbon alone, the Treasury would not be liable for market risk. Any fall in EUA price could be compensated for by an adjustment in CPS – as the policy is proposed to do anyway. Whether or not the contract is 'in the money' is therefore within the control of the government at the time.

Figure 4.1
Illustration of the carbon price support guarantee (£)



The remaining risk for the Treasury is pure policy risk: the chance that future governments decide to abandon the carbon price schedule that they currently promise. Issuing the guarantee would entail future governments having less room to manoeuvre; but that is precisely the aim of commitment devices designed to overcome time-inconsistent preferences. And as the consultation document points out: 'carbon price uncertainty is predominantly driven by wider regulatory uncertainties and the Government might therefore be better placed to manage some carbon price risk' (HM Treasury 2010: 16). If the government is unwilling to take on the liability implied by the CPSG, then it cannot expect investors to do so.

Depending on how carbon price support is determined, fixed expiry dates for the CPSG might, for example, be at every five years for 20 years into the future, with the 20 year commitment rolled forward every five years. Investors could, in effect, own a contractual put option on the difference between the carbon price floor and the EUA price (the latter can be hedged in the EUA forward market) for as long as 20 years. The CPSG could be made available for a nominal fee, akin to a small put option or insurance premium, to investors who have a demonstrable risk exposure to carbon prices.

The advantage of the CPSG is that it rescues the benefits that were claimed for a carbon price support. By reducing uncertainty, an underwriting mechanism would reduce the time value of a wait-and-see approach on the part of investors, accelerating investment and allowing for a lower overall carbon price floor trajectory. It would ensure that the cost of capital in investment spreadsheets was as low as possible. This would in turn allow the government's modelling to assume lower overall costs to the economy and would preclude the need for a series of further policy interventions designed to reassure investors.

Given the government's intention is to reduce investor certainty, the preceding analysis suggests that if it is to be done, it is better done with a CPSG.

Questions remain, however, about the full cost of implementing the CPS, whether credible or not. These are explored in the following section.

5. TEST 3: ARE THERE UNINTENDED CONSEQUENCES?

The Treasury has published benefit-cost analysis of the carbon price support (HM Treasury 2010). However, three important categories are left out:

A. Economic waste

B. Impact on low-carbon investment in the rest of Europe

C. Impact on other European governments.

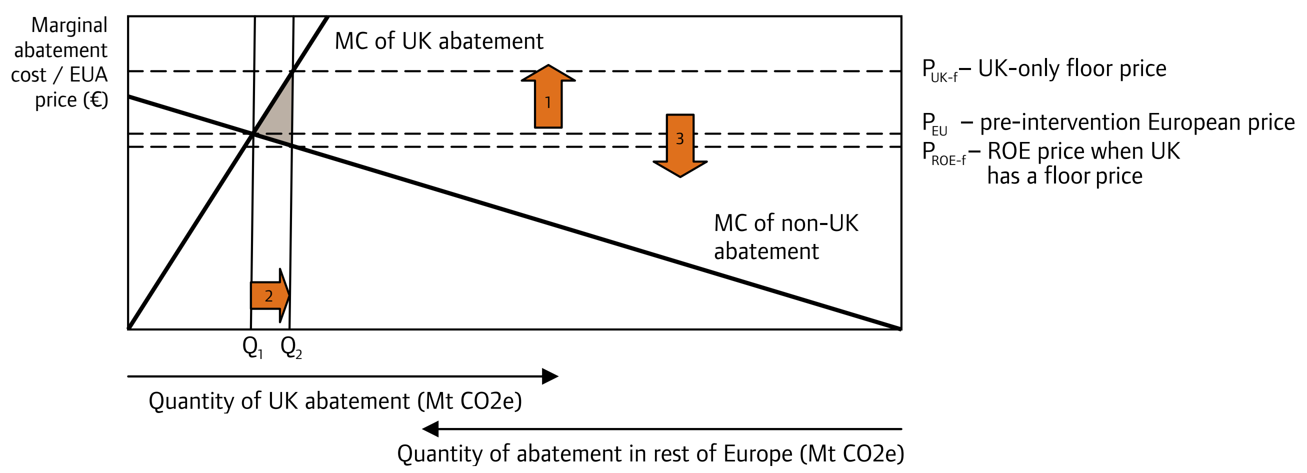
The fact that these were left out of government analysis is a consequence of costs and benefits being evaluated only from the perspective of the UK, rather than looking at the EU emissions trading system in which it operates.

A. Economic waste

As a result of the UK's floor price, the EU ETS will have not one price, but two: one for the UK, and one for the rest of Europe.

A UK-only floor price is therefore not simply a case of Britain shouldering carbon cuts on behalf of Europe: it also creates waste. In Britain, every additional tonne of carbon that needs to be cut costs more money than the last; in Europe, every additional tonne emitted as a result saves less money than the last. In effect, the government's plan swaps cheap carbon savings in Europe for expensive carbon savings in Britain.

Figure 5.1
Inefficiency caused by two prices



The inefficiencies of having more than one carbon price are well-explored in the literature. For example, Böhringer et al (2009) looked at the welfare costs of having separate carbon prices in Europe, one for the EU ETS and one for industries not covered by it. With two prices, welfare costs increased up to 50 per cent; with 28 carbon prices (one for the EU ETS and one for each member state), welfare costs increased a further 40 per cent.

The welfare loss of the government's proposal are first illustrated in the box diagram below, and then modelled.

In Figure 5.1, the quantity of UK emission reductions is measured from the left, and emission reductions from the rest of Europe (ROE) are measured from the right; because of the EU ETS, the two always total to the same amount.

With the introduction of the carbon price support, the tax-inclusive price of carbon in the UK increases from the market rate of P_{EU} to $P_{UK\text{-}f}$ (arrow 1). This leads to additional carbon savings, increasing UK abatement from Q_1 to Q_2 (arrow 2). As abatement in the rest of Europe must reduce by the same amount, this reduces the price for the rest of Europe, from P_{EU} to $P_{ROE\text{-}f}$ (arrow 3). The difference between $P_{UK\text{-}f}$ and $P_{ROE\text{-}f}$ creates the inefficiency, shown as the shaded triangle.

How significant is this inefficiency? A simple model is enough to illustrate the order of magnitude.

Marginal abatement curves are drawn for the UK and the rest of the Europe, producing a market-clearing price. The price in the UK is then artificially raised to the levels proposed by the UK government, allowing us to see the new quantities of abatement in the UK and rest of Europe, and the new price in the rest of Europe. The inefficiency is the difference in the areas under the abatement cost curves of the two regions.

The marginal abatement functions are adopted from a previous paper by Laing and Grubb (2010), based on scenarios in the Greenhouse Gas Initiative scenario database, conducted by the International Institute for Applied Systems Analysis (IIASA 2007). Annex A has further details.

This is not a complete examination of the welfare effects: only of the first round costs of mitigation. More detailed models include plant-by-plant modelling of energy generation and investment decisions (for example, Redpoint Energy 2010), and computable general equilibrium models showing the effects of trade, with multiple regions and multiple sectors (for example, Böhringer et al 2009). Nor does it look at the effects on investment. It does not include the possibility of non-continuous abatement functions. It does, however, given an approximate sense of activities in the EUA market, including levels of abatement in the UK and the rest of Europe, and relative abatement costs.

The model was further adapted to reflect uncertainty over business-as-usual emissions. Uncertainty, even around the same expected value, can substantially increase the costs. The IEA (2007, 2008), for example, found that their estimates of the cost of halving emissions by 2050 were two to three times higher under a Monte Carlo simulation with random variation around GDP growth, carbon intensity, and marginal abatement costs, compared to best guess point estimates of the same parameters.

We might expect a similar effect with the UK's floor price. The impacts of the policy are asymmetric in the face of changes to the central case. On the one hand, if values of BAU emissions are much lower than expected, the market price falls and the impact of the floor price increases without limit. On the other hand, if values of BAU emissions are *higher* than expected, the floor price is not binding, and so the abatement cost and inefficiency (and, in fact, every other impact) are zero.

For the effects of the policy to be zero, the market price must be above the floor price, and this is clearly easier when the floor price is low. As a result, uncertainty will have a greater impact on scenarios with a low floor price than a high floor price.

The UK government's reporting of the costs and impacts of the policy did not take account of how emissions uncertainty affects costs, looking instead only at scenarios for fuel prices.

To explore the effects of uncertainty, the model in this paper included random variation on the business-as-usual term, B, and the model was run 5,000 times.[6] Full results are given in Annex C.

Based on this model, Figure 5.2 (over) shows the amount of economic waste created by different floor prices.

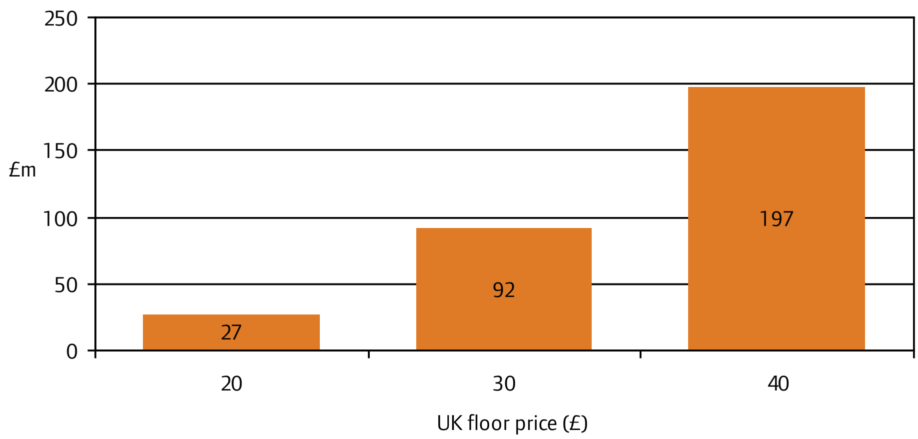
This shows that with the UK floor price of £30, the government would be creating £92 million of economic waste (2010, undiscounted).

The emission savings modelled here, of an average of 4, 10, and 15 Mt for floor prices £20, £30, and £40 respectively, compare to Treasury estimates of –1, 2, and 25 Mt in 2020 (HM Treasury 2010: 66).

These figures are for the single year 2020. A more complete model would look at the changing abatement cost function for each year, including how it responds to early investment. These figures can be used, however, to give a very approximate sense of scale over the period. It is likely that the inefficiency would be somewhat less in the years before 2020, and substantially more towards 2030. If, as a very rough indication, the economic waste is assumed to be equivalent in each year, then after discounting, the 2011 net present value of the waste is £1.18 billion in 2020. It should be stressed again, though, that this is not presented as an accurate estimate.

For context, £1 billion of waste is approximately equal to twice the total amount the government claimed to save by abolishing 192 quangos (Laws 2010). Equivalently, it is approximately enough to finance an extra carbon capture and storage demonstration project (DECC 2010c: 6).

Figure 5.2
Economic waste in 2020, by floor price (2010)



B. Impacts on European investors

The justification for this policy is reducing risk and uncertainty: the UK government's position is that low-carbon investors need certainty, and the possibility of low carbon prices harms investors.

6 Average inefficiency is 100% higher in the Monte Carlo than deterministic estimates for the floor price of £20, falling to 3% higher for the floor price of £40.

Worthy of a thought, then, is what happens in the rest of Europe if prices in the carbon market do turn out to be low, and the UK floor price comes into effect. The UK policy would price emissions out of the UK – and into the rest of Europe. The ROE price, already low, would become lower.

Wood and Jotzo (2010), who argued for additional fees on carbon permits as the most appropriate way to support the carbon price, suggested that its main advantage was the limited, or indirect, interaction with the international market.

Figure 5.3
The UK policy would lower expected prices in Europe

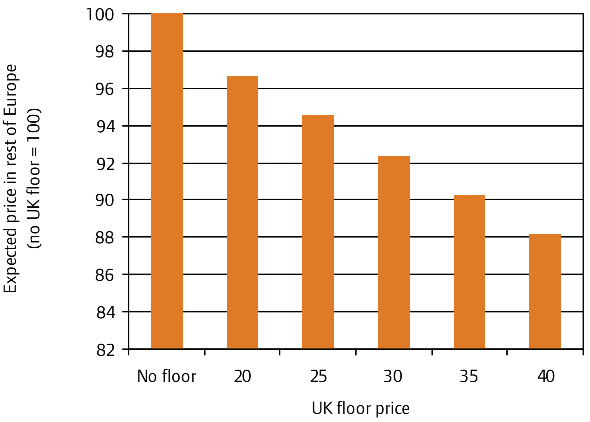
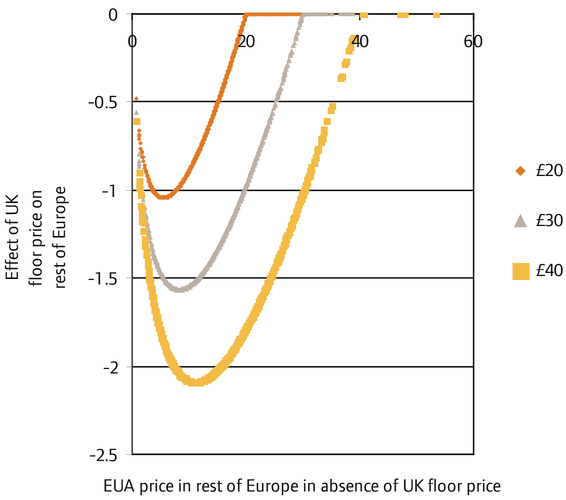


Figure 5.4
A UK floor price would lower the ROE price most when it is already low



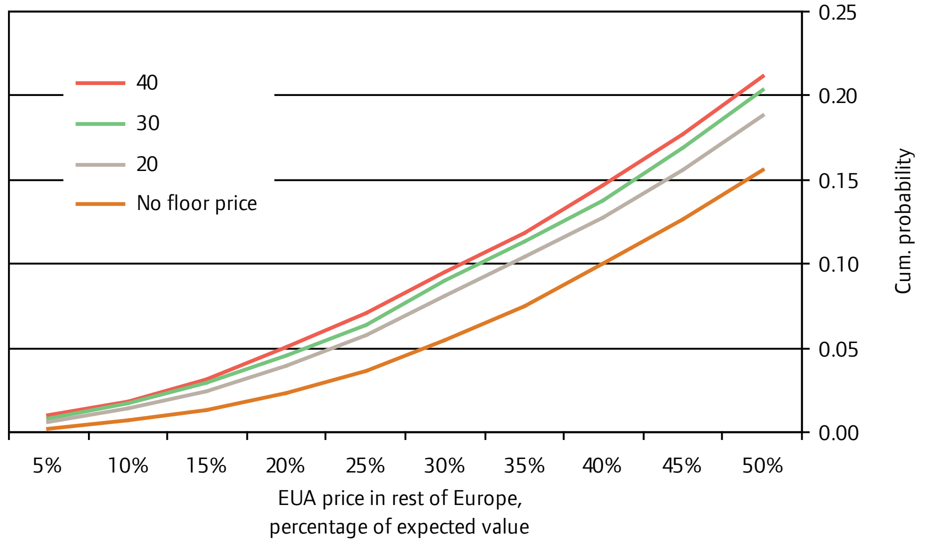
The average effect is moderate, with a floor price of £30 lowering prices on average by eight per cent (see Figure 5.4).

However, the question of timing is crucial. From the perspective of the low-carbon investor in the rest of Europe, the UK policy depresses their carbon price at the worst possible times: when carbon prices are already low. This extra risk, caused by the UK's policy, is therefore highly correlated with market risks they already face, investments in general (because a weak economy causes a low carbon price), and with low-carbon investments in particular. It therefore increases overall investment risk (in the terminology of the capital asset price model, the extra risk is likely to have a high ß).

This is illustrated in Figure 5.3, showing how the policy would reduce the ROE price for different levels of pre-intervention price, according to the Monte Carlo simulation. The most extreme, given a £30 floor price, is when the EUA price in the rest of Europe (P_{ROE}) is 25 per cent below its expected value. At this level the UK policy would cause it to fall a further 18 per cent, from £11.39 to £9.30.

An alternative way of showing this is to look at the probabilities of the ROE price falling below its expected value. Figure 5.5 shows the tail distributions for the EUA price in the rest of Europe, based on the Monte Carlo simulation. With a £30 floor price in the UK, the probability of the carbon price falling to half its expected level increases from 16 per cent to 20 per cent.

Figure 5.5
Higher UK floor prices mean fatter tails in distributions in ROE



These differences would be non-trivial, and may affect the financing costs of low-carbon investors in the rest of Europe. Commissioned by the government, the energy consultancy Redpoint demonstrated how a reduction in the tail risk for low-carbon investors in the UK would allow them to finance projects more cheaply (Redpoint Energy 2010). For those whose ultimate objective is lower carbon emissions, rather than government targets, the interesting question is the equivalent calculation for the rest of Europe: how much does the increased tail risk in Europe, caused by the UK government effectively exporting uncertainty, mean more expensive low-carbon investment across the continent?

C. Impacts on European governments

As well as reducing low-carbon investment incentives in the rest of Europe, the UK-only floor price could lead to a transfer in the rest of Europe from governments to greenhouse gas emitters.

The UK floor price reduces demand for EUAs in the UK, leading the price to fall across Europe. These prices are mostly paid to governments. Every government therefore raises slightly less money; every emitting firm pays slightly less to acquire EUAs. The UK, meanwhile, recovers some of its lost income through the new tax, the Climate Change Levy.

In total, about half of the EUAs are expected to be auctioned after 2013 (EC 2010). Receipts from auctions are retained by member states, with 88 per cent of EUAs distributed according to previous emissions, 10 per cent redistributed to poorer member states in the interests of solidarity, and two per cent distributed according to performance under the Kyoto Protocol.

EUAs that are not auctioned are mostly distributed free to industry and heating sectors, based on greenhouse gas performance-based benchmarks. Sectors deemed at significant risk of relocating production outside of the EU due to the carbon price will receive their full benchmarked allocation for free. Sectors not deemed at significant risk of carbon leakage will receive 80 per cent of their benchmarked allocation for free in 2013, declining to 30 per cent in 2020 and zero in 2027.

For the calculations below, it is assumed that 60 per cent of allowances are auctioned in 2020. In principle, a fall in the value of EUAs means that firms awarded free allowances receive a lower windfall gain. Along with other emitters, a lower price also means they have a lower opportunity cost of using permits, so if they use exactly their free allocation these two effects cancel out and they are unaffected. A fuller description of how welfare effects are calculated is given in Annex D.

As with the efficiency estimates, this is a first-order estimate, not a general equilibrium analysis. The degree to which it is incomplete depends, in part, on the extent to which international trade will relocate due to the carbon price support. The figures below are based on a deterministic model, without variance on the business-as-usual term.

Table 5.1
Welfare effects of the CPS in 2020 (£m)

	Floor price (£)		
Party	**20**	**30**	**40**
UK emitters	-956	-2,650	-4,289
UK recipients of free allocations	-49	-121	-179
UK government	992	2,684	4,261
Total UK	**-13**	**-86**	**-207**
ROE emitters	883	2,194	3,273
ROE recipients of free allocations	-353	-875	-1,303
ROE government	-529	-1,313	-1,955
Total ROE	**1**	**7**	**15**
Total effect	**-12**	**-80**	**-192**

It shows, however, that with a £30 floor price, the UK policy could cause governments in the rest of Europe to lose some £1.3 billion in 2020.

As with the inefficiency calculation, the true figure is expected to be less than this before 2020, and grow rapidly after 2020 as the carbon price support becomes increasingly large. If, as a very rough estimate, it is equivalent to the 2020 figure every year from 2013–30, then the 2011 net present value of the loss to ROE governments would be approximately £16.5 billion.

To put a £17 billion loss into context, the loss to European governments as a result of the UK policy is approximately as much as it would cost to quadruple the UK's EU budget rebate for one year (BBC 2010).

On the other hand, emitters in the rest of Europe will enjoy a windfall of around £16 billion due to the UK policy, with firms producing the most greenhouse gas enjoying the biggest windfall. The net effect for governments and emitters in the rest of Europe is very slightly positive.

D. Summary of unintended consequences

Overall, the best estimates are that a floor price of £30 in 2020 could lead to the following unintended consequences:

1. Economic waste of £92 million in 2020. If other years have equivalent amounts, the net present value in 2011 of the economic waste would be just over £1 billion.
2. A carbon price in the rest of Europe that is eight per cent lower on average in 2020, and up to an additional 18 per cent lower when the price is already low. This would make low-carbon investments riskier.
3. A reduction in auction revenues for other European governments of around £1.3 billion in 2020, to the benefit of emitters. If other years have equivalent amounts, the net present value in 2011 of the reduction in auction revenue would be £17 billion.

6. CONCLUSIONS

The charge sheet against the government's carbon price support is heavy:

- It is intended to improve investor confidence – but a policy to increase certainty must itself be certain, and it is far from clear that the CPS passes this test. If it does not, modelling commissioned by the government suggests the policy could do more harm than good.
- Its ultimate goal is to reduce greenhouse gas emissions. It does not do so, because it does not lead to any reductions in the number of permits in the EU ETS.
- It is likely to have significant unintended consequences, including economic waste, a reduction in incentives to invest in low-carbon generation in the rest of Europe, and a significant transfer from governments to emitters in the rest of Europe.

Hearing these criticisms of the CPS, one response might be that similar points can be made against all policies that overlap with the EU ETS. Support for renewable power, for example, also does nothing to reduce emissions under the ETS cap.

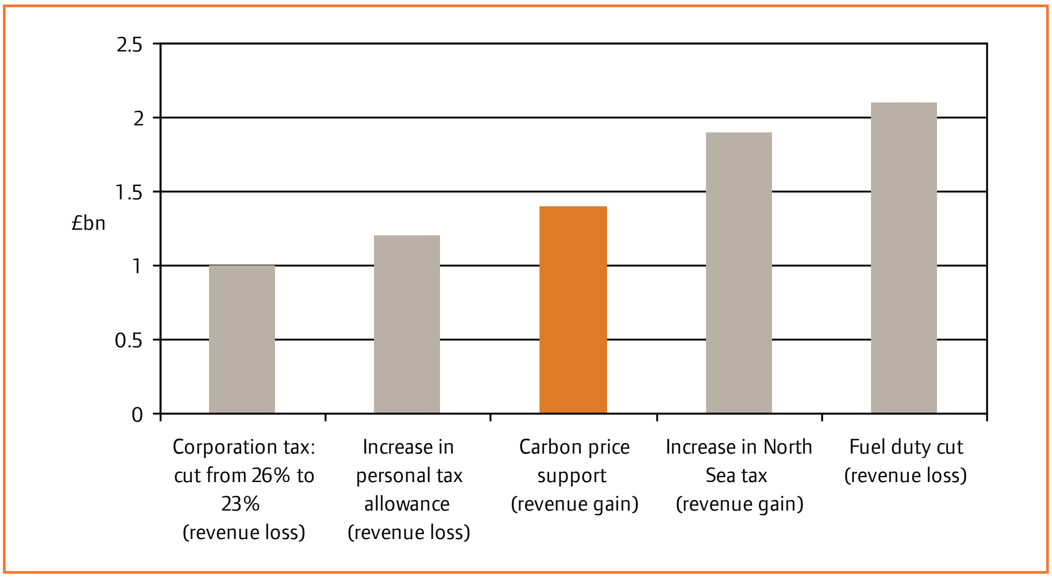
However, the crucial point about support for renewable power is that it targets a different externality: not the damages from greenhouse gases, but the social benefits of research, development, and deployment. As pointed out by Stern et al (2006), and many others, emissions and R&D are distinct externalities and need to be tackled separately. Overlap does not mean duplication.

The same argument cannot be made for the CPS and the EU ETS. They target the same externalities. The CPS is overlapped entirely by the EU ETS – and the overlap serves only to reduce cost-effectiveness.

And while the environmental case for the CPS is threadbare at best, those with suspicious minds may notice an additional motivation for the Treasury. The 2011 Budget document drew attention to three measures that it said will 'help to support the long-term sustainability of the public finances' (HM Treasury 2011: 21). One was the higher rate of VAT; one was the move to index benefits and taxes against CPI; and the third was the carbon price support.

It does, indeed, raise substantial sums, pulling in £740 million in 2013, increasing to £1.4 billion in 2015. This makes it the third biggest revenue change to that year – more than the amount spent on reducing corporation tax or increasing the personal tax allowance – and the second biggest revenue-raiser (see Figure 6.1).

Figure 6.1
Revenue impact in 2015 of the five biggest Budget policy decisions



Source: HM Treasury 2011

In a very tough Budget, it may well be that the level of the CPS was set with an eye more towards raising revenue than effects on greenhouse gases or low-carbon investment. In fact, the level that it starts at in 2013 was set almost five times higher than most analysts expected: at £4.94 instead of the £1 per tonne as suggested in the central policy scenario of the consultation.

If the true motivation is raising money, this is another reason for the CPS to be opposed by environmentalists. The CPS uses up some of the public's tolerance for green taxes, without delivering real benefits for the climate.

It provides a reason for the CPS to be opposed by progressives. The government estimated that a CPS of £3/tonne in 2013 would increase the number of households in fuel poverty by 30,000–60,000 a year from 2013 (HM Treasury 2010: 76). The actual CPS, of almost £5, would presumably cause many more households to enter fuel poverty. By 2020, according to the government figures, the number of households in fuel poverty is likely to be rising by 50,000–90,000 per year as a result of the CPS.

And it should prompt opposition from businesses. Even before the CPS, the impact of climate policies on non-domestic electricity prices was expected to triple from 20 per cent in 2010 to 43 per cent in 2020, largely as a result of subsidies for renewable energy (DECC 2010b: 29). Loading further costs on energy bills, unless rigorously justified as necessary for tackling climate change, undermines both support for green taxes and the competitiveness of British industry. It makes a very poor choice of cash cow.

Recommendations

With these arguments in mind, recommendations can be made at two levels.

An ambitious goal would be to recognise the broader point: market interventions must be at the same level of the market. A European-wide problem needs a European-wide solution. The government should argue for a floor price across the EU ETS, not in the UK alone.

This would secure much of the fundamental benefits claimed for floor prices: investors would benefit from more certainty, and the environment would benefit from a reduction in the number of permits if the price falls. As the literature made clear, these are highly significant.

At the same time, an EU-wide floor price would neutralise the criticisms made in this paper:

- On emission reductions: with a floor price at auctions, permits would be actually removed from the market if the price fell too low.
- On credibility: the very fact that EU-wide agreement is difficult would mean that a floor price, once established, would be hard to change.
- And on unintended consequences: the economic waste, export of uncertainty to Europe, and the reduction in government revenues in the rest of Europe would all be eliminated.

The analysis in previous sections suggests a possible coalition for this agenda: (a) greens, interested primarily in reducing emissions; (b) low-carbon investors in Britain, who require more certainty than the proposed policy can provide; (c) low-carbon investors in the rest of Europe, interested in carbon price stability; and (d) finance ministries in the rest of Europe, concerned about reductions in auction revenue.

There are, though, political barriers to refocusing completely from a UK to an EU floor price. The Treasury has already consulted on implementation, and brought the measure in through the Finance Bill. It was a Conservative manifesto commitment. And the existence of a floor price serves to make nuclear power more attractive without explicitly breaking the commitment of the Liberal Democrats to provide no public subsidy to nuclear power (although it is, of course, a consumer subsidy).

More patchwork solutions might therefore be appropriate. Most of the problems noted in this paper are inherent to the scheme design, but the issue of credibility can be substantially addressed through the Carbon Price Support Guarantee (CPSG).

As it is intended to do, this would bind future governments in, so the question is whether it is better to have an ineffective policy, with negative unintended consequences, that can at least be cancelled; or to have a policy which does achieve its purpose of reducing uncertainty, but which has same unintended consequences and cannot be cancelled without great cost.

A balance could be struck by introducing the CPSG, to provide credibility, but at a relatively low target level to minimise unintended consequences. In the modelling above, a floor price of £20 rather than £30 generated less than a third of the amount of economic waste, had less than half the impact on expected carbon prices in the rest of Europe, and had just less than half the impact on auction revenues for other European governments.

With a low target price, the policy would be focused properly on reducing investment uncertainty, rather than changing fundamentally the expected carbon price. With a credible mechanism, it would mean that, if Britain was paying the costs, it was at least also receiving some of the benefits of the policy, through reduced financing costs.

A low, guaranteed CPS could also be superseded by a European-wide floor price at a realistic level, once agreement has been achieved. If a low CPS low-carbon generation in Britain requires additional support, it can in any case be given through the more targeted and credible route of the energy market reforms, being consulted on separately by the Department of Energy and Climate Change.

Annex A: Model description

Source of abatement functions

The International Institute for Applied Systems Analysis (IIASA) (2007) B1 scenarios provide discrete points for shadow prices of greenhouse gases and volume of emissions for Western Europe (WEU) and Eastern Europe (EEU) as a whole. Laing and Grubb (2010) turn these into a continuous function of the form:

(1) $P = mA^2 = m(B - Q)^2$

Where:

P = Europe-wide EUA price in US$ per tonne CO_2

m = a coefficient, set at m = 0.000436

A = abatement below business as usual, in Mt CO_2

B = business-as-usual emissions

Q = the quantity of EUAs auctioned in 2020 in Mt CO_2

The function is appropriately scaled to fit the size of the EU ETS relative to European emissions in total.

For this paper, it is then scaled further, to represent the split between the UK power sector (nine per cent of EU ETS emissions) and the rest of Europe and the UK (also referred to as ROE).

Therefore the quantities of EUAs demanded in total, in the UK power sector, and the rest of Europe are respectively:

(2) $$Q = B - \left(\frac{P}{m}\right)^{\frac{1}{2}}$$

(3) $$Q_{UK} = u\left(B - \left(\frac{P_{UK}}{m}\right)^{\frac{1}{2}}\right)$$

And,

(4) $Q_{ROE} = Q - Q_{UK}$

Where:

Q_{UK} = Quantity of EUAs demanded for the UK power sector in millions (that is, Mt CO_2e)

P_{UK} = The EUA price facing power generators in the UK, set as the greater of the price floor, $P_{UK\text{-}f}$ and the European-wide price in the absence of a UK floor, P_{EU}

u = fraction of EU ETS represented by the UK power sector. Based on 2009, u = 0.09.

Q_{ROE} = Quantity of EUAs available to the rest of Europe in millions (that is, Mt CO_2e).

The subscript '-f' is used to denote the presence of a floor price in the UK, so that Q_{ROE} is the quantity of EUAs demanded in the rest of Europe without a floor price in Britain, and $Q_{ROE\text{-}f}$ is the quantity demanded in the rest of Europe when there is a floor price in Britain.

Note that ROE refers to both the rest of Europe, and UK firms outside of the power sector, who are not covered by the government's proposal.

Given the quantity of allowances available for sale in the rest of Europe, their price is set by the inverse demand function scaled up from the fraction of the EU ETS that represents the rest of Europe, $(1–u)$:

(5) $$P_{ROE} = m\left(\frac{A_{ROE}}{1-u}\right)^2 = m\left(\frac{B_{ROE} - Q_{ROE}}{1-u}\right)^2$$

Where:

A_{ROE} = The level of abatement in the rest of Europe

B_{ROE} = The BAU emissions of the rest of Europe = $B(1\text{-}u)$

The values and source of each parameter are given in Annex B.

In the stochastic model, variance on the business-as-usual term B was of a factor $\alpha \sim N(1, \sigma^2)$. Following Cambridge Econometrics (2008), the variance was set at 0.03 (55 Mt). Average inefficiency is 100 per cent higher in the Monte Carlo than deterministic estimates for the floor price of £20, falling to three per cent higher for the floor price of £40.

All estimates depend on the model and the simplifying assumptions that lie behind it, in particular: (a) the marginal abatement cost curve for 2020; (b) business-as-usual emissions in 2020; (c) the assumption that the UK power sector and ROE face the same (scaled) version of this curve; (d) the assumption that the UK power sector remains the same proportion of the EU ETS in 2020 as 2009; and (e) that shocks to business-as-usual emissions affect the UK and ROE to the same extent.

Measure of inefficiency

The inefficiency is the difference between the integrals under the marginal cost curves between the two values of Q, as in Figure 5.1. This can be shown algebraically as:

(6) $$\mathit{Inefficiency} = \int_{Q_{UK-f}}^{Q_{UK}} m\left(\frac{B_{UK} - Q}{u}\right)^2 .dQ - \int_{Q_{ROE}}^{Q_{ROE-f}} m\left(\frac{B_{ROE} - Q}{1-u}\right)^2 .dQ$$

$$= \left[-\frac{m(B_{UK} - Q)^3}{3u^2}\right]_{Q_{UK-f}}^{Q_{UK}} - \left[-\frac{m(B_{ROE} - Q)^3}{3[\![(u-1)]\!]^2}\right]_{Q_{ROE}}^{Q_{ROE-f}}$$

Annex B: Model parameters

Parameter	Description	Value	Notes
B	European business-as- usual emissions, 2020 (Mt CO_2e)	2007	Source: Laing and Grubb 2010
m	Coefficient of inverse demand curve	0.000436	From Laing and Grubb 2010, based on IIASA GGI scenario database
Q	The quantity of EUAs auctioned in 2020 in millions	1777	Source: EC 2010 http://ec.europa.eu/clima/policies/ets/cap_en.htm
u	Fraction of EU ETS represented by the UK	0.0993	Based on 2009 emissions (EC 2010)
σ^2	Variance of BAU emissions in the stochastic model	0.03	Based on a confidence interval of +/- 110 Mt (Cambridge Econometrics)
GBP/US$	Conversion from 2005 US$ to 2005 GBP	0.5497	From XE.com, average for 2005
GBP2010/GBP2005	CPI inflation from 2005 GBP to 2010 GBP	1.145	National Statistics

Annex C: Results of Monte Carlo analysis

Number of simulations: 5,000

	Change in Q_{UK} (£)				
	20	25	30	35	40
Mean	4.90	7.45	10.04	12.57	14.99
Standard error	0.07	0.08	0.08	0.09	0.09
Deterministic value	3.97	7.13	9.99	12.62	15.07
Monte Carlo/ Deterministic	1.24	1.04	1.00	1.00	0.99

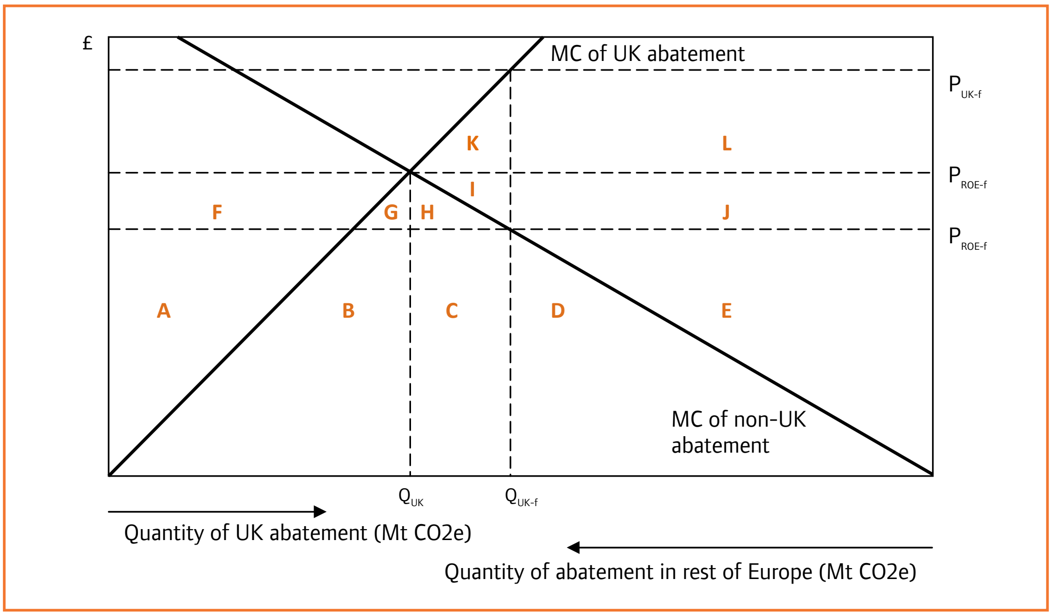
	Price reduction in ROE (£)				
	20	25	30	35	40
Mean	0.50	0.81	1.14	1.47	1.78
Standard error	0.01	0.01	0.01	0.01	0.01
Deterministic value	0.55	0.98	1.37	1.72	2.04
Monte Carlo/ Deterministic	0.90	0.82	0.83	0.85	0.87

	INEFFICIENCY (£m)				
	20	25	30	35	40
Mean	27	54	92	140	197
Standard error	0.51	0.77	1.06	1.34	1.61
Deterministic value	12	39	80	131	192
Monte Carlo/ Deterministic	2.33	1.38	1.16	1.07	1.03

Annex D: Distributional effects

The welfare gains and losses of each type of agent can be seen in the stylised diagram below (not drawn to scale).

Figure D1
Illustrations of welfare effects (including transfers)



Party	Welfare effect	Area in diagram
UK emitters	Extra abatement cost for UK emitters, over previous EUA price	K
	Extra cost to non-abated emissions due to CPS, over previous EUA price	L
UK government	Revenue from CPS	L+J
	Reduced revenue from EUA auctions	u * (F+G+H+I+J)
ROE emitters	Saving from lower abatement	H
	Saving from lower EUA prices on unabated emissions	F+G
ROE government	Reduced revenue from EUA auctions	(1–u) * (F+G+H+I+J)

The revenue reductions for the UK and ROE were then split 60/40 between governments (through auctions) and recipients of free allowances, as described in the text.

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