Discussion Paper No. 07-019

What Does Europe Pay for Clean Energy? – Review of Macroeconomic Simulation Studies

Astrid Dannenberg, Tim Mennel, and Ulf Moslener

ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

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Non-technical Summary

Energy conversion and use are major sources of environmental pollution. Emissions from transport or from burning fossil fuels to produce electricity contribute substantially to global warming and other environmental problems. In line with the economic theory of externalities, several environmental policy measures try to reduce emissions from energy use by influencing the costs of energy consumption. The most important environmental policies in European energy markets are the European emissions trading scheme (EU ETS), energy taxes, subsidies for renewable energy sources, and instruments specifically targeted at the transport sector.

A price increase of energy as an input increases production costs. This reduces the domestic and foreign demand for goods and services and, therefore, creates macroeconomic costs. Our paper presents a survey on selected studies on macroeconomic costs of environmental regulation in European energy markets. As some policy measures are initiated on the national level we also include experiences of single Member States, especially Germany.

The analysed studies show that the environmental regulation affects the European economy, particularly the energy intensive industries and the industries that produce internationally tradable goods. From a macroeconomic point of view, however, the costs appear to be relatively small. The reason for that is that some sectors benefit from the regulation. If, for example, the regulation creates government revenues which are used to lower non-wage labour costs, this may benefit the labour intensive sectors, such as services. Not surprisingly, macroeconomic costs tend to be higher for more ambitious environmental targets. In this case, also the efficiency of the regulation becomes a more important issue. There are numerous studies on the macroeconomic costs of the EU ETS. Here, the costs depend not only on the assignment of reduction obligations to the sectors participating in the EU ETS but also on the optimal allocation of emission permits between the sectors participating in the ETS and the rest of the economy. The macroeconomic costs are lower if the project-based mechanisms, Clean Development Mechanism and Joint Implementation, are less restricted and costly domestic emission reduction can be replaced by cheaper reduction abroad. In this case, the resulting GDP losses from implementing the Kyoto targets are typically around 0.4% as compared to business-as-usual (BAU), but lower than emissions reductions without the EU ETS. In the case of energy taxes, particularly the recycling of revenues and tax exemptions influence the amount of macroeconomic costs. Many studies conclude that the use of

revenues for reductions in labour costs and tax exemptions for energy intensive industries can limit GDP losses to well below 0.1% or even lead to slight rises in GDP. The energy taxes analysed typically lead to emission reductions on the order of 2 to 3%. Studies on clean energy policy in the transport sector cover a wide portfolio of instruments from fuel taxes or road charges to efficiency standards. Potential impact on GDP is found to be substantial, up to 1% by 2020, indicating that emission reductions in the transport sector are relatively expensive. Macroeconomic model simulation results for increasing the share of EU 15 renewable electricity production to 30% in 2020 surveyed in this paper range from roughly 0.1 to 1% as compared to BAU.

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Astrid Dannenberg, Tim Mennel, and Ulf Moslener
Centre for European Economic Research (ZEW), Mannheim

March 2007

Abstract: This paper analyses the macroeconomic costs of environmental regulation in European energy markets on the basis of existing macroeconomic simulation studies. The analysis comprises the European emssion trading scheme, energy taxes, measures in the transport sector, and the promotion of renewable energy sources. We find that these instruments affect the European economy, in particular the energy intensive industries and the industries that produce internationally tradeable goods. From a macroeconomic point of view, however, the costs of environmental regulation appear to be modest. The underlying environmental targets and the efficient design of regulation are key determinants for the cost burden.

Keywords: Environmental regulation, energy market, macroeconomic costs
JEL Classification: Q21, Q28, Q41, Q43, Q48

Acknowledgement: Parts of this survey evolved from work funded by the European Commission. We thank Machiel Mulder from the CPB Netherlands Bureau for Economic Policy Analysis for helpful comments and suggestions.

Contact: Astrid Dannenberg, Environmental and Resource Economics, Environmental Management, Center for European Economic Research (ZEW), L 7, 1, 68161 Mannheim, Germany, dannenberg@zew.de

1. Introduction

Energy conversion and use are a major source of environmental pollution. Emissions from burning fossil fuels for transport, to generate electricity or to produce industrial goods substantially contribute to urban ozone and other air pollution, acid deposition, regional haze and visibility problems as well as the build-up of greenhouse gas (GHG) concentration in the earth's atmosphere. The consequences are human health problems, damage of ecosystems, crops, and building material, amenity losses, and global warming (cf. European Commission, 2003). In line with the economic theory of externalities, several environmental policy measures try to reduce emissions related to energy use by inducing incentives to increase energy efficiency and to use clean energy sources. The most important instruments in European energy markets are the European emissions trading scheme (EU ETS), energy taxes, policy measures in the transport sector, and the promotion of renewable energy sources. All these policy measures typically imply higher energy prices for consumers and often also for producers.

An increase in the price of energy as an input raises production costs. This can reduce the domestic and foreign demand for goods and services and thereby create macroeconomic costs. This paper analyses the macroeconomic costs of environmental regulation in European energy markets. For this purpose, we review the results of selected simulation studies that analyse the macroeconomic effects of environmental regulation. Although environmental regulation creates external benefits, such as avoided damage from climate change or reduced non-GHG air pollution, this paper does not include these benefits but only the internal benefits from the reallocation of resources, such as the profit gain of producers of energy efficient technologies.

In our analysis we focus primarily on policy measures that are implemented or intended at the European level. The baseline in all modelling studies is business-as-usual (BAU). As some policy measures are initiated on the national level we also include experiences of single Member States, particularly Germany. Effects on the sectoral or firm level, e.g. the implication of an energy tax for energy intensive sectors or the household sector, are only addressed casually. However, due to differences in energy intensity and possibilities to substitute energy intensive technologies by more efficient technologies, the costs of environmental regulation can differ substantially between countries, sectors and firms. Higher energy prices reduce the profitability of energy intensive companies, whereas producers of energy efficient technologies may benefit. As the macroeconomic costs subsume all these effects they are usually smaller than the costs in the energy intensive sectors.

2. Theoretical Background

Energy conversion and consumption (e.g. burning fossil fuels) cause negative external effects in the form of environmental pollution and human health damages which a priori are not taken into account in production and consumption decisions. This leads to a level of emissions from energy consumption above the socially optimal level which considers both private and social costs. The solution to the welfare problem in the economic literature is the internalisation of external effects via a Pigouvian tax, tradeable permits, or other policy instruments. They tend to increase energy prices and try to limit emissions from energy consumption to the socially optimal level (Common and Stagl, 2005).

The aim of this article is to determine the macroeconomic costs of environmental regulation. Macroeconomic costs of environmental regulation do not contain external effects, such as ecological or human health damages. Similarly, the avoided damages are not taken into account. In this analysis, we consider only the economic consequences of higher energy prices caused by environmental regulation to quantify what Europe pays for clean energy. What Europe gains from clean energy is a question in its own right and beyond the purpose of our contribution. Nor are distributional issues of environmental regulation – e.g. the redistributive role of green taxation – taken into account.

According to the standard theory of optimal taxation, taxes levied on commodities generally create distortionary effects in form of deadweight losses (Atkinson and Stiglitz, 1980). Hence, energy taxes or other policy measures that increase energy prices generally create inefficiencies. The distortionary effect of a tax decreases with the elasticity of demand. It is zero if the demand is perfectly inelastic. The demand elasticity of electricity, for instance, is typically relatively small. The deadweight loss of electricity taxes, therefore, is expected to be small as well. Taxes on goods with an inelastic demand, such as electricity, can even have positive economic impacts if they replace more distortionary taxes on goods with higher elasticity of demand. This effect is called Double Dividend and it is extensively discussed in the economic literature.[1]

There are a number of policy instruments that are targeted at changing the costs of energy consumption and therefore at influencing the incentives of producers and consumers. They include energy taxes, tradeable permits, emissions abatement subsidies, and efficiency standards. As these instruments have different requirements in terms of information of the regulator, the effectiveness and efficiency can differ substantially on the microeconomic level (Perman et al., 2003). From a deterministic macroeconomic viewpoint, however, their economic impact depends essentially on the financial burden they put on input and output factors in equilibrium irrespective of the specific policy instrument used to levy the burden. In relation to labour and capital costs, energy prices are not very important for most firms and rarely a cause for relocation. Nevertheless, higher energy prices increase production costs. Thus, if companies face international competition and have only limited possibilities to reduce their energy consumption, unilaterally increasing energy prices reduce the profitability and competitiveness of these firms.

It is sometimes argued that higher electricity prices can also have positive impacts if they lead to the development and implementation of new energy efficient technologies. This effect is commonly known as the Porter Hypothesis. It states that stringent environmental regulations can in principal increase the competitiveness of firms, sectors and economies because they trigger environmentally benign innovations which may reduce production costs or create other competitive advantages. In addition, follower countries that also introduce ambitious environmental regulation may buy these new technologies (Porter and van der Linde, 1995; Porter 1999).[2] To our knowledge, simulation studies have not yet quantified the macroeconomic impacts of this effect.

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[1] For literature surveys see for example Goulder (1995), Bovenberg (1995), and Koschel (2001).

[2] The inclusion of innovations and technological progress in economic modelling is still in its infancy. Most simulation models set technological progress as an exogenous variable and therefore cannot testify to the Porter Hypothesis. The economic modelling with endogenous technical change is still at the beginning (cf. Löschel, 2002; Goulder, 2004; Bosetti et al., 2006a; Bosetti et al., 2006b). Many empirical studies that analyse the Porter Hypothesis do not find a significant correlation between environmental regulation and competitiveness, neither positive nor negative. For literature surveys, see for example Jaffe et al. 1995, Jenkins 1998, Taistra 1999, or Kaiser and Schulze 2003.

3. Results of Selected Simulation Studies

3.1 Selection of Simulation Studies

Our literature review is based on macroeconomic simulation studies that calculate the change of macroeconomic variables, such as GDP or welfare, caused by the introduction of certain environmental policy measures. The focus is on simulation studies using computable general equilibrium (CGE) models and macroeconometric models. Both types of models are able to quantify the economy-wide impacts and effects in secondary markets in the framework of a single-market or multi-market analysis. CGE models calculate a vector of prices such that all markets of the economy are in equilibrium. All demand and supply equations are derived from microeconomic principles. Originally, CGE models assumed only competitive markets; meanwhile, later versions sometimes also include market imperfections. Based on economic theory they show a high level of theoretical coherence. Parameters and coefficients of the assumed functional forms are typically calibrated to match a base year dataset. Macroeconometric models, in contrast, are structural empirical models and are developed fully based on coherent datasets. In particular, equations may not be derived from a microeconomic foundation of the economic relation they describe. The parameters of the equations are estimated with econometric methods.

The baseline scenario which serves as benchmark in all simulation studies is business-as-usual (BAU). It denotes the hypothetical scenario where the policy measure was never introduced. The macroeconomic costs of environmental regulation can therefore be interpreted as price for the improvement of environmental quality that comes along with the implementation of the instrument. Note that reaching a given environmental target may be more or less costly depending on the instrument and the regulatory design. It is the goal of economic instruments in environmental policy to efficiently reach environmental targets. Simulation models sometimes assume compliance with certain environmental targets in both the baseline scenario and the policy scenario. In these cases the baseline often represents the cost efficient way to achieve the targets. Thus, the differences between policy scenario and baseline scenario can be interpreted as price for choosing a policy different from the cost efficient policy. Such simulation studies are not the focus of this paper.[3]

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[3] For further discussion about the role of the baseline see Oberndorfer and Rennings (2007).

The remainder of the text is structured along the existing instruments in energy markets, namely the EU ETS, energy taxes, policy measures in the transport market, and policy measures to promote renewable energy sources. The main focus is on instruments that already exist on the national or the European level, e.g. the EU ETS or energy taxation in Germany. Some modelling studies analyse the impacts of instruments which exist but concede long transition periods to the Member States, e.g. the EU minimum tax rates on energy. A few models simulate the introduction of new instruments that would ensure the compliance with existing environmental targets, e.g. an EU-wide system of tradeable green certificates (TGC). Hence, our review also includes costs that will have to be paid in the future in order to reach existing environmental objectives.

3.2 European Emission Trading Scheme (EU ETS)

The EU ETS was launched at the beginning of 2005 to control the CO_2 emissions of the carbon intensive industry, mostly power generation and heavy industry. The aim of the EU ETS is to ensure emissions reduction at least costs. The cap-and-trade mechanism allows emissions reduction to meet the overall reduction target where and how it is cheapest to do so and without technical knowledge of the regulator. The initial allocation of emission allowances is decided by the Member States. Although they are required to be on the pathway to their Kyoto targets and the EU Burden Sharing Agreement, they have discretion over what share of their overall emissions reduction they plan to achieve in the EU ETS sectors that participate in the trading scheme, and how much they plan to abate in the sectors that do not participate (non-ETS sectors). The optimal split between the ETS sectors and the non-ETS sectors equals the marginal abatement costs in both sectors. Böhringer and Lange (2005a) show that the objectives of economic efficiency and free allocation of emission permits are incompatible with harmonized allocation rules which are often called for in order to avoid distorting the competition. For the actual allocation of the first phase, Böhringer et al. (2005) show that the Member States have failed to implement the optimal split in the first trading period from 2005 to 2007. Therefore, the use of the flexible mechanisms of the Kyoto Protocol, namely international Emissions Trading, Clean Development Mechanism (CDM), and Joint Implementation (JI), becomes an important issue. The cheap emissions reductions abroad can replace costly domestic reductions and therefore lower the macroeconomic costs of the EU ETS. Böhringer and Lange (2005b) study the EU ETS with a focus on the cost burden of different dynamic allocation rules. They find that – especially for high CO_2 prices –

an emission-based free allocation is more costly than an output-based free allocation. Welfare losses tend to be lower than 0.15% for permit prices around 30$US per ton of CO_2.

Oberndorfer and Rennings (2007) review the results of various simulation studies, including CGE models, partial models, and macroeconometric models, in order to assess the competitiveness effects of the EU ETS. They find small negative effects on the sectoral and the macroeconomic level, if the baseline is BAU. The losses in most sectors are modest except for the aluminium sector with its particular competitive situation, very limited options to reduce electricity consumption, and whose profits highly depend on electricity prices.

COWI (2004) presents an economic modelling of the EU ETS and calculates the economic impacts for the EU25 in the year 2010 under different assumptions about the technological change. The analysis uses the CGE model GTAP-ECAT of the world economy with a special emphasis on energy use and CO_2 emissions. The baseline is BAU where no climate change abatement policy has been conducted since 1997. Two policy scenarios are analysed: A sluggish short-term technology adaptation and a more rapid long-term technology adaptation. The inflow of CDM and JI credits into EU25 is exogenously fixed in the model at permits representing 100 Mt of carbon. National governments acquire 46 Mt. It is furthermore assumed that the optimal split between ETS sectors and non-ETS sectors can be implemented. Therefore, the estimated costs can be interpreted as the minimum costs for bringing the emissions into line with the Kyoto reduction requirements. The EU25 GDP is reduced by 0.36% with long-term technology adaptation and by 0.48% with sluggish short-term adaptation. The emissions reduction efforts by the EU ETS reduce the competitiveness of the EU25 countries compared with countries where no emission target exists. The reason is that increased final energy prices increase the costs of the EU25 output. This reduces the demand for goods and services. Total exports from the EU25 countries decline by 0.41% with the long-term technology adaptation and by 0.55% with the short-term adaptation.

Klepper and Peterson (2005) employ the CGE model DART to assess the effects of the EU ETS in the year 2012, when the Kyoto targets will have to be met. The baseline is BAU which keeps all climate policy measures introduced until the year 2002 in place but does not include any new climate policies. The simulation scenario includes the actual National Allocation Plan (NAP) of each EU15 Member State for the first trading period 2005 to 2007. The use of CDM and JI is unrestricted for the ETS sectors but the government purchases are restricted to the existing official plans. For the emissions reductions in the non-ETS sectors a uniform but regionally differentiated CO_2 tax is assumed. The implementation of the EU ETS leads to a welfare loss of 0.9% compared to the BAU baseline. The welfare loss is partly due to distortions between the ETS and the non-ETS sectors. The current NAPs generously endow the ETS sectors with emissions rights and thus require large emission reductions in the non-ETS sectors or abroad making use of CDM and JI. The analysis of alternative reductions scenarios shows that an efficient unilateral reduction policy without ETS would lead to welfare loss of 0.7%. The EU ETS with an unrestricted use of CDM and JI would cause a loss of only 0.1%. The welfare loss of the current ETS without the use of CDM and JI would rise to 1.7%.

Peterson (2006) applies the same CGE model to assess the effects of the NAPs for the second trading period, 2008 to 2012. The baseline is BAU without any climate policy measure enacted after 2001. It is assumed that both the ETS and the non-ETS sectors contribute a proportionate share in order to achieve the Kyoto target. The governmental purchases of international carbon credits are restricted to existing official plans. They do not increase the allowances allocation to the ETS sectors and therefore reduce the reduction burden of the non-ETS sector. The reduction target for the non-ETS sectors in each country is achieved through a uniform carbon tax. Total purchases of CDM and JI credits by the ETS sectors are restricted to 8% of total allowances in the EU ETS. The welfare loss vis-à-vis the baseline amounts to 1.1%. The analysis of other policy scenarios with different allowances allocations for the second trading period shows that the welfare loss would be considerably greater if more of the reduction burden were shifted from the ETS to the non-ETS sector.

3.3 Energy Taxes

Most EU Member States have implemented energy taxes on electricity, motor fuels and heating fuels. However, the level of taxation differs substantially. The new Member States and some southern countries of the EU15, such as Greece, Portugal, and Spain have low tax rates whereas Denmark, Germany, the Netherlands and Sweden have relatively high tax rates. In order to avoid distortion of competition, most Member States, especially those with relatively high tax levels, offer tax exemptions or rebates for the energy intensive industry as well as recycling of tax revenues, e.g. through cutting other taxes.

3.3.1 The National Level

As from 1 April 1999 the German environmental tax reform entered into force. It introduced a tax on electricity and raised the existing taxes on motor fuels and heating fuels. The tax rates were gradually increased each year until 2003. The aim of the tax reform is on the one hand to reduce energy consumption and the resulting emissions. On the other hand, as tax revenues are used for the most part to reduce pension insurance contributions for employers and employees, it is hoped that the tax reform increases employment. The reform contains special provisions for the business sector to prevent a distortion of competition. The manufacturing sector and agriculture pay a reduced tax rate of 60% of the regular tax rate. Additionally, where a manufacturing company's tax burden is greater than its tax relief from the reduction in pension contribution, the company is refunded 95% of the differential amount. As a result, the de facto marginal tax rate is 3% (5% of 60%). Kohlhaas (2005) analyzes the effects of the German environmental tax reform on GDP, employment and CO_2 emissions based on the empirical CGE model LEAN2000. The baseline is BAU where the environmental tax reform had never been introduced. The study shows that the environmental tax reform reduces CO_2 emissions between 2003 and 2010 by 2 – 3% per year. The economic effects compared to the baseline are positive. The change of GDP ranges within the investigated period between +0.13 and +0.47% per year. The increase of employment is between 0.41 and 0.76% per year. In the short-run the impacts on the trade balance are negative because exports decrease and imports increase until 2003. After 2003 imports slightly decrease compared to BAU and exports converge to the BAU level. Conrad and Löschel (2005) examine an environmental tax reform in Germany focussing on the double dividend hypothesis depending on the way tax revenues are recycled. With a fictitious tax on CO2 sufficient to reduce emissions as required by the Kyoto Protocol they find welfare losses of about 0.55% and employment losses of 0.15% if the tax revenues are recycled lump-sum. If the revenues are used to lower non-wage labour costs, welfare losses are reduced to 0.38% while the analysis finds employment increasing by about 0.43%, thereby presenting some support for a weak double dividend.

In the United Kingdom, the Climate Change Levy was announced in the 1999 Budget and introduced in April 2001. It determines tax rates for electricity, gas, coal, and liquefied petroleum gas (LPG). In contrast to the German tax scheme it applies only to industrial and commercial energy use and not to the household and transport sector. Most of the tax revenues are used to reduce employers' national insurance contributions. An 80% discount from the Climate Change Levy is awarded to energy intensive sectors which have negotiated Climate Change Agreement with the government, under which they have taken on collective quantitative targets with regard to energy efficiency and emission reduction. Agnolucci et al. (2005) apply the macroeconometric MDM-E3 model of the U.K. to analyse the effects of the Climate Change Levy. The baseline is BAU which presumes that the Climate Change Levy and the Climate Change Agreement had never been implemented. Total CO_2 emissions are reduced between 2002 and 2010 by 2 – 2.3% per year compared to the baseline. The effect on GDP is very small. By 2010, it is 0.06% above the BAU reference case. Here, the effect of higher energy prices is outweighed by the lower industrial costs caused by the reduction in employers' national insurance contributions. Despite the lower industrial costs, the Climate Change Levy leads to a slight deterioration of the trade performance because the net effect of the tax reform is to slightly raise the costs for those industries producing tradable goods.

3.3.2 The European Level

On the European level, the EU Directive 2003/96/EC on the harmonisation of energy taxation covers electricity, transport, and heating for private, commercial, and industrial use. It defines minimum tax rates for all energy products, namely coal, oil, gas, and electricity, but contains a number of general and Member State specific exemptions and allows for transitional periods before implementation in the new Member States. The changes of national energy taxation due to the EU Directive differ among the Member States. For most EU15 countries energy tax rates are above the EU minimum level anyway. The directive will lead to more important changes in some southern countries and in most of the new Member States.

Kohlhaas et al. (2004) investigate the economic effects of the EU directive by means of the CGE model GTAP-E. They assume that all EU25 countries fulfil the minimum tax rates and all countries with higher tax rates hold them on the higher level. The additional tax revenue is allocated to government spending, private consumption, and private savings in the same proportions as total spending in the initial situation. The baseline is BAU as if the EU directive had never been introduced. After the implementation of the minimum tax rates in those countries that have lower tax rates, the CO_2 emissions decrease in all Member States, particularly in the new Member States. The effects on the national GDPs are very small. They range from – 0.01 to – 0.18% for those countries which need to substantially increase their energy taxes, namely the new Member States. The reduction in GDP must be due to either tax distortions in the economy or a deterioration of terms of trade. Changes in terms of trade play a major role only in the Czech Republic and Poland where the terms of trade decrease by about 0.1%. These two countries also show the largest reduction in GDP. The effects on terms of trade in the other accession countries are negligible.

Koschel (2001) demonstrates that within the framework of CGE models it typically depends on a number of model assumptions – such as substitution patterns in production, the foreign trade specification or the labour market specification – whether employment will increase or not in response to an ecological tax reform. For testing the sensitivity of model results she uses two versions of the GEM-E3 model: the single-country version for Germany and the multi-country EU-14 version. In the standard versions of both models with a neoclassical labour market a (unilaterally in Germany or rather EU-widely imposed) revenue-neutral CO_2 tax leads to higher employment, while CO_2 emissions are reduced by 10%. These positive impacts on employment can be explained by tax shifting effects from labour to the foreign sector and towards capital income. In addition, Koschel (2001) shows that the introduction of labour market imperfections enlarges the opportunity for an employment double dividend.

Kouvaritakis et al. (2003) also use the CGE modelling framework GEM-E3 to analyse the impacts of three different energy tax schemes in the EU15. The tax schemes apply to final energy demand including coal, oil, gas, and electricity. As the demand for motor fuels is not a separate category in an Input-output framework, the implementation of the tax on motor fuels in GEM-E3 remains approximate. The baseline is BAU including existing energy taxes levied for climate change in some Member States. Three policy scenarios are investigated: first, minimum energy tax rates corresponding approximately to the above mentioned EU Directive 2003/96/EC, second, a more climate friendly energy tax scheme that better reflects the carbon content of each energy product, and third, the EU minimum energy taxation when the Kyoto target is fulfilled by EU ETS and a domestic carbon tax. Tax revenues are directly recycled through a decrease of social security contributions. The introduction of minimum energy tax rates in the first scenario reduces CO_2 emissions by 0.5% vis-à-vis BAU. The induced price increase is very small. It is outweighed by the reduction in labour costs. Therefore, GDP does not change and welfare increase slightly by 0.01%. The loss on the export market of 0.02% is very small. In the case of the more climate friendly energy taxation CO_2 emissions are reduced by 2.7%. Both GDP and welfare increase slightly by 0.02%. The price increase reduces slightly the EU exports by 0.08%. The economic impacts remain rather small because the induced price increase is still small and the negative effects on domestic and foreign demand are partly compensated by lower labour costs. As the CO_2 constraint is stronger in the third policy scenario, the economic impacts become negative. GDP decreases by 0.09%, welfare by 0.5% and exports by 0.27%. The efficient design of the EU ETS and the tax revenue recycling strategy still allow avoiding high macroeconomic costs even in countries where the reduction compared to BAU emissions is high. It is also important to remember that in most countries the intra-EU exports represent more than 50% of total exports and this limits the negative effect on exports when a harmonised policy is implemented in the EU.

These results are confirmed by a more recent study based on the same CGE model (Kouvaritakis et al., 2005) which analyses the impacts of an energy tax scheme in the enlarged EU.[4] The baseline is BAU with minimum tax rates of the EU Directive or national tax rates (if they are higher) in the EU15. In the new Member States only the current tax rates apply, regardless of whether they are higher than the minimum tax rates or not. As before, three policy scenarios are considered: first, the introduction of the EU minimum energy tax rates in the new Member States, second, the EU-wide implementation of a more climate friendly tax, and third, the EU minimum energy taxation when the Kyoto target is fulfilled by EU ETS and a domestic carbon tax. The overall economic effects (GDP, welfare, exports) as well as the effects on CO_2 emissions are minor in the case of EU minimum energy taxation or the more climate friendly energy taxation. The impacts on the EU economy are negative if the Kyoto target is to be achieved. An efficient initial allocation of emission allowances and tax revenues recycling may limit these negative effects.

3.4 Policy Measures in the Transport Sector

The former section dealt with broad energy taxes which in part include tax rates on motor fuels. This section is devoted to simulation studies on environmental instruments applied explicitly to the transport sector. The Member States have implemented or discussed several policy measures in order to control emissions of transport activities, including road charges, fuel taxes, or fuel efficiency standards.

3.4.1 The National Level

The German government uses a combination of fuel taxation, voluntary commitment of the automotive industry and road charges for heavy goods vehicles in order to curb the emissions of the transport sector. The German environmental tax reform raised the existing tax rates on transport and heating fuels gradually over five years until 2003. Further increases did not take place due to political and public resistance. Distelkamp et al. (2004) analyse the macroeconomic effects if the tax rates on motor fuels had been further increased in annual steps until 2008 in order to foster emission reduction in the transport sector. For this purpose

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[4] For numerical results see table 2 in the conclusion.

they extend the macroeconometric model PANTA RHEI by a transport module. By 2020, the CO_2 emissions are almost 0.4% below the BAU level. The economic impacts of continuing the tax reform are small. The calculation for 2020 shows no significant change in GDP. Employment increases slightly by 0.2% because the additional tax revenues are used to reduce non-wage labour costs. The shift of tax burden from labour to energy benefits in particular the labour intensive sectors (the Double Dividend effect).

Furthermore, the authors analyse the economic implications of a tax on kerosene in Germany. They assume a Europe-wide introduction of a tax rate of 0.302 € per litre kerosene in 2005.[5] The tax raises the kerosene price for the aircraft companies by 200% and reduces the gross production of this sector by about 7% per year. The impacts for Germany on the macroeconomic level are rather small because the tax revenues are assumed to be used for a reduction of the non-wage labour costs. The GDP does practically not change. Employment increases by around 0.16% from which particularly the service sector benefits. CO_2 emissions decrease by around 0.2%.

The German Association of the Automotive Industry (VDA) and the Association of the European Automotive Industry (ACEA) have committed to increase the fuel efficiency of their automobiles and to limit CO_2 emissions to 140 g/km until 2008. Boeters et al. (2003) examine the economic implications if this standard is introduced already in 2005. They quantify the impacts by means of the CGE model PACE-T covering the EU as well as other major world regions, such as the USA or OPEC. Results are reported for the regions Germany and Austria. The introduction of the standard in 2005 corresponds to a 30% increase of fuel efficiency. It reduces CO_2 emissions of the transport sector by roughly 19% in 2015 and 23% in 2035. Standards are implemented as an implicit fuel tax to reach the standard. The tax revenues are then fully redistributed as (earmarked) subsidies to the transport services sector. The standard reduces the welfare of the representative household by 0.3% per year. As it applies to all EU Member States there are no distortions within Europe. This work suggests that this emissions reduction policy limited to Europe has small effects on large countries outside Europe. E.g. in the United States, welfare of the representative household increases slightly by 0.01% per year. The CO_2 emissions increase by 0.26% in 2015 and 0.56% in 2035. This leakage effect is due to globally decreasing oil prices because of the decreasing demand

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[5] According to the EU Directive 2003/96/EC on the harmonisation of energy taxation, the minimum tax rate for kerosene is 0.302 €/l. Article 14 of the Directive, however, allows the taxation of kerosene used in the non-private air navigation only for domestic flights or between two Member States that have a bilateral agreement. In such cases the Member States may apply a level of taxation below the minimum level.

for motor fuels in Europe. The remainder of Boeters et al. (2003) investigates the economic impacts of a tax on motor fuels. The fuel tax is endogenously determined in the model such that the CO_2 reduction equals the reduction under the efficiency standard. The tax decreases the welfare of the representative household by 0.23%. The macroeconomic costs are slightly smaller because the fuel tax reduces CO_2 emissions by increasing fuel efficiency and decreasing volume of traffic whereas the standard only increases fuel efficiency.

3.4.2 The European Level

Schade and Doll (2005) present a macroeconomic analysis of several transport pricing policies. The policies differ in terms of where and for which modes charges are introduced and how revenues are reallocated to the economic actors. The charging levels are defined on the basis of existing European estimates of infrastructure and environmental costs. The assessment covers the economic impacts for the EU15 until 2020 using the model ASTRA for the transport sector which is able to integrate macro-level modules with micro-level modules. The baseline is BAU which includes all transport policies that are implemented in 2005, e.g. the Trans-European Networks (TEN) and the EURO IV and V emission standards. The results show that the introduction of charges on all modes oriented at levels that would cover the social marginal cost (SMC) of each mode, generates revenues of about 330 billion Euros annually. The revenues are recycled to the economy through lower labour costs. The implementation of charges reduces the GDP by 0.62% and exports by 3.04% relative to BAU. The recycling of tax revenues allows limiting the decline of the GDP but it does not outweigh the cost effect for the industries that produce international tradeable goods. The CO_2 emissions also decrease by 0.62%. The introduction of interurban roads charges leads to revenues of about 70 billion Euros annually. The economic and environmental effects depend on the allocation of the revenues. If they are used to reduce labour costs the GDP and CO_2 emissions decrease by 1.79%. Exports decrease by 2.21% against BAU. If, in contrast, revenues are used for investments into the road mode GDP and CO_2 emissions increase by 0.35% and exports decline by 1.77%. These values suggest that the charge can deteriorate the trade balance. If the revenues are used for investments into road mode, the decline in exports is outweighed by additional economic activity. The positive impact on the GDP, however, goes along with rising CO_2 emissions.

3.5 Policy Measures to Promote Renewable Energy Sources

According to the EU Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources, 22% of total electricity consumption of the EU15 is to be produced from renewables in 2010, compared to 14% in 1997. Taking into account the national targets of the ten new Member States, the collective objective of the EU25 amounts to 21%. The EU Directive does not specify any particular instruments in order to achieve the targets but rather leaves the responsibility for the implementation of appropriate measures with the Member States. The analysis of the policies and measures currently in place in the EU15 indicates that they will probably achieve a share of only 18 – 19% in 2010. Only Denmark, Germany, Spain, and Finland are on track whereas the remaining countries in the EU15 have to implement further measures to reach their targets (European Commission, 2004). A longer term target, stated at the Renewables Conferences 2004 in Berlin and Bonn, is a 20% share of renewable energy sources in primary energy consumption in 2020.

The dominating support system in the EU15 are feed-in tariffs which exist for instance in Germany, Denmark, and the Netherlands. The second important support system are quota obligations associated with a system of tradable green certificates (TGC) which exist for instance in the U.K., Sweden or Italy. Feed-in tariffs are specific prices for green electricity, normally set for a fixed-term period, which electricity companies have to pay to producers of green electricity. The prices are typically differentiated by the type of renewables source, namely hydropower, wind, biomass, and solar. The additional costs of electricity generation due to a larger use of renewables are usually passed on to power consumers by premiums on end-user prices. In the case of a TGC system electricity consumers are required to purchase a certain share of green electricity, i.e. green certificates, according to their electricity consumption. Alternatively producers can be obliged to produce a certain share of green electricity according to their production. In order to exploit the cheapest possibilities consumers or producers are free to trade the green certificates. Thus, in addition to the power market there is a market for green certificates. The TGC scheme has, at least in theory, the advantage that a given share of green electricity can be generated at least costs, whereas a feed-in tariff system would require perfect information on marginal generation costs of all technologies. Feed-in tariffs instead allow for differentiated treatment of technologies, taking other objectives into account than just ‘greening’ of electricity, i.e. it allows for supporting long-term technologies which are not yet competitive.

3.5.1 The National Level

The German renewable energy source act (EEG) entered into force at the beginning of 2000 and it was revised in 2004. It mainly consists of fixed-term feed-in tariffs for renewable energy sources differentiated with respect to technology, installed electrical power, and commissioning date. The additional costs resulting from a higher share of green electricity are distributed among electricity consumers through an explicit premium on electricity prices. A special regulation for electricity intensive companies limits the price increase for these companies and thereby enforces the price increase for the remaining consumers. Schulz et al. (2003) analyse the economic effects of the renewable energy source act over a period from 2004 to 2010 based on an integrated macroeconometric input-output model. The baseline is BAU without promotion of renewable energy sources. The renewable energy source act ends in 2003 und the share of green electricity remains at roughly 8%. In the policy scenario the renewable energy source act applies to the whole period and the target of 12.5% green electricity will be achieved. At first, the GDP increases by 0.11% in 2004 and 0.07% in 2006 because the additional investments in power plants and the supply system encourage economic growth. Afterwards the positive effects of the initial investments are overcompensated by the higher costs of electricity. By 2010 the GDP declines by 0.02% compared to the baseline. The development of employment is similar. The positive developments on the labour market last for a few years but by 2010, the employment is below the BAU level. The exports do not change in the beginning. From 2008 on, the simulations show a slight decline by 0.01% per year.

3.5.2 The European Level

The studies of Uyterlinde et al. (2004 and 2005) survey simulation results with the macro-econometric NEMESIS model and the CGE model NEWAGE-W to assess the economic impacts of a high penetration of renewables in the European electricity sector. The models show the consequences of increasing the share of green electricity up to roughly 30% by 2020, which corresponds to the long term EU target of 20% renewable energy sources in primary energy consumption. Similar to a TGC system, the 30% target is achieved through a quota financed by either endogenous uniform subsidies or premiums on electricity prices. The baseline in all simulation models is BAU including all policy instruments existent by the end of 2003 and a moderate carbon tax from 2012 onward, representing the future European climate policy. The NEMESIS model assumes uniform subsidies from 2005 to 2020 in order to meet the 30% target. The subsidies are passed on to consumers through higher electricity prices. The impacts on macroeconomic indicators for the EU15 are negative. By the end of the simulation period in 2020 both GDP and private consumption decrease by about 0.18%, employment decreases by 0.15% compared to the BAU baseline. The energy price increase reduces the competitiveness in Europe, resulting in a fall of 0.28% for exports. In the NEWAGE-W model the introduction of the 30% quota results in substantially higher electricity prices and higher product prices. The GDP loss of the EU15 amounts to 0.3% in 2010 and 0.8% in 2020. One can observe increasing oil imports to Western Europe whereas gas and coal imports decrease. The GDP loss in Western Europe is not followed by a significant GDP change in neighbouring regions. Böhringer and Löschel (2006) simulate a 30% quota on renewable electricity production with the CGE model PACE. Here,the quota is also achieved through an endogenous uniform subsidy. The result is a relatively modest welfare loss for the EU15 ranging from 0.03% in 2010 to 0.08% in 2020.

4. Summary and Conclusion

Tables 1 to 4 summarise the results. The last column in each table shows the macroeconomic costs of the respective policy instrument as stated in the study. The baseline in all studies is BAU. This means that we consider the effects of environmental policy measures in comparison to the development of the economy without that policy measure. The costs can therefore be seen as price for the improvement of environmental quality if implemented by the regulatory instrument which is analysed. The main focus of this survey is not to evaluate the efficiency of the regulation but to compare their costs as they result from different simulation results.

Table 1 shows the macroeconomic costs of the EU ETS compared to BAU. All policy scenarios assume compliance with the Kyoto targets. Most important for the macroeconomic costs of the EU ETS are the National Allocation Plans (NAPs) and the use of the project-based mechanisms CDM and JI. Both the NAPs and the use of CDM and JI determine how the reduction burden is divided between ETS sectors, non-ETS sectors and reductions abroad. The costs are the lowest, if the optimal split between ETS sectors and non-ETS sectors is implemented and the use of CDM and JI is unrestricted. The comparison of scenarios with different NAPs shows that the macroeconomic costs of the EU ETS increase if reduction burden is shifted from the (energy intensive) ETS sectors to the non-ETS sectors. Considering the restriction of the use of CDM and JI, the more governments and ETS companies can replace costly domestic reductions by cheap reductions abroad the lower are the costs of the EU ETS.

Table 1 Environmental effects and macroeconomic costs of the EU ETS compared to BAU

Study	Model	Policy	Level	Design	Year	Environmental Effect	Macroeconomic Costs
Oberndorfer and Rennings (2007)	Survey	EU ETS	EU15			Kyoto compliance	Small negative effects on macroeconomic variables
COWI (2004)	GTAP-ECAT	EU ETS	EU25	Optimal split between ETS and non-ETS sectors	2010	Kyoto compliance	GDP – 0.36% Export – 0.41% (long-term technology adaptation) GDP – 0.48% Export – 0.55% (short-term adaptation)
Klepper and Peterson (2005)	DART	EU ETS	EU15	Restricted use of CDM/JI	2012	Kyoto compliance	Welfare – 0.9%
Böhringer and Lange (2005b)	PACE	EU ETS	EU15	Permit allocation rules (output vs. emission-based)	2010	Kyoto compliance	Welfare – 0.15% (for permit price ca. 30€ per ton CO_2)
Peterson (2006)	DART	EU ETS	EU25	Restricted use of CDM/JI	2012	Kyoto compliance	Welfare – 1.1%

Table 2 presents the macroeconomic effects of energy taxes on the national or the European level. The macroeconomic costs of policy measures that apply solely to the transport sector are shown in Table 3. The analysis of these instruments shows that particularly revenue recycling and tax exemptions influence the cost burden. The use of revenues for reductions in (non-wage) labour costs benefits the labour intensive sectors and limits the negative effects on GDP and welfare. In some cases they may even create positive effects (Double Dividend). Tax exemptions for energy intensive industries also reduce the macroeconomic costs because they disburden companies that otherwise would have been heavily affected. Obviously this comes at the costs of environmental effectiveness or reduces the regulatory efficiency because comparatively cheap abatement options in these sectors will be ignored.[6]

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[6] For discussion of environmental tax differentiation between industries and households see Böhringer 2002.

Table 2 Environmental effects and macroeconomic costs of energy taxes compared to BAU

Study	Model	Policy	Level	Design	Year	Environmental Effect	Macroeconomic Costs
Kohlhaas (2005)	LEAN 2000	Energy tax	Germany	Tax exemptions and revenue recycling	2010	CO_2 –3.10%	GDP +0.13% Employment +0.46% Exports –0.03%
Conrad and Löschel (2005)	PACE	CO_2 tax	Germany	Tax revenue recycling	2010	Kyoto compliance	Lump sum recycling Welfare –0.55% Employment –0.15%
							Lower labor cost Welfare –0.38% Employment +0.43
Agnolucci et al. (2005)	MDM-E3	Energy tax	U.K.	Tax exemptions and revenue recycling	2010	CO_2 –2.3%	GDP +0.06%
Kohlhaas et al. (2004)	GTAP-E	Energy tax	EU 25		2004	CO_2 reductions in all MS from –0.04% to –3.23%	GDP reductions in a few MS from –0.01% to –0.18%
Koschel (2001)	GEM-E3	CO_2 tax	Germany	Tax revenue recycling	5 years after impl.	CO_2 –10%	GDP +0.11% Employment +0.59% Exports –1.17%
			EU14		1 year after impl.	CO_2 –10%	GDP –0.04% Employment +0.58% Exports –1.02%
Kouvaritakis et al. (2003)	GEM-E3	Energy tax	EU15	Tax revenue recycling	2010	CO_2 –0.5%	GDP +/–0% Welfare +0.01% Exports –0.02%
						CO_2 –2.7%	GDP +0.02% Welfare +0.02% Exports –0.08%
						Kyoto compliance	GDP –0.09% Welfare –0.50% Exports –0.27%
Kouvaritakis et al. (2005)	GEM-E3	Energy tax	EU25	Tax revenue recycling	2010	CO_2 –0.5%	No effects
						CO_2 –3.5%	GDP + 0.01% Welfare + 0.03% Exports – 0.14%
						Kyoto compliance	GDP – 0.10% Welfare – 0.13% Exports – 0.56%

Table 3 Environmental effects and macroeconomic costs of policy measures in the transport sector compared to BAU

Study	Model	Policy	Level	Design	Year	Environmental Effect	Macroeconomic Costs
Distelkamp et al. (2004)	PANTA RHEI	Motor fuel tax	Germany	Revenues used for labour costs reduction	2020	CO_2 – 0.4%	GDP +/– 0% Employment + 0.2%
		Kerosene tax				CO_2 – 0.2%	GDP +/– 0% Employment + 0.16%
Boeters et al. (2003)	PACE-T	Efficiency standard	Germany & Austria		2015	CO_2 in transport sector – 19%	Welfare – 0.3%
		Motor fuel tax					Welfare – 0.23%
Schade and Doll (2005)	ASTRA	Interurban road charges	EU15	Revenue used for labour costs reduction	2020	CO_2 – 1.79%	GDP – 1.79% Exports – 2.21%
				Revenue used for road investments		CO_2 + 0.35%	GDP + 0.35% Exports – 1.77%
		Charges according to SMC of each mode		Revenue used for labour costs reduction		CO_2 – 0.62%	GDP – 0.62% Exports – 3.04%

Table 4 shows the results for policy measures to promote renewable energy sources. Regarding the economic effects of the promotion of renewables, it is often assumed that the promotion of renewables enhance employment and economic growth. The arguments are that renewable energy production is more labour intensive than conventional energy production and that renewable energy production requires less imported goods and services. Indeed, some studies find positive effects on GDP and employment in the short run. In the long run, however, higher generation costs often dominate the net effect.

Table 4 Environmental effects and macroeconomic costs of policy measures to promote renewable energy sources compared to BAU

Study	Model	Policy	Country	Design	Year	Environmental Effects	Macroeconomic Costs
Schulz et al. (2003)	Input-output model	Promotion of renewables	Germany	Feed-in tariffs	2010	12.5% green electricity	GDP – 0.02% Exports – 0.01%
Böhringer and Löschel (2006)	PACE (Hybrid Bottom-up – Top-down)	Promotion of renewables	EU15	Subsidy	2020	30% green electricity	Welfare –0.08%
Uyterlinde et al.	NEMESIS	Promotion of renewables	EU15	TGC	2020	30% green electricity	GDP – 0.18% Employ. – 0.15% Exports – 0.28%
(2004) and (2005)	NEWAGE-W	Promotion of renewables	EU15	TGC	2020	30% green electricity	GDP – 0.8%

Due to a variety of assumptions in the models, the results in the four tables should be neither combined to assess total costs of environmental regulation[7] nor compared directly with each other. The model assumptions differ with regard to the BAU baseline, technological progress, time frame, the elasticity of domestic and foreign demand, and – last but not least – by the specific regulatory design.

Considering these results, we can conclude that the environmental regulation affects the European economy. The macroeconomic costs, however, appear to be relatively small. Most studies find losses clearly below 1%, some even indicate macroeconomic gains.[8] The values in the tables show only the effects on the macroeconomic level. They do not show the distributional effects on the sectoral level. The impacts of environmental regulation are likely to be more severe on the sectoral than on the macroeconomic level creating winners and losers. Recycling of government revenues raised by environmental regulations in the energy sector tends to benefit labour intensive sectors, such as services and the building industry, and penalises energy intensive sectors, such as the power industry and agriculture. The effects on exports in the simulation studies are typically negative. The loss for the entire economy is somewhat smaller because there are also sectors that benefit from the regulation. It is important to remember that our analysis contains only the economic costs or benefits. It does not include the ecological or indirect economic benefits that result from the regulation in form of avoided climate change damages or reduced non-GHG air pollution. On the whole, the costs are lower the more flexible the instrument is, i.e. the better it allows for ‘where’, ‘what’, and ‘when’ flexibility.

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[7] Such an assessment would have to consider furthermore the overlapping impacts of the policy measures. For discussion on overlapping instruments in European carbon emission regulation, see Böhringer et al. (2006).

[8] A recently published review on the economics of climate change (Stern 2006) – albeit disputed – concludes that reducing greenhouse gas emissions on a global level to “avoid the worst impacts of climate change” is possible at costs below 1% of global GDP per year.

References

Agnolucci, P., D. Anthony, T. Barker, P. Ekins, B. Etheridge, B. Gardiner, S. Junankar, O. Lofsnaes, and J. Stenning (2005), *Modelling the Initial Effects of the Climate Change Levy*, University of Cambridge and the Policy Studies Institute (PSI).

Atkinson, A. B. and J. E. Stiglitz (1980), *Lectures on Public Economics,* London.

Boeters, S., C. Böhringer, A. Löschel, and C. Glück (2003), *Klimaschutzoptionen im Verkehrsbereich*, Research Report on behalf of the Volkswagen AG, Wolfsburg (not published).

Böhringer, C. (2002), *Environmental Tax Differentiation Between Industries and Households,* ZEW Discussion Paper No. 02-08, Mannheim.

Böhringer, C., H. Koschel, and U. Moslener (2006), *Efficiency Losses from Overlapping Economic Instruments in European Carbon Emissions Regulation,* ZEW Discussion Paper No. 06-018, Mannheim.

Böhringer C., T. Hoffmann, A. Lange, A. Löschel, and U. Moslener (2005), Assessing Emission Regulation in Europe: An Interactive Simulation Approach, *The Energy Journal* 26 (4), 1-22.

Böhringer, C. and A. Lange (2005a), Mission Impossible!? On the Harmonization of National Allocation Plans under the EU Emission Trading Directive, *Journal of Regulatory Economics* 27 (1), 81-94.

Böhringer, C. und A. Lange (2005b), Economic Implications of Alternative Allocation Schemes for Emission Allowances, *Scandinavian Journal of Economics* 107 (3), 563-581.

Böhringer, C., and A. Löschel (2006), Promoting renewable energy in Europe: A Hybrid Computable General Equilibrium Approach, Special Issue of *The Energy Journal,* Hybrid Modeling of Energy-Environment Policies: Reconciling Bottom-up and Top-down, 135-50.

Bosetti, V., C. Carraro, and M. Galeotti (2006a), The Dynamics of Carbon and Energy Intensity in a Model of Endogenous Technical Change, *The Energy Journal*, *Special issue*, 191-205.

Bosetti, V., C. Carraro, and M. Galeotti (2006b) Stabilisation Targets, Technical Change and the Macroeconomic Costs of Climate Change Control, *Nota di Lavoro* 2.2006, Fondazione Eni Enrico Mattei (FEEM), Milan, Italy.

Bovenberg, A. L. (1995), Environmental Taxation and Employment, *De Economist* 143, 111-140.

Common, M. and S. Stagl (2005), *Ecological Economics – An Introduction,* Cambridge.

Conrad, K. und A. Löschel (2005), Recycling of Eco-Taxes, Labor Market Effects and the True Cost of Labor - A CGE Analysis, *Journal of Applied Economics* 8 (2), 259-78.

COWI (2004), *Competitiveness and EU Climate Change Policy,* Interim Report COWI for UNICE.

Distelkamp, M., C. Lutz, B.Meyer, and M. I. Wolter (2004), *Schätzung der Wirkung umweltpolitischer Maßnahmen im Verkehrssektor unter Nutzung der Datenbasis der Gesamtrechnung des Statistischen Bundesamtes,* GWS Discussion Paper 2004/05, Osnabrück.

European Commission (2003), External Costs – Research results on socio-environmental damages due to electricity and transport, Brussels.

European Commission (2004), *The share of renewable energy in the EU,* Communication from the Commission, COM (2004) 366 final.

European Union (2001), *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market,* Official Journal of the European Union 27.10.2001.

European Union (2003), *Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity,* Official Journal of the European Union 31.10.2003.

Goulder, L. H. (2004), *Induced Technological Change and Climate Policy,* Pew Center on Global Climate Change.

Goulder, L. H. (1995), Environmental Taxation and the Double Dividend: A Reader's Guide, *International Tax and Public Finance* 2, 157-183.

Jaffe, A. B., S. R. Peterson, P. R. Portney, and R. N. Stavins (1995), Environmental Regulation and the Competitiveness of the U.S. Manufacturing: What does the Evidence Tell Us? *Journal of Economic Literature* 33, 132-163.

Jenkins, R. (1998), *Environmental Regulation and International Competitiveness: A review of Literature and Some European Evidence,* United nations University, Institute for new technologies, Discussion paper Series 9801, Maastricht.

Kaiser, K. and G. G. Schulze (2003), *International Competition and Environmental Expenditures: Empirical Evidence from Indonesian Manufacturing Plants,* HWWA Discussion Paper 222, Hamburg.

Klepper, G. and S. Peterson (2005), *Emissions Trading, CDM, JI, and More – The Climate Strategy of the EU,* Kieler Working Paper No. 1238, Kiel.

Kohlhaas, M. (2005), *Gesamtwirtschaftliche Effekte der ökologischen Steuerreform,* Forschungsprojekt im Auftrag des Umweltbundesamtes, FKZ 204 41 194, Berlin.

Kohlhaas, M., K. Schumacher, J. Diekmann, D. Schumacher, and M. Cames (2004), *Economic, Environmental and International Trade Effects of the EU Directive on Energy Tax Harmonisation,* DIW Discussion Papers 462, Berlin.

Koschel, H. (2001), *A CGE Analysis of the Employment Double Dividend Hypothesis – Substitution Patterns in Production, Foreign Trade, and Labour Market Imperfections,* Universität Heidelberg, Wirtschaftswissenschaftliche Fakultät (http://archiv.ub.uni-heidelberg.de/volltextserver/volltexte/2002/1839/pdf/koschel-diss.pdf 01.03.2007)

Kouvaritakis, N., L. Paroussos, and D. Van Regemorter (2003), *The macroeconomic evaluation of energy tax policies within the EU, with the GEM-E3-Europe model,* Final Report of the Study for the European Commission, TAXUD/2002/DE/302.

Kouvaritakis, N., N. Stroblos, and L. Paroussos (2005), *Impacts of Energy Taxation in the enlarged European Union – Evaluation with GEM-E3 Europe,* Final Report of the Study for the European Commission, TAXUD/2003/DE/308.

Löschel, A. (2002), Technological Change in Economic Models of Environmental Policy: A Survey, *Ecological Economics* 43, 105-126.

Oberndorfer, U. and K. Rennings (2007), Costs and Competitiveness Effects of the European Union Emissions Trading Scheme, *European Environment* 17 (1), 1-17.

Perman, R., Y. Ma, J. McGilvray, and M. Common (2003), *Natural Resource and Environmental Economics,* Harlow.

Peterson, S. (2006), *Efficient Abatement in Separated Carbon Markets: A Theoretical and Quantitative Analysis of the EU Emissions Trading Scheme*, Kieler Working Paper No. 1271, Kiel.

Porter, M. E. and C. van der Linde (1995), Towards a new Conception of the Environment-Competitiveness Relationship, *The Journal of Economic Perspectives* 9 (4), 97-118.

Porter, M. E. (1999), Nationale Wettbewerbsvorteile, in: Porter, M. E. (Ed.), *Wettbewerb und Strategie,* München, 165-206.

Schade, W. and C. Doll (2005): Macroeconomic analysis of transport pricing regimes for the EU, in: Jaszkiewicz, A., M. Kczmared, J. Zak, and M. Kubiak (Eds.) *Advanced OR and AI Methods in Transportation,* Poznan, 318-325.

Schulz, W., M. Peek, C. Gatzen, M. Bartels, M. Kalies, M. Nill, B. Hillebrand, M. Bleuel, J.M. Behringer, and H.G. Buttermann (2003), *Gesamtwirtschaftliche, sektorale und ökologische Auswirkungen des Erneuerbare Energien Gesetzes (EEG)*, EWI, IE, RWI, Gutachten im Auftrag des Bundesministeriums für Wirtschaft und Arbeit.

Stern, N. (2006), *Stern Review: The Economics of Climate Change*, Cambridge.

Taistra, G. (1999), *Die Porter-Hypothese zur Umweltpolitik*, Wiesbaden.

Uyterlinde, M.A., G. H. Martinus, E. van Thuijl, N. Kouvaritakis, L. Mantzos, V. Panos, M. Zeka-Paschou, K. Riahi, G. Totsching, I. Keppo, P. Russ, L. Szabo, S. Kypreos, P. Rafaj, C. Böhringer, A. Löschel, I. Ellersdorfer, M. Blesl, P. le Mouël, A. S. Kydes, K. Akimoto, F. Sano, T. Homma, and T. Tomoda (2004), *Energy Trends for Europe in a Global Perspective,* CASCADE MINTS project, Vol. 1.

Uyterlinde, M. A., G. H. Martinus, H. Rösler, N. Kouvaritakis, V. Panos, L. Mantzos, M. Zeka-Paschou, S. Kypreos, P. Rafaj, M. Blesl, I. Ellersdorfer, U. Fahl, I. Keppo, K. Riahi, C. Böhringer, A. Löschel, F. Sano, K. Akimoto, T. Homma, T. Tomoda, F. Pratlong, P. le Mouël, L. Szabo, P. Russ, and A. Kydes (2005), *The Contribution of Renewable Energy to a Sustainable Energy System*, CASCADE MINTS project, Vol. 2.