File: Abatement costs

Estimating the costs of abating pollution.

How much does it cost to reduce pollutant emissions? Obviously, the costs will depend on

Abatement costs are classified into three types:

(a) possible GDP gains (negative costs) from correction of market failures: so-called 'no regret' policies;

(b) continuing costs in the form of losses from curtailed energy use or fuel substitution, consisting of foregone output or resource costs from energy-saving measures;

(c) transitional costs, due to disruption and premature scrapping of capital, and short-run labour immobility.

Categories (a) and (b) suggests that the costs will depend on how much abatement takes place; category (c) on how quickly it is implemented.

Most empirical studies concentrate on category (b) costs. Several approaches can be identified in the attempts to measure these costs:

1. ad hoc estimates of marginal costs per unit CO_2 saved for each abatement strategy considered in isolation;
2. input-output models (see Chapter 8);
3. the incorporation of a technical abatement module into a macroeconomic model, which measures abatement costs of alternative carbon emission scenarios in terms of foregone consumption possibilities;

There are many ways in which estimates can be made of the costs of pollution abatement. Two broad classes can be identified:

- Engineering models
- Economic models

In practice, most studies have used linked engineering-economic models, but the relative attention paid to each component varies widely.

Engineering models
These typically use what is called a "bottom-up" approach. An emissions abatement objective is defined. Then all the techniques by which this target could be achieved are listed. For each technique, the researcher calculates the expected expenditures by

firms on pollution abatement equipment and other investments, fuel, operation, maintenance and other labour costs. The costs incurred by each firm are then added up to arrive at the total economy-wide abatement cost. Hence the name “bottom-up”. For a complete accounting of control costs, expenditures incurred by regulatory agencies should be added in. Best achievable abatement costs are those which are the minimum among those techniques studied.

A more modest variant of this approach would involve the researcher obtaining cost estimates of one technique rather than all available. This requires making assumptions about the form of responses of firms to the controls they face.

There are some desirable properties in estimating abatement costs in this way. They are simple to understand, and simple (at least in principle) to undertake. Engineering models are typically highly disaggregated. They consider technology options in a rich, detailed way, providing large amounts of information at the micro production level. This technology-rich property means that engineering models are very well suited to costing specific projects, such as using wind power to generate 25% of a country’s electricity.

They are also capable of dealing in a careful way with some kinds of “no-regret” or “free lunch” possibilities arising from technical and economic inefficiencies in existing method of production. In one report (IPCC, 1995b), it concluded from an examination of so-called ‘bottom-up’ studies that the cost of reducing emissions up to 20% below 1990 levels are negligible or even negative. These studies suggest that in the longer term even larger cuts of up to 50% are available at no net cost.

But this approach also has some serious limitations. Each technology is assessed independently via an accounting of its costs and savings, but possible interdependencies (or linkages and feedback) between the elements being studied and the economy as a whole are not taken into account. This leads to biased estimates of the true costs of abatement. Some examples of important linkages that matter – but which are typically ignored by engineering models - are

- productivity changes induced by regulatory control
- changes in unemployment
- change in overall industrial structure of the economy

The most fundamental problem is that engineering models ignore changes in relative prices, and the associated impacts on factor substitution and the behaviour of firms and individuals. Results can be seriously misleading because of this, particularly when long-term effects are being investigated.

The *ad hoc* approach is exemplified by many of the pairwise comparisons of abatement strategies (e.g. Keepin and Kats, 1988 for nuclear power *vis a vis* energy efficiency; Hohmeyer, 1988 for fossil versus renewable fuels), by the papers submitted by national governments to the IPCC Policy Panel (e.g. Department of Energy, 1989 for the UK), and by the McKinsey Report to the Ministerial Conference on Atmospheric Pollution and Climatic Change (McKinsey, 1989). These *ad hoc* studies attempt to find least-cost abatement techniques, but they do so without taking into account substitution possibilities and relative price effects. Their conclusions, therefore, have serious limitations.

Economic models

These are typically "top-down" models.[i] They are constructed around a set of aggregate economic variables, the relationships among which are determined by (micro or macro) economic theory and equilibrium principles. These relationships are estimated econometrically, using time-series data. Alternatively, relationships are calibrated to match with data for one chosen base year. To obtain cost estimates, some project of interest such as the introduction of a carbon tax is taken as an exogenous shock. The model is solved for equilibrium before and after the shock. By comparing the values of relevant variables in the baseline and shocked case, cost estimates are obtained.

The top-down nature of these models means that they tend to be highly aggregated, and that they do not have the richness of detail (particularly about energy technology options) that can be captured in engineering models. The strength of economic models lies in their ability to deal with supply and demand relationships, and to capture behavioural changes and substitution effects that are important for making inferences about long term consequences. In addition, they are good for the analysis of distributional effects, and for simulating the use of economic instruments.

But economic models alone treat the energy sector as a relatively undifferentiated whole, and so are of limited information for answering questions that involve changes within the energy sector. Aggregate output-energy use relationships tend to be relatively inflexible, and so economic models are not well suited to examining possible decoupling effects.

Linked or integrated engineering-economic models

Ideally, one would like to base cost estimates on models that combine the advantages of economic and engineering models. This might be done by linking the two, or by more systematically developing an integrated modelling approach. Among the many attempts that have been made to do this, we find the following types:

Input-Output Models

Capture sectoral interdependencies via system of simultaneous linear equations. But the fixed coefficients preclude modelling of behavioural changes and factor substitution effects as relative prices change. Technical change purely exogenous (if treated at all). Useful for short-run modelling where highly disaggregated detail is required.

Macroeconomic models

Top down

Key role given to changes in effective demand. Resulting in quantity changes. But more sophisticated versions available. Can describe dynamics and adjustment to new equilibria as result of shocks. Useful for short-run and medium term modelling where highly disaggregated detail is not required. Parameters estimated from time series data. Can look at employment and balance of payments.

The approach is exemplified by the work of Manne and Richels (1989, 1990), using a model which simulates CO_2-energy-economy interactions and which can be used to estimate the costs of carbon emissions limits. The model focuses on long-run energy-economy interactions, and permits a variety of assumptions to be made concerning elasticities of substitution (both between energy sources and between energy and other productive inputs) and rates of technological improvement. Manne and Richels examine the costs of emission limits under several scenarios, and demonstrate that the costs can be significantly reduced by adoption of the least-cost technologies.

Computable general equilibrium models (CGE)
Top down
Behaviour of agents based on optimising microeconomic theory. General equilibrium models. Models solved for sets of prices and wages that generate general equilibrium. Equilibrium only. Parameters calibrated. Attempt to form a money measure of welfare costs such as the Hicksian equivalent or compensating variation (see Chapter 12 for an explanation of these concepts). The use of a computable general equilibrium (CGE) framework (see Chapter 8 for details) also permits a rich examination of policy options and yields conclusions about long-run cost savings. Most CGE models focus on static efficiency in the allocation of resources, with endogenous relative prices serving as the means by which efficient, equilibrium outcomes are achieved after carbon taxes (or other abatement instruments) are deployed.

Dynamic Energy Optimisation Models (E-E)
Bottom up
Rich Technology oriented.
Partial equilibrium energy sector models.
Minimise cost of the energy sector over long term horizon. giving a partial equilibrium for energy markets. Sophisticated versions allow energy demand to respond to price.
Are often linked with macro models.
Dynamic study capital stock changes.

LEAST-COST EQUILIBRIUM MODELLING ?
Partial equilibrium versions: Consider all actions together and optimise bundles of actions. Typically yield higher abatement costs than engineering models.
Problem: typically assume an optimal baseline and do not consider negative cost potential.

Integrated Energy-System Simulation models (E-E)
Bottom up representation of energy demand and supply technologies. Include rich technology. Often highly disaggregated.
Models simulate scenarios

Most models in practice are hybrids. But creates problems of inconsistency between components.

e.g. Sophisticated engineering models: Calculation of direct technical costs + observed technology-adaptation behaviour of markets + welfare losses due to demand reductions + revenue gains and losses due to trade changes.

APPLICATION: CO_2 ABATEMENT COSTS TO REACH Kyoto targets: (Discussed at greater length in Chapter 9)

Gross Costs to attain Kyoto targets depend on

1. magnitude of emissions reduction required to meet the target (so emissions baseline is critical) Emissions baseline (growth rate of CO2) depends on: GDP growth; rate of decline of energy per unit output; rate of decline of CO2 emissions per unit energy)
2. Assumptions made about marginal sources of supply (cost and availability of carbon-based and carbon-free technologies)
3. Short and long run price elasticities
4. Whether or not there is emissions trading (and how extensive this is)

Net costs depend on gross costs AND

1. Availability of no regrets efficiency gains (e.g. can revenues be used to reduce marginal rates on other distortionary taxes [income, sales, employment] OR reduce other technical/economic inefficiencies)
2. Other ancillary benefits
3. Induced technical progress (also important here, for TIMING, is whether the route is R&D or learning-by-doing).

IPCC Simulations

Multi-model comparison
Energy sector models
Emissions reduced by carbon taxes
Tax revenue recycled via lump sum payments to whole economy
Value of tax reqd to achieve target indicates MAC

DOUBLE DIVIDEND

Weak form: For a revenue neutral environmental reform, total real resource costs are lower for a scheme where revenues used to reduce marginal rates of distortionary taxes than where the revenues used to finance lump sum payments to households or firms.

Strong form: The real resource costs of a revenue neutral environmental tax reform are zero or negative.

Table x

Marginal abatement costs (1990 US$/tC) for attainment of Kyoto target by 2010.

Model	No trading				Annex 1 trading	No trading
	US	OECD-Europe	Japan	CANZ		
ABARE-GTEM	322	665	645	425	106	23
AIM	153	198	234	147	65	38
CETA	168				46	26
Fund					14	10
G-Cubed	76	227	97	157	53	20
GRAPE		204	304		70	44
MERGE3	264	218	500	250	135	86
MIT-EPPA	193	276	501	247	76	
MS-MRT	236	179	402	213	77	27
RICE	132	159	251	145	62	18
SGM	188	407	357	201	84	22
WorldScan	85	20	122	46	20	5
Administration	154				43	18
EIA	251				110	57
POLES	135.8	135.3	194.6	131.4	52.9	18.4

Source: IPCC(III) 2001, Table TS.4, page 56.

One set of results (Oxford) has been omitted from this table, as it had not been fully reviewed at time of writing, and relied on early 1980's data for initial parameterisation.
Models do not take account of induced technical progress, CDM, sinks, negative cost options, targeted recycling of revenues, ancillary benefits, inclusion of non-CO2 gases, or inefficiencies in implementation.
Models here are typically GE rather than bottom-up technology rich models.

Table y

GDP loss in 2010 (in % of GDP) for attainment of 2010 Kyoto target.

Model	No trading				Annex I trading				Global trading			
	US	OECD-Europe	Japan	CANZ	US	OECD-Europe	Japan	CANZ	US	OECD-Europe	Japan	CANZ
ABARE-GTEM	1.96	0.94	0.72	1.96	0.47	0.13	0.05	0.23	0.09	0.03	0.01	0.04
AIM	0.45	0.31	0.25	0.59	0.31	0.17	0.13	0.36	0.20	0.08	0.01	0.35
CETA	1.93				0.67				0.43			
G-Cubed	0.42	1.50	0.57	1.83	0.24	0.61	0.45	0.72	0.06	0.26	0.14	0.32
GRAPE		0.81	0.19			0.81	0.10			0.54	0.05	
MERGE3	1.06	0.99	0.80	2.02	0.51	0.47	0.19	1.14	0.20	0.20	0.01	0.67
MS-MRT	1.88	0.63	1.20	1.83	0.91	0.13	0.22	0.88	0.29	0.03	0.02	0.32
RICE	0.94	0.55	0.78	0.96	0.56	0.28	0.30	0.54	0.19	0.09	0.09	0.19

Source: IPCC(III) 2001, Table TS.5, page 57.
One set of results (Oxford) has been omitted from this table, as it had not been fully reviewed at time of writing, and relied on early 1980's data for initial parameterisation.

Sources: IPCC III, 2001, page 55-56 Table

[i] See IPCC, 1996a for further analysis of bottom up and top down models.