3 Methodology

Key points

- What all emissions-reduction policies have in common is that they generally impose costs that someone must pay in order to reduce emissions. It is in this sense that the Commission has interpreted 'effective' carbon price loosely to mean the cost of reducing greenhouse gas emissions. This applies both to individual emission-reductions policies and in aggregate.
- The Commission has adopted a partial equilibrium, comparative static approach that compares, in the latest year for which data are available, a snapshot of the post-policy situation to the counterfactual snapshot of no policy. Ideally the impacts would be measured in terms of changes in economic welfare, taking into account influences on both the supply and demand sides, divided by the abatement achieved.
- On the supply side, the Commission has estimated subsidy equivalents as proxies for resource costs. The subsidy equivalent is the amount of explicit or implicit subsidy provided for low-emission products.
  - While it overstates the resource costs involved, this measure provides some basis for comparing the cost-effectiveness of different policies within and across countries.
  - Subsidy equivalents are also useful indicators of the resources that respective governments are prepared to devote to encouraging abatement, either directly through explicit financial subsidies or indirectly through higher prices paid by consumers.
- On the demand side, the Commission has also endeavoured to estimate the overall product price 'uplift' that results from the various supply and demand-side interventions in each sector for each country, and using this information make some inferences about consumption costs and demand-side abatement.

The terms of reference for this study essentially ask the Commission to capture the various emissions-reduction policies being applied in a number of countries in a single metric — an 'effective' carbon price. This would be a relatively straightforward task if all countries applied economy-wide carbon taxes or quota schemes.

In that case, the carbon 'price' would be observable and comparable. But, as chapter 2 has illustrated, none does, eschewing broadly-based explicit pricing for a myriad of less transparent, more narrowly-focused interventions designed to assist the production and consumption of selected, less emissions-intensive technologies, or penalise particular emissions-intensive products and processes. Even those countries that have carbon pricing schemes apply them only to a limited range of emitting activities. This fragmented approach increases the cost of achieving any given level of abatement, but it also makes comparable measurement problematic.

This chapter discusses the methodology used in this study. Section 3.1 outlines how emissions-reduction policies work and section 3.2 looks at measurement issues. Section 3.3 then considers summary measures. Some key terms used in this study are outlined in box 3.1.

Box 3.1 **Subsidy equivalent, abatement and cost terminology**

- *Production subsidy equivalent* — the assistance provided per unit of output through a particular policy measure (implicitly or explicitly) to suppliers of low-emissions, but high cost, products to enable them to be competitive with high emission but low cost products.
- *Subsidy equivalent* — the production subsidy equivalent multiplied by output.
  - The *total subsidy equivalent* is the sum of the subsidy equivalents at the sectoral level.
- *Abatement* — a reduction in greenhouse gas emissions. In this study abatement has been calculated by comparing the emissions of the low-emissions product or technology supported by a policy measure with the emissions of the counterfactual high-emissions product or technology.
  - *Total abatement* is the sum of abatement from all policies at the sectoral level.
- *Implicit abatement subsidy* — the subsidy equivalent divided by the amount of abatement. An indicator of relative cost effectiveness.
  - The *average implicit abatement subsidy* is the total subsidy equivalent divided by total abatement.
- *Resource costs* — the value of labour, capital and other primary factors of production used directly and indirectly in the production of a good or service.
- *Consumption costs* — households' valuation of the goods that they give up as a result of a price rise, less their valuation of other goods that are purchased with the diverted expenditure. (When a tax on a good increases its price, households use less of the good than they would otherwise prefer and divert more expenditure to other, less-preferred goods.)

3.1 How emissions-reduction policies work

Understanding how different policies operate is an important first step to measuring and aggregating their effects.

'Carrots and sticks'

Despite the variety of policy instruments, all policies designed to promote lower greenhouse gas emissions essentially must either provide incentives to abate or disincentives to emit greenhouse gases, or both. Broadly speaking, all policies can be classified as those that:

- encourage substitution of low-emissions technologies and products (for example, renewable electricity and biofuels) for higher-emissions technologies and products (such as coal-generated electricity and fossil fuels) — these policies essentially focus on the production or supply side
- discourage consumption of products that generate emissions, either through price increases of those products and/or non-price induced decreases in demand for emissions-intensive products — these policies work through the demand side.

But whichever side of the market policies target, they will have implications for the other. Policies that effectively tax one commodity implicitly subsidise others. Effective subsidisation of a commodity implicitly taxes others. Put another way, to achieve their objective, policies that seek to reduce greenhouse gas emissions must alter relative prices to favour products that involve low emissions and to discourage products with the opposite characteristics.

Carbon taxes and quotas

It is generally recognised that the most direct and, consequently, most efficient way of implementing the 'relative price' change required to discourage consumption of high-emission products in favour of low-emission ones, is through a global, broadly-based carbon tax or quota scheme (emissions trading scheme). Placing a 'price' on emissions through these mechanisms means that an additional cost must be taken into account in all decisions involving production and consumption of competing products that have varying amounts of emissions embodied in them or which emit varying amounts of carbon in their use. Production of emissions-intensive products will decline as consumers reduce their purchases in response to higher prices, and as producers switch to comparatively cheaper, low-emission production technologies and intermediate inputs. Because these adjustments can be made on the basis of consumer and producer assessments of relative costs and benefits to them, any given amount of abatement will be achieved at least cost.[1]

Emissions trading schemes (ETSs) limit the total quantity of emissions, but in effect work in a similar fashion to taxes, by directly raising energy prices to consumers and implicitly subsidising producers of ‘clean’ products. Therefore, any ETS has a ‘tax equivalent’ that would deliver precisely the same amount of abatement from the same sources for the same resource cost. Assuming perfect compliance, the two approaches also would have identical distributional impacts, delivering the same revenues to government, if permits were auctioned.

However, no country currently imposes an economy-wide tax on greenhouse gas emissions or has in place an economy-wide ETS. Of the study countries, the United Kingdom, Germany, some parts of the United States and New Zealand have emissions trading schemes operating — but these apply only to particular sectors, such as electricity generation. In some cases too the imposition of generous caps, combined with the impacts of economic recession, have meant that, at least in the early years, the caps have not been binding to any great extent and prices of emission permits have been low (for example, the Regional Greenhouse Gas Initiative in the United States).

Emissions trading schemes or taxes that focus on the electricity sector alone nevertheless work in the same way as more broadly-based taxes and quotas, though the potential abatement options are more limited. They increase the price of non-renewable energy and reduce energy consumption overall (assuming some price sensitivity of demand).[2] At the same time, they implicitly subsidise lower emissions-intensity energy production, because they raise the price that renewable energy producers can charge energy buyers (and still compete with other producers). Non-renewable energy production will thus be squeezed on two ‘margins’ — by lower demand for energy overall, and by the increased competitiveness of renewable energy production.

An emissions tax in the electricity sector effectively taxes consumption of *all* energy. The revenue raised from taxation of high emissions-intensity energy production accrues to government, and the revenue from higher prices for low

1 This presumes that the tax or quota scheme is costless to implement. In practice, the costs of administration and compliance would make it uneconomic to attempt to cover all goods and services in all situations, and hence price effects will differ. However, to the extent that such exemptions are based on marginal benefits and costs, the resulting consumption patterns would be optimal from the community’s perspective.

2 Reductions in energy consumption could be countered by compensation payments, particularly arrangements linked to energy use, such as rebates rather than lump-sum income supplements.

emissions-intensity energy production accrues to producers as an effective subsidy (box 3.2). The rate of subsidy, or producer 'price uplift', for renewable production is equal to the rate of tax on emissions-intensive production.

Subsidies, renewable targets or mandated production standards

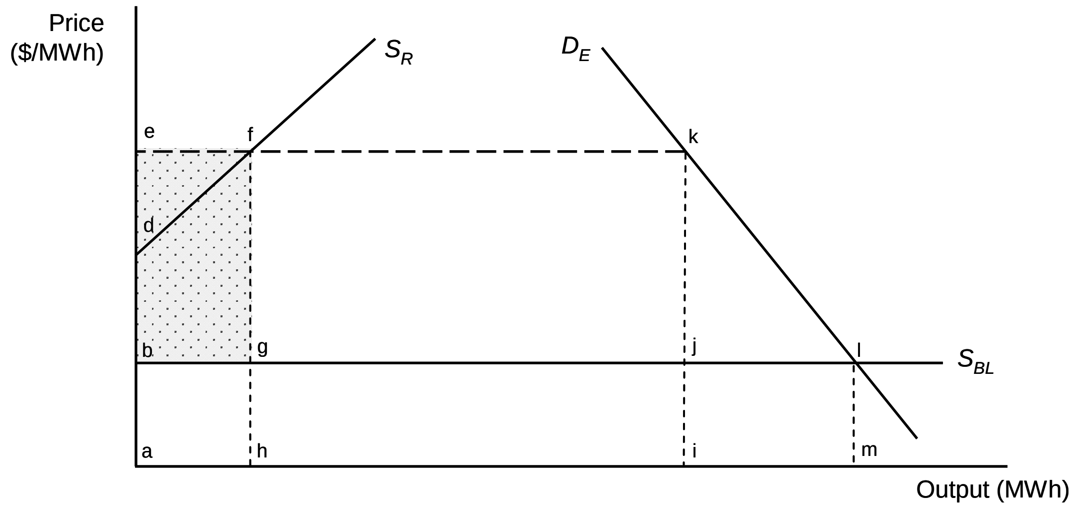
Chapter 2 sets out an extensive range of policies that subsidise the production or consumption of particular 'clean' technologies, or that mandate targets for the use of these technologies by producers.

Regulations or schemes that set quotas, standards or targets for renewable energy, or which mandate prices for generating certain types of renewable energy (such as solar feed-in tariffs), implicitly subsidise their production (box 3.3). In this case, the subsidy rate is equal to the producer price uplift required to induce the amount of renewable energy set by the target or quota. The 'subsidy equivalent' of a policy will equal this subsidy rate times the quantity of renewable energy produced.

Except for explicit, taxpayer-funded subsidies, such schemes must also 'tax' consumers to pay for the higher cost of supplying energy from renewable technologies. Higher energy prices in turn will induce some reduction in overall energy use, leading to some additional abatement. To the extent that energy consumers were compensated for the additional energy cost, this additional source of abatement could be diminished, depending on the nature of the compensation payment.

It is important to note, however, that even if the full costs of implicit production subsidies are passed on to energy consumers, the resultant increase in the price of energy will not have the same effect as imposing a tax on emissions that led to the same uplift in consumer prices. Such a tax would induce different, lower-cost abatement and, almost certainly, would generate different levels of abatement (higher or lower) than the renewable target.

Box 3.2 **How emissions taxes and permits work**



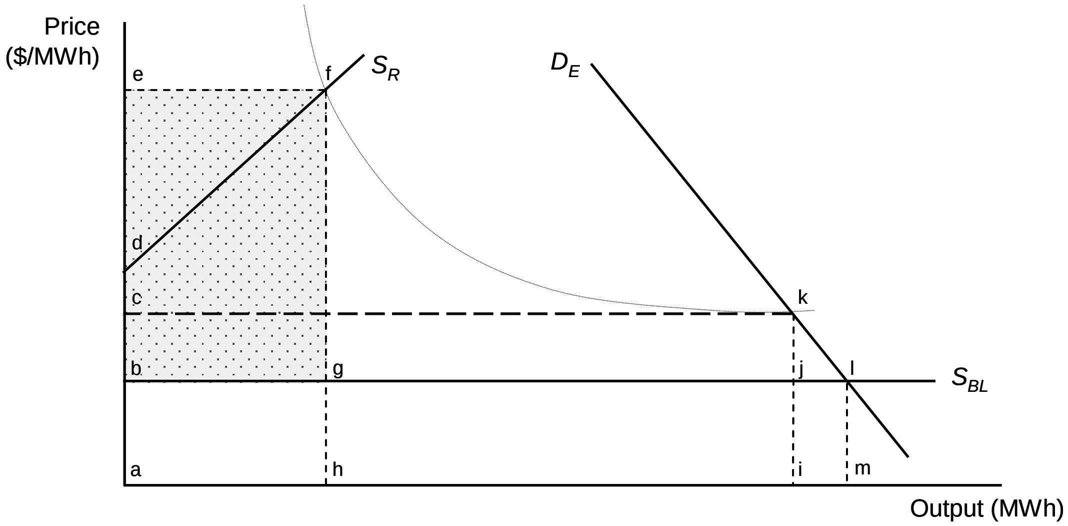
This figure presents a stylised market for electricity generation with non-renewable baseload electricity being provided at a constant unit cost equal to price *ab*, and no renewable electricity generation (represented by the supply curve S_R). A carbon tax is then imposed, driving up the price of electricity from *ab* to *ae*.

This higher price will have two effects. One, household and business demand for energy falls (from *am* to *ai*) (they use less energy either through adopting more energy efficient processes or by curtailing activities and production that use energy). Two, at the same time, provided the tax is high enough, energy generated from renewable or less emissions-intensive sources will come on line in response to the higher consumer price for energy from non-renewable sources (as drawn, supplying *ah*).

Amount *hi* is still supplied from non-renewable energy sources. Tax revenue collected from non-renewable energy production is represented by area *gfkj*. A quota or permit scheme that only allowed total emissions consistent with this output from non-renewable sources would have the same price and abatement effects as the tax, but the distribution of the revenue represented by area *gfkj* will depend on whether permits or quota entitlements are given away or sold.

Shaded area *befg* represents the ‘subsidy equivalent’ to renewable energy producers, paid by consumers of energy. The economic costs of the scheme are the additional *resource cost* of producing renewable energy (area *bdfg*) plus the *consumption cost* (the loss of consumer surplus represented by triangle *jkl*). Consumers, however, not only curtail their energy consumption, but pay more for what they continue to consume — in total, area *bekj*, which comprises tax payments to government (or payments for permits) and the ‘subsidy’ to producers of renewables.

Box 3.3 **How subsidies and renewable energy targets work**



This figure again depicts a stylised electricity generation market, with non-renewable baseload electricity being provided at a constant unit cost equal to price *ab*, pre-intervention. Total consumption is *am*. A mandatory renewable energy target is introduced that is assumed to induce supply from low-cost (for example, biomass), medium-cost (wind) to high-cost (solar) sources. The supply curve for these options is shown as S_R. If the renewables target is set at quantity *ah*, the price required by marginal generators will be *ae*.

- The implicit subsidy paid per MWh to renewable producers is *be*, and the total subsidy equivalent (*TSE*) the shaded area, *befg*. Total abatement would be equal to the difference in emissions intensities of the baseload generator and the renewable generators, multiplied by the amount of renewable electricity *ah*.
- Part of the *TSE*, area *def*, is producer surplus to renewable suppliers — the size of this depends on the excess of the price received over their costs of production. The remainder (area *bdfg*), is the additional resource cost of supplying *ah* (that is, additional to the cost of the baseload generation being replaced).

The renewables target will increase the average cost of generating electricity and lead to an increase in the electricity price from *ab* to *ac* (as drawn, the full cost of the subsidy is passed on to consumers so area *befg* is the same as area *bckj*). This will induce a reduction in consumption of energy and some additional abatement. If the subsidy to renewable energy producers was paid by taxpayers instead, the consumer price of electricity would not change, but the average cost of producing energy would still rise.

Biofuel policies

There are a range of assistance measures designed to increase the production of biofuels and displace the consumption of cheaper but more emissions-intensive conventional fuels (petrol and diesel). These include production subsidies as well as fuel content mandates that specify a minimum percentage of biofuel in the volume of petrol or diesel sold. The mandated increase in demand allows biofuel producers to sell at a higher price than conventional fuels (adjusted for energy content) and thus provides an implicit subsidy for their production (box 3.4).

Fuel taxes

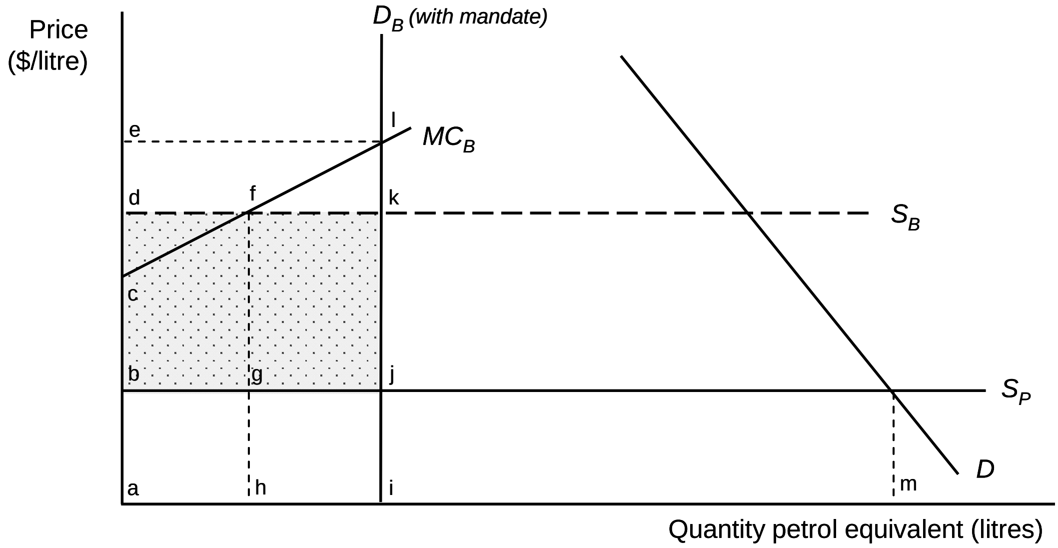
Fuel taxes raise the price of fuel and therefore reduce fuel consumption and greenhouse gas emissions from fuel use. Thus they result in abatement on the demand side. As with supply-side abatement there is a cost, but in this case it is less obvious than the additional resource costs that are involved in supply-side abatement. With demand-side abatement, consumers end up driving less and diverting more of their expenditure to other goods than they otherwise would prefer. Measurement of this consumption cost requires assumptions about the demand curve and how responsive consumers are to increases in fuel prices.

Energy efficiency measures

In addition to policies that increase prices of energy products, there are many policies designed to compel or encourage consumers and firms to invest in more energy-efficient durable products, such as fuel-efficient cars and energy-efficient appliances. The switch to such products is intended to reduce the demand for energy and, hence, emissions. However, the ultimate impact on emissions will also be a function of the level of their use. Because the energy operating costs are reduced, ‘rebound’ effects can mean usage can increase, offsetting some of the initial savings. Further, the effect on abatement in some instances will depend on the emissions intensity of energy or fuel production displaced — higher-cost renewable products could be displaced instead of cheaper but more emissions-intensive products.

There are substantial difficulties in evaluating these programs and calculating their effects. There are resource costs in producing the additional energy-efficient durables, but there are also expected future savings in resource costs from using less energy (box 3.4). And both the additional production costs and the expected future cost savings are difficult to measure.

Box 3.4 **How fuel content mandates work**



This figure depicts a market where both petrol and biofuel can be supplied by imports at world prices *ab* and *ad* and the two are considered to be perfectly substitutable in use after adjusting for energy content. Without intervention, *am* litres of petrol are consumed and no biofuel is consumed as it is not competitive with petrol.

Consider the introduction of a binding fuel content mandate that requires demand for biofuel to be *ai* and allows this to be met by imports or domestic production. The domestic biofuel price is set by the world price and the quantity of domestic production depends on its marginal costs MC_B. At price *ad* domestic production of biofuel is *ah* and imports are *hi*. The additional costs required to replace petrol with biofuel are *bcfkj* which are the additional resources used in producing domestic biofuel *bcfg* and to purchase the biofuel imports *gfkj*. The subsidy equivalent of the biofuel mandate is the shaded area *bdkj*, which is greater than the additional resource costs by the value of producer surplus *cdf*.

In contrast, where imports are not permitted to meet the mandate *ah*, the price that domestic biofuel producers receive will reflect domestic costs of production. That is, the price will be determined by domestic producers' marginal cost at the mandated quantity of biofuel. In this case, with domestic biofuel price *ae* domestic production of biofuels is *ai*, the total subsidy equivalent is *belj*, the additional resource costs are *bclj* leaving producer surplus *cel*.

Although not shown in the figure, the fuel mandate also increases the price of the petrol-biofuel blend and thus also has demand-side effects.

The difficulty in measuring production costs of additional energy efficiency is that energy efficiency products generally do not exist on their own. Instead, energy efficiency attributes are embodied in durable products along with other attributes.

Measuring the expected decrease in future energy costs is also difficult, because it depends on whether investors underestimate the benefits of energy savings (box 3.5). The 'energy paradox' is that there appears to be a reluctance to invest in seemingly cost-effective energy-efficient durables. Why this is so is contentious. The net result depends on whether the apparent reluctance reflects investor misperceptions, or whether it reflects some unobserved cost of additional energy efficiency (such as search costs, high borrowing costs, or a preference for product attributes other than energy efficiency).

Therefore, the net costs of efficiency standards depend critically on assumptions regarding investor perceptions. For example, Parry, Evans and Oates (2010) provided estimates suggesting that in the United States, the marginal costs of using auto standards to reduce economy-wide emissions by several percent can vary from roughly –US$100 to +US$100 per US (short) ton of CO_2.

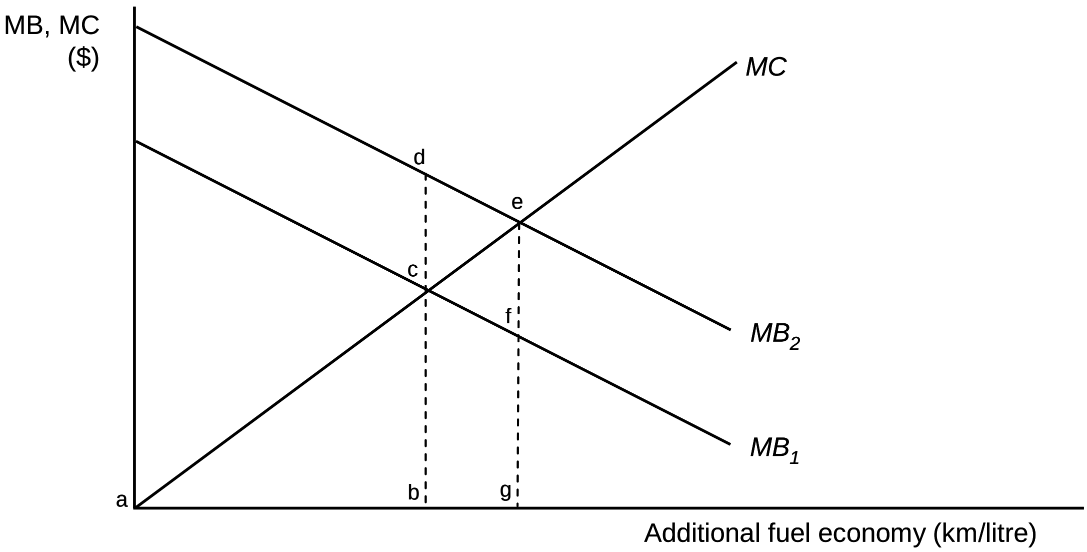
3.2 Measurement issues

The crux of the challenge for this study is how disparate, limited policies of selective application can be measured and aggregated in a useful way. If all greenhouse gas emissions were 'priced' directly, comparing prices across countries would be meaningful. Even so, any differences in carbon prices would not reveal whether some were too high or some too low — that would require an assessment of the desirable level of abatement globally. Some differences would also occur where the coverage of schemes differed.

In the absence of explicit carbon prices or taxes being imposed on all emissions in an economy, the total economic (welfare) costs of individual policies and their associated abatement effects ideally need to be estimated.[3] Measurement of total costs and abatement would allow calculation of average costs per tonne of CO_2 abated *under the schemes analysed*, which in turn would allow comparison of the cost-effectiveness of the various policies.

3 Price and quantity adjustments induced in markets will also likely generate real adjustment costs involving capital write-offs and labour relocation. Implementation and ongoing administration and compliance costs should also be taken into account but are difficult to measure.

Box 3.5 **How energy efficiency standards work**



A large number of policies promote the production of and investment in more energy-efficient durable products, buildings and equipment, with the objective of reducing the demand for energy. The above figure is a stylised representation of the marginal benefits and costs of investing in a durable product (a car) that gives greater fuel economy. Marginal costs represent the resource costs used in producing the product, whereas the marginal benefit to investors depends on the value of expected future fuel savings discounted over the product lifespan (less any other transaction costs).

Expected fuel costs are the discounted value of the expected distance travelled in each future year, multiplied by the expected price of petrol divided by the fuel economy (km/litre). Marginal benefits are the change in fuel savings (that is, the negative of the change in expected fuel costs) from a change in fuel economy. With higher petrol prices, greater distance travelled and/or a lower discount rate, there are larger marginal benefits.

Many studies have suggested that buyers seemingly undervalue increased fuel economy. That is, marginal benefits are perceived to be MB_1 rather than the ‘true’ MB_2 and actual investment *ab* is less than the desirable level *ag*. This ‘energy paradox’ could result from imperfect information or excessive discounting. In this case, a mandatory vehicle fuel economy standard *ag* is seen as achieving the desired production level and net benefits — the increase in production costs *bceg* is less than fuel savings *bdeg* giving net benefits *cde*.

However, if investors correctly evaluate fuel savings, then marginal benefits are represented by MB_1 and a mandated fuel economy standard *ag* results in additional production costs *bceg* less fuel savings *bcfg*. In this case, the vehicle fuel economy standard leads to over-investment in fuel economy with net costs *cef*. Thus, the costing of mandated energy efficiency standards such as fuel economy is particularly problematical and depends critically on the assumption about the extent to which investors may misperceive costs and benefits (to themselves).

An inherent difficulty of these measurements is that they involve comparing an existing situation with an unobserved ‘counterfactual’. Calculating the effects of an existing or committed policy requires an assessment of what would have happened in the absence of the policy. This requires assumptions about, or estimates of, the supply and demand responses to the policy. Yet there is often considerable uncertainty about these responses, and the underlying models that are used to measure them can be quite different (and are sometimes only implicit). Some models are based on engineering estimates with little behavioural response, whereas others allow for behavioural supply and demand responses.

These considerations are especially important when attempting to construct comparable measures across diverse policies and countries. In some cases, sophisticated models allow consistent measurement across policies in a single country,[4] but for most there are no available models, and also significant data limitations. Costs of a policy derived from even a fully-specified model in one country will not be comparable to those calculated from more ad-hoc methods in another.

For policies that assist producers of low-emission products, the value of the assistance (‘subsidy equivalent’) is more easily calculated than their resource costs and is more comparable across policies and countries. These production subsidy equivalents[5] are of interest in themselves, because they capture the often hidden transfers to producers. Also, they are indicative of the true (resource) costs, though they generally will overstate them.

Measuring economic costs and subsidy equivalents

A (relatively) simple case: explicit production subsidies for low-emissions products

Measurement is simplest in the case of production of low-emission products such as renewable energy and where it is assumed that:

1. there is an explicit subsidy paid for each unit of production of the low-emissions product

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4 For the United States, a comprehensive and consistent measurement of the economic cost effectiveness of a wide range of energy policies has been produced by Resources for the Future and National Energy Policy Institute using a version of the US Energy Information Administration’s National Energy Modelling System (NEMS) (Krupnick et al. 2010).

5 The OECD (2010) uses the terminology ‘producer support estimates’ for these measures in relation to agricultural assistance policies.

2. it is assumed that there would be no production of the low-emissions product without the assistance policy
3. consumers consider the low-emissions product (for example, electricity generated from renewable sources) to be perfectly substitutable for a higher-emissions product (such as electricity generated from coal)
4. the higher-emissions product is produced at constant marginal costs.

In this case, the subsidy equivalent from government — the production subsidy equivalent multiplied by annual production — provides additional revenue to low-emissions producers that is used to pay for the additional resource costs of producing their output[6] and, depending on costs, leaves some producer surplus.

On the basis of the commonly-used approximation that the marginal costs of producing the low-emissions product is linear, the additional resource costs will be greater than one-half of the subsidy equivalent and at most equal to the subsidy equivalent. To split the subsidy equivalent into additional resource costs and producer surplus, the marginal cost of producing low-emissions products is needed[7], but is generally unknown. For this reason, it is necessary to rely on an estimate of the subsidy equivalent as a proxy for the additional resource cost, even though it will generally overstate it.

More complicated cases

In addition to explicit production subsidies (assumption 1) there are a large number of other less transparent policies that assist the production of low-emissions products and thus implicitly subsidise them. In these cases, it is necessary to estimate the production subsidy *equivalents*.

This is straightforward with renewable energy certificate schemes, where the certificate price is equivalent to a production subsidy. And the production subsidy equivalent of a feed-in tariff is the tariff rate less the wholesale price of electricity.

In other cases, estimation of production subsidy equivalents is less straightforward. With input subsidies, for example, it is necessary to convert them to a per unit of output basis to make them equivalent to a production subsidy. Up-front lump sum capital subsidies have to be converted to an annual basis to determine the production subsidy equivalent. With an ETS, the production subsidy equivalent for

6 These resource costs of producing the low-emissions product are those additional to the cost of producing the higher-emission equivalent.

7 This can be seen in boxes 3.1 and 3.2 where the subsidy equivalent is area *befg*, additional resource costs are area *bdfg* and producer surplus is area *def*.

a low-emissions producer is equal to the permit price times the difference between their emissions intensity and that of higher-emissions producers.

If assumption 2 is relaxed — that is, there would have been some production of the low emission product without the policy — the link between the subsidy equivalent and the additional resource costs of the policy becomes less direct. This is because, depending on scheme design, the subsidies may flow to existing production as well as incremental production, while the additional resource costs of the intervention come only from the incremental units. For this reason, it is important that the subsidy equivalent calculations used for cost comparisons across policies and countries only included policy-induced production.

More measurement difficulties arise where high-emissions and low-emissions products are imperfect substitutes (assumption 3 does not hold). For example, biofuels are not perfect replacements for their conventional fuel counterparts. In these cases measurement is difficult because in principle it is necessary to know the supply and demand of the low-emissions product and how these change in response to the policy. In practice, with biofuels it has been assumed that, after adjusting for energy content, they are perfectly substitutable with conventional fuels (chapter 5).

There are further issues if assumption 4 is relaxed and there are increasing marginal costs of producing the high-emissions substitute. This has implications for the breakdown of the low-emissions product's subsidy equivalent into additional resource costs and producer surplus. Nonetheless, it remains the case that (with linear marginal costs) the additional resource costs for low-emissions production will be half or more of its subsidy equivalent.

Measuring price uplifts and consumption costs

Any policy that raises product prices to consumers will reduce their consumption and impose costs on them. However, rather than considering the consumption costs of each individual supply-side policy in a sector, the Commission has estimated the price uplift for all policies combined and then made some illustrative estimates of consumption costs.

The price uplift depends on who pays the subsidy equivalents. Where these are paid for entirely by consumers, the uplift will equal the sum of the subsidy equivalents for the sector divided by post-policy consumption (box 3.3). However, where it is known that the subsidy equivalents were funded by taxpayers, they have been excluded from the price uplift estimates. Where the subsidy equivalents are paid by consumers, the price uplift is estimated using the subsidy equivalent on all production, not just the subsidy equivalents on policy-induced production (which are used as a proxy for resource costs).

The consumption cost is a measure of the value to consumers of foregone consumption of a good, minus the value of other goods that can be purchased instead.[8] In chapter 4, consumption costs are approximated by taking one half of the product of the change in quantity and price uplift. This commonly-used approximation (based on the demand curve being linear) is best for small price changes. For the larger fuel price changes considered in chapter 5, consumption costs have been calculated assuming a constant elasticity of demand.

It is also important to note that there are also costs if the subsidies are paid by taxpayers and not consumers. Because additional taxes further distort individual decision-making, they reduce efficiency and thus introduce an additional excess burden or welfare cost on the broad economy. However, no estimates have been made of these costs.

Measuring abatement

In addition to measuring the subsidy equivalents of individual policies, it is necessary to calculate the abatement brought about by each policy. The difficulty again is that this requires a counterfactual; namely, how much abatement would have happened in the absence of the policy?

Another issue is that policies aimed at supply-side abatement can also generate demand-side abatement if they raise product prices by reducing the quantity demanded and thus emissions. However, it is more convenient to consider first the supply-side abatement of individual policies, and to introduce later the effects of all the sectoral supply-side policies on the demand for the sector's product and emissions.

Supply-side abatement

A simple case is a policy that encourages production of a low-emissions product that then replaces production of a higher-emissions product. In this case, abatement is the additional quantity of the low-emissions product multiplied by the difference in carbon intensities between the high-emissions and low-emissions products.

8 In boxes 3.2 and 3.3, the consumer valuation of the foregone consumption is *iklm*, while *ijlm* would be diverted to the consumption of other goods and reflects the valuation of those other goods. This leaves the consumption cost, that is, a net loss, of *jkl*.

Nonetheless, identifying the counterfactual can be complicated where the marginal operator varies depending on the circumstances (for example, peak-load electricity), and this can have a substantial impact on the amount of abatement that might reasonably be attributed to a policy. In the case of electricity generation, it is conceivable that at certain times some types of renewable electricity production replace (relatively low emissions) hydro or gas-fired electricity rather than (relatively high emissions) coal-fired electricity, for example.

It is even more complicated when a number of piecemeal, seemingly independent, policies interact. Here, the unintended consequence can be that the abatement impacts of the policies are not additive. One policy may increase the production of a zero-emissions product such as electricity from solar, but it may act to displace another zero-emissions product such as electricity from wind generation.[9]

Furthermore, it is necessary to measure *net* abatement in cases such as biofuels which, by replacing conventional fuels, reduce emissions, but in their production use fossil fuels, which increases emissions. This necessitates using a life-cycle approach to measuring emissions.

Demand-side abatement

Demand-side abatement is important for policies that push up the price of products that embody emissions. These policies obviously include explicit carbon taxes, ETSs and fuel taxes. In addition, to the extent that subsidies increase the prices to users — and demand elasticities are not zero — this will provide an additional source of abatement and, ideally, should be taken into account. In this study the Commission has used estimates of the elasticities of demand for electricity and transport fuels to make some inferences about the likely short-term abatement that the policy measures might achieve, presuming that all costs are passed through to consumers.

Other measurement issues

The timeframe

Ideally, emissions-reduction policies would be assessed over multiple years. This is because:

9 In these cases, as abatement from one policy goes to zero then abatement costs per tonne of CO_2 for that policy goes to infinity. Nonetheless, the combined abatement and costs from the two policies would be included in the sectoral averages.

- policies are often designed to induce capital investments, such as the building of renewable electricity generation, which can take years to complete and result in abatement over many years
- it is common for policies to be phased in over a period of years, such as an increasingly stringent target for the share of electricity generated from renewable sources.

However, this can add considerable complexity, and so its advantages have had to be weighed against the time constraint on the study. In measuring the costs and abatement of policies, the Commission has adopted a partial equilibrium, comparative static approach that compares, in the latest year for which data are available, a snapshot of the post-policy situation to the counterfactual snapshot of no policy.

This is not to say that longer-term issues cannot be accommodated in the framework. For example, a capital subsidy that encourages investment in low-emissions generation, has a one-off upfront cost, but may contribute to abatement over many years. To account for this divergence in costs and benefits, the value of the subsidy can be amortised over the life of the project and expressed on an annualised basis. This can also be done for previous years' capital subsidies, as some of these previous up-front payments also contribute costs today when considered on an annualised basis. Similarly, the costs of policy measures that bring forward investment that might reasonably be assumed to have occurred in the future can be approximated in similar ways by use of appropriate discount rates (chapter 4).

'Additionality'

Some policies promote other domestic objectives (such as revenue raising or reducing local pollution), while having the 'by-product' effect of achieving emissions reductions. (This issue is more likely to arise for policies that are not explicitly intended to target greenhouse gas emissions, such as fuel excise.) Where such policies deliver domestic benefits and would have been undertaken regardless of their impact on greenhouse gas emissions, the marginal costs of any associated abatement will be negligible. Given that policies can have multiple objectives and that it in most cases it is not possible to decompose abatement estimates (or for that matter costs), it is arguable how much can or should be attributed to abatement objectives.

Sensitivity analysis

Given the measurement challenges just outlined, it is inevitable that there will be a degree of uncertainty associated with estimating abatement costs. The Commission has accordingly produced a range of estimates, rather than a single number, for different policies and for each sector in each country. This involved sensitivity analysis, with key assumptions varied within plausible ranges.

3.3 Adding it up

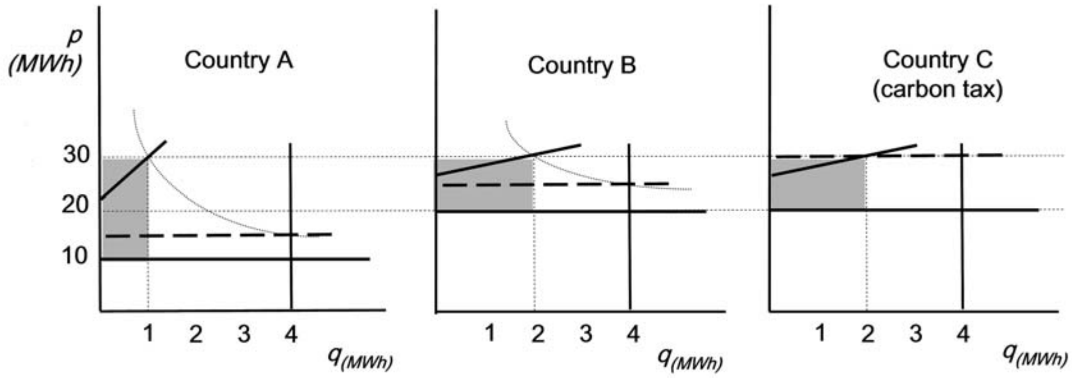
Ideally, the full economic costs and abatement of the various interventions in the study countries would be measured. Given the measurement challenges, for each policy measure, a subsidy equivalent (as a proxy measure of resource costs), and where possible, an implicit abatement subsidy (cost per tonne of CO_2 abated) have been reported. Implicit abatement subsidies could not be estimated for every measure, because,, as noted earlier, in some cases it has not been possible to isolate the abatement effects of individual policies.

Although these proxy measures will typically overstate resource costs, to the extent that they do so consistently across countries, they provide some basis for comparing the *cost effectiveness* of different measures within and across countries in these sectors. They will also be useful indicators of the resources that respective governments are prepared to devote to encouraging abatement, either directly through explicit financial subsidies or indirectly through higher prices paid by consumers.

As far as possible, the Commission has also endeavoured to estimate the overall product price increase or 'uplift' that results from the various interventions in each sector for each country. This information has been used to make some inferences about consumption costs and demand-side abatement. It has been done only after aggregating the subsidy equivalents for each sector. But given the large degree of uncertainty about demand elasticities, estimates of consumption costs can only be illustrative.

The Commission's approach to estimating the sectoral price uplift resulting from the various policies is essentially the same as that followed by Vivid Economics (2010) in a report it undertook for the Climate Institute. Vivid Economics weighted its estimates of the costs of each policy by the share of electricity generation to which that policy applied, to give the price uplift (box 3.6). Vivid Economics referred to this as the sectoral 'implicit carbon price' by expressing it per tonne of CO_2.

Box 3.6 **Issues in 'implicit carbon prices'**



In its report for the Climate Institute, Vivid Economics calculated the cost of abatement for each policy measure, weighted these results by the proportion of electricity generation to which that measure applied, and then summed them. The result was termed the 'implicit carbon price' for that country's electricity-generation sector.

This weighting system is appropriate for calculating electricity price uplifts (when all costs are passed on to consumers). However, it will give a different result for countries that are identical in abatement and costs, but which differ in their cost and emissions intensity of baseload electricity. The result also depends on whether the assistance provided to renewable generators comes via direct intervention or by imposition of a carbon tax or ETS.

Take three countries, each of which devotes the same amount of resources (as proxied by the total subsidy equivalent, and shown as the shaded area in each diagram above) to supporting renewable generators. In country A the quantum of assistance provides one unit of renewable electricity, and in country B it provides two units. This is because in country A, baseload is half the cost in country B, and twice as much subsidy is required to induce the renewable technology supported by country A's intervention. (To simplify the figure, country A and B are assumed to target different technologies hence the different cost functions, but this does not affect the outcome.)

If baseload electricity in country A is assumed to be twice as emissions-intensive as in country B (2 t CO_2/MWh compared with 1 t CO_2/MWh), each country achieves the same amount of abatement at the same additional cost (and hence would have the same implicit abatement subsidy). But Vivid Economics' weighting would mean that country A's assistance would be weighted by a factor of 0.25 (one unit of renewable electricity in four units in total) and country B's would be weighted by 0.5. In other words the 'implicit price of carbon' in country B would be twice that of country A, despite both having the same amount of abatement and the same cost of abatement per tonne of CO_2.

(Continued next page)

Box 3.6 (continued)

Now let country C (which has the same characteristics as country B) impose a carbon tax instead of a technology-specific regulation or subsidy. In this example, the carbon tax provides the same uplift in the prices received by renewable generators, and the same total subsidy equivalent. But because the Vivid Economics approach gave the carbon tax (for its estimate of the United Kingdom) a weighting of 1.0, it contributes more again to the implicit price.

In summary, the abatement subsidy is \$10/t CO_2 for all three countries and they all achieve the same abatement, but the implicit prices that would be derived from the Vivid Economics' approach are \$2.50, \$5.00 and \$10.00/t CO_2 for countries A, B and C respectively.

This is a highly stylised example that uses large hypothetical differences in emissions intensity and cost, but it serves to illustrate some of the issues in interpreting a single measure of costs that is weighted by shares of generation.

These three scenarios can also be used to illustrate what would happen to electricity prices if the full amount of the tax equivalent was passed through to customers. The tax equivalent for countries A and B is equal to the subsidy equivalent, but in country C the total tax equivalent equals the full revenue from the carbon tax, some of which accrues to renewable generators as a subsidy and some to government. For both country A and country B the price uplift would be \$5/MWh, but because of the different cost base this would represent a 50 per cent increase in country A and a 25 per cent increase in country B. Full pass-through of the carbon tax in the case of country C would result in a \$10/MWh rise in electricity prices, a 50 per cent increase. Thus, in this example, country A with the lowest 'implicit carbon price' has the (equal) highest percentage increase in electricity prices.

This example also illustrates that the Vivid Economics 'implicit carbon price' can be interpreted as (and is equivalent to) the price uplift per MWh divided by the baseload emissions intensity. That is, dividing the price uplift for each country (\$5, \$5 and \$10/MWh for A, B and C respectively) by their emissions intensity (2.0, 1.0 and 1.0 t CO_2/ MWh) gives the country's 'implicit carbon price' (\$2.50, \$5 and \$10/ t CO_2). Thus, all else the same, the higher the emissions intensity, the lower the 'implicit carbon price'.

To demonstrate this, the Commission has calculated from Vivid Economics' published figures that their average abatement subsidies for Australia and the United States would be US\$15.27 and US\$15.38/t CO_2, respectively. Using Vivid Economics weighting, these translate into electricity price uplifts in the two countries of US\$2.45 and US\$4.80/MWh. Based on emissions intensities for the two countries (1.05 and 0.95), their 'implicit carbon prices' are US\$2.34/t CO_2 and US\$5.05/t CO_2.

Finally it is important to note that these 'implicit carbon prices' cannot be compared to *explicit* carbon prices of the same value. In the above example as drawn if country B converted its 'implicit carbon price' of \$5 into an explicit carbon tax of \$5, it would achieve no abatement and have no abatement costs (with demand unresponsive to price) while raising \$20 in revenue.

The Commission’s estimates of price uplift are expressed per unit of output and comparisons are made across countries of the percentage increase in output prices as a result of the emissions-reduction policies examined. While these price uplifts are one important metric in cross-country comparisons of the effects of carbon policies, it is necessary also to compare abatement achieved and the economic costs incurred. Countries could have similar abatement and costs with different price uplifts or vice versa (box 3.6).

It is also important to note that the estimated price uplift is not a *carbon price* equivalent. That is, the imposition of an economy-wide carbon price that would result in the same price uplift would not achieve the same abatement as the existing sectoral policies, nor would it have the same costs of abatement.

Conceptually, there are a number of different economy-wide carbon prices that are equivalent to existing sectoral policies in a *single* aspect of their impacts but not others (box 3.7). The imposition of an economy-wide carbon price that would result in the same amount of abatement as existing policies would not involve the same cost nor would it achieve the same price uplift. Or the imposition of an economy-wide carbon price that imposed the same costs as existing policies would not result in the same abatement. In other words, there is no single economy-wide carbon price that would bring about precisely the same level, type and cost of abatement as a scheme that assists a narrow subset of abatement options.

Box 3.7 The elusive 'implicit' carbon price equivalent of a subsidy

There are a number of different carbon price equivalents that could capture a particular aspect of the impacts of a subsidy scheme.

First, it would be possible to estimate the carbon price or tax that would deliver the *same average increase in electricity prices* as a renewables subsidy (assuming that the subsidy is paid for by electricity consumers rather than taxpayers). But this carbon price would be too low to support the level of renewable production that the subsidy brings forth and, indeed, too low to generate much abatement from any other low-emissions technology. Moreover, for any given abatement cost, this particular carbon price will be lower, the greater the emissions intensity of baseload generation.

Second, there will generally be a carbon price level or rate of tax capable of inducing the *same amount of renewable energy* as a renewables subsidy. Indeed, that carbon price or tax would need to equal the (explicit or implicit) unit subsidy. But unlike the subsidy scheme, this level of carbon price or tax would also lead to additional abatement by increasing consumer prices and reducing consumption of electricity overall, and by encouraging other production technologies (for example, gas-fired generation). (And the broader the base of the carbon price or tax, the greater the abatement for any given price.)

Third, there will be a carbon price or tax that would generate the *same costs* as the subsidy scheme, but this carbon price will be lower than the unit subsidy and would also likely generate greater abatement from different sources to the subsidy scheme (again depending on the coverage of the carbon price scheme).

A fourth approach would be to calculate the carbon price or tax that would deliver that *same total amount of abatement* as the renewables subsidy, from the most efficient (lowest-cost) sources. While this would be equivalent to the subsidy in that particular respect, the resulting abatement would not come from the same sources or occur at the same cost. That said, such a calculation would usefully highlight to governments the relative cost effectiveness of the mitigation policies they have in place. (But these 'efficient' carbon price equivalents, assuming they could be estimated for each country, would still provide little guidance as to whether countries should undertake more or less abatement.)