Resource Productivity, Environmental Tax Reform and Sustainable Growth in Europe

Environmental tax reform (ETR) is a shift in the target of taxation from 'goods' such as labour (e.g. income taxes, social security contributions) or capital (e.g. corporation taxes) to 'bads' (pollution, resource depletion). The objectives of ETR are to increase the efficiency of resource use, to improve the environment, and ultimately to increase human well-being through both economic and environmental pathways.

This research programme used econometric and resource flow modelling techniques, surveys, and interviews to explore the implications – for Europe and the rest of the world – of a large-scale ETR in Europe designed to achieve the EU's greenhouse gas reduction targets by 2020.

The results show that a broadly based ETR across Europe could play a very important role in meeting the EU's emission reduction targets. However, different national political, economic, institutional and cultural contexts mean that it will not be a politically straightforward policy instrument to introduce.

Paul Ekins has a PhD in economics from Birkbeck College and is Professor of Energy and Environment Policy at the UCL Energy Institute, University College London. His academic work focuses on the conditions and policies for achieving an environmentally sustainable economy, with a special focus on: energy and climate policy and the modelling of the energy system; innovation; the role of economic instruments such as environmental taxes; sustainability assessment; and environment and trade. He is the author of numerous books, papers and articles on environmental taxation and other sustainable development issues, and has three (co-)edited forthcoming books on environmental taxation.

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Paul Ekins

**Anglo-German Foundation
for the Study of Industrial Society**

2009

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Author's Note

The body of this report was written by Paul Ekins, based either on project working papers, which are cited as appropriate, or on contributions by Martin Jänicke and Roland Zieschank (Chapter 1), Hector Pollitt and Christian Lutz (Chapter 2), Stefan Speck (Chapter 3) and Stefan Giljum, Christine Polzin and Christian Lutz (Chapter 4). Full details of programme partners and the researchers involved are given on pages 58–59.

Foreword

For over 35 years, the Anglo-German Foundation for the Study of Industrial Society has promoted study and discussion of the processes of wealth generation and social development in the United Kingdom and Germany. Over this time, it has made a significant contribution to our understanding of modern industrial society, and has been instrumental in establishing focused comparative research as an essential component of evidence-based policy development.

Towards the end of 2004, the Foundation's Trustees recognised a need to draw together the various strands of work funded over the preceding three decades. They were increasingly concerned that the traditional organisation of research into distinct academic disciplines and associated policy domains was leading to a damaging compartmentalisation in government, so that policies adopted by one department often ran counter to the objectives of policy in other departments. The pressing need, the Trustees believed, was for a broader, more integrative approach, rather than for ever more detailed and specialised knowledge.

The Foundation therefore decided to launch a major project designed to counter-act that tendency while building on the comparative knowledge and expert networks established in its traditional priority areas. The title of the new initiative – *creating sustainable growth in europe* – confronts the central challenge facing both countries over the coming decades: how to reconcile the desire for growth with environmental and social sustainability.

An international Academic Advisory Board was convened under the chairmanship of Professor Sir Tony Atkinson, the distinguished economist and former Warden of Nuffield College Oxford, to advise the Foundation on the structure and content of the initiative. It was decided that the research should be organised in linked but largely autonomous programmes, each addressing one or more core themes within the general topic. The themes chosen were:

- innovation, productivity and growth
- environment and resources
- welfare, employment and social justice.

The initiative was formally launched in spring 2005 with a call for proposals. The research communities in Germany and the UK were invited to submit bids for programmes lasting up to three years and addressing one or more of the three core themes. The budget for the initiative was over £4 million. At the end of a rigorous selection process, the Foundation awarded grants to four programmes:

- Explaining Productivity and Growth in Europe, America and Asia (based mainly at LSE London, ZEW Mannheim and LMU Munich, and led by Professor Tobias Kretschmer, Ludwig-Maximilians-Universität Munich)

- Resource Productivity, Environmental Tax Reform and Sustainable Growth in Europe (based at six centres: King's College London (KCL); GWS Osnabrück; FU Berlin; Cambridge Econometrics; the University of Economics, Prague; and SERI, Vienna, and led by Professor Paul Ekins, then at KCL, now at University College London)

- The Economics and Politics of Employment, Migration and Social Justice (based at WZB Berlin, the Universities of Frankfurt and Hannover, and UCL and LSE London, and led by Professor Christian Dustmann, University College London)

- Sustainable Welfare and Sustainable Growth (based at Queen's University Belfast and FU Berlin and the Universities of Bremen, Edinburgh, Göttingen, Kent, Oxford and Southampton, and led by Professor Jochen Clasen, University of Edinburgh).

Meeting the challenge of sustainability will require far-reaching changes in institutions, processes and lifestyles. In launching its initiative, the Foundation wished to demonstrate the key role research could play in defining those changes and in identifying a fair division of the costs and burdens they would impose. Behind the innovative structure of the initiative lay the intention that each programme's distinctive contribution to knowledge and policy within its own academic and political area would be informed by contact with ideas and approaches from other disciplines and policy domains; and that the four programmes when viewed as a whole would add up to more than the sum of their parts. Their contribution would extend to how policy-makers think of their task – the breadth of data and knowledge to be drawn upon, and the nature and range of the implications to be considered.

The economic and political assumptions prevalent when *creating sustainable growth in europe* was launched have now been severely shaken. Many commentators argue that the present unprecedented conjuncture of financial, economic and ecological crises represents a crucial moment in the trajectory of capitalism. Many also argue that these crises represent an urgent call, and also a unique opportunity, for systemic rethinking, of a kind that happens only once in a generation. The findings of *creating sustainable growth in europe*, as summarised in the Foundation's series of four reports and in the accompanying set of *Reflections* by Tony Atkinson, are thus even more relevant and urgent than was originally foreseen. Taken together, they represent the essence of a generation's work by the founders, Trustees, staff and researchers associated with the Anglo-German Foundation, and the key component of its legacy.

Ray Cunningham
Director, Anglo-German Foundation
September 2009

Executive Summary

Environmental tax reform (ETR) is a shift in the target of taxation from 'goods' such as labour (e.g. income taxes, social security contributions) or capital (e.g. corporation taxes) to 'bads' (pollution, resource depletion). The objectives of ETR are to increase the efficiency of resource use (resource productivity) and improve the environment. In addition, ETR is thought to be able to increase human well-being through both economic and environmental pathways – by reducing resource use and pollution, by increasing output, employment and resource productivity, and by stimulating innovation and the development of green technologies, which in turn deliver further economic and environmental benefits.

ETR was implemented on a relatively small scale in a number of north European countries in the 1990s and early 2000s, with broadly positive results. The purpose of this *csge* programme was to explore the economic, environmental and resource implications, for Europe and the rest of the world, of a large-scale ETR in Europe that could achieve the EU's greenhouse gas (GHG) reduction targets by 2020.

The project made use of a range of methodologies – from micro-econometric and macro-econometric and resource flow modelling to questionnaires, surveys, and interviews.

Energy prices versus energy use

The first part of the project produced results which suggest that energy use (and any associated unabated emissions) tends to rise with income, and that increases in energy prices tend to reduce energy use. These results are consistent with others in the literature.

The relationship between energy use and income suggests that, if cuts in energy use are required (in order to cut GHG emissions). it will be necessary to use the price mechanism to make energy more expensive. Otherwise people will use more of it as they become richer. This view is reinforced by the existence of the 'rebound effect' – the phenomenon whereby measures to increase energy efficiency do not reduce energy use by as much as expected, because lower prices for energy services such as heat, light or power mean that people increase their demand for them.

Regulatory strategies to increase energy efficiency will therefore not succeed in reducing energy demand unless they are supported by increasing energy prices. ETR is a strategic use of the price mechanism for this purpose, and it will, of course, tend to increase energy efficiency as well as reduce energy demand.

ETR and the environment industries

The study looked at four specific areas where ETR has already had an impact on the environment industries of Britain and, especially, Germany: low-energy houses; fuel efficiency of cars; industrial recycling; and green electricity. In each of these areas, government intervention – generally through a policy mix of different instruments – was essential to the achievement of the environmental and economic benefits (which included innovation, growth, exports and employment).

The study found that the change in relative prices – whether through taxes, subsidies (feed-in tariffs (FITs)) or market price movements – was the dominant influence across the case studies.

The combination of the price mechanism and regulation was also important. Taxation was a strong driver in the first two cases (fuel-efficient buildings and cars); regulation was important in the case of industrial recycling, but the role of the price mechanism was also visible in the case of industrial waste management.

However, the dominant conclusion is that relative price changes, whatever their cause (taxes, subsidies, or market dynamics), had the strongest steering effects. Though subsidies (including FITs) have proved to be important as specific market support for certain technologies, environmental tax reform complemented by regulation seems the best general mechanism to stimulate a broader range of innovations.

This is an important message for all economies at a time when government spending and investment, and the scope for tax cuts, are likely to be constrained because of past fiscal stimulus spending, but when rising unemployment calls for measures to reduce the cost of labour.

Modelling the links between ETR, the economy and CO_2 emissions

The EU has set a target of reducing GHG emissions by 20% (from the 1990 baseline) by 2020 (with an additional target of a 30% reduction in a context of global cooperation).

In order to investigate whether a substantial shift towards ETR can deliver these targets, six 'scenarios' were developed and modelled, using two well-known macro-econometric models: E3ME and GINFORS. (Two independent models were used because this can generate extra insights and allow more robust conclusions to be drawn.)

There were two baseline scenarios:

- baseline with low energy prices (BL)
- baseline with high energy prices (BH)

There were four further scenarios, which simulated the effects of environmental tax reforms:

- S1L – ETR with revenue recycling designed to meet unilateral EU 2020 greenhouse gas (GHG) target (low energy prices)
- S1H – ETR with revenue recycling designed to meet unilateral EU 2020 GHG target (high energy prices)
- S2H – ETR with revenue recycling designed to meet unilateral EU 2020 GHG target (high energy prices) (where a proportion of revenues are spent on eco-innovation measures)
- S3H – ETR with revenue recycling designed to meet the 'international cooperation' EU 2020 GHG target (high energy prices)

Overall, the results suggest that ETR is an effective environmental instrument that can reduce the EU's CO_2 emissions to the extent required by the targets.

Both models produce nearly identical results concerning labour and resource productivity, so both models give the same message:

- an environmental tax reform that meets the 20% GHG emissions reduction target will raise employment and lower resource consumption. and will have only small effects on GDP.

The carbon prices that are needed to reach the GHG targets are in the order of €53–€68 (in scenarios S1H and S2H), and lower in S2H, when some of the revenues from the taxes are invested in low-carbon technologies.

Achieving the 30% target (S3H) requires a much higher carbon price (€180–200). However, the global environmental benefits, which are insignificant in scenario S1H, are substantial in the scenario of global climate cooperation (S3H). Under those conditions, global CO_2 emissions would be effectively stabilised by 2020, and global resource consumption would drop by more than 5%. For both the EU and globally, even the highest estimate in this project of the costs of large-scale CO_2 abatement is comparable to that of the Stern Review (Stern 2007), and is far below that Review's estimates of the costs of unabated climate change.

Furthermore, the results in scenario S2H show that investment in green technologies in the EU could significantly reduce both the carbon price and GDP loss in reaching the 20% target. Detailed work on the expanding environmental industries sector in Germany

suggests that, with stimulation through public policy (but not without), they are likely to be a major source of economic growth and employment in the future.

Political implications of ETR

The results from the research are entirely consistent with the hypothesis that ETR could be an important policy instrument to increase human well-being through its environmental and economic effects. This does not mean that it will be politically straightforward to introduce.

At the EU level, its introduction would need to be by consensus across the EU-27, which will be anything but easy to achieve. Its relationship to the EU Emissions Trading Scheme (ETS) would need to be carefully thought through. At the national level, its implementation would need to be very sensitive to the different national political, economic, institutional and cultural contexts, some of which do not seem particularly auspicious for the introduction of ETR.

However, this research suggests that a broadly based ETR across Europe could play a very important and cost-effective role in meeting the EU's emission reduction targets for 2020, especially in a context of global cooperation on climate policy. Certainly it is not clear that there is any other policy that would perform as well both economically and environmentally across countries as diverse as the EU.

The recent science of climate change has established the urgency of finding an immediate and effective means of achieving large-scale reductions in GHG emissions. If ETR has an important role to play, as this research suggests, then it is surely up to Europe's policy makers to find a way of implementing it.

1 Environmental Tax Reform: Implications for the Environment and Industry

Environmental tax reform (ETR) is a policy instrument that seeks to apply revenue-raising economic instruments such as taxes or auctioned permits (in an emissions trading scheme) to resource use and pollution. The objective is to increase the efficiency of resource use (i.e. resource productivity) and improve the environment, and to reduce other taxes such that the policy is revenue neutral overall. ETR is therefore often described as a 'tax shift', whereby taxation is shifted from 'goods' such as labour (e.g. income taxes, social security contributions) or capital (e.g. corporation taxes) to 'bads' (pollution, resource depletion).

The policy hypothesis is that ETR will reduce the use of environmental resources and pollution by making them more expensive, and will reduce distortionary taxes on labour and capital, making them cheaper – and thus lead to increased output, employment and resource productivity. In addition, ETR will affect the development of technology, particularly stimulating green innovation and green technology development. Like most public policy, the underlying rationale for ETR is that it is thought to have the potential to contribute to human welfare, as illustrated in Figure 1.1.

Figure 1.1
Hypothesised paths from ETR to higher human well-being
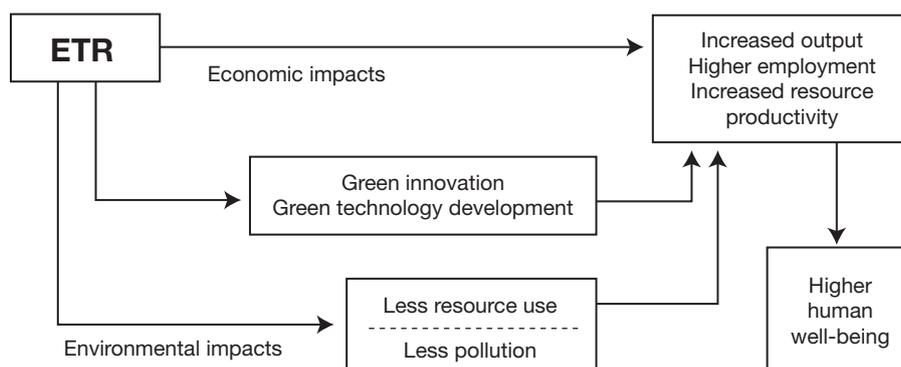
There has now been substantial experience in Europe with ETR on a relatively small scale. The purpose of this project, therefore, was to test the various elements of the underlying hypothesis with a much larger scale ETR, particularly in respect of the use of fossil fuels. There are three main reasons for this focus:

- fossil fuel use leads to the emission of carbon dioxide (CO_2), the principal contributor to anthropogenic climate change

- there is mounting concern about fossil fuel depletion and the concentration of remaining resources in relatively few countries
- the data is available for fossil fuels to perform the kind of detailed analysis reported here, which is less true for other resources, although in principle the analysis and results for energy and carbon productivity given below are applicable to resource productivity more broadly.

The effectiveness of ETR needs to be analysed in respect of the three pathways in Figure 1.1: Does ETR reduce energy use and pollution (in this case CO_2 and associated emissions)? Does ETR stimulate green innovation and green technology development? Does ETR increase output, employment and resource productivity? The first two of these questions will be explored in this section, using methodologies that included literature review, desk-based research and data analysis, and micro-econometric and decomposition analysis. All three questions are investigated in more depth in Chapter 2, principally through macro-econometric modelling. Explanations of these terms and further details of these methodologies are given on pages 62–6.

This chapter therefore reviews the purpose, experience and effectiveness of ETR in Europe, and then reports on findings from the literature review and from the econometric analysis of the effect of ETR on the 'environment industries', i.e. the industries that reduce pollution, increase resource productivity, or encourage a switch from non-renewable to renewable resources. The data analysis looked at four specific areas where ETR has had an impact on the environment industries of Germany: low-energy houses; fuel consumption of cars; industrial recycling; and green electricity. Germany was chosen because in these areas it is one of the most advanced European countries.

The purpose, experience and effectiveness of ETR

ETR implementation in Europe goes back to the early 1990s, with the early adopters – Sweden, Denmark, Norway, Finland and the Netherlands – being followed by the UK and Germany in the late 1990s (EEA 2000, 2005a, Andersen and Ekins 2009 forthcoming), as well as some new EU member states more recently.

The actual implementation of the rather simple concept of a tax shift differs from one country to another depending on their starting position and political objectives (see Speck and Jilkova 2009 forthcoming). However, the momentum of ETR in Europe has certainly declined in the new century. Partly this is due to the emergence of the EU Emission Trading Scheme (EU ETS), following the rejection of the proposals of the European Commission in the 1990s to introduce an EU-wide carbon/energy tax.

The EU ETS is now the main policy at EU level for the reduction in carbon emissions. However, the decision that from 2013 the majority of EU ETS allowances will be auctioned (with 100% to be auctioned by 2027) means that governments will have a new source of

environment-related revenue. This has resulted in a broadening of the concept of ETR in this project, along the lines of the World Bank's usage of the term environmental fiscal reform (EFR); this involves the use of 'a range of taxation or pricing instruments that can raise revenue, while simultaneously furthering environmental goals' (World Bank 2005, p.1). EFR also includes the removal of environmentally distorting subsidies, as well as pricing instruments. It is worth noting here that the ETR described in Chapter 2 of this report includes not only the revenues generated from carbon taxation but also those resulting from the auctioning of EU ETS allowances. It does not include the removal of subsidies, which is why the term ETR rather than EFR has been used throughout this report.

One part of the project adopted a relatively simple micro-econometric approach to investigate the impacts of the British and German ETRs, implemented in 2001 and during 1999–2003 respectively, on different economic sectors and on the labour market (Agnolucci 2008a). Focusing on energy use in industrial sub-sectors (this time in the UK and Germany), the analysis explored how this varies with price and sectoral gross value added (Agnolucci 2009).

The results suggest that ETR could have quite a powerful effect on energy use:

- the price elasticity of energy demand has a central estimate of −0.64 – implying that a 10% increase in the energy price will reduce energy consumption in the industrial sub-sectors by 6.4%.

(Note that this result is for the UK sectors only, because the data for the German sectors proved inadequate for a robust application of the methodology.)

This estimate of the energy reductions caused by the ETRs is similar to results obtained from more complicated econometric models, such as those which produced the results reported in Chapter 2.

A second result of this part of the project (obtained using the same basic methodology) increases the rationale for energy taxation:

- energy use tends to increase with value added with an elasticity of +0.5 – implying that a 10% increase in value added will tend to increase energy consumption by 5%.

Other things being equal, this means that if a sector (or by implication the economy as a whole) is growing, its energy use will be growing too, unless it is restrained by a rising energy price.

There has already been substantial research to suggest that ETR is both environmentally effective (i.e. it does reduce both energy use and CO_2 emissions), and neutral or beneficial for the wider economy (see, for example, Bosquet 2000, Ekins & Barker 2001, Patuelli et al. 2005).

Such evidence also emerged from the *Explaining Productivity Growth* programme in the Anglo-German Foundation's *csge* initiative, which reported in respect of the UK Climate Change Levy (the principal instrument in the UK ETR): 'We find that the Levy had a strong impact on energy intensity and power consumption of firms. However, we find no significant effect on productivity or indeed other economic variables such as employment.' (Martin 2009, p.8, reporting on Martin et al. 2009).

The results from this work are therefore consistent with the findings of a number of reviews in the literature, which suggest that the effect of ETRs on energy consumption and therefore CO_2 emissions can be substantial.

Moreover, in respect of the economic impacts of ETR, the results here are again consistent with the literature, which found that the effects of ETRs on employment tend to be small and can be positive, depending on the size of the reduction in the labour costs effected by the ETR (this depends on the size of the labour tax reduction that is made possible by taxing energy use) and the extent to which labour use increases as energy become more expensive.

The implication is that ETRs may be an effective policy approach to reducing energy use and CO_2 emissions, while leaving the level of employment qualitatively unchanged.

ETR and the environment industries

Environmental tax reform will tend to reduce pollution and resource use simply by making them more expensive. However, if ETR introduces a substantial change in the relative prices of labour and environmental resources, it may also be expected to change the trajectory of innovation and technological development, as companies devote more effort to increasing resource and environmental productivity, and less to increasing labour productivity.

Those industries that reduce pollution, increase resource productivity or foster a switch to renewable from non-renewable resources are collectively called the 'environment industries'. These industries are important to sustainable growth in Europe as a source of activity, jobs and exports in themselves. But they are perhaps more important because, without these industries, uncontrolled negative environmental factors could introduce constraints on both economic growth and the welfare to be derived from it. Overall, the environmental industries may therefore be regarded as a condition for sustainable growth, as well as creating global markets that seem likely to be of increasing world-wide importance.

The environmental industries have two quite distinct components:

• industries that supply traditional pollution control technologies and services ('end-of-pipe treatment');

- industries concerned with resource management (management of materials and energy).

Figure 1.2
Different impacts of environment industries
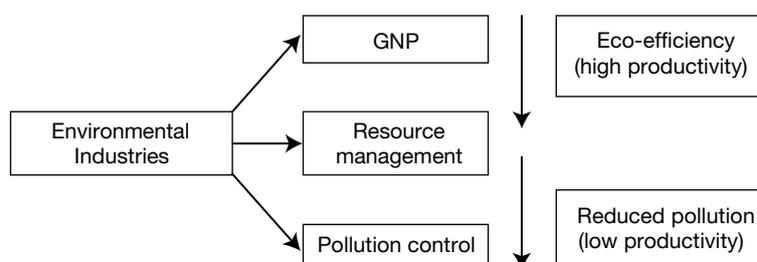
Source: Authors

Both components of the sector (illustrated in Figure 1.2) have contributed to environmental improvement in the EU. For example, pollution control treatment continues to be of great importance in moderating the environmental impacts of industrial growth and remains a field of possible innovation (e.g. membrane technology or carbon capture and storage, CCS). But it may increase industrial costs and material use, and therefore reduce resource productivity, and there will be a trade-off between the environmental improvement it delivers and GDP growth. More efficient resource use (eco-efficiency), however, is more likely to increase resource productivity and contribute to cost reductions in companies as well as environmental improvement. It therefore makes sense to differentiate between these two components of the sector.

By 2004, the environment industries in the EU-25 countries already had a turnover of at least €270 billion (more than 2.6% of GDP) and provided at least 3.4 million full-time job equivalents, with Germany, France and UK being the major countries (Ernst & Young 2006). Employment in the environment industries in 2006 in Germany was at least 1.8 million by 2006 (4.5% of total employment); and in the UK this sector accounted for 0.9 million jobs (3.1% of total employment) (BMU 2007, Innovas 2009).

Figure 1.3 shows different countries' market share of the global environment industries sector, highlighting that Germany has easily the largest share among European countries; its share has increased constantly since 2000, surpassing that of the US in 2003.

Table 1.1 gives a breakdown of the environment industries for the EU-25, for Germany and for the UK, measured by turnover. This data shows that the resource management component of the sector is now easily the largest, accounting for 62% of the sector's turnover. Resource management is also the fastest growing part of the environment industries sector, with the demand for pollution control technologies having largely stagnated in advanced European economies such as Germany.

Figure 1.3
Environmental industries: world market share of OECD countries
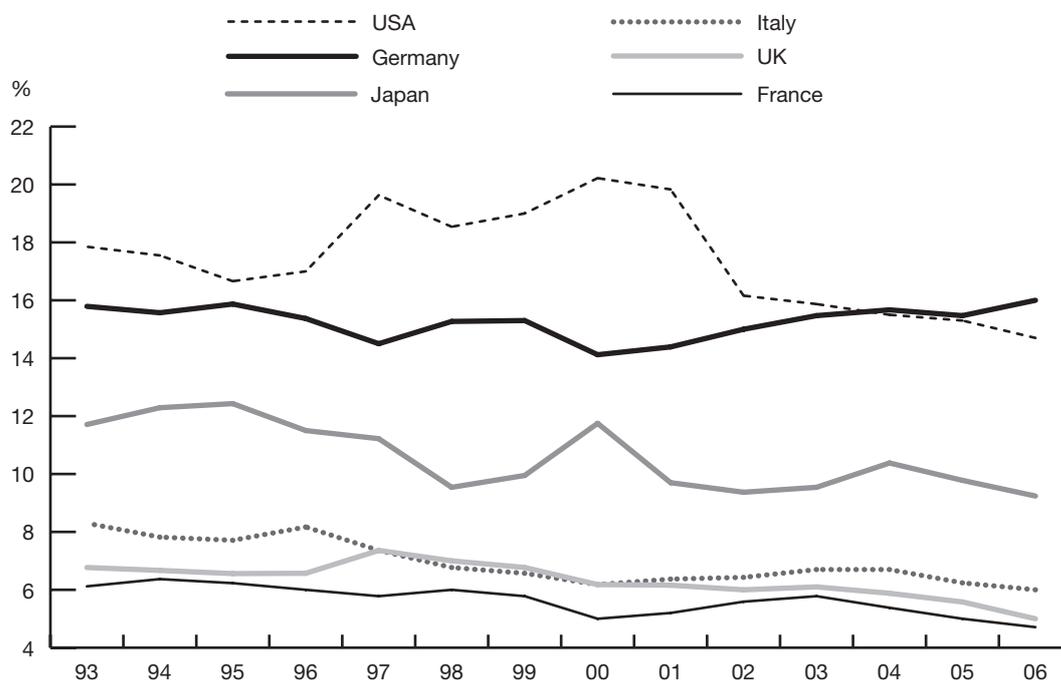
Source: BMU/UBA 2007

Table 1.1
Environmental industries: EU-25, Germany and UK: turnover 2004 (billion €)

	EU25	Germany	UK
A) Pollution control:	**82.0**	**26.5**	**4.7**
Waste water treatment	52.2	19.3	1.6
Air pollution control	15.9	4.5	1.7
Remediation/clean up of soil/groundwater	5.2	1.1	0.3
Noise and vibration control	2.0	0.4	0.1
Environmental monitoring/instrumentation[1]	1		
Nature protection[2]	5.7	1.2	1.0
B) Resource management:	**168.5**	**75.3**	**14.8**
Solid waste management and recycling[1]	52.4	14.9	6.4
Recycled materials	24.3	6.8	3.5
Renewable energy production	6.1	2.2	0.4
Water supply	45.7	11.4	4.5
Eco-construction (estimated)	>40[2]	40 (2005)[2]	
C) Administration, management, research[1]:	**19.8**	**4.4**	**2.0**
General public administration	11.5	4.4	1.6
Private environmental management	5.8		0.4
Environmental research and development	2.5[2]		
TOTAL	**>270.3**	**>106.2**	**>21.5**

Source: Ernst & Young 2006; authors' compilations
[1] revised classification
[2] estimations (not included in the totals of the study)

Taken together, the data presented in Figures 1.3 and Table 1.1 illustrate the rationale for focusing on four case studies of resource management sectors from Germany.

The four areas of the environment industries sector selected for study deliver both environmental and economic benefits. They are also the areas in which German companies have played a prominent role in Europe. The areas are:

- energy-efficient buildings
- fuel-efficient cars (especially fuel-efficient diesel cars)
- industrial recycling
- green electricity.

These areas illustrate the large potential of resource-efficient innovation stimulated by ambitious environmental policy measures.

Energy-efficient buildings

A policy to improve the energy efficiency of buildings was part of the climate programme of the Social Democrat/Green coalition government in Germany, beginning in 1998. The policy mix included energy efficiency standards (for insulation, heating systems) and financial mechanisms, including the eco tax (1999) and a market incentive programme.

The effect of this policy was a reduction in the CO_2 emissions of the residential sector in Germany of 43 megatonnes (Mt) between 1995 and 2007. UK CO_2 emissions, in contrast, from its smaller residential sector changed little over the same period (Figure 1.4).

Figure 1.4
CO_2 emissions (Mt) from the residential sector in UK and Germany 1990–2007
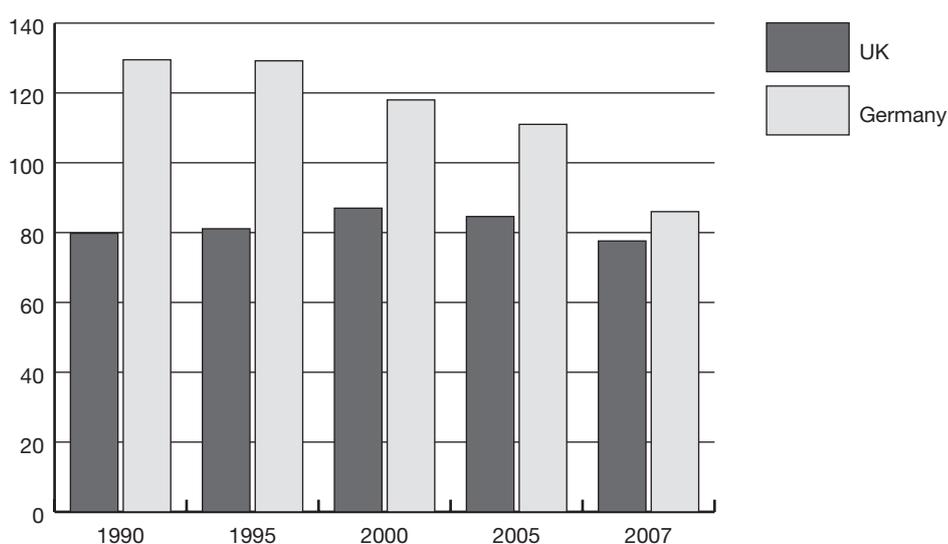
Source: Ziesing 2009, DEFRA 2009

Support for energy-efficient construction and re-development is a special activity of the state-owned bank Kreditanstalt für Wiederaufbau (KfW). An investment of €29 billion was stimulated in 2007 creating or maintaining 480,000 jobs. The average energy saving was about 50% (KfW 2008).

There has been a rapidly expanding market for both new and refurbished low-energy houses in Germany since 1999. The creation of more than 14,000 very-low-energy new buildings (<4 litres oil/m^2) has been supported by the KfW between 1999 and 2007. The annual growth rate was more than 30%. 'Passive houses', the most energy-efficient sub-group of these buildings – with typical energy requirements of <1.5 litres oil/m^2 – had a similar growth rate, as shown in Figure 1.5. There are as yet no comparable financial arrangements in the UK, despite part nationalisation of the banking sector in 2008.

Figure 1.5
Passive houses in Germany
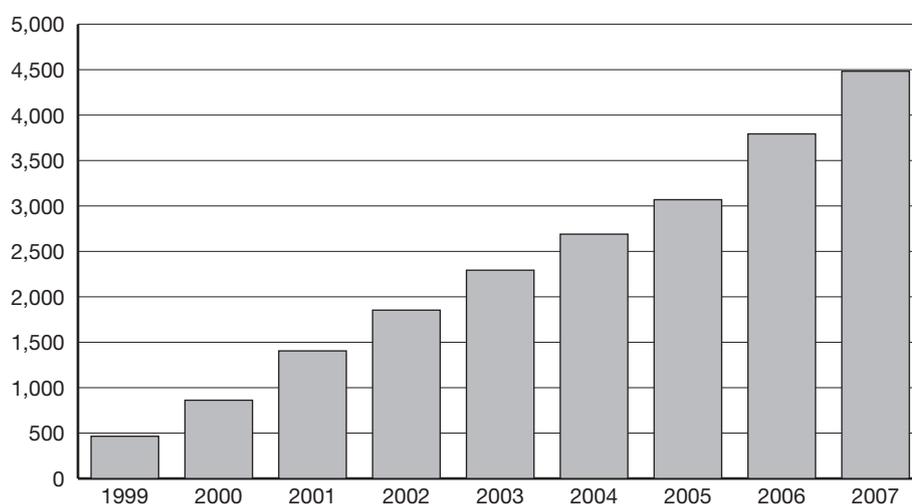
The cost difference between new standard and passive houses is only around 8%. The subsidy for such houses was increased in 2007, together with a 30% tightening of the efficiency standard, for both new and refurbished houses (which after 2012 will be strengthened again by 30%). The present energy standard (2002) is about 7 litres oil/m^2 for single houses. The average energy consumption of older houses in Germany is 25 litres oil/m^2.

The investment in new and refurbished energy-efficient buildings in Germany amounted to €40 billion in 2005 (BMU/UBA 2009). The construction industry – after a long recession – in 2008 noticed a new revival mainly due to the new energy and climate policy. The market for special components of low-energy houses (e.g. insulation materials) is rapidly increasing. This development puts Germany in a strong position to meet its EU target of a 14% reduction in CO_2 emissions in the housing and construction sector by the year 2020, and to benefit from the European Commission's adoption of the passive house standard in due course.

Fuel-efficient diesel cars

It may be surprising to consider diesel cars as part of the environment industries sector; but cars with a fuel efficiency double that of the existing car fleet are certainly worth putting in this category.

Diesel cars with a fuel consumption of 3 or 5 litres/100 km came on the market in Germany in 1999 following a differentiation in car tax (introduced in 1997) that explicitly supported fuel-efficient cars with a high tax bonus. Only diesel cars with fuel injection achieved the supported performance level. The eco-tax was introduced in 1999 and added to the mineral oil tax which had already been strongly increased in the early 1990s. The result was not only a market success of fuel-efficient diesel cars, but also a general decrease of fuel consumption since 1999 (shortly after the start of the Social Democrat/Green coalition government) which also influenced the CO_2 emissions of cars in general (see Figure 1.6). The economic result was a clear world market success for German diesel cars.

Figure 1.6
CO_2 emissions (Mt) of road traffic in Germany and UK 1990–2007
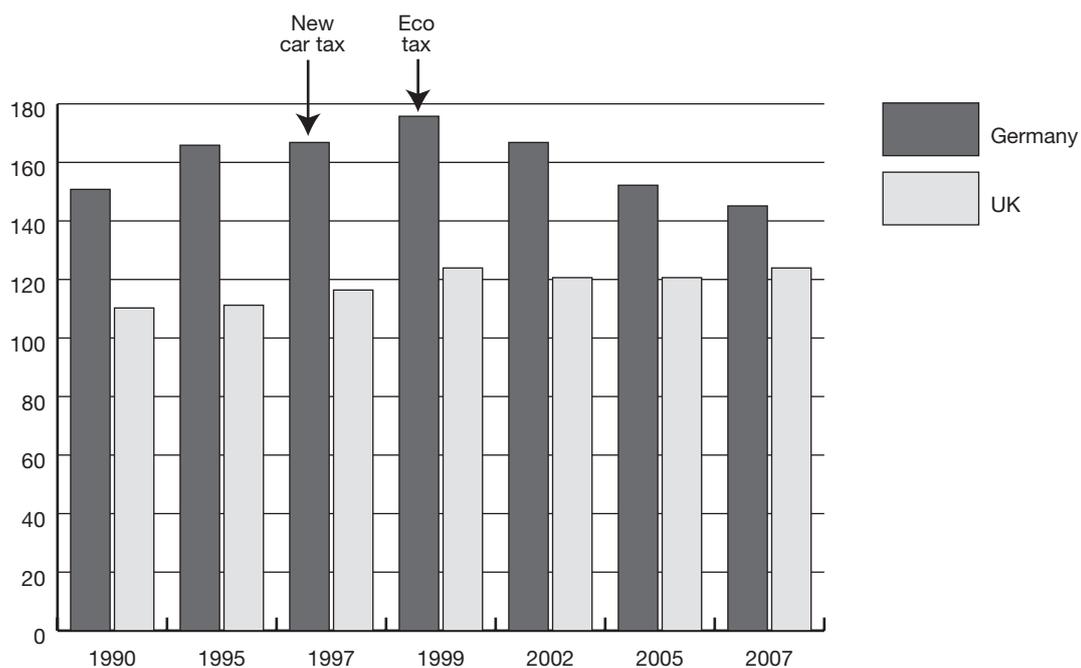
Source: Statistisches Bundesamt 2009, DEFRA 2009

Industrial recycling

The strategic economic role of recycling for sustainable resource use is widely acknowledged, but so far clear statistical evidence of its achievement has been limited. However, changes in modern economies seem likely increasingly to validate the worth of recycling.

At present, some 45% of all production costs for German industry are due to costs of resources, with this share increasing in the longer run. Labour costs, however, account for

less than 20% (Statistisches Bundesamt 2009). This means that energy and raw materials which are wasted will become recognised as a 'wasted resource'; and therefore in times of rising resource prices and CO_2 costs, energy- and material-intensive industries in particular will have problems sustaining their competitiveness.

On the other hand, recycling metal can use just one fifth the energy of the virgin resource, so 'waste' resources could become very competitive, with society having an incentive to substitute away from using new energy and raw materials, and recycling becoming an essential component of economic as well as resource efficiency.

In 1994, Germany introduced an ambitious recycling policy, which was strengthened in 2001 by a regulation that included a target to prevent any landfill without pre-treatment by 2005. The German sustainable development strategy also included a target to increase German resource productivity by 100% between 1994 and 2020.

Apart from a successful voluntary agreement with the construction industry, German waste policy has been and is likely to remain driven by regulation (Töller, 2007). The policy caused an increase of recycling rates together with heat recovery from incineration, and it reduced the rate of final disposal to landfill from 63.5 Mt in the year 1998 to 45.7 Mt in 2005 (Statistisches Bundesamt 2007).

This also had a positive effect on the waste intensity of the economy. Figure 1.7 shows that there has been a clear decoupling of GNP growth and waste generation beginning in 2000. Compared with the UK (and most other EU member states) the German regulation resulted in a significantly higher share of waste being recycled or incinerated and conse-quently a significantly lower proportion of waste being deposited in landfills. Figure 1.7 also shows the effect of the price mechanism, with the price increases of raw materials in recent years seeming to have had a strong influence, especially on industrial recycling.

Figure 1.7
Recycling rates in Germany 2002–2006 (including energetic use, %)
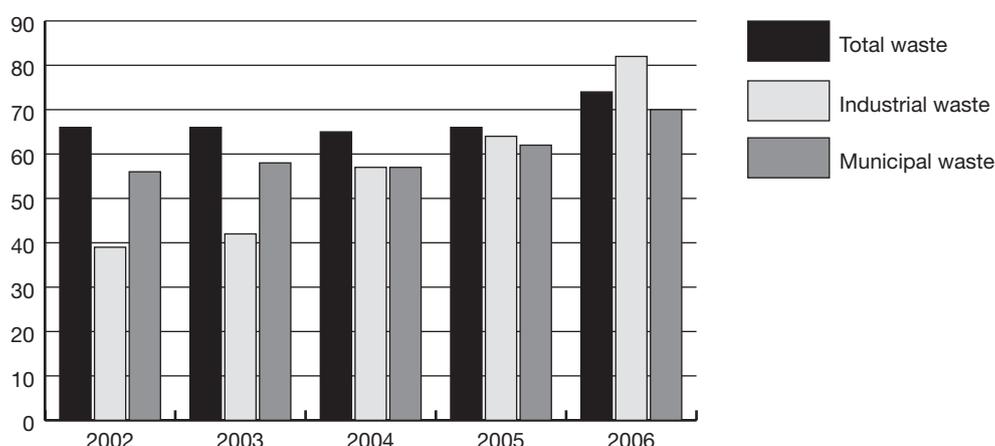
Source: Statistisches Bundesamt 2009

The economic co-benefit of this policy was rapid growth and increased employment in the waste industry and the recycling sector. The Ministry of Environment calculates a turnover of the waste industry of about €50 billion and employment of about 250,000 jobs. In addition, there was an annual saving of raw material imports of about €3.7 billion. The recycling sector reached an annual growth of turnover and employment of 13% and 9% respectively between 2004 and 2006, and is expected to grow by 11% and 7% respectively between 2007 and 2009. German recycling technologies have a 25% share of the global market, with a market share of automatic separation technologies – a fast growing market – of 64% (BMU 2007).

Green electricity

An ambitious regulation to stimulate renewable energy in the power sector in Germany was introduced in 1998. This policy was very effective and has caused a rapid increase in the availability of renewable electricity. The original target of a 12.5% share of electricity in 2010 was exceeded in 2007, when it reached 14.2%. A new target of 25–30% in 2020 was fixed in 2007.

The main instrument, which changed the relative prices of renewable and conventional power, has been the feed-in-tariff (FIT), whereby generators of renewable power are paid for the power they feed into the grid. FITs have also been widely adopted in other countries. The FIT already existed in Germany in the 1990s, through the Electricity Feed-In Act 1990, but was significantly increased and broadened in 1998 by the Renewable Energy Resources Act (EEG), which guaranteed attractive prices to generators for renewable electricity. In 2005 total tariff payments amounted to €4.19 billion, increasing electricity costs for households by 3%.

The increase in renewable power has been remarkable. Between 1991 and 2001 green power production doubled (from 19 tera-Watt-hours per year to 37 TWh/year); however, the next doubling took place within only five years with 73 TWh generated in 2006 and 86.7 TWh in 2007. Figure 1.8 shows this acceleration in the quantity of renewable generation. The positive impact on air pollution should also be mentioned, avoiding some €8.6 billion in unaccounted environmental damage costs in 2007. Economically, in 2007 the turnover in the green power sector was €25 billion, up from €12.3 billion in 2004. The direct and indirect employment effect in 2008 was 276,000 jobs.

The additional costs of making FIT payments to renewable generators, which are paid by all households, was 1 cent per kWh in 2007 (and is estimated to be 1.5 cents per kWh in 2020). The unit rate of the FIT is being lowered over time as technologies become more competitive, but its total cost rises as more and more renewables are deployed.

The payment to renewable generators through the FIT could be viewed as an investment in the development of a strong export position for Germany in photovoltaics (PV) and wind energy. It could also be seen as a public investment in a remarkable innovation process. Immediately after 1998 a rapid increase of inventions (patents) in the area of renewable energy could be observed in Germany. The global market share of German patents for biogas technologies is 65%, for PV 41% and for wind energy 24% (BMU 2007).

Figure 1.8
Share of renewable energy in Germany 1998–2008 (%)
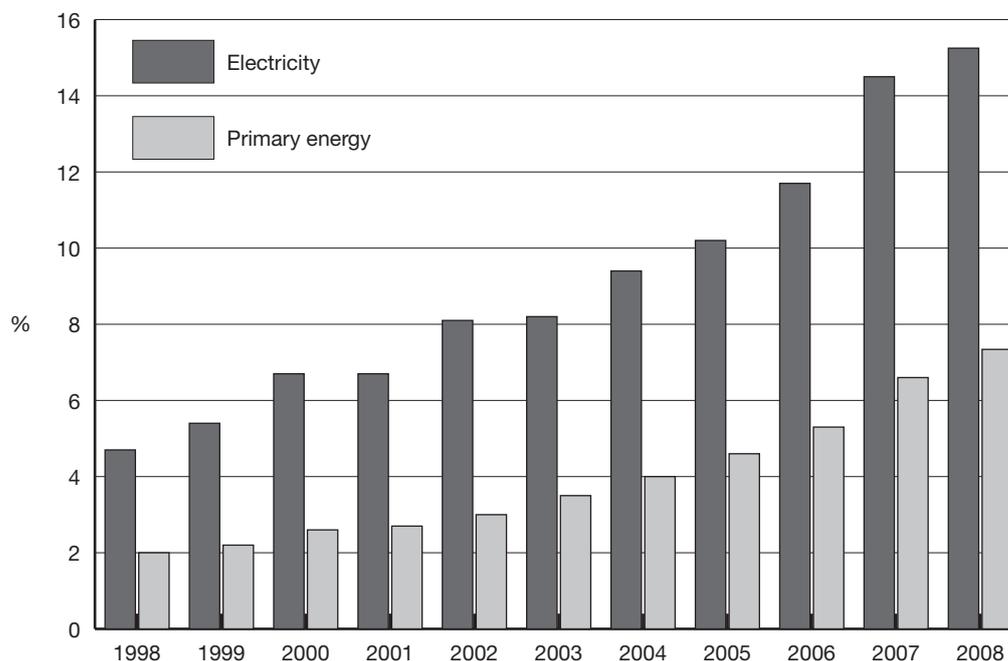
Source: BMU/BEE 2008

The structure of the renewable energy industry will change rapidly when current dynamics relating to innovation processes and 'economies of scale' work their way through. Expert estimates suggest that in 2010, in south Germany, the production costs of solar energy will reach the level of €0.15 per kWh (in California €0.11 and in Spain about €0.10 per kWh). In this case solar energy will reach parity with the household retail price of grid electricity, and should be fully competitive with coal-fired power plants, if there is a significant change in the price of CO_2.

Under these conditions, there is no apparent limit to the market for the production of solar energy plants, and countries with established industries, know-how and intellectual property will stand to reap rich rewards.

Policy implications

In each of the four case study areas, government intervention – generally through a policy mix of different instruments – was essential to the achievement of the environmental and economic benefits. The economic benefits included innovation, growth, exports and employment. Environmentally, German 'green power' in 2007 avoided 115 Mt CO_2 emissions, up from 85 Mt in 2005. The most recent forecasts suggest that CO_2 savings could amount to more than 200 Mt in 2020 (BEE 2009).

The improvements in waste management have also reduced greenhouse gas emissions, with savings since 1990 of around 40 Mt CO_2-equivalents, mainly by closing down landfill sites.

The German eco-tax of 1999 seems to have played an important role in the reduction of traffic-related CO_2 and the reduction of the use of heat energy by households. More generally, the change in relative prices – whether through taxes, subsidies (feed-in tariffs) or market price movements – seems to have been the dominant influence across the case studies.

The combination of the price mechanism and regulation was also important. Taxation was a strong driver in the first two cases (fuel-efficient buildings and cars); regulation was important in the case of industrial recycling, but the role of the price mechanism was visible in the case of industrial waste management as well.

These environmental policy measures stimulated innovation. The cases of energy-efficient buildings and renewable energy show clear feed-back in the innovation cycle from diffusion to invention, suggesting that environmental policy can also enlarge the technical potential and the available options.

However, the dominant conclusion is that relative price changes, whatever their cause (taxes, subsidies, or market dynamics), had the strongest steering effects. Though subsidies (including FITs) have proved to be important as specific market support for certain technologies, environmental tax reform complemented by regulation seems the best general mechanism to stimulate a broader range of innovations.

This is a message that has considerable importance for all economies at a time when government spending and investment, and the scope for tax cuts, are likely to be constrained because of past fiscal stimulus spending, but when rising unemployment calls for measures to reduce the cost of labour.

2 ETR in Europe: Macroeconomic Implications

The environmental tax reforms carried out to date in Europe have been relatively small scale in terms of the proportional tax shift towards environmental taxes that they brought about.

This chapter investigates what would happen if there were to be a much more substantial tax shift at the European level. This research was conducted using computer modelling techniques, based on two well-developed macro-econometric models of the EU: E3ME and GINFORS.

The use of two independent models, as opposed to a single model, can generate extra insights and allow more robust conclusions to be drawn.

The findings that are reported in this chapter use two baseline situations:

• baseline with low energy prices (BL)
• baseline with high energy prices (BH)

Both baseline scenarios were modelled using E3ME and GINFORS.

Further modelling then simulated the effects of environmental tax reforms, creating the following scenarios:

• S1L – ETR with revenue recycling designed to meet unilateral EU 2020 greenhouse gas (GHG) target (low energy prices)
• S1H – ETR with revenue recycling designed to meet unilateral EU 2020 GHG target (high energy prices)
• S2H – ETR with revenue recycling designed to meet unilateral EU 2020 GHG target (high energy prices), i.e. as S1H, but with a proportion of revenues being spent on eco-innovation measures
• S3H – ETR with revenue recycling designed to meet the higher 2020 GHG reduction target (high energy prices), in the event that international cooperation on mitigating climate change results from the 2009 Copenhagen climate change conference.

The first part of this chapter describes the scenarios in more detail, and discusses briefly the differences between the models (crucial to interpreting their results). The second part of this chapter reports the separate results of the two models, before going on to compare the results and draw conclusions.

Models and scenarios

The GINFORS model is described in Meyer et al. (2007), Giljum, Behrens et al. (2008), Lutz et al. (2009), Lutz and Meyer (2009a); and the E3ME model is described in Cambridge Econometrics (2009). A more detailed comparison of the models may be found in Barker et al. (2007a).

The general structure of the two models is very similar. Both cover the interactions between the energy and economic systems, material demands and the environment, at a similar level of detail for each sector. The main difference is in geographical coverage: GINFORS is a global model, while E3ME covers only Europe. Further similarities and differences are outlinedon pages 62–66 and discussed in more detail in Speck (2009).

For this project, E3ME and GINFORS projections for the baseline with low energy prices (BL) were calibrated to the 2007 baseline generated by another model (PRIMES), published by the European Commission in May 2008, and use the same (low) oil-price assumptions. An ETS price of €18/tCO$_2$ in constant 2008 prices is assumed for 2020.

For the high energy price baseline (BH) and for the scenarios with high energy prices (oil, coal and gas), there is stronger price growth over 2008–10 and higher prices are maintained thereafter (see Figure 2.1). With the lower oil price, a stronger ETR (with higher environmental taxes, revenues, and other tax reductions) is required to reach the GHG reduction target.

Figure 2.1
EU energy import prices in $ (2008)/barrel oil equivalent (boe)
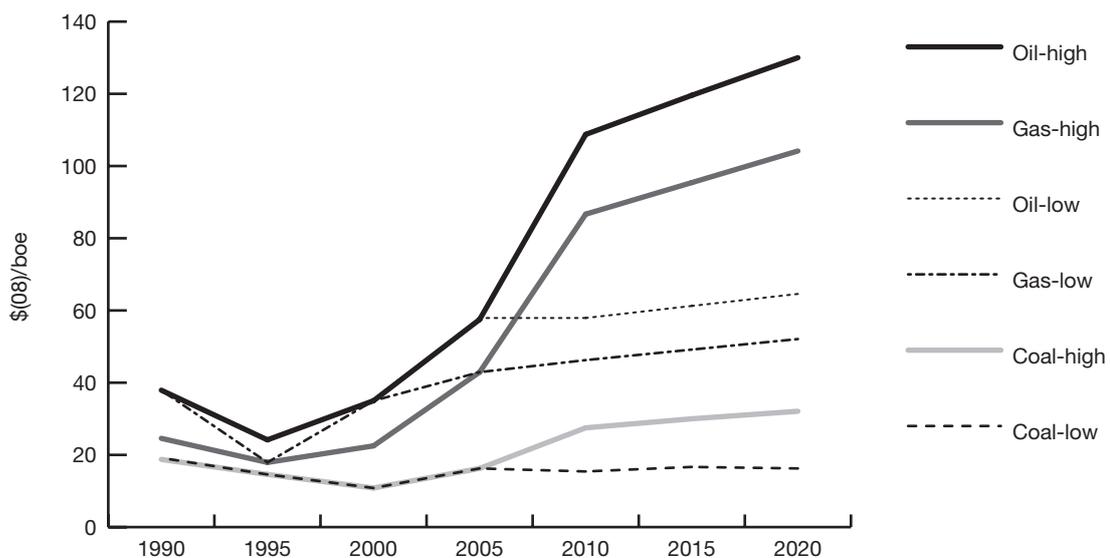
Source: European Commission, Cambridge Econometrics, GWS

The baselines and scenarios do not take account of the recession that began late in 2008. However, this does not affect the results obtained during this study because all the results are reported as differences between the baselines and scenarios (and both would have been similarly affected by the recession). However, rising unemployment associated with the recession does make more relevant the possibility of ETR stimulating greater employment.

Each of the ETR scenarios has the same key taxation components:

- a carbon tax is introduced for all non-EU ETS sectors, and is the carbon price in the EU ETS, such that an overall 20% reduction in GHGs (15% CO_2) by 2020 is delivered – extended to a 30% GHG reduction (25% CO_2) for S3H, the 'international coopera-tion' scenario
- aviation is included in the EU ETS at the end of Phase 2 in 2012
- power generation sector EU ETS allowances are 100% auctioned in Phase 3 of the EU ETS (from 2013)
- all other EU ETS allowances are 50% auctioned in 2013 increasing to 100% in 2020
- taxes on materials are introduced at 5% of total price in 2010 increasing to 15% by 2020.

In S1L, S1H and S3H environmental tax revenues are recycled through reductions in income tax rates (for households) and social security contributions (for businesses) in each of the member states, such that there is no direct change in national tax revenues. In S2H 10% of the environmental tax revenues are recycled through spending on eco-innovation measures, and the remaining 90% are recycled through the same measures as the other scenarios. The eco-innovation spending is split across three areas:

- power generation
- transport
- housing.

S3H is used to investigate the effect that international cooperation would have on com-petitiveness and resources. This scenario assumes that the rest of the world takes action towards reducing carbon emissions, such that the major non-EU countries face a carbon price equivalent to 25% of that imposed in the EU. Such international action could be expected to reduce the loss of competitiveness the EU would face if it embarked on uni-lateral action. However, in this scenario, the tax levied is greater and is designed to reduce GHG emissions by 30% in 2020 (25% CO_2), rather than 20% in the other ETR scenarios.

E3ME scenario results

This section describes the results from modelling the scenarios described above, using the E3ME model.

In all cases, comparisons are between a scenario and the relevant baseline. Therefore the effects of the low-price ETR (S1L) and the high-GHG reduction scenario (S3H) are greater, because the ETR has to be larger to reach the specified GHG reduction.

The scale of taxation

The 2020 emissions reductions targets can be met for all scenarios if there is a relatively large carbon price. In S1L this is €142/tCO$_2$ (2008 prices), equivalent to an extra 33 euro-cents per litre of petrol. With higher oil prices (S1H), the required carbon price falls to €59/tCO$_2$ (14 euro-cents per litre of petrol), but this is still markedly higher than previous ETS prices, even before the onset of the financial crisis and the subsequent global economic downturn. If there is investment in low-carbon technology (S2H), the required carbon price is lower, €53/tCO$_2$. A higher carbon price of €204/tCO$_2$ is required to meet the 30% GHG target in S3H.

The largest shift in taxation (S3H) represents a shift of 7.5% of GDP. This is much larger than any ETR that has been implemented previously in Europe, the largest of which shifted around 1.2% of GDP (see NERI, 2007). The ETR being modelled here is therefore well outside previous experience of such a policy.

Energy/environment results

*   **European and national level** – The scenarios are defined so that CO$_2$ emissions fall by 15% in 2020 compared to 1990. With the expected reduction in non-CO$_2$ greenhouse-gas emissions this translates into a 20% GHG reduction. Results for CO$_2$ emissions and employment for different EU countries are given in Chapter 3 (Tables 3.1 and 3.2), but it should be noted that these are often driven by the sectoral structure of the country, discussed next.

*   **Sectoral level** – Table 2.1 shows the sectoral reductions in CO$_2$ emissions. Power generation has the largest range of options, but many of these require long lead times so effects up to 2020 are somewhat limited. The largest reductions tend to come from the energy-intensive industries, some of which still use coal. Road transport is a sector where there are strong potential energy reductions through efficiency improvements. but existing taxes are high so the relative effects of the carbon tax are less. On the other hand, air transport has a larger reduction because fuel is currently tax-free. The sectors with the smallest reductions in energy use are households and commerce (other final use). Although gas and electricity prices both increase, these sectors have relatively low price elasticities so the reaction is not so large.

Table 2.1
Reduction in CO_2 emissions by sector, E3ME, 2020

	S1L	S1H	S2H	S3H
Power generation own use	−15.7	−7.6	−7.6	−18.2
Other energy own use	−17.3	−4.2	−3.7	−14.7
Iron and steel	−26.1	−11.6	−9.6	−29.1
Non-ferrous metals	−30.8	−17.2	−15.9	−31.4
Chemicals	−32.7	−18.4	−16.6	−37.7
Non-metallic minerals	−18.0	−6.5	−5.6	−19.1
Ore extraction (non-energy)	−26.3	−12.6	−11.7	−27.0
Food, drink and tobacco	−15.7	−7.2	−6.3	−17.1
Textiles, clothing and footwear	−20.1	−10.0	−9.0	−22.9
Paper and pulp	−34.2	−17.5	−15.5	−37.9
Engineering etc	−21.0	−11.3	−12.1	−24.0
Other industry	−23.9	−7.7	−6.3	−23.2
Rail transport	−17.9	−6.1	−5.4	−16.8
Road transport	−16.3	−5.8	−5.0	−15.9
Air transport	−19.6	−5.3	−4.3	−18.0
Other transport services	−16.6	−5.4	−5.0	−14.3
Households	−9.9	−4.8	−8.0	−12.0
Commerce (other final use)	−12.7	−5.1	−4.9	−14.0
Non-energy use	0.0	0.0	0.0	0.0
Total	**−15.6**	**−6.6**	**−6.6**	**−16.7**

Note: Results show percentage difference in scenarios from relevant baseline

- **By energy carrier** – Demand for all of the main energy carriers (fuels) falls in response to the higher carbon price (see Figure 2.2). As expected, the largest reduction is in coal, which has the highest carbon content. However, there is some time lag in the fuels used by power generation (coal and gas) as replacement plants need to be built. Effects on the other fuel types are more immediate but less over time.

- **Material consumption** – The scenarios include taxes on both biomass and mineral inputs. Direct material consumption (DMC) falls as a result. The largest fall in DMC is in construction minerals which, in weight terms, accounts for the largest share of total material consumption. In S1L, consumption of construction minerals falls by more than 5% in 2020 compared to base (see Figure 2.3); results are similar in the other scenarios. Demand for food and ores also falls by around 4% as a result of the tax, but there are smaller reductions in consumption of industrial minerals, feed and forestry production. Given the relatively small tax increase on materials in the ETR being modelled here, these results suggest that, as with energy demand and CO_2, the price mechanism would be an effective way to reduce material consumption, if the political will to do so existed.

Figure 2.2
Energy demand by carrier in S1L in E3ME (% difference from relevant baseline)
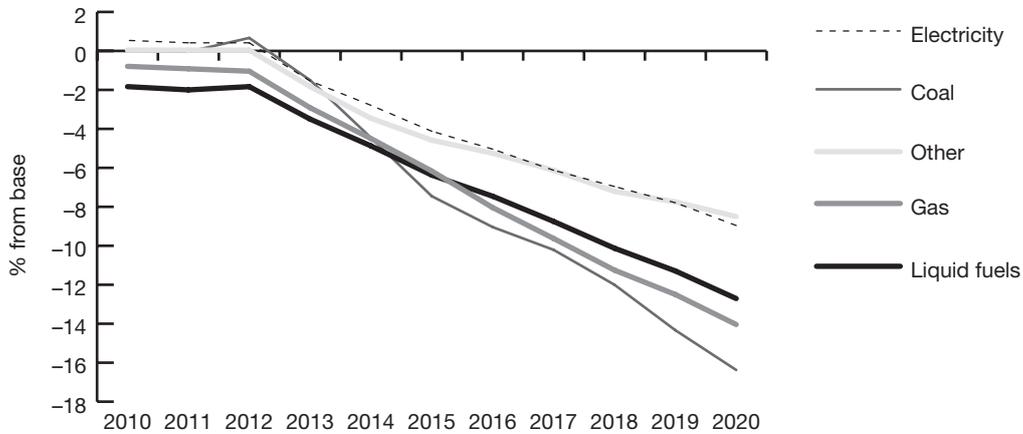
Figure 2.3
Direct material consumption (DMC) in S1L, E3ME (% difference from relevant baseline)
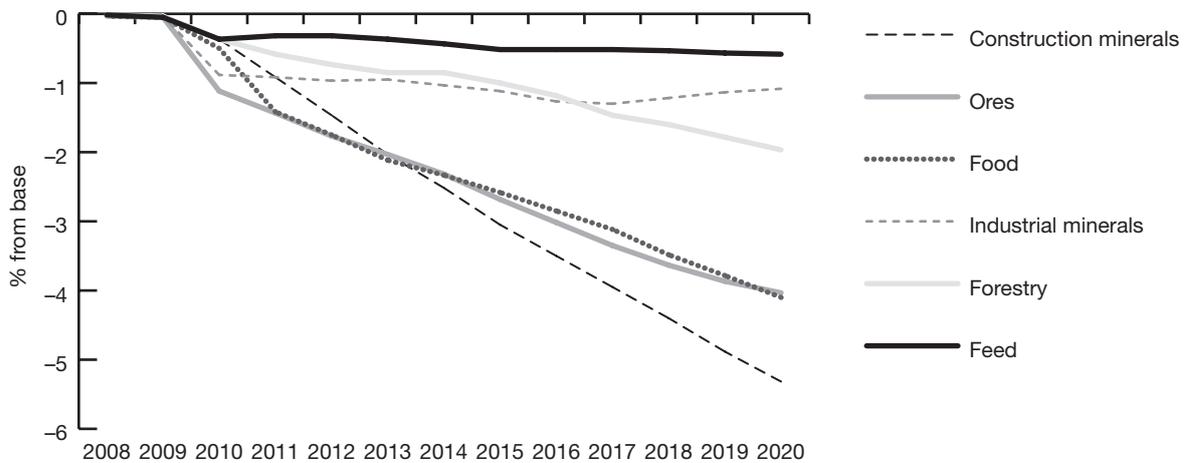
Economic results

At the European level, economic activity in these scenarios is affected by both the higher energy and material prices, and by the revenue recycling. Higher physical input costs erode real incomes and reduce domestic spending (in real terms). These costs also have the potential to reduce international price competitiveness. The revenue recycling (through lower income and employers' taxes) increases employment and real income. The model results show that the effects of the revenue recycling are greater than those of the higher energy costs and there are increases in both GDP and employment when compared to the baseline. This is shown in Figures 2.4 and 2.5. In Figure 2.5 the extra 2.7% employment shown by 2020 in scenario S3H amounts to an extra 6 million jobs across the EU.

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Figure 2.4
GDP in the ETR scenarios, E3ME (% difference from relevant baseline)
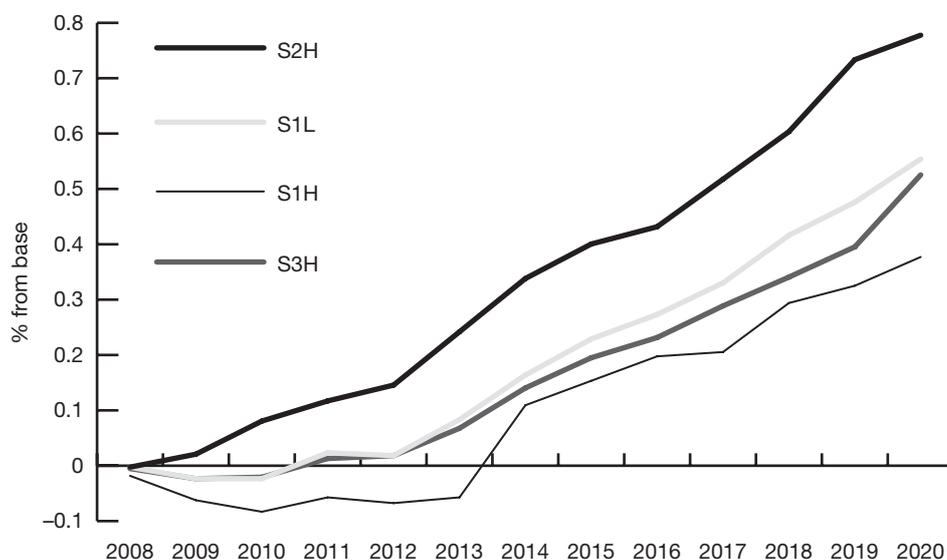
Figure 2.5
Employment in the ETR scenarios, E3ME (% difference from relevant baseline)
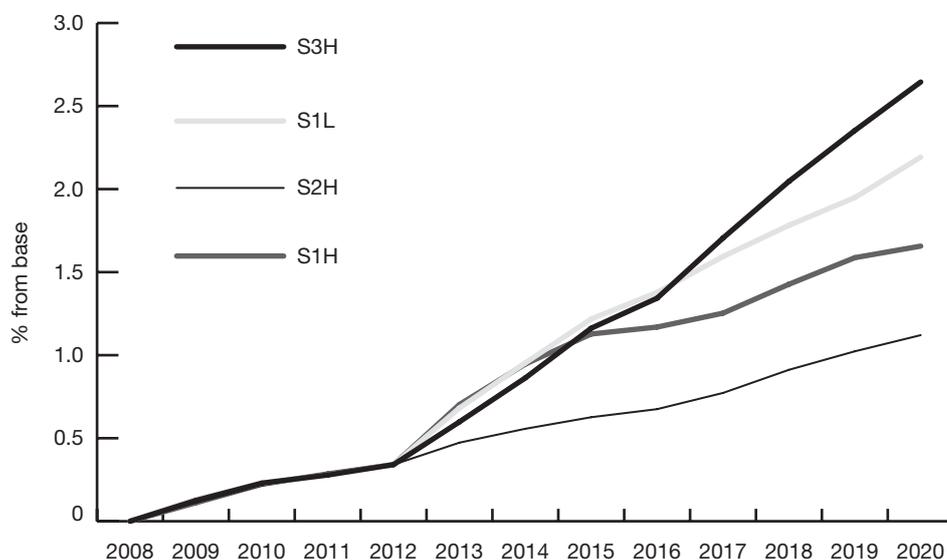
At the sectoral level, most, but not all, sectors benefit from the ETR. The sectors that lose out are primarily those that supply energy or material inputs – namely agriculture, mining, non-metallic mineral products, basic metals, electricity supply and gas supply. Some of the energy-intensive sectors, including air transport, also see declines in output. The sectors that benefit the most are the labour-intensive service sectors that are not intensive in their use of energy and material inputs. Sectors that rely on demand from households, such as retail, also benefit from lower income taxes (which are reduced for households

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through the recycling of environmental tax revenues). When a proportion of the revenues from the auctioned allowances, carbon taxes and energy taxes are used to finance low-carbon investment, the sectors that produce investment goods also benefit. The motor vehicles sector is an obvious example, but suppliers (e.g. electronics, metal goods, rubber and plastics) also see higher demand for their products.

GINFORS results

To give a broader picture of the modelling results, analysis of GINFORS results is focused on the high energy price scenarios, with the main assumptions and results of the simulation runs in GINFORS grouped together in Table 2.2.

In the baseline scenario with high energy prices BH, EU-27 carbon emissions in 2020 will be 7.2% below the 1990 level. (For reference, in the Kyoto protocol the EU-15 countries agreed to reduce their total GHG emissions to 8% below 1990 levels in the period 2008–2012.)

Table 2.2
Main results from the different scenarios, GINFORS

| | | CO_2 price | GDP | | Employment | CO_2 reduction | |
| | Target in 2020 | Euro2008/t | % change from baseline | | % change from baseline | % change from 1990 | % change from baseline |
Scenario	in year	2020	2015	2020	2020	2020	2020
BH		18				−7.2	0.0
S1H	20% GHG	68	−0.2	−0.6	0.36	−15.1	−8.4
S2H	20% GHG	61	−0.1	−0.3	0.41	−15.2	−8.5
S3H	30% GHG	184	−1.2	−1.9	0.77	−25.0	−19.1
BL		18				2.8	10.9
S1L	20% GHG	120	−1.2	−3.0	0.02	−14.9	−17.2

In scenario S1H, the ETS price and carbon tax rate will have to increase to €68/tCO$_2$ to reach the 20% GHG reduction target, which is equal to a 15% reduction of CO$_2$ emissions against 1990 as other greenhouse gases have already been reduced above average. Compared to the baseline BH, CO$_2$ emissions are 8.4% lower in 2020, which means an additional annual reduction of 1% in the period 2012 to 2020. GDP will be about 0.6% lower compared to the baseline in 2020. This means that annual average growth rates will be less than 0.1% lower than in BH. As the recycling mechanism for businesses reduces labour costs (by reducing social security payments) and the tax burden is shifted from labour-intensive to carbon-intensive sectors, employment will be 0.36% (or more than 800,000 jobs) higher than in the scenario BH.

Scenario S2H shows that a policy mix that includes investing part of the revenues in low-carbon technologies could decrease the negative impacts on production and create additional jobs – the carbon price is lower (€61/tCO$_2$ in 2020) and GDP loss is halved compared to scenario S1H to only 0.3%. This is because the investment in low-carbon technologies is assumed to be additional to the endogenously calculated investment. Employment impacts will be more positive than in scenario S1H. The 10% investment in low-carbon technologies will amount to more than €20 billion in 2020. It is worth noting that the Obama administration in the US currently plans to invest US$15 billion per year in that area in the next four years.

Figure 2.6 shows the GDP impacts of GHG emission reductions in the EU in relation to high and low energy prices.

The comparison of scenarios S1L and S1H with their respective baseline demonstrates the importance of international energy prices for fixed volume targets. In a world of low energy prices it will require stronger policy to reach the EU GHG target. The macroeconomic costs of reaching emission reductions strongly depend on the future level of international energy prices. For instance, the GDP loss in scenario S1L against the baseline BL with low energy prices will be 3% (and the carbon price reaches €120/tCO$_2$ in 2020), considerably greater than the GDP loss with higher energy prices (S1H compared to BH).

The impact of high energy prices on GDP (BH against BL) is about as high as the impact of GHG emissions reduction in scenario S1L against scenario BL in 2020. In the case of high energy prices, the impact of GHG emission reduction is much lower (scenario S1H against BH) because the required carbon price is lower.

However, by comparing S1L with S1H in Figure 2.6, it can be seen that achieving the emission reduction in 2020 results in a higher GDP with low energy prices (S1L) than when prices are high (S1H). This is because, with ETR, the revenues from the higher energy prices stay in the countries concerned and permit compensating reductions in other taxes, whereas with international energy price rises the extra payments for energy go to energy-producing countries.

To give an idea of the scale of the environmental tax reforms, in scenario S1H total revenues amount to around 2.2% of GDP of EU-27 in 2020, with the following breakdown: ETS revenues (0.65%), material tax revenues (0.56%), and carbon tax revenues (0.6% business, 0.4% households). For comparison, it may be noted that the German ETR from 1999 to 2003 raised an additional €17 billion, which was about 0.75% of German GDP at that time.

It is interesting to compare these modelling results with other simulations of European carbon emissions reduction. For example, the EU assessment of the macroeconomic impact of reaching the targets set for 2020 is reported at 0.58% of EU GDP in 2020 in a 'cost-efficient scenario' calculated with the CGE model GEM-E3 (EC 2008, p.22). A carbon price of €39/tCO$_2$ (in prices of 2005) and an additional renewable energy incentive of 4.5 cent/kWh would be needed in a scenario of low energy prices. Employment impacts

Figure 2.6
GDP of EU-27 in different scenarios, GINFORS
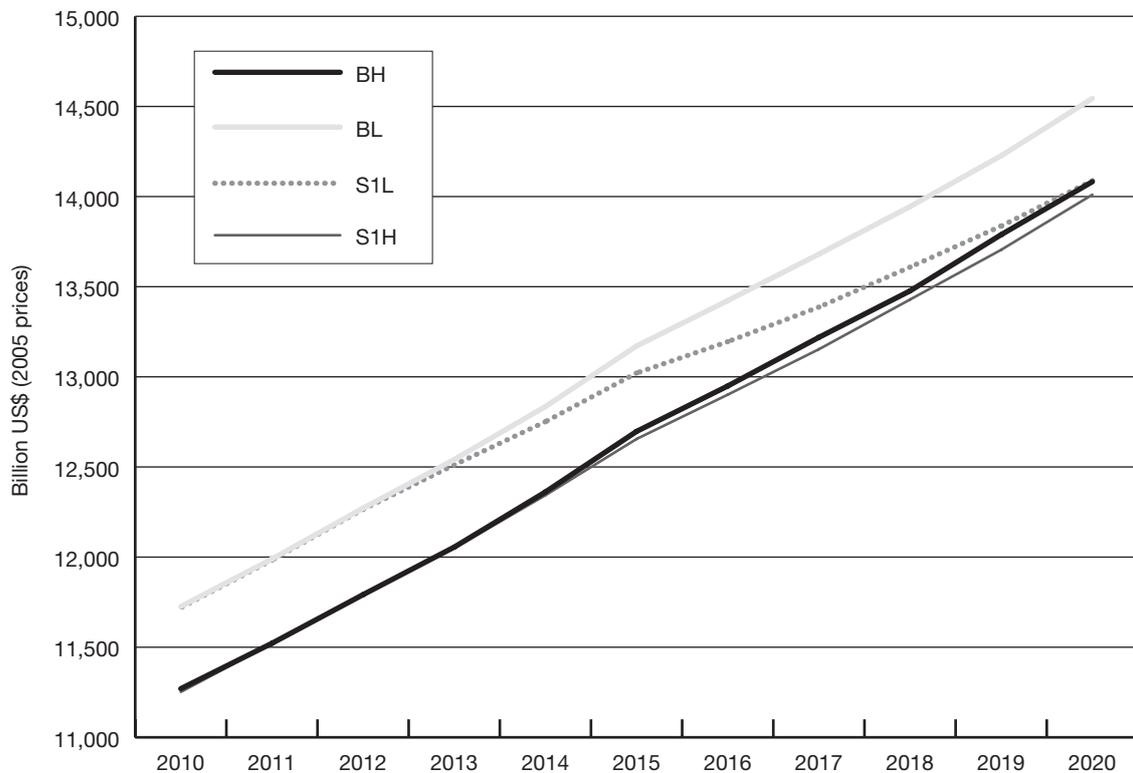
are slightly negative. These results can best be compared to scenario S1L with a carbon price of €120/tCO$_2$. Due to higher carbon prices, the GINFORS simulations conducted for this study show higher GDP losses (3%) than the GEM-E3 model used in the EU's impact assessment. One reason is that an optimised policy scenario with a mix of policies is assumed in the EU's impact assessment, illustrating the importance of using other policies to complement a carbon tax.

If, following an international agreement, the EU-27 wants to reach its 30% reduction target (i.e. a 25% carbon reduction) using domestic measures only, this could be done – the carbon price in scenario S3H will reach €184/tCO$_2$ in 2020 in the EU-27 and €46/tCO$_2$ in the major emerging economies. Again, for comparison, the IEA (2008) reports a global price of carbon of US$180 in 2030 to reach the 450 parts per million (ppm) stabilisation for GHGs, which is reachable with scenario S3H. With S3H, GDP reduction in the EU-27 against the baseline would be 1.9% in 2020, partly due to lower international trade and production in other parts of the world (see Table 2.2). Employment will be 0.77% higher than in the baseline, which amounts to about 1.7 million extra jobs across the EU.

EU energy, carbon and material productivity will improve in all scenarios compared with the baselines. Labour productivity will decrease mainly due to the structural shift from energy and carbon intensive to labour-intensive industries (see Table 2.3).

Table 2.3
EU-27 productivity: percentage deviations against respective baselines in 2020, GINFORS

Scenario	Material Productivity	Energy Productivity	Labour Productivity	Carbon Productivity
S1H	0.91	6.04	−0.93	8.59
S2H	0.84	7.15	−0.71	8.99
S3H	1.78	15.48	−2.61	21.35
S1L	1.97	12.21	−3.02	17.17

Comparison of E3ME and GINFORS modelling results

Comparing the central outcomes obtained from the models helps to identify the key issues and uncertainties that are likely to be important in any implementation of ETR.

Table 2.4 gives the simulation results of both E3ME and GINFORS for scenarios S1L, S1H, S2H and S3H. Both models calculate very similar effects for the CO_2 price and labour productivity, but there are systematic differences in the GDP and employment impacts: E3ME calculates positive and GINFORS negative GDP effects, which increase with carbon prices.

Comparing the results for S1L with those for S1H, using GINFORS, the higher CO_2 price is connected with a stronger negative effect on GDP, whereas using E3ME with a higher CO_2 price brings a more positive effect on GDP. These differences can be explained by the different model structures:

•   E3ME assumes that higher energy prices have partly positive effects on exports via investment. In GINFORS, a unilateral rise of energy prices in the EU reduces its shares in international trade, which diminishes EU exports and GDP.

•   Labour supply is assumed to be more restricted in GINFORS. The price-wage mechanism in GINFORS may work more towards higher wages and prices, which limits job creation through international competition, whereas in E3ME higher wages create more income and demand, which is produced by additional employees. Even so, for EU-27 as a whole employment increases by more than 800,000 in S1H when using GINFORS compared to the corresponding baseline, and by around 1.7 million in S3H.

Comparing S2H with S1H for both models shows the same basic effect: the tax revenue in S2H is now partly used for pushing investment in renewable energy and energy efficiency. Under these conditions, both models calculate a lower CO_2 price to meet the targets in S2H than is needed in S1H, and there is a positive effect on GDP (moving from S1H to S2H) in both models.

Table 2.4
Simulation results for central macroeconomic variables of E3ME and GINFORS for EU27 in 2020 (percentage deviations from the respective baselines)

Scenario	CO$_2$ price Euro2008/t	GDP % change from baseline	Employment % change from baseline	Labour productivity % change from baseline
S1L				
E3ME	142	0.6	2.2	−1.6
GINFORS	120	−3.0	0.0	−3.0
S1H				
E3ME	59	0.2	1.1	−0.9
GINFORS	68	−0.6	0.4	−1.0
S2H				
E3ME	53	0.8	1.1	−0.3
GINFORS	61	−0.3	0.4	−0.7
S3H				
E3ME	204	0.5	2.7	−2.1
GINFORS	184	−1.9	0.8	−2.6

In scenario S3H (international cooperation), both models calculate a higher CO$_2$ price, because the reduction target is now 30% instead of 20% in S1H. The effects on EU trade shares are much lower than in the unilateral scenario S1H, but in S3H there are negative effects on the GDP of other countries (see Chapter 3), which reduces their imports and thus EU exports and GDP. This explains why GINFORS calculates far higher GDP reductions under the S3H conditions than for S1H (−1.9% as against −0.6%). With E3ME, the higher CO$_2$ price in S3H induces more investment and GDP than in S1H, but this is compensated by the reductions in EU exports, so that the difference is relatively small (GDP is up 0.5% in S3H compared to 0.2% in S1H).

Both models arrive at the result that the GHG reduction targets of scenarios S1H and S2H can be reached with only small influences on GDP: E3ME calculates a slightly positive, GINFORS a slightly negative effect. The deviations from the relevant baseline are less than half of the average growth of one year. Over a period of 10 years the average growth rate will be affected by less than 0.1, which is in the range of 'white noise'.

In S1H the tax revenues are used to reduce social security payments, which reduces labour costs. Both models estimate a plausible reduction of labour productivity against the baseline. For E3ME the result is −0.9, for GINFORS −1.0, which is nearly identical. In S2H, only 90% of the tax revenue is recycled in social security. Both models react with an increase of labour productivity (E3ME from −0.9 to −0.3; GINFORS from −1.0 to −0.7). So the differences in the results for employment are not driven by labour productivity, but mainly by GDP.

In summary, with respect to GDP effects, it can be argued that E3ME has the more optimistic, GINFORS the more pessimistic structure. Since both models are estimated from past data, the modelling results may be taken as the range within which the 'true' effects on GDP are likely to lie. The range is relatively small.

Both models produce nearly identical results concerning labour and resource productivity, so both models give the same message:

• an environmental tax reform that meets the 20% GHG emissions reduction target will raise employment, lower resource consumption and will have only small effects on GDP.

Since both the specification of the models and their parameterisation are based on empirical estimations, this result is quite robust.

3   ETR in Europe: Implications for Different EU Member States

EU countries are very different, so environmental tax reforms may be expected to have different impacts on different countries. There are particular differences between the older member states and those that have joined since 2000. In addition, while there is some experience of ETRs in the older member states, there is little or none in new member states. It is unlikely that ETR will be equally appropriate to all member states, or that all of them would implement ETR in the same way.

The country results for the scenarios described in Chapter 2 confirm that different EU member states will experience different economic and environmental impacts as a result of ETR, in terms of both aggregate effects on output, employment and carbon emissions and the percentage energy price rises which ETR will induce.

ETR causes price increases and tax reductions across the economy, so it will inevitably create winners and losers. These factors, and the different histories of environmental policy-making in different countries, together with their different institutional structures and cultures of governance, mean that strategies to introduce ETR will need to be informed by a deep understanding of the prevailing political economy as well as economic arguments.

The two models described in Chapter 2 produced a rich variety of results for the various EU member states, which can only very briefly be reported on here. This chapter drills down into the detail of the data generated by the modelling to investigate the likely outcomes for individual EU member states in terms of CO_2 emissions, GDP and employment, and end-user energy prices. It also considers the implications of revenue-recycling policies (i.e. raising environmental taxes and correspondingly lowering taxes on, for instance, income or employment) and the political implications of ETR.

Impacts of ETR on CO_2 emissions

In general, country-level results strongly depend on country-level specifics including: energy use; fuel mix and ease of fuel switching; economic structure and sectoral composition of energy demand; and different social systems and behaviour such as reactions to labour cost changes.

Table 3.1 shows how the level of CO_2 emissions in each country is affected in the scenarios in the E3ME model. It shows that energy-related carbon emissions are reduced in all EU countries against the baseline. In countries with high carbon intensity, revenues and

expenditures of emissions trading schemes and ETRs are higher than in countries with lower carbon intensity. In particular, countries that are able to close coal power stations (or not build new ones) over the forecast period have options for large-scale decarbonisation, if the price signal is strong enough. Denmark is one example of this.

High energy intensity and low energy prices, as exist in some new member states, may also predispose to relatively large emission reductions.

Table 3.1
Reduction in CO$_2$ emissions by country, 2020, E3ME

	S1L	S1H	S2H	S3H		S1L	S1H	S2H	S3H
Belgium	−12.6	−5.0	−4.9	−15.3	UK	−15.5	−4.8	−5.4	−12.6
Denmark	−24.2	−4.3	−5.8	−12.3	Czech Republic	−22.0	−11.7	−11.7	−27.6
Germany	−15.7	−5.0	−5.3	−15.8	Estonia	−8.0	−1.4	−1.3	−3.7
Greece	−17.2	−6.6	−6.0	−16.4	Cyprus	−9.0	−3.5	−3.7	−8.3
Spain	−13.4	−4.9	−3.8	−12.9	Latvia	−10.1	−4.4	−4.1	−10.4
France	−15.7	−6.3	−7.6	−17.2	Lithuania	−10.7	−5.2	−5.0	−11.2
Ireland	−11.8	−4.2	−3.7	−17.2	Hungary	−17.3	−7.0	−5.1	−14.5
Italy	−9.8	−10.8	−11.1	−15.8	Malta	−13.0	−4.9	−4.6	−10.6
Luxembourg	−20.2	−6.8	−7.5	−17.6	Poland	−22.2	−8.1	−7.4	−21.0
Netherlands	−14.0	−5.8	−5.0	−15.3	Slovenia	−13.7	−5.4	−4.7	−13.3
Austria	−10.9	−3.1	−2.7	−8.1	Slovakia	−14.1	−6.3	−4.1	−15.3
Portugal	−17.7	−9.4	−8.4	−22.8	Bulgaria	−24.7	−5.9	−5.2	−26.2
Finland	−9.7	−4.3	−4.2	−14.2	Romania	−22.8	−10.2	−8.8	−31.7
Sweden	−21.3	−8.8	−7.8	−23.3	**EU27**	**−15.6**	**−6.6**	**−6.6**	**−16.7**

Note: Results show percentage difference in scenarios from relevant baseline

Impacts of ETR on GDP and employment

Table 3.2 shows the output (GDP) and employment results of scenario S1L from E3ME by country (patterns are similar in other scenarios).

All countries see an increase in employment, though this varies by country, and the great majority also see an increase in output. In some countries, the negative effects of the higher energy costs outweigh the benefits of the revenue recycling. Exports fall in many countries. This means that countries which rely on exports, particularly through price-sensitive industries, tend to lose out more; Spain is an example. Another possible reason for countries not seeing an increase in output is if the lower employers' taxes do not lead to significant additional employment. This tends to happen in countries with more highly regulated labour markets (for example Sweden, in these results).

Table 3.2
GDP and employment results by country, 2020, scenario S1L, E3ME

	GDP	Employment		GDP	Employment
Belgium	1.8	1.9	UK	0.4	0.7
Denmark	1.4	2.6	Czech Republic	0.9	4.2
Germany	0.3	2.6	Estonia	1.1	3.6
Greece	1.1	1.6	Cyprus	0.0	0.5
Spain	−0.9	1.1	Latvia	0.0	1.3
France	0.9	1.2	Lithuania	1.0	2.1
Ireland	0.7	0.5	Hungary	−0.2	1.6
Italy	0.1	4.4	Malta	0.1	1.8
Luxembourg	0.5	1.3	Poland	2.3	3.1
Netherlands	1.6	1.9	Slovenia	0.3	1.7
Austria	1.7	2.0	Slovakia	2.7	4.8
Portugal	1.8	1.3	Bulgaria	0.2	2.4
Finland	0.4	3.4	Romania	0.9	6.0
Sweden	−0.3	0.5	**EU27**	**0.6**	**2.2**

Source: E3ME
Note: Results show percentage difference in S1L from baseline BL.

In contrast, using the GINFORS model, with its rather more pessimistic structure (see Chapter 2), the GDP impacts of scenario S1H are between +1% and −2% of GDP in 2020 for different EU member states, with most showing a GDP reduction as a result of the ETR. However, the employment impacts of scenario S1H in GINFORS are positive for almost all EU countries, because lower labour costs increase labour demand and labour intensity. The highest absolute increases occur in Germany, the Netherlands, Italy and the UK.

Impacts of ETR on end-user energy prices

The level of carbon tax used for the modelling exercises was designed to deliver the specified carbon reduction targets. The tax will increase the price of carbon-based energy to final consumers. This raises the question of how large this increase might be for different member states. This increase has been calculated for a few cases, using a carbon price of €68/tCO_2 (as calculated by GINFORS in scenario S1H, see Table 2.4). In the calculations that follow it should be remembered that the price increases are for 2020, which is when the carbon price reaches its level of €68/tCO_2.

Transport fuels are already relatively highly taxed, so they are faced with the lowest percentage increase in end-user prices as a result of the ETR. The additional CO_2 tax caused by a carbon price of €68/tCO_2 would add around €0.158 per litre (excluding VAT) to the end-user price of unleaded petrol. Given that end-user prices for unleaded petrol in early

2008 in Germany and the UK were €1.35 per litre and €1.40 per litre respectively, the tax would therefore increase the end-user prices by around 11 percent (including VAT) in both Germany and the UK. The percentage increase in the end-user prices in the new EU member states would tend to be higher because their current (2008) energy taxes and prices are generally lower.

The percentage increases in the end-user prices for diesel are higher because the additional CO_2 tax would amount to about €0.180 per litre and the end-user prices at the pump, except in the UK, are lower than the unleaded petrol prices.

The situation is different for other energy products, in particular for natural gas and electricity. A tax of €68/tCO_2 levied on natural gas would be about €13.7 per MWh (€3.8 per GJ). The inclusion of this carbon tax would increase the early-2008 pre-tax household end-user price by about 25% in Germany and 28% in the UK. The increases in the end-user prices in the new EU member states would be even higher, amounting to more than 34% in Hungary and to around 31% in the Czech Republic.

The carbon price effect on end-user prices for electricity depends on the energy mix of the electricity industry, which is different for each EU member state. Utilities in those countries that generate electricity using nuclear power or renewable energy (e.g. Sweden, France) have a rather low carbon emission coefficient compared to those countries that rely heavily on coal or gas power plants (e.g. Germany, UK). These differences mean that the increases caused by a carbon price of €68/tCO_2 range from €3.0 per MWh (Sweden) to €27.5 per MWh (Germany) and €33 per MWh (UK). Households in Germany and the UK would therefore face an increase in the electricity prices of about 17% (Germany) and 19% (UK), compared with the price in early 2008.

Again, relative increases would be much higher in many of the new EU member states, for example amounting to 29% in the Czech Republic. The relative increases in industry end-user prices would be even higher because industries face a lower price of energy compared to households in all EU member states.

ETR and revenue recycling: the scope of tax reductions

The core principle of ETR is that environmental tax increases are offset by reductions in other taxes, in this case the reduction of income taxes and social security contributions (SSC) paid by employers. The tax reductions are known as 'revenue recycling'.

In scenario S1H, as modelled by GINFORS, the revenues from increases in environmental taxes amount to around 2.9% of German GDP in 2020. For comparison, the revenues from all taxes levied on energy products amounted to around 2% of GDP in 2005.

Table 3.3 shows the broad scale of the tax reductions that the increase in environmental tax revenues would allow. Columns 2 and 3 show the ratios of different taxes to GDP in

Germany and the UK in 2005 without ETR, and columns 4 and 5 show these ratios with ETR, with the ratio of total tax to GDP kept constant (38.8% for Germany and 37% for the UK).

Table 3.3
Implications of the ETR on the taxation structure in Germany and the UK

	Germany (2020 based on the 2005 tax structure)	UK (2020 based on the 2005 tax structure)	Germany (2020 based on 2005 tax structure plus ETR)	UK (2020 based on 2005 tax structure plus ETR)
	% of GDP	% of GDP	% of GDP	% of GDP
Total tax including SSC	38.8	37	38.8	37
Personal income tax	8.60	10.52	8.23	10.06
SSC – paid by employers	7.0	3.9	5.1	2.4
SSC – total	16.3	6.9	14.4	5.5
Environmental tax	2.5	2.5	4.8	4.5

Source: Eurostat, Taxation trends in the European Union, Data for the EU Member States and Norway – 2008 edition and own calculation based on results of scenario S1H (GINFORS model).
NB: these projections do not take into account any effects of the 2008 recession.

The table shows that, for scenario S1H, the recycling of the ETR revenues reduces SSC paid by employers by 27% (from 7.0% to 5.1% of GDP) in Germany and by 38% (from 3.9% to 2.4% of GDP) in the UK, while personal income tax in the two countries will fall by 4.3% and 4.4% respectively.

It would be possible to structure this income tax reduction, for example through tax credits or negative income tax payments, so that vulnerable households were not disproportionately affected by the energy price rises. However, this would depend on different countries' tax-benefit systems, and is not further explored here.

The political economy of ETR

Introducing environmental tax reforms will inevitably lead to winners and losers among different economic sectors and different households. There has been extensive research into the political economy of ETR (see, for example, OECD 2006a), which cannot be reviewed in any detail here. Two issues that always emerge as important in such research are: competitiveness effects and the distributional effects on households of energy price rises. The former points to the desirability of implementing ETR across a broad group of countries (i.e. across the EU). The latter requires analysis related to household conditions and tax-benefit arrangements in the country concerned to show how the effects of ETR on vulnerable households can be mitigated.

More generally, it is clear that the design of ETR in each country would need to consider and take account of a wide range of country-specific political, economic and social issues.

Many such issues were shown to be important in the case study of environmental tax reform for the Czech Republic (Šauer et al. 2008), which was carried out as part of this project.

In brief, the case study found that awareness of the concept in the Czech Republic is low, and it is not easily understood. Other factors that have militated against the introduction of ETR in this country include:

• historical experience with environmental charges and support for the further environmental protection that they could generate
• fear from the Ministry of the Environment that it would lose a source of revenue
• distrust that the revenues from environmental taxes would be recycled
• a preference by businesses for regulation that did not charge them for residual emissions.

The Czech case study demonstrates that modelling results can be insufficient in themselves to persuade policymakers to introduce ETR, no matter how convincing the data may appear. The obstacles to such introduction may be broader. In such circumstances it seems likely that, in addition to economic arguments, a successful strategy for ETR will need to draw on a deeper analysis of the political economy of the situation – an analysis that allows these obstacles to be identified and overcome.

4   ETR in Europe: Global Implications

The EU is a relatively open economy, in terms of its trade with other world regions. It is also heavily dependent on other world regions for imports of the majority of its energy resources and large amounts of raw materials. The Organisation for Economic Co-operation and Development (OECD) – and the EU within it – has far higher per capita resource consumption than less developed world regions, and the EU has higher net imports of resources, and also imports a greater proportion of its resources, than any other world region (including the United States). However, the EU produced less than 20% of global CO_2 emissions in 2005, and accounted for less than 10% of global used material extraction. Both shares are expected to fall in coming years due to strong growth in emerging economies. The EU therefore has potentially serious problems of resource security, with a high import dependency, and faces increasing competition for resources. The highest dependence is on fossil fuels and metal ores, of which only few reserves are left in Europe.

While the overall level of resource use in Europe has stabilised over the past 20 years, the source of these resources has shifted abroad. This shift from domestic material extraction to physical imports through international trade has also shifted part of Europe's environmental burden abroad. Recognising the impacts that the production and consumption activities within the EU have on other world regions, the European Commission has called for a more sustainable management of natural resources along with a de-coupling of resource consumption and environmental degradation from economic growth in Europe, in order to diminish the environmental impact the EU has on the rest of the world and thus to contribute to global sustainable development.

The EU has adopted a number of policy measures to address resource security, resource productivity and related environmental concerns. Among these are the Raw Materials Initiative (2008), the Sustainable Consumption and Production Action Plan (2008), the trade strategy Global Europe (2006), and the Thematic Strategy on the Sustainable Use of Natural Resources (2005).

Given current patterns of trade and resource flows, it is likely that European environmental tax reform measures will not only have economic and environmental effects in Europe but also in the countries it trades with. Estimating these effects is important in order to analyse the effects of environmental policies aimed at reducing the overall resource use in industrialised countries on the opportunities for economic growth in developing countries.

In order to investigate the global implications if the EU were to adopt substantial ETR, the research team developed the Global Resource Accounting Model (GRAM) – a multi-regional input-output material flow model (described on pages 62–66). GRAM is the first model to depict global resource use and material flows for different world regions.

This chapter reports on results obtained from simulations using both the GRAM and the GINFORS model. The results show that although the economic impacts on the rest of the world of a major ETR in Europe (in a cooperative global context) are small, the environmental benefits could be significant.

World-wide patterns of extraction and flows of materials: results from GRAM

This section discusses the results of simulations based on the GRAM. All data presented below refer to the year 2000 because, at the time of the construction of the GRAM, this was the most recent base year for which data on economic structures (in the form of input-output tables) were available for a large number of countries (OECD, 2006b).

The results are for:

• material extraction and consumption of world regions
• physical trade balances of countries
• resource dependency of world regions.

Note that the group of Anchor countries comprises the emerging economies of Argentina, Brazil, China, India, Indonesia, Philippines, Russia, South Africa, and Thailand; the 'rest of the world' (RoW) group consists of aggregated data for all countries of the world, excluding the EU-25, Bulgaria, Romania, OPEC, non-EU OECD countries, and the Anchor countries.

Material extraction and consumption of world regions

Figure 4.1 presents the indicators of domestic material extraction (DE) and raw material consumption (RMC), in billion tonnes and tonnes per capita, in four different world regions.

The model calculations show that in absolute terms domestic extraction (DE) of resources is highest in the group of Anchor countries (17.6 billion tonnes), followed by non-EU OECD countries (14.8 billion tonnes), whereas RMC is slightly higher in the non-EU OECD countries than in the Anchor countries (16.1 billion tonnes compared to 15.8 billion).

A considerable share of resources extracted in Anchor countries (1.8 billion tonnes) thus flows directly or indirectly (i.e. embodied in traded products) to other world regions through international trade. Similarly, the 'Rest of the World' (RoW) region is a net exporter of natural resources (resource extraction is 1.4 billion tonnes higher than resource consumption). The EU-25, in contrast, consumes more resources than it extracts, but its DE (6.1 billion tonnes) and RMC (7.4 billion tonnes) are significantly lower in absolute numbers compared to other world regions.

Figure 4.1
Domestic material extraction (DE) and raw material consumption (RMC) in different world regions (total, per capita) in 2000, GRAM
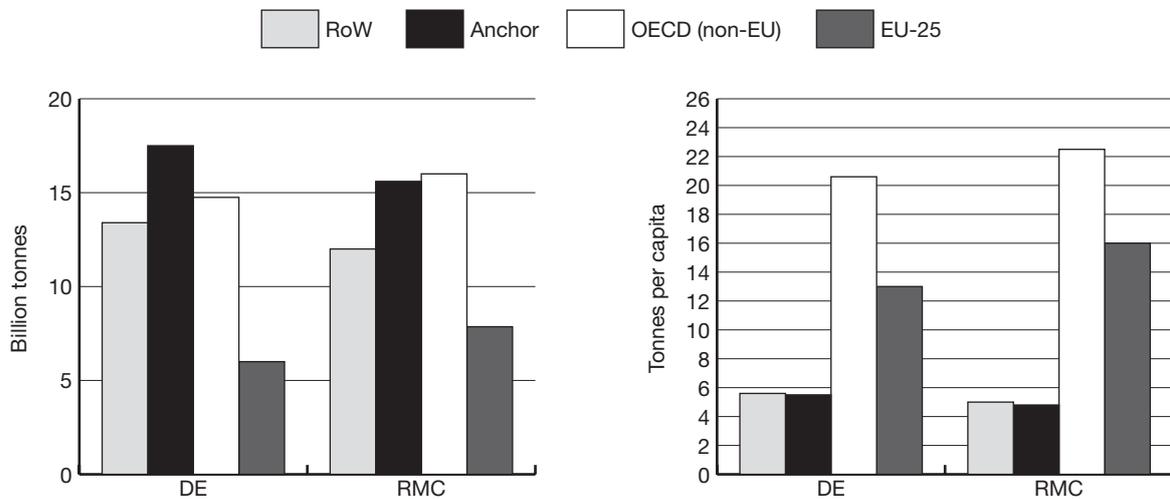
Notes: We could not include Bulgaria and Romania in the EU-27, as these countries are not explicitly reported in the OECD dataset used to construct GRAM.

The picture changes considerably when turning to a per capita perspective. Domestic extraction per capita in the EU-25 countries (13.3 tonnes) and in the non-EU OECD countries (20.8 tonnes) is significantly higher than in other world regions. Per capita consumption of raw materials is even higher (16.1 tonnes for the EU-25 and 22.6 tonnes for the non-EU OECD).

These figures thus confirm that industrialised countries use more resources in the production of products for final consumption than they extract. The Anchor countries, which count almost 3.2 billion inhabitants, lead in terms of total resource extraction but fall far behind all other regions in terms of per capita values, followed by the RoW where per capita consumption (5.0 tonnes) was again lower than the already low level of extraction per person (5.6 tonnes).

Physical trade balances of countries

Figure 4.2 illustrates a ranking of the importers and exporters of direct and indirect (embodied) material resources in the world economy.

According to the model calculations, the EU-25 region leads the ranking of net importers (1.3 billion tonnes), followed by the US and Japan. At the other end of the spectrum, the largest net exporters are the group of OPEC countries, followed by Russia and the region Rest of the World.

Figure 4.2
Physical trade balance (PTB) of different countries in 2000, GRAM
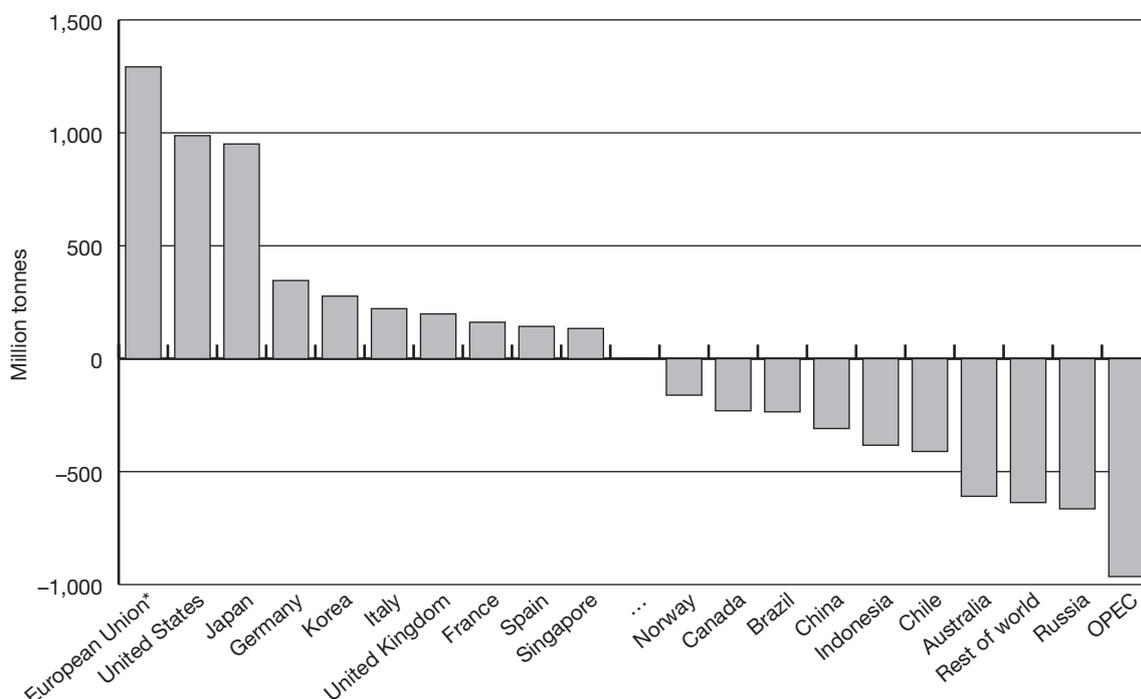
* For illustrative purposes the region EU-25 (European Union*) is included in this country ranking

The data refers to the year 2000, so it can be expected that shifts have taken place since then, especially for China. According to the World Bank's World Development Indicators database (World Bank 2009), China doubled its GDP (in PPP) between 2000 and 2006 (where PPP is 'purchasing power parity' – a method of adjusting GDP to reflect the purchasing power of money in different countries). It is likely that China changed from a net-resource exporter in 2000 to a net importer in 2008, given its huge increase in natural resource demand.

Resource dependency of world regions

Linking net-trade flows to domestic extraction in the GRAM shows to what extent different world regions are outsourcing material and energy-intensive production processes abroad.

For example, the EU-25 has a ratio of 'resource dependency' (i.e. the physical trade balance (PTB) divided by domestically extracted materials) of 21.5% – higher than any other region.

This means that the EU-25 is the world region that out-sources the highest proportion of resource extraction required to produce goods for final demand (private and public consumption and investment). Furthermore, the highest differences between domestic extraction and consumption are within the material category 'metal ores', where

net imports exceed domestic extraction by 197%. The non-EU OECD countries are also dependent on raw material imports, but to a smaller extent (9% ratio of resource dependency) than the EU.

Global impacts of ETR scenario simulations: results from GINFORS

Results for the baseline scenario BH

In the baseline scenario with high energy prices (BH), population development, economic growth, energy consumption and emission development are based on national and international projections.

Simulations using the GINFORS model yield the following results.

Annual average GDP growth in the EU-27 is expected to fluctuate between 2.2% and 2.5% until 2020. With population growth and fast industrialisation, average annual GDP growth rates in the Anchor countries are expected to be between two and three times higher than in the EU and non-EU OECD countries.

This trend leads to a shift of global economic power from the traditional industrialised countries.

In 2000 the EU and OECD countries together accounted for almost 62% of world GDP (in terms of PPP; purchasing power parity), but this share is expected to shrink to around 46% in 2020. Emerging and developing countries together will produce around 54% of global GDP. Increasing international trade and deeper integration of different world regions result in a continuous growth of total exports and imports in monetary terms across all regions from 2000 to 2020. Exports grow fastest for the group of emerging Anchor countries, while from 2010 to 2020 the growth of imports to these countries can be expected to be twice as high as that in the EU-27.

These economic developments drive material extraction of different resource categories, CO_2 emissions and other environmental indicators around the world. Figure 4.3 shows the energy-related CO_2 emissions in the BH scenario.

Under the BH scenario conditions, the expected future emissions of the EU remain almost constant, while those of the other three country groups will grow continuously until 2030. The most notable increase will happen in the emerging countries, especially in China.

At the global level, these figures are in line with the Reference Scenario of the 2008 World Energy Outlook (IEA, 2008) – three quarters of the increase in global CO_2 emissions arises in China, India and the Middle East, and 97% in non-OECD countries as a whole. Figure 4.4 presents results for global used material extraction disaggregated into nine

Figure 4.3
Energy-related CO$_2$ emissions, baseline scenario BH, GINFORS (in Mt CO$_2$)
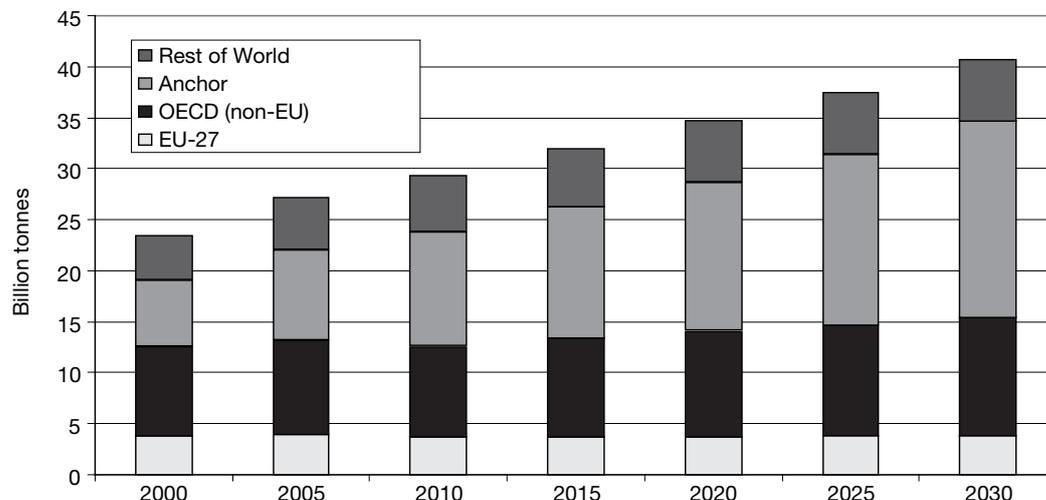
material categories in the BH scenario. The historical trend of increasing extraction continues in BH, with total used extraction reaching more than 80 billion tonnes in 2020 and more than 100 billion tonnes in 2030.

Growth rates are unevenly distributed among the main material categories. Figure 4.4 illustrates that construction minerals, non-ferrous metals and iron ores are the categories

Figure 4.4
Global used material extraction, baseline scenario BH, GINFORS
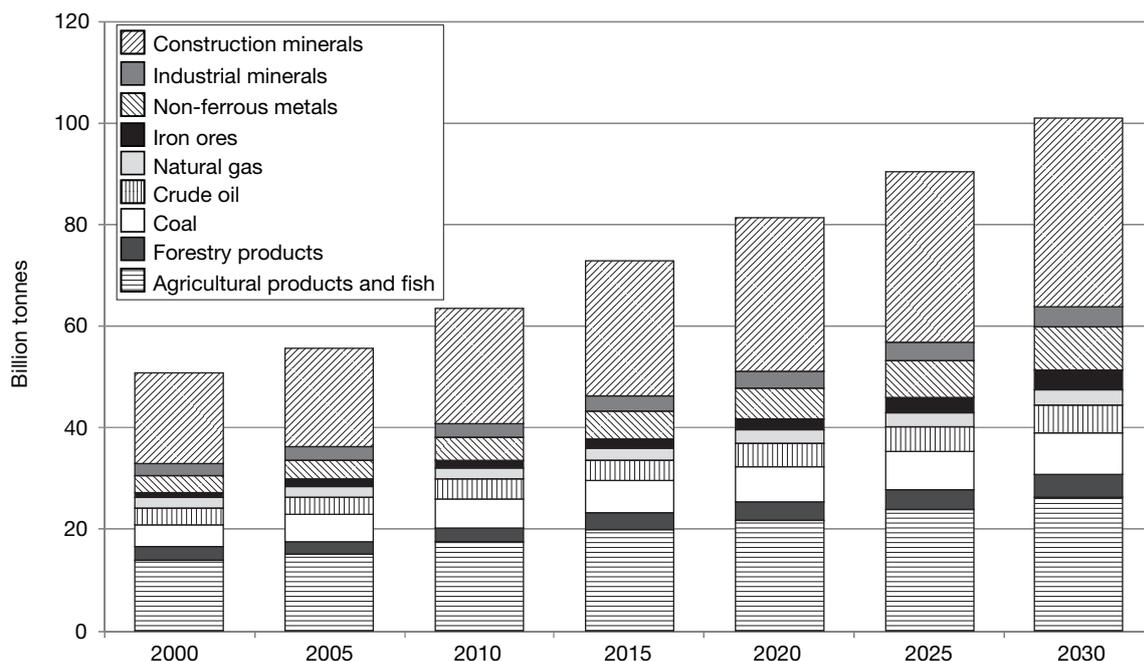
with the highest growth rates. By 2030, the extraction of construction minerals will be more than twice as high as in 2000, an indication of the importance of this category of materials for resource-intensive industrial development, especially in the emerging markets such as China.

The shift in global material extraction and production patterns is illustrated in Figure 4.5, which shows that shares of EU-27 and other OECD countries will decrease continuously to less than 30% in 2030.

Figure 4.5
Global used material extraction for country groups in the baseline BH, GINFORS
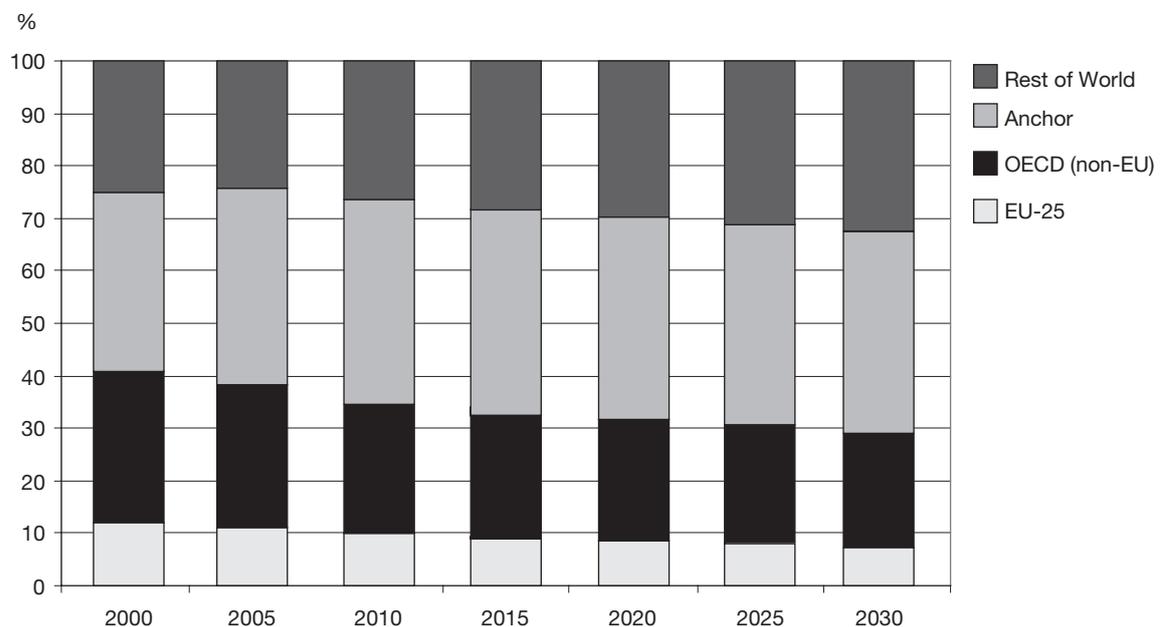
Results for policy scenarios

While the BH scenario showed likely developments in the absence of policy measures, scenario S1H assumes certain policy measures in the EU (a tightened EU ETS cap, the introduction of a carbon tax on the non-ETS sector, and introduction of materials taxes, as discussed in Chapter 2); and S3H also includes a carbon tax (at 25% of the rate in the EU) in the major non-EU OECD countries as well as in the five major emerging economies of China, India, Brazil, South Africa and Mexico (G5).

Following the introduction of policy measures, Table 4.1 illustrates the impacts on world GDP under the policy conditions stipulated for S1H and S3H.

Table 4.1
GDP in different world regions, three scenarios, GINFORS (in billion US$ 2000, PPP)

GDP in 2020	Total value of GDP, BH (in billion US$, PPP)	Absolute deviation of S1H from BH in 2020	Percentage deviation of S1H from BH in 2020	Absolute deviation of S3H from BH in 2020	Percentage deviation of S3H from BH in 2020
EU-27	15,931	−92	−0.6	−297	−1.9
OECD (non-EU)	27,840	28	0.1	−78	−0.3
Anchor countries	43,699	53	0.1	−688	−1.6
RoW	8,033	6	0.1	−266	−3.3
World total	94,926	−3	0.0	−1313	−1.4

Overall, the impacts of the policy measures on world GDP are very limited:

- the introduction of the policy measures only in Europe (S1H) reduces world GDP by only US$3 billion compared to the baseline scenario BH

- a more substantial decline can be observed for S3H with a reduction of US$1,313 billion (US$1.3 trillion), i.e. 1.4% lower than in BH.

It is also worth noting that the relative position of each region's share in the total value of global GDP does not vary significantly between the different scenarios. All three (BH, S1H, S3H) scenarios predict a shrinking of the EU-27 and OECD (non-EU) groups' shares of global GDP in the period from 2000 to 2020.

Turning to the environmental effects of the different ETR regimes, Figure 4.6 illustrates the global development of material extraction – which would continue to grow in all three scenarios.

Figure 4.6
Global used material extraction, three scenarios, GINFORS
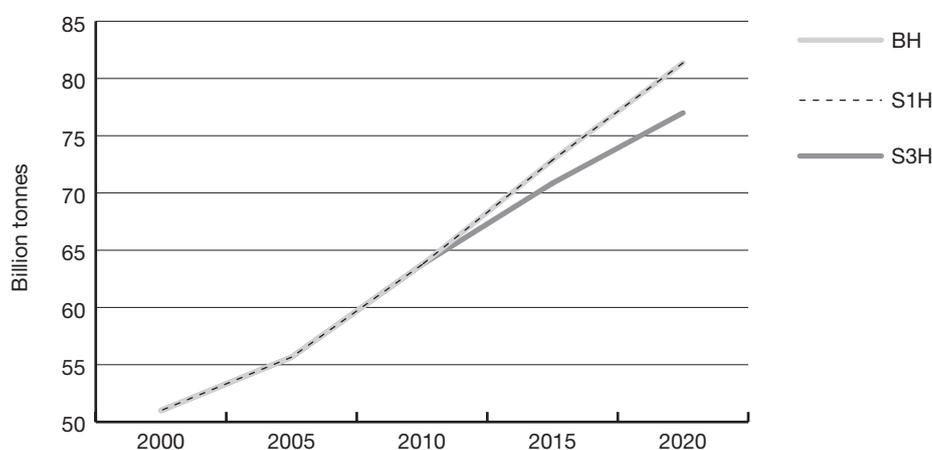
With less than 0.1% reduction, the world-wide effects of the measures implemented in S1H are negligible. S3H measures lead to a decrease of 5.3% compared to the baseline, but overall levels of extraction continue to grow. In S1H the largest reduction in extraction happens to natural gas, which would be –1.4% lower than in scenario BH in 2020. The global extraction of industrial minerals will be 0.1% higher than in BH. Comparing S3H with BH in 2020, the global amount of extracted coal would be 23.1% lower, followed by natural gas (–11.5%), crude oil (–10.7%) and iron ores (–10.1%), non-ferrous metals (–6.1%), industrial minerals (–3.5%), and construction minerals (–2.5%).

Comparing the effects of policy measures in scenarios S1H and S3H with BH in terms of material extraction in the year 2020, S1H decreases material extraction in the EU-27 by 1.5%, and in RoW by 0.1% (see Table 4.2). In the OECD (non-EU) and emerging countries, by contrast, material extraction increases slightly by 0.1% and 0.03% respectively.

Table 4.2
Impacts of an ETR on material extraction in S1H and S3H, GINFORS

Country group	Total extraction, BH, 2020 (in billion tonnes)	Absolute deviation of S1H from BH (in billion tonnes)	Percentage deviation of S1H from BH	Absolute deviation of S3H from BH (in billion tonnes)	Percentage deviation of S3H from BH
EU-27	6.8	–0.1	–1.5%	–0.2	–3.6%
OECD (non-EU)	18.7	0.02	0.1%	–1.0	–5.5%
Anchor countries	31.5	0.01	0.03%	–2.2	–7.1%
RoW	24.2	–0.02	–0.1%	–0.8	–3.3%
Global total	81.2	–0.1	–0.1%	–4.3	–5.3%

On the other hand, S3H policies are expected to reduce global material extraction by 5.3% (or 4.3 billion tonnes) in 2020. In this scenario, material extraction declines most significantly in the Anchor countries (–7.1%), followed by the OECD (non-EU) group (–5.5%), the EU-27 (–3.6%) and the rest of the world (–3.3%).

Table 4.3 presents the detailed numbers for CO_2 emissions in the four world regions.

Table 4.3
Impacts of an ETR on energy-related CO_2 emissions, GINFORS

Country group	Total energy-related CO_2 emissions in BH, 2020 (in Mt)	Total change in S1H from BH (in Mt)	Relative change in S1H, % against BH	Total change in S3H from BH (in Mt)	Relative change in S3H, % against BH
EU-27	3776.3	–318.8	–8.4%	–722.4	–19.1%
OECD (non-EU)	10244.6	10.4	0.1%	–1829.1	–17.9%
Anchor countries	14835.5	2.3	0.02%	–2741.9	–18.5%
RoW	5854.9	0.4	0.01%	–141.4	–2.4%
Global	34526.7	–272.8	–0.8%	–5398.6	–15.6%

As with material extraction, the global impact of scenario S1H is very limited: while the CO_2 reduction in the EU is substantial (−8.4%), all other regions show slight increases in CO_2 emissions. Global CO_2 reduction only equals −0.8%. However, the measures implemented in scenario S3H lead to a reduction in CO_2 emissions in all world regions, with similar substantial reductions in the EU, the OECD and the Anchor countries (the reduction in RoW is smaller, as the policy measures have not been implemented in this country group). Global CO_2 emissions are 15.6% below the baseline scenario BH. Figure 4.7 shows that the measures in S3H bring about the stabilisation of CO_2 emissions between 2010 and 2020 in absolute terms (though further measures will have to be taken after 2020 to stop them rising thereafter).

Figure 4.7
Global energy-related CO_2 emissions, three scenarios, GINFORS
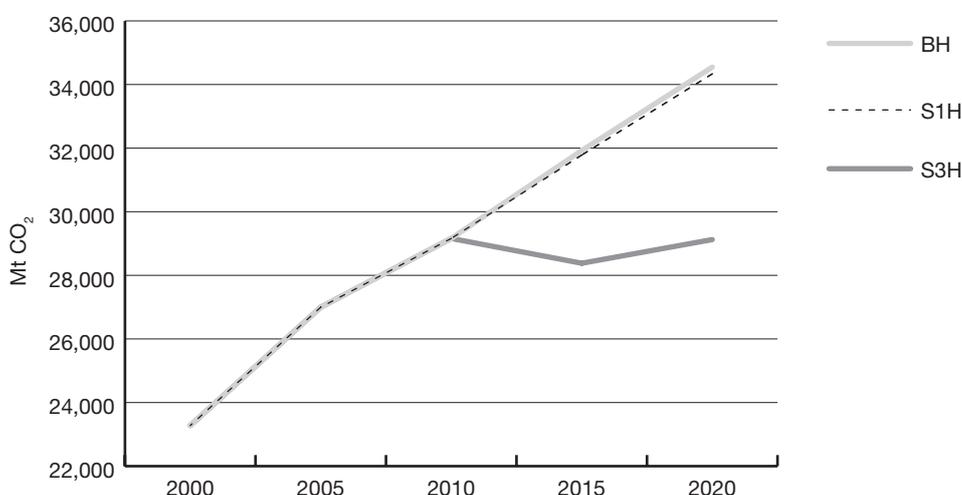
Policy conclusions

The GRAM has been useful in illustrating the uneven distribution of resource extraction and resource consumption across the planet.

The very different levels of resource extraction per capita in different regions of the world are reinforced through international trade. Trade thus allocates additional natural resources from southern countries to material consumption in northern countries. The general trade pattern of net imports of resources in northern countries is particularly visible in the EU, which faces the strongest dependence on resource imports of all investigated world regions, in particular regarding fossil fuels and metal ores.

The GINFORS results show that implementing environmental tax reforms in order to achieve large-scale CO_2 reductions (either unilaterally in the EU or in cooperation with

other countries) would have a relatively small effect on the economic opportunities of emerging countries, and on the ability of rest of the world to achieve economic growth.

The results also suggest that Europe should more actively address the potential conflict between its economic goals (i.e. ensuring its access to resources around the globe) and development goals (i.e. raising the material standard of living in developing countries).

The trends in all scenarios show a dramatic increase in natural resource extraction – which is already beyond sustainable levels in many resource-rich countries and causes substantial environmental, social, and environmental impacts (see EEA, 2005b; UNEP, 2007).

It is frequently suggested (for example, Stern, 2007) that increased technical and financial assistance should be given to developing countries for measures to reduce emissions and adapt to climate change. However, the OECD (2005) has suggested a joint reform of fiscal and environmental measures, which is more in line with the policy approach taken and modelled in this project. The results suggest that such reforms may protect the environment as well as raise tax revenue and reduce the pressure on natural resources.

Assessing the policy scenario simulations in a global perspective, a clear message can be derived: the environmental policy objectives of the EU, such as the 2°C target for the global temperature increase due to climate change, cannot be achieved through measures in the EU alone – international cooperation is crucial. Ensuring that the large emerging economies are part of a post-Kyoto agreement on climate change must therefore be one of the key objectives at the Copenhagen climate summit at the end of 2009.

5   Conclusions and Recommendations

This project proceeded from a hypothesis that environmental tax reforms could increase human well-being through two routes – environmental improvement and the generation of economic activity and employment (including through the stimulation of green technologies and new environmental industries) – and that each route could make an important contribution to a more sustainable growth in Europe.

The direct route of environmental improvement is well understood. By increasing the relative prices of pollution and resource use, these are reduced. For those industrial sectors investigated, the research found a price elasticity of energy demand of about –0.6, which is of the same order of magnitude as other estimates in the literature. Moreover, it also found an income elasticity of energy demand of 0.5. This means that, in a context of economic growth, energy demand (and any associated GHG emissions) will increase, unless the underlying growth in energy demand is choked off by simultaneous increases in energy prices.

The rationale for environmental taxes in this context is quite clear. Moreover, it is not clear how political commitments on dramatic reductions in energy-related GHG emissions over the next decade can possibly be achieved without them, or without an equivalent carbon pricing mechanism, such as emissions trading.

Taxes generate revenues and the ETR approach recommends that these are (mainly) used to reduce other taxes, especially those on the productive factors of labour and capital. Reducing such distortionary taxes may increase labour and output – a direct economic benefit from ETR.

The macro-econometric modelling undertaken in this research has confirmed the positive employment effect of ETR. However, the impact of ETR on output is inconclusive, except that in both models the effect was small. What is more certain, though, is the indirect effect that ETR would have through its stimulation of green innovation and environmental industries.

For instance, there is strongly suggestive evidence that the growth of the environmental industries in Germany, in particular, has been driven by the financial incentives that have been implemented (such as feed-in tariffs, reduced-rate loans for energy efficiency in buildings, and the previous German ETR). The effectiveness of the incentives apart from ETR are a strong argument for using some of the ETR revenues to deploy and develop new low-carbon technologies, as part of a portfolio of policies that tackle various barriers to these technologies.

The environmental industries not only mitigate or prevent the costs of environmental damage generated by industrial growth. They also make a double contribution to

that growth, both as a fast-growing part of the national economy themselves, and by improving the productivity of other sectors by reducing the costs of resource use. The environmental industries thereby promote European competitiveness and generate economic welfare, as well as environmental improvements, which are all necessary characteristics of sustainable growth.

EU economic activity and environmental impacts are a relatively small, and declining, share of global totals, so that where the EU (but not the rest of the world) introduces ETR by itself, the impact on both the environmental and economic global totals is small, even though the economic and environmental impacts in Europe may be substantial. However, where the ETR is undertaken in a context of global cooperation on climate policy, the global impact on both CO_2 emissions and resource consumption is significant. This provides a strong motivation for considering ETR as part of the policy mix to inform the climate negotiations in late 2009 in Copenhagen, and thereafter.

ETR therefore represents an excellent policy opportunity to address global and regional environmental challenges in a way that is both cost-effective, and supportive of employment, technological innovation, and the creation of new industries (which can contribute significantly to long-term economic development). These are substantial benefits for public policy.

The politics of achieving them is, however, far from straightforward.

One inevitable result of environmental tax reforms that focus on carbon is that the prices of fossil fuels increase. This is, of course, part of their purpose. In the S1H scenario these increases are up to about 30% for electricity, for a high-carbon electricity mix, 25–30% for natural gas, and somewhat less for road fuels (11%), because they are relatively highly taxed already. Although these price increases would be offset by tax reductions, the promise of tax reductions may not have public credibility – and even if it did, that may not fully offset the unpopularity of energy price rises.

This in turn suggests that, to be effective, ETR would need to be embedded in a more general package that includes stronger regulation for carbon and energy efficiency, e.g. for buildings, vehicles and power stations. Modelling work (for example, Barker et al., 2008) suggests that regulation can supplement carbon prices to achieve more stringent targets at lower carbon prices.

The context for the implementation of ETR will also differ widely across countries. Fiscal systems are a complex and deeply embedded part of a country's institutional structure, and proposals for fiscal reform will inevitably interact with a range of other important issues – most obviously business competitiveness and distributional impacts on household expenditure – which are politically very sensitive. Countries will, therefore, wish to approach and implement ETR in very different ways, and would be well advised to do so in a way that is well informed by analysis of political, institutional and cultural, as well as economic, factors.

The radical differences in historical background, current context and public perception between different European countries, combined with the fact that taxation is an issue which requires unanimity in the European Council, make the prospects for a Europe-wide ETR seem rather remote. However, political priorities and perceptions can alter quite quickly in times of radical change such as the present.

The scientific imperative for strong action on climate change is strengthening inexorably; the impending auctioning of EU ETS permits means that there is in prospect a source of revenues at the European level from a European environmental instrument; and it has long been recognised that an auctioned environmental permit scheme has much in common with an environmental tax. Having implemented the former, the European Council may be prepared to re-consider the latter, especially where it can strengthen and make more effective the EU ETS. Alternatively auctioning in the ETS may be supplemented by a carbon-energy tax in the non-ETS sectors.

Moreover, there is now an EU Energy Tax Directive, which sets minimum levels for energy taxes, and proposals from the European Commission to differentiate the tax rates between energy and carbon. There is therefore already an instrument at EU level that could gradually raise the level of energy/carbon taxes in all EU countries.

Finally, for reasons related to do with ease of implementation, there are good arguments in favour of preferring a carbon tax instead of emissions trading at the global level – at least in the short term – perhaps as a transitional instrument to a global trading scheme. These arguments are increasingly being rehearsed in the context of post-Kyoto negotiations and, in particular, of how to include emerging and developing economies appropriately in a post-Kyoto agreement.

None of this means that a European ETR is going to be easy to implement. But this research strongly suggests that the economic, as well as the environmental, benefits of doing so are great.

Environmental tax reforms emerge from this analysis as an important, and perhaps essential, part of the policy mix that will be required to achieve steep cuts in greenhouse gas emissions. It is surely up to the politicians and policy makers to find a way of realising these benefits on behalf of the EU as a whole.

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Programme Structure and Participants

The Research Programme PETRE (Resource Productivity, Environmental Tax Reform and Sustainable Growth in Europe) was carried out by:

> Professor Paul Ekins (Programme Co-ordinator), then at King's College London (KCL), now at the UCL Energy Institute, University College London (UCL), UK
> Dr Terry Barker, Hector Pollitt, Cambridge Econometrics (CE), UK
> Professor Bernd Meyer, University of Osnabrück and Institute of Economic Structures Research (GWS), Osnabrück
> Dr Christian Lutz, GWS
> Professor Martin Jänicke, Roland Zieschank, Freie Universität (FU), Berlin
> Dr Stefan Giljum, Dr Stefan Speck, Sustainable Europe Research Institute (SERI), Vienna
> Dr Petr Šauer, Ondrej Vojáček, University of Economics (UEP), Prague

and other colleagues from the above institutions.

The purpose of the project was to explore the potential contribution of resource productivity – and of environmental tax reform (ETR) which may promote it – to sustainable growth in Europe. For the purposes of this project, 'sustainable growth' means sustainable economic growth, which is not the same as a sustainable increase in human welfare because this depends on other factors than economic growth including, importantly, the environment.

This project linked the concepts of resource productivity and ETR in order to contribute, at a European level, to the joint pursuit of the Lisbon Strategy, to provide a new impetus to growth and competitiveness, and the EU Sustainable Development Strategy.

The key research questions were:

1. What are the long-term relationships between energy and resource prices, and energy and resource use, environmental quality, economic growth and competitiveness?

2. What have been the effects so far of European environmental tax reforms on employment, economic growth and competitiveness? What are the medium-term implications of such reforms in the UK and Germany for the national, European and global economies? Do they give any grounds for expecting that ETR will be able to increase economic growth and employment while reducing local and global environmental impacts?

3. What implications follow from this analysis for the design of further ETRs for both old and new EU member states?

The research was divided into five linked 'work packages' (WPs). Taken together the WPs investigate the major issues related to resource productivity and ETR, including both economic and environmental implications and impacts, in single countries, within the EU and in the global economy.

- WP1 explored the link between resource use, economic performance and environmental quality, specifically seeking to characterise the relationship between trends in resource productivity, resource (especially energy) prices, environmental quality, economic growth and competitiveness. WP1 was divided into three parts: WP1A focused on productivity, prices and growth issues; WP1B on growth, environmental quality and well-being issues; and WP1C on the economic and environmental contribution of the environmental industries.

- WP2 focused on the resource and labour impacts of European ETRs to date, seeking to determine the resource and labour impacts of the reforms that have been implemented in Germany and the UK.

- WP3 used two EU-wide macro-econometric models to model the single-country, European and global economic and environmental effects of different ETR regimes, and to make projections to 2020. It explored the possible impacts on labour and resource productivity, resource use and employment, and the environmental impacts, of major ETRs in the UK, Germany and the EU, and the reasons for any differences in the models' projections.

- WP4 explored the implications of the analyses undertaken in WPs 1–3 for the new EU member states in central and eastern Europe, and made recommendations for ETR design and implementation in these countries.

- WP5 focused on the global dimensions of sustainable growth in Europe, investigating the positive and negative implications of higher European resource productivity for European competitiveness, for worldwide patterns of natural resource extraction and of production, trade and consumption, and for other (especially developing) countries, and the policy implications.

By exploring these issues in a specific, rigorous and quantitative way, the PETRE project sought to make an innovative and durable contribution to one of the most important issues facing Europe and the world today: how to integrate environmental and economic objectives, reducing global environmental impacts while enhancing economic competitiveness and improving quality of life.

Programme Publications

Agnolucci P. (2009) 'The Relationship between CO_2 Emissions and Economic Growth in the British and German Industrial Sectors', submitted to *Environmental and Resource Economics*.

Agnolucci, P. (2009) 'Environmental Kuznets Curve and CO_2 Emissions: A Methodological Note', submitted to *Ecological Economics*.

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Methodology

This project used a range of methodologies: micro-econometric analysis (Work Package 1, WP2); decomposition analysis (WP1); literature review (WP1, WP3); desk-based analysis and synthesis of data (WP1); macro-econometric modelling (WP3); questionnaires, surveys, and interviews (WP4); and input-output modelling (WP5). This brief note gives details of some of these methods. References are in either the main list of references (pages 53–57) or the list of programme publications (pages 60–61).

Micro-econometric analysis

Micro-econometric analysis is the joint application of economic theory and statistical regression analysis at the firm, sector or household level.

ETR operates by raising the prices of resource use and pollution through taxation. To be feasible, taxation should apply broadly to a range of sectors in the economy. An issue that affects the appropriateness of energy-related policy is whether the differences in energy use between sectors are deterministic (that is, they derive from particular characteristics of the sector, and will persist over time in a way that can be forecast relatively accurately) or stochastic (that is, they are affected by random processes within or between the sectors, and, although they persist across over time, they fluctuate in an unpredictable way making any forecast particularly difficult and potentially inaccurate). Determining whether sectoral energy use is deterministic or stochastic requires the use of complex econometric analysis of the sectors concerned, which can take account of any radical changes (structural breaks) in energy use within the sectors which may have occurred during the period concerned. Results of this analysis are reported in Agnolucci & Venn (2009).

Econometric analysis was also used to explore how energy use in industrial sub-sectors (this time in the UK and Germany) varies with price and sectoral gross value added (Agnolucci 2009).

Such analysis was also used (Agnolucci 2008b) to investigate the environmental Kuznets curve (EKC) hypothesis for 10 British and German industrial sub-sectors over 1978–2004. (The EKC hypothesis states that, while economic growth might indeed cause negative environmental effects in the early stages of economic development, as incomes rise the negative impacts will cease at some point and the environment will begin to improve.)

Finally, econometrics was also used to investigate the impacts of the British and German ETRs, implemented in 2001 and over 1999–2003 respectively, on the economy and on the labour market. This produced estimates of the energy reductions caused by the ETRs that

are similar to those obtained from more complicated multi-sectoral econometric models (Agnolucci 2008a).

Decomposition analysis

Decomposition analysis is the determination of the relative contribution of different factors to an overall effect. Three factors are commonly identified as affecting energy use: economic growth (the scale effect), which produces an increase in energy use; the technology used (the technical effect), and because new technology tends to be more energy efficient than the technology it replaces, this normally reduces energy use; and the structure of the economy or sector (the composition effect). Economies that are becoming more oriented towards services, which use less energy than manufacturing, will tend to have a negative composition effect, tending to reduce their energy use. These three effects were investigated for the German economy over 1994–2004, as reported in Jungnitz (2008).

Literature review, desk-based research and data analysis

These methodologies were used in relation to the previous implementation of ETRs, the extent and growth of the environmental industries, and the relationship between economic growth, the environment and human well-being. The first two areas are well covered in this report. For the research on human well-being see Venn (2007a,b) and Ekins and Venn (2009).

Macro-econometric modelling: the E3ME and GINFORS models

The general structure of the two models is very similar, and the underlying approach of both models is post-Keynesian, based on 'new economics' or 'complexity econom-ics' (Beinhocker, 2006), which draws on institutional factors and evolutionary and chaos theory. Model parameters for behavioural relationships are derived empirically using econometric methods applied to historical time-series data sets. This approach contrasts with the neoclassical or text-book equilibrium theory that underpins CGE (computable general equilibrium) models, in which the introduction of a new tax such as ETR will reduce GDP by definition, as an assumed optimum is distorted. Econometric estimation in both models shows that country and sector specifics can lead to either positive or nega-tive effects at country and sector levels.

Both are 'E3' (energy-environment-economy) models – meaning that they fully integrate economic development with activities in the energy system (supply and demand) and environmental emissions through explicitly defined two-way linkages (Lutz & Meyer 2009b). In both models this structure has been extended to include industry demand for raw materials (see Pollitt 2007, 2008 for the treatment in E3ME).

In both models the economic structure is fully consistent with that of the national accounts, as defined by ESA95 (Eurostat, 1995). Both models are solved on an annual basis. Their main features are as follows:

- **Geographical coverage** The most obvious difference between the two models is their coverage of countries. E3ME covers all 27 EU Member States plus Switzerland and Norway at national level, and treats the rest of the world as exogenous. GINFORS is a global model and includes a much larger number of countries, 50 in all, plus two more aggregated regions (OPEC and Rest of World) to meet global totals. This difference in geographical coverage is the main reason behind some of the other differences between the two models, for example in data and estimation methods.

- **Sectoral coverage** Both models are estimated and solved at the sectoral (meso-) level, with macro-economic aggregates being formed as the sum of the sectors. The sectoral approach is key to both models because relations between the environment and the economy are sector-specific, and the sectors have been shown to have significantly different behavioural responses, which are reflected in the models' parameters (Barker and de-Ramon, 2006). GINFORS includes 41 economic sectors and E3ME includes 42. In both cases the sectors are linked by input-output tables showing inter-industry relationships, although these are not always available for countries outside Europe. Bilateral trade relations are also modelled on the sector level.

- **Data and data sources** The data requirements for the two models are similar; both models require annual time series meeting the regional and sectoral disaggregations described above. The sources used for the economic data, however, differ somewhat due to the different geographical coverage of the models. GINFORS primarily uses the OECD (STAN) database, supplemented by data from the IMF, Eurostat, the UN (COMTRADE) and national sources. E3ME is able to use Eurostat as the primary source, with additional data taken from DG Ecfin's AMECO database and the OECD. Both models use IEA data for energy balances and prices but different sources are used for materials data.

- **Econometric methods** In both models, equation parameters are estimated separately for each sector and country, so that factors specific to that sector and country are accounted for. In both cases the approach to estimating parameters is econometric, based on the time-series data described above. An important point to note is the difference in the econometric techniques used. E3ME's equations are specified in terms of cointegration and error correction (Engle and Granger 1987, Hendry et al. 1984) which allow short-term dynamic changes converging to a long-term outcome (i.e. the results include transitional effects). The nature of global data

provides less support for this approach so the OLS-based method is used in GINFORS focusing on long-run outcomes.

- **Exogenous inputs** The exogenous inputs (assumptions and variable values imported from outside the models) to the two models are similar and can be summarised as: demographics; government activity; and international energy prices. E3ME also requires assumptions about activities outside Europe.

- **Technical progress** E3ME adopts an approach whereby technical progress is defined by accumulated investment enhanced by R&D (adapted from Lee et al. 1990). This features in nine of the model's estimated equations, so that technological progress can influence the underlying performance and growth of the economy. As global R&D data are not available, GINFORS models technical progress implicitly, assuming that relative prices are cost-push determinants of technical progress.

- **Labour markets** In their treatment of the labour market and wage formation, both models use a complex union-bargaining system, taking into account productivity and unemployment effects, with levels of market power varying across sectors (see Lee and Pesaran 1993). However, GINFORS estimates wages for six broad sectors, while E3ME uses the full 42. This factor is potentially very important in the scenarios used in this project, because it determines whether the revenue recycling creates additional employment or drives up wages.

- **Energy demand** In both models, total energy demand is estimated by sector and then split between fuels. However, E3ME includes a separate, non-linear treatment of the power-generation sector, based on engineering principles (Barker et al., 2007b) that differs markedly from the approach used in GINFORS.

- **International trade** There are large differences in the ways the two models treat international trade. GINFORS models trade bilaterally using Armington-type price elasticities (Armington 1969) with different elasticities estimated for each sector, origin and destination. This forms a central pillar of the global model. E3ME does not attempt to model trade on a bilateral basis and instead models trade via a funds approach, based on an international 'pool' that estimates exports and imports without explicitly trying to link one country's exports to another's imports.

Qualitative research

Qualitative research was used for the analysis of the ETR preparation and implementation in the Czech Republic. The aim of the study was to explain the behaviour of the particular stakeholders in the environmental tax and ETR agenda. Thus the study simultaneously focused on various aspects of ETR as well as the identification of the practical barriers and obstacles to ETR implementation in the Czech Republic.

Questionnaires were designed for semi-structured interviews with open questions and were progressively amended, based on the previous interviews. Interviews were conducted

with a total of 24 subjects. Six were government representatives; six were representatives of key relevant businesses; another six were from SMEs; three were NGOs representatives; one was a representative of labour unions; and two were academic consultants. Some of the key stakeholders were interviewed several times over a longer time and thus against the background of different political contexts and different ETR implementation stages, so that any mental shift could be reflected in the research results (Šauer and Vojáček, 2009, and Vojáček and Klusák 2007).

Input–output modelling

The project constructed the Global Resource Accounting Model (GRAM) so as to illustrate European trade patterns from the perspective of material flows and to analyse how the introduction of an ETR in Europe would impact the economies and the environment in other world regions.

GRAM is a multi-regional input–output material flow model (Giljum, Lutz et al. 2008). Like GINFORS, it disaggregates 52 countries and world regions, represented with so-called input–output (IO) tables on the level of economic sectors and linked by bilateral trade flows in 25 product groups and one service sector. GRAM was constructed to calculate comprehensive material consumption and resource productivity indicators and to determine the resource base of the European economy in a comprehensive manner, fully including the international trade dimension.

The model allows the calculation of aggregated indicators of extraction versus consumption of raw materials of countries and world regions respectively, taking into account resource requirements along international production chains (also referred to as 'natural resources embodied in traded products'). In this way, comprehensive physical trade balances for individual countries or regions can be calculated and the main net-importers and net-exporters of different categories of natural resources in the world economy can be identified.

GRAM results thus show the extent to which an economy is dependent on natural resource imports from abroad. These types of calculations are currently also being undertaken for the issue of CO_2 embodied in traded products (Peters 2008) and are the empirical basis for the discussion as to whether producer or consumer countries are responsible for related environmental impacts.