Climate Change Economics, Vol. 1, No. 3 (2010) 1–17

DOI: 10.1142/S2010007810000169

COMBINING MULTIPLE CLIMATE POLICY INSTRUMENTS: HOW NOT TO DO IT

SAMUEL FANKHAUSER*, CAMERON HEPBURN† and JISUNG PARK‡

*Grantham Research Institute and Centre for Climate Change Economics and Policy London School of Economics

†Grantham Research Institute London School of Economics Smith School of Enterprise and the Environment and New College, Oxford

‡Oxford Department of International Development and Magdalen College Oxford University

Putting a price on carbon is critical for climate change policy. Increasingly, policymakers combine multiple policy tools to achieve this, for example by complementing cap-and-trade schemes with a carbon tax, or with a feed-in tariff. Often, the motivation for doing so is to limit undesirable fluctuations in the carbon price, either from rising too high or falling too low. This paper reviews the implications for the carbon price of combining cap-and-trade with other policy instruments. We find that price intervention may not always have the desired effect. Simply adding a carbon tax to an existing cap-and-trade system reduces the carbon price in the market to such an extent that the overall price signal (tax plus carbon price) may remain unchanged. Generous feed-in tariffs or renewable energy obligations within a capped area have the same effect: they undermine the carbon price in the rest of the trading regime, likely increasing costs without reducing emissions. Policymakers wishing to support carbon prices should turn to hybrid instruments — that is, trading schemes with price-like features, such as an auction reserve price — to make sure their objectives are met.

Keywords: Carbon trading; Carbon tax; climate change policy.

1. Introduction

When it comes to climate change, governments are apt to think that more policy instruments are better than fewer. Often, multiple policy instruments are considered or introduced in tandem — including carbon taxes, permit trading schemes, technology-specific subsidies and regulatory standards. Occasionally these are neatly dovetailed as part of an overarching climate change strategy. More often than not, however, the use of multiple instruments reflects an incremental ad-hoc approach to climate policy, and

December 13, 2010 5:48:06pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

instruments are introduced in a piecemeal, overlapping way, often driven more by politics than by economic considerations.

In Europe, a number of countries including Sweden, Norway, Denmark, the UK and most recently Ireland have introduced carbon taxes or climate change levies on top of the already existing European Emissions Trading Scheme (EU ETS). In addition, many EU ETS member states — most notably Germany and Spain — provide generous subsidies for renewable electricity. Simultaneous trade-based systems are also emerging. The UK's recently-introduced CRC Energy Efficiency Scheme[1] will set up a cap-and-trade system for commercial and public-sector carbon emitters, such as supermarkets and schools, even though they mostly consume electricity, which is already regulated under the EU ETS.

But whether these overlapping policies offer a superior — or even coherent — solution is debatable. Combining policy instruments is not necessarily unfounded from an economics standpoint. In the presence of multiple externalities, the use of multiple policy instruments is likely to be justified (Bennear and Stavins, 2007; Goulder, 2008). It is often argued, for example, that asymmetric information and principal agent problems in energy efficiency, alongside knowledge spillovers and the public good nature of technological innovation for climate mitigation merit a policy response in addition to the carbon price. Market signals alone may lead to underinvestment in high-potential technologies like renewables (Rosendahl, 2004; Jaffe *et al.*, 2005; Hepburn, 2006; Richels and Blanford, 2008; Fischer, 2008). In the presence of multiple market failures, a variety of models suggest that an optimal portfolio of policies can reduce emissions at a significantly lower social cost than any single policy (Grimaud and Lafforgue, 2008; Popp, 2006a,b; Schmidt and Marschinski, 2009; Acemoglu *et al.*, 2010). What is still debated is whether existing R&D policies are sufficient to address these market failures (which pertain to all types of innovation) or whether carbon-specific intervention is needed, for example because of design flaws in existing R&D policies.

In addition, behavioural factors, capital constraints, and risk aversion may provide further justification for setting performance standards or mandating a particular suite of technologies on certain sectors (De Canio, 1998).

The economics literature also suggests that there may be good reasons to combine certain features of both price-based (tax) and quantity-based (cap and trade) instruments to create so-called *hybrid* policies.[2] Despite an ongoing debate about the relative merits of a tax or a permit trading system on its own (for example, Hoel and Karp 2001; Newell and Pizer, 2003; Fell *et al.*, 2008), economists broadly agree that it can be advantageous to combine certain features of both price- and quantity- based instruments in the form of hybrid policies.

[1]The acronym CRC refers to the former name of the scheme, the Carbon Reduction Commitment.

[2]These reasons have been spelled out quite extensively in the economic literature by Weitzman (1974), Roberts and Spence (1976), Pizer (2002), Jacoby and Ellerman (2004), Jaffe *et al.* (2005) and Hepburn (2006).

December 13, 2010 5:48:06pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

The essential logic is that a combination of price and quantity instruments can better mimic the shape of the marginal benefit function, which is unlikely to ever be completely flat (like a tax) or completely vertical (like a cap).[3] Recently, a number of authors including Jacoby and Ellerman (2004), Fell *et al.* (2008), Murray *et al.* (2009) and Philibert (2009) have argued that a hybrid system such as a *safety valve,* in which a carbon tax acts as an effective price ceiling on a cap-and-trade system, may yield superior welfare consequences to any price- or quantity-based system on its own. In such a system, firms would be required to pay either the pre-specified tax (safety valve price) or surrender permits, but not both. The same holds true for *price-floor* versions of hybrid instruments (Fankhauser and Hepburn, 2010a).

However, simply stacking multiple instruments together, as some governments seem intent to do, does not guarantee that in sum they will achieve the intended aggregate effect. In other words, the use of *multiple* instruments is not the same as the use of a *hybrid* instrument. Moreover, additional climate policies are sometimes added in ways that do not address knowledge spillovers or other externalities explicitly. Quite often, an additional instrument — say, a unilateral carbon tax by an EU member state — is introduced under the aegis of additional mitigation; that is, multiple instruments are utilised to address the same market failure, and are not combined in complementary ways (e.g. as hybrid systems).

The economic rationale of such a simultaneous approach seems tenuous at best. As the number of policy instruments grows, so the potential for interaction between different instruments increases (Smith and Sorrell, 2001; Goulder, 2002). Depending on how the policy instruments are combined, this interaction can be detrimental or beneficial. A clear and unsurprising finding from emerging empirical research is that additional instruments to support renewable energy consistently reduce cap-and-trade prices.[4] In the case of a unilateral carbon tax on top of the EU ETS, the primary effect of the tax will most likely be to shift the burden of payment, and to depress the carbon price, rather than to achieve any additional emission reductions, unless the tax is so high that it replaces and indeed intensifies the price signal from the trading scheme.

This paper employs basic economic theory to explore the potential for adverse consequences from using multiple climate instruments to achieve a given environmental goal. For shorthand we use the terms “simultaneous” and “overlapping” to describe policy instruments that subject firms to multiple types of regulation at the same time. The focus is on the impact of simultaneous instruments on the carbon price,

[3]Hybrid systems can, in theory, better mimic the “true” marginal benefits curve, by creating a supply schedule that, rather than being fully flat (a tax) or fully vertical (a cap), is stepwise and upward sloping (Fankhauser and Hepburn, 2010a).

[4]For instance, Unger and Ahlgren (2005), Saenz de Miera *et al.* (2008) and Rathmann (2007) model the impact of renewable energy support on carbon and electricity prices in the Nordic countries, Spain and Germany, respectively. De Jonghe *et al.* (2009) study the Benelux countries, France and Germany, and Morris *et al.* (2010) model the effects of combining a renewable portfolio standard (RPS) with a cap-and-trade program for the United States. In Germany, Rathmann (2007) estimates that retail electricity prices during 2005–07 (the first EU ETS trading period) were lowered by approximately €2.6 per MWh due to additional renewable support policies.

December 13, 2010 5:48:07pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

rather than broader impacts such as the magnitude of tax distortions (e.g. Goulder *et al.*, 1997).

The paper is organized as follows. Section 2 introduces a simple theoretical model of policy interaction in the context of simultaneous taxes and cap-and-trade, and extends the analysis to other possible combinations, including subsidies-and-trade combinations and trade-and- trade combinations. In Sec. 3, we explore the consequences of asymmetric policies, where the second policy instrument applies only to a subset of firms or geographies: for example, renewable energy subsidies, or unilateral carbon taxes by a member of the EU ETS. Section 4 concludes by discussing ways in which hybrid alternatives might be used instead to achieve the intended policy goals more effectively.

2. Symmetric Policy Combinations

The simplest way to combine a carbon tax with cap and trade is to impose the tax on the same sectors that are already subject to a cap. In this section we consider a highly simplified model of firm behaviour under simultaneous taxes and trade, before examining some real-world complications.

2.1. *Tax and trade*

Consider the optimization problem of a carbon-emitting firm that is both subject to a carbon tax, t, in Euros per tonne of carbon dioxide, and a cap-and-trade scheme with a carbon price of $p > 0$, also in Euros per tonne of carbon dioxide. Under this system, the firm must pay the per-unit tax on all of its emissions, while also procuring carbon permits covering its emissions for the compliance period. Let e_0 represent the firm's initial baseline level of emissions, and let e represent the firm's emissions after abatement activity, such that in the compliance period the firm abates $a = e_0 - e$. Let $c(a)$ denote the firm's abatement costs, which are increasing and convex with abatement effort, such that: $c' > 0; c'' > 0$. The firm minimises costs by selecting a level of emissions (e) to achieve

$$\text{Min}_e \; c(e_0 - e) + te + pe \tag{1}$$

We assume that firms are too small to influence the carbon price, so $p > 0$ is exogenous to the firm's decision. Note that, for simplicity, we assume p is strictly positive and so do not present the analysis of behaviour at the boundary condition. The first order condition of this problem is simply

$$c'(e_0 - e^*) = t + p \tag{2}$$

This implicitly defines the optimal level of emissions $e^*(t, p)$ for the firm over the compliance period. The second order condition is positive, confirming that e^* minimises costs. Differentiating the first order condition (2) with respect to t, holding p constant, shows that increases in the tax rate reduce emissions: $e_t^* = -1/c'' < 0$. The identical result holds for increases in the permit price, and indeed $e_p^* = e_t^*$.

December 13, 2010 5:48:07pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

The regulator sets an aggregate emissions cap, E, in tonnes of carbon dioxide, such that the aggregate emissions from all firms is equal to the cap. For simplicity, suppose all firms are identical and there are n firms. It follows that:

$$E = ne^* \tag{3}$$

The effect of the cap on the market-clearing permit price p can be derived by differentiating (3), to give

$$\mathrm{d}E = ne_t^*\mathrm{d}t + ne_p^*\mathrm{d}p \tag{4}$$

If tax rates are held constant (so $dt = 0$) then it follows that $\mathrm{d}p/\mathrm{d}E = (\mathrm{n}e_p^*)^{-1} < 0$, confirming the expected (and obvious) fact that a more lenient (higher) emissions target reduces the permit price.

More interestingly, for a fixed emissions target (so $\mathrm{d}E = 0$), it follows that

$$\frac{\mathrm{d}p}{\mathrm{d}t} = -e_t^*/e_p^* = -1 \tag{5}$$

A small increase in the tax rate results one-for-one in an equivalent reduction in the permit price, such that the total carbon penalty faced by a firm, $p + t$, remains constant. As long as the emission target E is constant and binding, the two policy instruments will cancel each other out.

This result may be obvious to economists, but it is not intuitive to many policy-makers. In effect, the demand curve for permits represents the marginal abatement schedule of firms, in this case with emissions increasing along the x-axis (Fig. 1). The marginal abatement cost is the opportunity cost of switching over to a lower-carbon method of production. For example, the marginal abatement cost of using wind

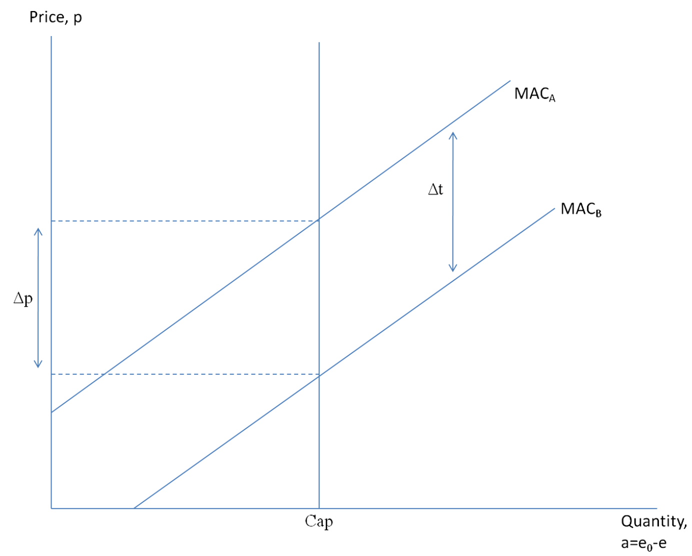

Figure 1. A change in level of tax Δt leads to a corresponding shift in firms' marginal abatement costs, and shift permit prices (Δp).

generation is not the total price tag associated with a wind turbine but rather how much extra it costs (on a per KWh basis) to generate electricity using wind compared to the cheapest alternative.[5] An increase in the carbon tax effectively reduces the marginal abatement cost schedule because it reduces the opportunity cost of, say, wind generation. That is, the opportunity cost of abatement at any point along the curve has decreased, since the firm will have to pay a higher penalty *not* to abate.

There is nothing in principle that makes this type of interaction seriously problematic. As long as the policymaker is aware of the effect that changes in level or stringency of one policy have on the other, it can simply be another (if somewhat odd) way of achieving the given policy goal, with admittedly much increased transaction costs. What can make the simultaneous imposition of taxes and trading systems problematic, however, is the *political context* in which they are imposed.

It is often the case that carbon taxes are levied under the premise of bringing about additional abatement. From Eq. (5), however, we can see that imposing a carbon tax on firms already regulated by a permit trading system will only work to lower the permit price — the level of abatement will be the same, unless the tax is so great that the trading scheme is effectively replaced in its entirety, which seems unlikely. Unless the new tax is coordinated with an explicit reduction in the number of permits, no additional mitigation will be induced. From a political economy standpoint, the simultaneous policy may end up expending scarce political capital (Keohane *et al.*, 1997) with very little additional abatement to show for it. Insofar as the decision to introduce an additional carbon tax requires political capital and may generate (or be intended to generate) the perception that "more is being done", it can create an illusion.

A second, more tangible effect of the policy is on the functioning and credibility of the carbon market itself. Levying a simultaneous tax on an existing carbon market reduces the average carbon price and increases the risk of a price collapse. If the level of the new carbon tax is higher than permit prices in the existing system, then demand for permits is likely to fall to zero, and the tax will de facto *replace* the permit system. Perversely, a policy introduced to induce more mitigation, may thus actually undermine the existing climate change policy regime. Any additional reductions that are achieved thanks to the increased stringency imposed by the tax will have come at the additional cost of whatever institutional investments had been made in setting up the permit trading system initially. These costs may not be trivial, especially in the case of larger, international systems such as the EU ETS.

2.2. *Subsidies and trade*

A similar problem occurs when a regulator combines a permit trading system with a per-unit subsidy rather than a tax. For simplicity, let us assume that a unit subsidy, s, applies equally to all firms and technologies (instead of a specific suite of technologies

[5]For this simple example we have abstracted away from issues of intermittency, capacity factors, and merit order. Strictly speaking, marginal abatement costs should be calculated to include these factors.

December 13, 2010 5:48:19pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

such as renewables).[6] Specifically, suppose the subsidy is provided according to the level of abatement achieved, $a = e_0 - e$. Let us also assume, as we did before, that all firms are small and identical, and individually do not influence the market price of carbon. Each firm's optimization problem is:

$$\mathrm{Min}_e \; c(e_0 - e) - s(e_0 - e) + pe \tag{6}$$

The first order condition of this problem is $c' = s + p$, and, following the same algebraic steps as above, we find that:

$$\frac{\mathrm{d}p}{\mathrm{d}t} = -e_s^* / e_p^* = -1 \tag{7}$$

In short, the higher the unit subsidy, the lower the prevailing market price for permits. Analytically, the subsidies and trade case is identical to a tax and trade regime.

This result occurs because of the way in which unit subsidies affect firms' marginal abatement schedules. A higher level of subsidy for abatement technologies means that the cost of abatement at any given level of production has decreased (Fig. 1). For a given level of emissions cap, demand for permits will be lower, and hence so will prices.

2.3. *Trade and trade*

A third possible situation would see firms faced with two overlapping permit-based systems: a *trade on trade* interaction. For example, two separate trading programs may apply upstream to firms that produce electricity and downstream to firms that consume it. This is the current situation in the UK, where a new Carbon Reduction Commitment (CRC) applies to firms and organizations that are primarily electricity consumers, and the ETS applies to major power companies. The EU 20/20/20 directive, which specifies national targets for renewable generation also features a series of renewable credit trading schemes that overlap with the EU ETS in a similar way.

In this setting, compliance by upstream firms results in higher electricity prices for downstream firms. Analytically, this higher electricity price is equivalent to a tax on energy consumption, indirectly linked to upstream carbon prices. In other words, downstream firms are faced with an implicit price on carbon in the form of higher electricity prices *in addition to* the requirement that they hold permits for their own emissions. An increase in upstream permit prices will be offset by a decrease in downstream permit prices, due to its effect on downstream firms' marginal abatement costs. The magnitude of the offsetting effect will depend upon the level of cost pass-through by upstream firms, which depends on the upstream market structure (Hepburn *et al.*, 2010), the extent to which electricity consumption occupies downstream firms' total emissions, and the abatement options available to both sets of firms.

[6] We discuss the consequences for tech-specific subsidies in Sec. 5.

2.4. *Standards and trade*

Finally, another important simultaneous policy combination takes the form of performance standards imposed in conjunction with a cap-and-trade system: the *standards and trade* case. Renewable portfolio standards (RPS), which mandate electricity producers to generate a certain proportion of their electricity using renewables, are one increasingly popular example. Because regulatory standards such as this are by design mandated on a particular technology or suite of technologies, it is only useful to explore their effects in an asymmetric context. This asymmetric — or non-comprehensive — overlap of climate policies is covered in the next section.

In all of the cases examined, stacking climate policies on top of one another without explicit coordination (notably by adjusting the level of the existing carbon cap) can lead to unintended consequences. The key analytical result is that when policies are administered simultaneously, the effect on firm behaviour becomes *co-determined*; that is, the carbon price in a permit trading system becomes affected not only by firms' marginal abatement costs, but also by the *level of stringency* of the other policy tool.

3. Asymmetric Policy Combinations

So far we have considered situations where a government imposes a tax (or another policy) on exactly the same set of activities that are already covered by cap and trade. In reality, this will rarely be the case. More often we observe technology-specific measures: subsidies such as feed-in-tariffs (FITs) targeted at renewable generation, or regulatory standards that mandate a particular type of technology, such as a renewable portfolio standard (RPS). Similarly, in a regional trading system like the EU ETS, any carbon tax is only likely to be introduced by a subset of countries. In such cases, the interaction between the tax (or subsidy) and the permit price does not correspond one-to-one, and the damage done (in terms of efficiency losses) is greater.

In this section, we outline two general cases where the application of multiple policies is not comprehensive across all relevant players. First, we examine the imposition of an asymmetric change in tax (or subsidy) on a *subset of otherwise identical firms*. This is the case of a unilateral carbon tax in one or several EU ETS countries. Second, we consider the case where the policy applies to a *subset of differing firms*. We can think of this as support for particular technologies, such as renewables.

3.1. *Unilateral tax and trade*

Initially we maintain the assumption that firms are identical, with optimal emissions $e^*(t,p)$ and where $e_p^* = e_t^* = -1/c'' < 0$ as in Sec. 2. But we now assume that the tax change affects only a fraction, f, of the firms (and hence, because firms are identical, a fraction f of system-wide emissions). This subset of firms could for example be located a particular country in an international system.

For a small change in tax applying just to fraction f of firms, Eq. (4) becomes

$$\mathrm{d}E = fne_t^* \mathrm{d}t + ne_p^* \mathrm{d}p \tag{8}$$

where $0 \leq f \leq 1$ and given that $e_p^{*f} = e_p^{*1-f}$. The impact of the tax change on the permit price is

$$\mathrm{d}p/\mathrm{d}t = -fe_t^*/e_p^* = -f \tag{9}$$

which is, of course, just a generalisation of (7). The impact of the unilateral tax change on permit prices is diluted by the fraction f. The unilateral tax does not affect the overall emissions cap, but it does realign the abatement burden among firms. The emissions of firms subject to the higher tax fall further, while those of the other firms rise on the back of falling permit prices and a weaker carbon price signal. Denote firms bearing the tax change with superscript f, and the remaining firms with superscript $1-f$. The impact on emissions from the unilateral tax change in the two categories is as follows:

$$\mathrm{d}e^{*f}/\mathrm{d}t = e_t^{*f} + e_p^{*f}\mathrm{d}p/\mathrm{d}t = -(1-f)/c'' < 0 \tag{10}$$

$$\mathrm{d}e^{*1-f}/\mathrm{d}t = e_p^{*1-f}\mathrm{d}p/\mathrm{d}t = f/c'' > 0 \tag{11}$$

Overall, there is no change in total emissions:

$$\mathrm{d}E = fn\,\mathrm{d}e^{*f}/\mathrm{d}t + (1-f)n\,\mathrm{d}e^{*1-f}/\mathrm{d}t = 0 \tag{12}$$

However, the realignment creates a wedge between the marginal abatement costs of higher-taxed and lower-taxed firms, which were previously equal. The first order condition (2) still holds, but firms will re-optimize to reflect the change in price p, which all firms experience, and the change in tax, t, which only affects the subset f. The impact this has on marginal cost for taxed firms, c'^f, is

$$\mathrm{d}c'^f/\mathrm{d}t = 1 + \mathrm{d}p/\mathrm{d}t = (1-f) > 0, \tag{13}$$

and for the firms unaffected by the tax change the effect is:

$$\mathrm{d}c'^{1-f}/\mathrm{d}t = \mathrm{d}p/\mathrm{d}t = -f < 0. \tag{14}$$

The result is an increase in overall mitigation costs. Diverging marginal costs means that the gains from trade are, at least in part, reversed.

To illustrate the effect, we construct a numerical example for three EU countries, which have recently considered, or are still deliberating, a unilateral carbon tax on top of the EU ETS: France, Ireland and the UK.[7] Table 1 shows what would happen to the

[7]France had planned a carbon tax of €17 per tCO_2 on households and businesses, due to take effect on January 1, 2010, but it was blocked by the French Constitutional Council. Ireland has introduced a carbon tax of €15 per tCO_2 into the 2010 budget, to apply to a range of liquid fossil fuels but not electricity. This looks set to rise in coming years given their budgetary pressure. The UK introduced the "Climate Change Levy" in 2001, but it is in fact a tax on energy use by non-domestic consumers.

December 13, 2010 5:48:21pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

Table 1. The impact of an overlapping tax by France, Ireland, the UK, or all three on the EU allowance price in 2010.

	Tax level			
	5€ per tCO_2	10€ per tCO_2	15€ per tCO_2	20€ per tCO_2
France	−0.18€	−0.37€	−0.55€	−0.73€
Ireland	−€0.03	−€0.06	−€0.09	−€0.12
UK	−€0.34	−€0.67	−€1.01	−€1.34
France + Ireland + UK	−€0.55	−€1.10	−€1.65	−€2.19

Table 2. The impact of an overlapping tax by France, Ireland, the UK, or all three on the EU mitigation costs by 2010 (per cent increase).

	Tax level			
	5€ per tCO_2	10€ per tCO_2	15€ per tCO_2	20€ per tCO_2
France	0.3%	1.1%	2.4%	4.2%
Ireland	0.0%	0.2%	0.3%	0.6%
UK	0.6%	2.3%	5.1%	9.0%
France + Ireland + UK	1.2%	4.6%	10.4%	18.5%

European carbon price if the three countries individually or jointly introduced unilateral taxes of between €5 and €20.

The results are illustrative and based on a simple quadratic cost function that only very loosely resembles mitigation costs under the EU ETS. More detailed modelling work would be required for more accurate results. However, the simple calculations illustrate well the powerful side-effects of unilateral action. If the three countries acted together with carbon taxes of €20 per tCO_2 they would reduce the European carbon price by over €2 per tCO_2, about 15 per cent of the November 2010 spot price.

While carbon prices fall, EU-wide mitigation costs rise. By 2020 the costs of meeting the (unaltered) carbon constraint could rise by almost 20 per cent (in the €20 tax case) as a result of unilateral taxes in France, Ireland and the UK (Table 2). This is because more expensive technologies in countries with unilateral tax would substitute out more cost-effective emissions reduction technologies in countries without a tax.

3.2. *Technology policies and trade*

We next turn to the case of technology-specific policies,that is to a situation where, in addition to the asymmetry in tax incidence, the entities facing overlapping regulation are not identical to other capped firms. It is easier to think of this case as a targeted subsidy, indeed technology-specific policies usually take the form of technology subsidies — a feed-in tariff for renewable energy, for example.

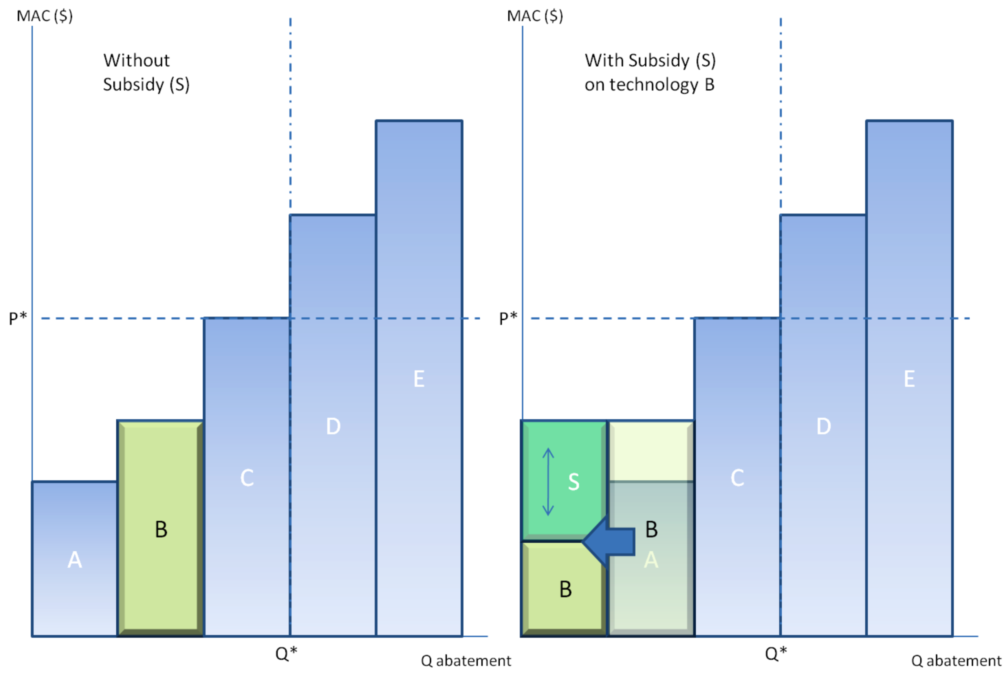

Figure 2. Subsidizing abatement technology B (by amount S per unit), changes its position along the MAC curve, but does not affect the permit price (p^*) because the cost of technology B stays below the margin both before and after the subsidy. The total amount of abatement (Q^*) remains the same.

Instead of shifting the entire MAC curve down (as in Fig. 1), a technology-specific measure only affects parts of the MAC curve and will lead to a compositional re-orientation of the curve. Depending on the level of subsidy and the pre-subsidy cost of the targeted technology relative to the activity on the margin, the subsidy may or may not have an impact on permit prices.

For example, assume the regulator offers a per-unit subsidy on a particular abatement technology (B, E, and D in Figs. 2, 3 and 4 respectively) on the power sector in a closed economy where a permit-trading system already exists. Prior to the subsidy, the activity on the margin for the system as a whole is activity C, which could for example be fuel switching from coal to gas.[8]

Three scenarios are then possible, though only two are likely. First, the cost of converting to the subsidized technology (B) may theoretically already be lower than the activity on the margin, in which case the unit subsidy has no effect on permit prices (Fig. 2). All it does is create extra rent.

Similarly, Figure 3 illustrates the case where the price of the particular technology (this time E) before the subsidy is higher than the activity at the margin (C), and the cost inclusive of the subsidy is still greater. Here, the imposition of the subsidy (or any

[8]The market price of carbon will, in theory, equilibrate around the cost of the abatement technology used at the margin.

December 13, 2010 5:48:34pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

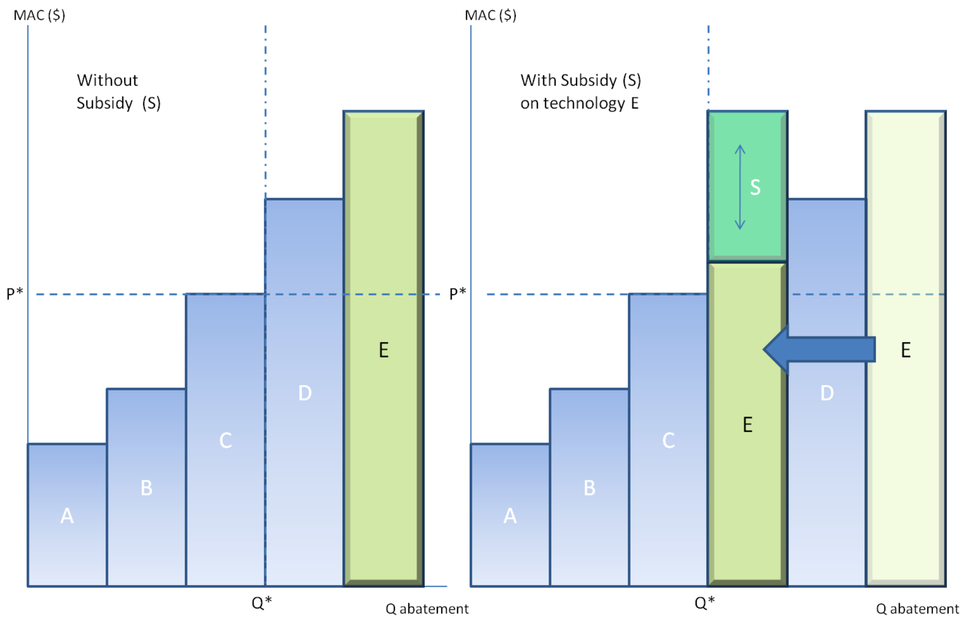

Figure 3. Subsidizing abatement technology E (by amount S per unit) changes its position along the MAC curve, but does not affect the permit price (p^*), because the cost of technology E with subsidy remains above the margin. The total amount of abatement (Q^*) remains the same.

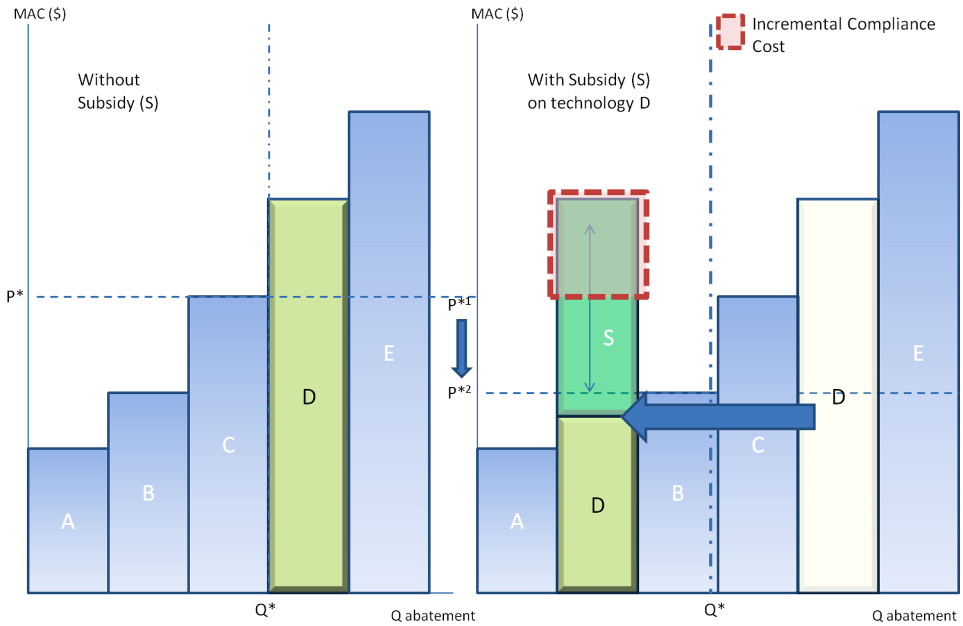

Figure 4. Subsidizing technology D by a sufficient amount (S) per unit moves the technology inter-marginally. This lowers the permit price (from p^{*1} to p^{*2}), since the total amount of abatement (Q^*) remains unchanged, and resulting in an increase in the total mitigation cost. Note that we assume bars to be of equal width for simplicity.

December 13, 2010 5:48:59pm WSPC/265-CCE 00016 ISSN: 2010-0078 1st Reading

changes in the level thereof) will also have no effect on the permit price. The activity will remain too costly to be viable even with the subsidy.

If, however, the price of a given technology (D) inclusive of the subsidy comes to be less than the cost of the marginal activity (C), then the level of subsidy will decrease the permit price and increase overall mitigation costs (Fig. 4).

More generally, the imposition of a simultaneous subsidy or tax on a particular technology will influence the permit price if the subsidy or tax moves that particular technology or suite of technologies *inter-marginally*. Denote P_{TECH} as the cost of the particular technology at hand, P_{TECH-S} as the cost of that technology net of the subsidy, P_M as the cost of the activity on the margin, S as the level of subsidy (which is positive), and p as the permit price, then the following will be true:

(a) If $P_{TECH} < P_M$, then $\mathrm{d}p/\mathrm{d}s = 0$
(b) If $P_{TECH} - S > P_M$, then $\mathrm{d}p/\mathrm{d}s = 0$
(c) If $P_{TECH} - S < P_M$, and $P_{TECH} > P_M$, then $\mathrm{d}p/\mathrm{d}s < 0$

In case (c), although the trading price has fallen, this does not imply that mitigation costs have been reduced. On the contrary, mitigation costs have in fact risen, because an economically more expensive abatement option is forced into the mix.

A special case of technology-specific policies are performance standards. Renewable portfolio standards (which require a certain amount of renewable energy production) or energy performance standards (which prescribe maximum emission levels per unit of output) are often mandated in conjunction with a permit-trading system in a system that may be called *Standards and Trade*.

Standards function in much the same way as technology subsidies or taxes in that they force a particular technology into the emission reduction mix. If the mandated technology is already cost-effective, the regulation is non-binding and the permit price will be unaffected (per Fig. 2). If the mandated technology is not cost-effective at current market prices, the standard will force the expensive solution into the mix and change emission reduction behaviour at the margin. The result may be to lower system-wide permit prices (Fig. 4).

Of course, as we have seen above, there may be other good reasons to impose a tech-specific standard of some kind. In the presence of multiple market failures a portfolio of different policies can reduce emissions at a lower social cost than any single policy. What we demonstrate here, however, is that the imposition of technology-specific policies can have potentially undesirable consequences on the total cost of mitigation and the price of carbon in the existing permit market.

4. Conclusion

This paper makes a relatively intuitive economic point that tends to be overlooked by policymakers: stacking multiple policies in an attempt to control carbon prices is often ineffective and inefficient, and can have several adverse consequences. In particular, we have shown that combining taxes, subsidies or standards with cap-and-trade instruments can undermine the carbon price and increase mitigation costs. This is counter to the original objective of many of these policies, which seek to underpin the carbon price and / or address price fluctuations.

Still, policymakers are not wrong to be concerned to avoid extreme fluctuations in the carbon price and the excessive or insufficient signal they may send. While a reasonable amount of fluctuation in permit prices (and hence mitigation costs) can be expected for any given permit-trading scheme, excessive price volatility can be unnecessarily costly in the short term. Similarly, a minimum carbon price can give firms some certainty over the return on investment in abatement technologies and reduces the risk faced by innovating firms (Fankhauser and Hepburn, 2010a).

For these reasons, a stable, positive carbon price remains a desirable policy objective. However, there are more promising ways of achieving this goal than combining instruments in an overlapping manner. These include longer periods with banking (and perhaps limited borrowing) and/or *hybrid systems* combining price and quantity features in ways that complement each other, instead of subjecting firms to *both* tax and cap simultaneously. There are two main types of hybrids: those in which firms pay the *minimum* between two instruments (often referred to as a "safety valve") and those in which firms pay the *maximum* (also known as a "price floor"). Combining both ceilings and floors creates a "cap and collar" system, where the carbon price is bounded both from below and above.[9]

One of the more attractive hybrid systems simply incorporates a "minimum reserve price" for the periodic auction of allowances, so that no allowances are released onto the market if the reserve auction price is not met (Hepburn *et al.*, 2006). This would require a large enough proportion of permits to be auctioned (instead of being "grandfathered" free of charge), and auctions to be held periodically throughout the commitment period. Other structures to provide greater price certainty include contracts for difference (CFDs), which can be designed to function as a tax between the carbon price and a designated price floor, and long-term carbon contracts between firms and governments.

Despite some disagreement over specific design, hybrid policies can potentially help address concerns of carbon market volatility. Many economists would also be in favour of complementing the instrument which puts a price on carbon with additional measures aimed at other market failures, such as those related to innovation and energy efficiency. However, any additional instruments should be targeted carefully to resolving these other market failures. Simply succumbing to the temptation of adding more instruments, so that politicians are seen to be "doing something", can result in a

[9]Which of these solutions is used depends on the regulator's primary policy concerns. In the US and Australian discussion, for example, many proposals have combined taxes and carbon trading to create a safety valve against excessive mitigation costs. The risk of price spikes and excessive cost burden is a major political concern in these countries, much more so than in Europe.

December 13, 2010 5:48:59pm WSPC/265-CCE 00016 ISSN: 2010-0078 1stReading

series of perverse effects. In addition to unintended market distortions which raise the resource costs of emission reduction policies, discussed in this paper, there are some less tangible costs in terms of (1) wasted political capital for little or no environmental gain, (2) changes in distributional equity, and (3) undermining the credibility of regulators, both because continual tinkering creates instability in the policy regime and because markets will be more likely to experience price collapses and be more susceptible to criticism that they do not send a sufficiently strong price signal. In a vicious circle, this may trigger yet more policy intervention.

Policymakers should be concerned about non-carbon market failures, along with extreme fluctuations in the carbon price. However, they need to be wary of unintended consequences when trying to address these concerns. Stacking on multiple instruments is unlikely to provide an economically rational response. Instead, other interventions (hybrid instruments, banking and borrowing) can more effectively manage the risk of volatile carbon prices. While both safety valves and price floors are not without their own drawbacks (which, if not accounted for in the design process, can be seriously damaging), they represent a more coherent application of economic principles to the issue of climate policy design than the simultaneous application of overlapping, often incompatible, policies.

Acknowledgments

We are grateful to Alex Bowen, Paul Ekins, Sasha Golub, Tom Greenwood, Nat Keohane, Robert Mendelsohn, Luca Taschini, Gernot Wagner, and Dimitri Zenghelis for their comments and feedback. Fankhauser and Hepburn 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.

References

Acemoglu, D, P Aghion, L Bursztyn and D Hemous (2010). The environment and directed technical change. Harvard Universtiy. Mimeo, April 28, http://www.economics.harvard.edu/faculty/aghion/files/Environment%20and%20Directed.pdf.

Bennear, LS and RN Stavins (2007). Second-best theory and the use of multiple policy instruments. *Environmental Resource Economics*, 37, 111–129

De Canio, S (1998). The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments. *Energy Policy*, 26(5), 441–54.

De Jonghe , E Delarue, R Belmans and W D'Haeseleer (2009). Interactions between Measures for the Support of Electricity from Renewable Energy Sources and CO_2 Mitigation. *Energy Policy*, 37(11), 4743–4752.

Del Rio Gonzalez, P (2007). The interaction between emissions trading and renewable electricity support schemes. *Mitigation and Adaptation Strategies for Global Change*, 12, 1363–1390.

Fankhauser, S and C Hepburn (2010a). Designing Carbon markets part I: Carbon markets in time. *Energy Policy*, 38, 4363–4370.

Fankhauser, S and C Hepburn (2010b). Designing Carbon markets part II: Carbon markets in space. *Energy Policy*, 38, 4381–4387.

Fell, H, I Mackenzie and W Pizer (2008). Prices versus quantities versus bankable quantities. *Resources for the Future Discussion Paper*, RFF DP 08–32-REV.

Fischer, C (2008). Emissions pricing, spillovers, and public investment in environmentally friendly technologies. *Energy Economics*, 30(2), 487–502.

Goulder, L, I Parry and D Burtraw (1997). Revenue-raising vs. other approaches to environmental protection: The critical significance of pre-existing tax distortions. *RAND Journal of Economics* 28 (4 Winter), 708–731.

Goulder, L (2002). Environmental policymaking in a second-best setting. *Journal of Applied Economics*, I(2), 279–328.

Goulder, L (2008). Instrument choice in environmental policy. *Resources for the Future* Discussion Paper: RFF DP 08–07.

Grimaud, Andre and Gilles Lafforgue (2008). Climate change mitigation policies: are R&D subsidies preferable to a carbon tax? LERNA Working Paper 08.31.275, University of Toulouse.

Hepburn, C (2006). Regulating by prices, quantities or both: an update and an overview. *Oxford Review of Economic Policy*, 22(2), 226–247.

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

Hepburn, C, J Quah and R Ritz (2010). Emissions trading with profit neutral permit allocation. Working Paper EV 42. Oxford Institute for Energy Studies.

Hoel, M and LS Karp (2001). Taxes and quotas for a stock pollutant with multiplicative uncertainty. *Journal of Public Economics*, 82, 91–114.

Jacoby, HD and AD Ellerman (2004). The safety valve and climate policy. *Energy Policy*, 32, 481–491.

Jaffe, AB, RG Newell and RN Stavins (2005). A tale of two market failures: Technology and environmental policy. *Ecological Economics*, 54, 164–174.

Keohane, NO, RL Revesz and RN Stavins (1997). The positive political economy of instrument choice in environmental policy. Resources for the Future Discussion Paper 97-25.

Metcalf, GE (2009). *Cost Containment in Climate Change Policy. Alternative Approaches to Mitigating Price Volatility*, NBER Working Paper 15125, Cambridge MA, July.

Murray, B, RG Newell and WA Pizer (2009). Balancing cost and emissions certainty: An allowance reserve for cap-and-trade. *Review of Environmental Economics and Policy*, 3(1), 84–103.

Morris, J, J Reilly and S Paltsev (2010). *Combining a Renewable Portfolio Standard with a Cap-and-Trade Policy: A General Equilibrium Analysis*. Report 187, MIT Joint Program on the Science and Policy of Global Change.

Newell, RG and WA Pizer (2003). Regulating stock externalities under uncertainty. *Journal of Environmental Economics and Management*, 45(2), 416–432.

Nordhaus, W (2010). Carbon Taxes to Move Forward Fiscal Sustainability. *The Economists' Voice*, www.bepress.com/ev, September.

Philibert, C (2009). Assessing the value of price caps and floors. *Climate Policy*, 9, 612–633.

Pizer, WA (2002). Combining price and quantity controls to mitigate global climate change. *Journal of Public Economics*, 85, 409–434.

Popp, D (2006a). ENTICE-BR: The effects of backstop technology R&D on climate policy models. *Energy Economics*, 28, 188–222.

Popp, D (2006b). Comparison of climate policies in the ENTICE-BR model. Energy Journal, Endogenous Technological Change and the Economics of Atmospheric Stabilisation Special Issue, pp. 163–174.

Rathmann, M (2007). Do support systems for RES-E reduce EU-ETS-driven electricity prices? *Energy Policy*, 35, 342–349.

Richels, RG and GJ Blanford (2008). The value of technological advance in decarbonising the US economy. *Energy Economics*, 30(6), 2930–2946.

Roberts, MJ and M Spence (1976). Effluent charges and licences under uncertainty. *Journal of Public Economics*, 5, 193–208.

Rosendahl, KE (2004). Cost-effective environmental policy: Implications of induced technological change. *Journal of Environmental Economics and Management* 48, 1099–1121.

Saenz de Miera, G, P del Rio Gonzalez and I Vizcaino (2008). Analysing the impact of renewable electricity support schemes on power prices: The case of wind electricity in Spain. *Energy Policy*, 26, 3345–3359.

Schmidt, RC and R Marschinski (2009). A model of technological breakthrough in the renewable energy sector. *Forthcoming in Ecological Economics*, doi: 10.1016/j.ecolecon.2009.08.023.

Smith, A and S Sorrell (2001). Interaction between environmental policy instruments: Carbon emissions trading and Integrated Pollution Prevention and Control. *International Journal of Environment and Pollution*, 15(1), 22–41.

Stavins, RN (2007). *A US Cap and Trade System to Address Global Climate Change,* Research Working Paper 07–052, Kennedy School of Government, Harvard University.

Stern, N (2009). *Blueprint for a Safer Planet*. London: The Bodley Head.

Unger, T and E Ahlgren (2005). Impacts of a common green certificate market on electricity and CO_2 emission markets in the nordic countries. *Energy Policy* 33, 2152–2163.

Weitzman, ML (1974). Prices vs. quantities. *Review of Economic Studies*, 41(4), 477–491.