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The EU-ETS and existing energy taxes

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Abstract

Imposing emission ceilings with freely tradable permits is an efficient way of meeting climate change objectives in an undistorted world. However, the efficiency of such a system is reduced because of the many distortions that are pre-existing. Of these we focus on existing energy taxes within EU-member states. These taxes differ widely, by energy carrier, by user and by member state. Making use of the global general equilibrium model WorldScan, we assess the efficiency gains associated with tax reforms that bring energy taxes more in line with the objective of abating global warming. Moreover, the overall efficiency of the EU system aiming at emissions reduction is also assessed vis-à-vis a cap-and-trade system that covers the complete economy. Finally, we show the additional benefits of specific forms of revenue recycling when permits are auctioned over and above recycling in a lump-sum fashion.

Key words: cap-and-trade, energy taxation, tax harmonization, revenue recycling, double dividend

JEL code: D58, D61, H3, Q25, Q48

Contents

1 Introduction

Under the Kyoto Protocol, the European Union has committed itself to reduce its greenhouse gas emissions over the period 2008-2012 by eight percent below 1990 levels. One of the major tools that have been put in place to achieve this commitment is the EU Emissions Trading Scheme (EU-ETS). This cap-and-trade system is currently in its first, 2005-2007, start-up phase. It puts a cap on CO_2-emissions from large combustion installations with a capacity exceeding 20 MW. It covers power and heat production plants, oil refineries, coke ovens, metal ore and steel installations, cement kilns, glass and ceramics manufacturing, and paper, pulp and board mills. Together these installations account for nearly half of EU-25 fossil fuel CO_2 emissions. Accession to this scheme of other emitters and other greenhouse gases is possible in its second stage that coincides with the Kyoto period 2008-2012. Emission permits are allocated to firms by national governments (subject to approval by the European Commission) and are freely tradeable. Most of the permits have been grandfathered but the directive allows for permit auctions as well, albeit subject to a maximum of ten percent in the second phase (EU, 2003). The EU-ETS establishes a uniform emissions price for all installations that it covers throughout the member states. Hence, emissions abatement will be efficient and undertaken at the lowest possible costs.

The aim of this paper is to analyse the interactions between the EU-ETS and EU energy taxation and to assess the importance of these interactions. Cap-and-trade systems and taxation are intimately related. We distinguish three relationships.

First, the cap would alternatively materialize if CO_2 emissions would be taxed at exactly the level of the permit price. Hence, the claim that a cap-and-trade system is cost-effective presumes that energy use is not taxed in additional non-uniform ways. Energy taxes are abundantly present, however, especially in the member states of EU-15, and widely varying by energy carrier, by user and by member state. The relative height of energy taxes bears no relation whatsoever to CO_2 emissions. In general, coal (that is the leading emitter of CO_2 per unit of energy burned) is hardly taxed while transport fuels are taxed most severely. Taxation of energy inputs for consumption generally exceeds taxation of energy use in production and bulk users of energy tend to be taxed much more mildly than small-scale users. Fuel excises in transportation are high, but generally not applied in aviation and overseas shipping. Hence, with pre-existing energy taxes abounding and widely diverging by carrier, user and member state the cost-effectiveness of an additional cap-and-trade system is not guaranteed.

Second, though the coverage of EU-ETS (large combustion installations) may be extended in its second phase, there is no doubt that the cap will continue to be imposed on only part of the economy (henceforth: the regulated sectors). As by the EU Burden Sharing Arrangement each member state has taken on a cap on total emissions, permit allocation to the regulated sectors implicitly puts a complementary, national cap on emissions from the other (hereinafter: nonregulated) sectors. Reduction of emissions from these sectors is to be addressed by a large variety of policies at EU and national levels: caps at the sectoral level, either absolute (*e.g.* for Dutch horticulture) or relative (*e.g*. under the Climate Change Levy system in the United Kingdom), voluntary agreements (*e.g*. with personal car manufacturers at EU-level to reduce CO_2 emissions), prescribed standards (*e.g*. required minimal shares of biofuels in transportation at the national level) or additional taxation. Moreover, national governments may purchase credits under the Clean Development Mechanism (CDM) in non-Annex I countries or Join Implementation (JI) projects outside EU-25, to cover excess emissions of the nonregulated sectors. There is evidence that marginal emission reduction costs in the regulated sectors are on average below those of the nonregulated sectors (Böhringer *et al*., 2005). In general, marginal abatement costs of the regulated sectors under the EU-wide cap will differ from the marginal costs incurred by the nonregulated sectors while the latter also will differ among member states due to the Burden Sharing Arrangement. Compliance costs of the nonregulated sectors depend directly on the amount of permits allocated to the regulated sectors. The tighter the cap will be for the latter, the easier emission reduction will be for the former. The separation of emissions reduction within EU-25 in many different compartments thus raises questions concerning the efficiency of the overall abatement effort (Egenhofer *et al*., 2006). Over- or underallocation of permits to the regulated sectors may have an important impact on marginal abatement costs in the nonregulated sectors. The latter can be summarised by the implicit tax on nonregulated emissions that would be required to meet their national ceiling. As the emissions price of the regulated sectors is equivalent to an emissions tax, this price can be used as a benchmark with which the abatement costs of the nonregulated sectors can be compared. That is, again presuming that pre-existing taxes are absent.

The third connection between cap-and-trade and taxation is rather more direct. When emission permits are auctioned, the auction receipts can be recycled back into the economy. Though the possibilities to do so are numerous, the economic literature suggests that using these receipts to slash existing tax distortions improves economic welfare more than a lump-sum transfer to the economic agents. According to the weak double dividend hypothesis, revenue recycling through cuts in distortionary taxes improves economic welfare relative to recycling through lump-sum payments. The strong double dividend hypothesis suggests that substitution of an environmental tax for a distortionary tax will improve economic welfare. Hence, the introduction of an environmental tax would not only enhance environmental quality but also non-environmental welfare (double dividend). Note that the weak hypothesis compares two alternative policy simulations (each with a different way of recycling revenues) with a common baseline whereas the strong hypothesis compares just one policy change with the status quo (Bovenberg, 1999). Though the weak double dividend hypothesis is generally undisputed, Babiker *et al.*, 2003, give a counterexample. Their model simulations suggest that recycling EU permit revenues back into the economy by reducing non-energy taxes on household consumption decreases economic welfare relative to revenue-recycling in a lump-sum fashion. The reason for this outcome is that EU energy taxes on household consumption are high relative to the non-energy taxes on consumption and become even more distorting when the latter are reduced. The assertion of the strong double dividend hypothesis is seldomly confirmed in empirical work. Yet, model simulations by Kouvaritakis *et al.*, 2005, show that economic welfare may improve when EU permit revenues are used to reduce employer's social security contributions. Obviously, verification of the double dividend hypotheses requires model simulations in a particular empirical setting.

In this paper we use a dynamically recursive global applied general equilibrium model, WorldScan, as a tool to analyse and assess the impacts of EU cap-and-trade and EU energy taxation. This tool is well-suited for this purpose for several reasons. First, being an applied general equilibrium it enables to assess the impacts of policy changes on economic welfare. Next, because the model has global coverage, it will show the extent of carbon leakage when the efforts made in emission reductions are unevenly distributed over countries. The model is calibrated to the 2001 baseyear data of GTAP-6 (Dimanaran and McDougall, 2006). This database covers national accounting data, fully connected by bilateral trade flows, for 87 (groups of) countries and 57 sectors. As WorldScan can be tuned to arbitrary reclassifications of these data, its simulation outcomes can reflect enough detail at the country and sectoral levels to be of interest to policy makers. One should bear in mind however that the outcomes are of a long term nature. In particular, adjustment costs of structural adjustment are not reflected: sectoral employment adjusts instantaneously and does not temporally raise unemployment.

The paper is organised as follows. In section 2 we briefly present the characteristics of WorldScan, the baseline and EU energy taxation. Section 3 focuses on energy tax harmonisation as an alternative to installing a cap-and-trade system for emissions reduction. Section 4 assesses the overall efficiency of EU emissions abatement and compares abatement costs for the sectors regulated by the EU-ETS with the implicit costs that have to be borne by the nonregulated sectors to meet the remaining national cap imposed by the Burden Sharing Agreement. Section 5 assesses the benefits of alternative ways of revenue recycling when the permits are auctioned. The final section concludes.

2 Characteristics of WorldScan, the baseline and EU energy taxation

2.1 WorldScan

WorldScan is an applied general equilibrium model for the world economy. The model was developed in the nineties for long term scenario development and has thereafter often been used for scenario studies, assessments of EU-accession impacts and analyses of climate-change and trade policies. WorldScan is well suited to simulate scenario developments on demography, technology, energy and globalisation. The model consists of several types of equations: behavioural equations which describe the behaviour of firms and consumers, identities and accounting relations and is documented in Lejour *et al.*, 2006. The model version used in this paper is further extended over and above the description in Lejour *et al.*, 2006 in the following way. In OECD-countries labour supply is made to respond to deviations of the net real wage from the base line with an elasticity of 0.25. The value of this elasticitity is based on a meta-analysis by Evers, de Mooij and van Vuuren, 2006. Modelling the response of labour supplyin this way is admittedly rather *ad hoc* because labour supply is not explicitly derived from the maximization of househould utility containing leisure as an argument. The extension has nevertheless been added in order to give the assertion of the strong double dividend hypothesis a more realistic chance to materialise.

General equilibrium models are based on microeconomic behaviour of all relevant agents. Producers maximize profits and consumers maximize utility. Production technologies relate output to inputs, so a potential increase in the output of a sector leads to extra demand for inputs. This links output to input markets. Moreover, trade flows between countries, and in particular two-way intra-industry trade, are explicitly modelled. The integration of national goods and services markets and of capital markets creates the possibility to analyse spillovers between countries. Another advantage is that the model may distinguish many different sectors in many countries simultaneously. Here, we face the boundaries of analytical tractability and computability though. Hence, the number of sectors and countries that can be distinguished simultaneously has its limits.

The version of WorldScan used in this paper distinguishes 9 goods and services markets, a labour market, and a capital market for each of the 21 countries and regions distinguished (see Table 2.1). Five energy carriers are distinguished: coal, petroleum and coal products, natural gas, commercial biomass and renewables. Renewables are inclusive of nuclear energy. Only the first three of these are contributing to fossil fuel CO_2 emissions. Biomass and renewables are assumed to be untradeable and their input-output structure is derived from the sectors 'Agriculture' and 'Other services' respectively.

Table 2.1 Overview of regions, sectors and production inputs in WorldScan

Regions	Sectors	Inputs
Germany	Agriculture	Factors
France	Minerals	Low-skilled labour
United Kingdom	Oil	High-skilled labour
Italy	Coal	Capital
Spain	Petroleum, coal products	Fixed factor
Netherlands	Natural gas	
Rest of EU-15	Electricity	Energy carriers:
New member states	Energy intensive products	Coal
Other Europe	Chemical products	Petroleum, coal products
Turkey	Consumer goods	Natural gas
United States	Capital goods and durables	Commercial biomass
Canada	Transport	Renewables
Australia	Other services	
Other OECD		Other intermediates:
Former Soviet Union		Agriculture
China		Minerals
India		Oil
Brazil		Electricity
Other Latin America		Energy intensive products
Middle East and North Africa		Chemical products
Rest of World		Consumer goods
		Capital goods and durables
		Transport
		Other services

A disadvantage of applied general equilibrium models is that these models sometimes lack an empirical underpinning. These models are calibrated on macroeconomic and input-output data of a certain base year. The calibration determines a number of parameters in the model, but the values of quite a few other parameters have to be taken from the literature. Not all of these parameters are estimated well within the context of a AGE model. Moreover, the models are calibrated only at one point in time. WorldScan is a dynamic model and enables analyses of policy variants over long time periods. Moreover, we have spent much time to underpin the behavioural equations empirically. Examples of these equations are those decribing consumer behaviour, savings behaviour and international capital mobility.This remedies to some extent the disadvantage mentioned above: WorldScan is empirically better underpinned than many other AGE models. Yet, not all parameters have been estimated. Hence, the outcomes should be interpreted with some care.

Finally, we do not carry out a complete welfare analysis. In the model consumer utility depends on consumption, but not on leisure, environmental quality or inequality. By consequence, the simulation outcomes do not represent a trade-off between higher consumption and leisure or environmental quality, or between efficiency and equity. These limitations of our quantitative analysis have also to by borne in mind when interpreting the simulation outcomes.

2.2 Baseline

In order to assess the impacts of policy measures a baseline is needed that describes how the economies would develop in the absence of such policies. We adopt the WEC/IIASA 'Middle

Course' scenario B as our reference case (WEC, 1998). This scenario is characterized by a cautious approach to technological change and energy availability as well as modest economic growth. It does not include climate change policies or carbon taxation. We update the scenario for observed GDP-growth over the period 2001-2004.

We briefly summarize the characteristics of this scenario. Table 2.2 shows the 2001 baseyear data for population, GDP, energy use and emissions. It also gives the energy intensity (the ratio of energy use and GDP) and emissions-intensity (the ratio of emissions and energy use) relative to the values of these ratios in the USA. Energy intensities are relatively high in non-OECD countries and the new member states. The emissions-intensity is relatively high in the new member states because coal is still the dominant energy input in these countries. In contrast, the emissions-intensity in non-OECD countries is rather low because of the large share of biomass in total fuel use.

Table 2.2 Base-year data, 2001

	Population	GDP	Energy use[a)]	Emissions	E-Intensity	CO_2-Intensity
	(mln)	(bn $)	(Mtoe)	($GtCO_2$)	(USA=100)	(USA=100)
EU-25	453	9169	1670	3,73	87	94
Germany	83	2057	367	0,83	86	95
France	60	1463	183	0,39	60	89
United Kingdom	59	1584	259	0,54	78	89
Italy	57	1215	200	0,41	79	87
Spain	41	647	127	0,28	94	95
Other EU-15	79	1802	330	0,71	88	91
New Members	75	402	204	0,57	243	117
United States	288	11194	2335	5,52	100	100
Other OECD	317	6618	1065	2,58	77	102
Non-OECD	5008	7738	5228	10,92	324	88
World	6067	34719	10298	22,75	142	93

a) Sum total of coal, petroleum, natural gas, commercial biomass and renewables

The projected growth in the baseline of these indicators, as shown in Table 2.3, indicates a reduction of energy intensities in all countries and decreasing emission intensities as well, except in non-OECD.

Table 2.3 Baseline characteristics, average annual growth, 2001-2020

	Population	GDP	Energy use	Emissions	E-Intensity	CO_2-Intensity
	%	%	%	%	%	%
EU-25	0,3	1,8	0,6	0,1	-1,1	-0,5
Germany	0,3	1,7	0,6	0,0	-1,2	-0,6
France	0,3	1,7	0,3	-0,4	-1,4	-0,7
United Kingdom	0,3	1,7	1,0	0,5	-0,8	-0,5
Italy	0,3	1,7	0,7	0,1	-1,1	-0,6
Spain	0,3	1,7	0,2	-0,5	-1,6	-0,7
Other EU-15	0,3	1,7	0,6	0,0	-1,1	-0,6
New Members	0,3	2,6	0,8	0,6	-1,8	-0,2
United States	0,6	1,9	0,8	0,7	-1,2	-0,0
Other OECD	0,8	1,5	0,5	0,0	-1,0	-0,6
Non-OECD	1,4	3,5	2,2	2,2	-1,3	0,1
World	1,3	2,2	1,5	1,4	-0,7	-0,1

2.3 EU energy taxation

Different fuels are taxed at very different rates within almost all European countries, and the same fuel is taxed at very different rates from one country to another. This raises the question why energy is taxed at all. Several justifications for energy excise taxes have been advanced (Newberry, 2005): as an optimal import tariff, where each trading bloc has considerable market power, as a carbon tax or equivalent permit charge to reflect global warming, as a second-best method of charging vehicles for road use and as a corrective device to address failures elsewhere in the tax system (primarily failures due to income tax evasion). Newberry concludes that in most cases the taxes predate environmental concerns, are not related in any systematic way to environmental damage, and do not meet minimal criteria for so doing. Coal is almost invariably the most environmentally damaging fuel, but it is usually the least heavily taxed. If road fuel taxes can to a considerable extent be justified as road user charges, there is little evidence that road taxes are set on the basis of charging the long-run marginal cost of expanding roads. In addition, income distributional and competitiveness concerns also play a role in energy taxation (OECD, 2003, and OECD, 2006). In the United Kingdom, for example, consumers are exempt from the Climate Change Levy and receive sizable VAT rebates on household use of coal, natural gas and electricity (cf. Appendix, Table A.1), while in many countries bulk users of energy are taxed at lower rates than small-scale users (see OECD, 2003, for examples).

Table 2.4 Energy taxes, expressed in euro per ton CO_2, by primary energy carrier and user, excluding normal VAT for consumers, 2001

	Producers:			Consumers:		
	Coal	Petroleum	Natural gas	Coal	Petroleum	Gas
EU-25	0	79	7	0	213	12
Germany		80	10	0	295	10
France		76	8	0	195	-1
United Kingdom	3	144	3	-2	304	-6
Italy		86	9	0	197	47
Spain		49	7	0	121	0
Other EU-15		72	7	0	165	11
New Members		32	3	0	181	0
United States		19	3	0	14	0
Other OECD	1	42	4	0	113	0
Non-OECD	1	13	3	0	27	1
World	1	31	3	0	62	4

Source: WorldScan

Because energy tax rates in the GTAP-6 database are not always accurate, we updated them with rates obtained from IEA, 2006 and scaled the outcomes for total fuel excises to the tax revenues reported by OECD, 2006. The rates adopted are given in the appendix (Table A.1 and Table A.2). Van Leeuwen, 2006, documents the rules of thumb used in the upgrading process and compares the rates adopted with the rates of GTAP-6. It should be noted that the rates adopted do not reflect firm-level tax-rebates and exemptions (as, for example, applied on deliveries to bulk users).

In order to facilitate a comparison with emission permit prices we express existing energy taxes on a euro per ton CO_2 basis by dividing tax revenue by emissions (Table 2.4). The differences in implicit emission taxes in this table stem from two sources: differences in tax rates adopted on primary energy use and differences in the emission intensity of this use. Note that a normal VAT is deducted for consumers. Hence, households may receive a subsidy on the use of coal (as in the United Kingdom) and natural gas (United Kingdom and France). The table shows that petroleum is predominantly taxed and that consumers are almost everywhere – the USA being an exception – taxed more severely than producers. Compared to the member states of EU-15 producers are relatively mildly taxed in the new member states.

Energy taxation expressed as carbon taxation also differs by sectoral destination. This is shown in Table 2.5. Taxes in the transport sector are much higher than in the other sectors and primary energy carriers used by the electricity sector tend to be taxed relatively mildly.

Table 2.5 Energy taxes on total primary energy usage, expressed in euro per ton CO_2, by sector , 2001

	Agricul-ture	Minerals and fuels	Electri-city	Energy intensive	Chemical products	Consu-mer and capital goods	Trans-port	Other services	All sectors
EU-25	19	2	2	13	22	14	155	15	37
Germany	17	1	1	10	16	13	196	15	34
France	20	1	3	14	18	11	132	15	51
United Kingdom	32	5	3	20	27	19	274	19	60
Italy	30	1	9	21	25	20	145	30	55
Spain	9	1	2	8	9	8	94	9	29
Other EU-15	24	3	4	17	39	18	126	19	36
New Members	7	0	1	5	6	3	76	5	8
United States	3	2	1	2	3	2	28	3	6
Other OECD	16	2	3	7	9	9	103	8	19
Non-OECD	4	2	2	2	4	3	25	3	5
World	9	2	1	5	8	6	60	6	12

Source: WorldScan

Aggregating the carbon tax equivalents of existing energy taxes over destinations yields total taxes by primary energy carrier as shown in Table 2.6.

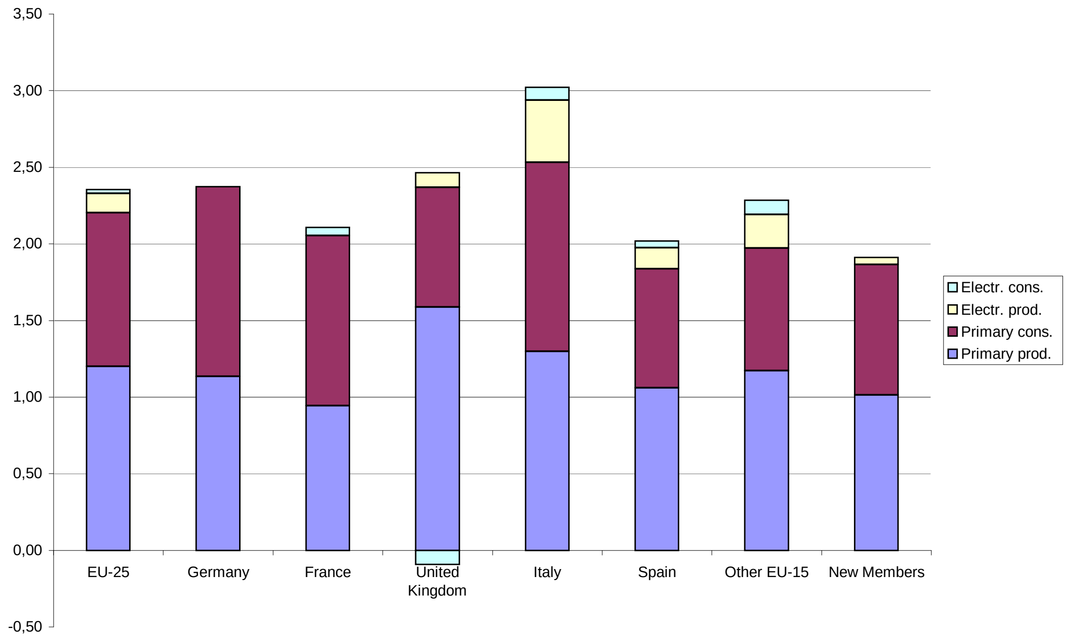
Table 2.6 Energy taxes, expressed in euro per ton CO_2, on total usage by primary carrier, on electricity by user and in total, excluding normal VAT for consumers, 2001

	Total primary			Electricity			Grand total
	Coal	Petroleum	Natural gas	Total	Producers	Consumers	
EU-25	0	111	9	54	11	2	58
Germany	0	130	10	59	0	0	59
France	0	114	5	78	0	40	80
United Kingdom	2	176	-1	69	9	-9	69
Italy	0	114	29	75	69	15	90
Spain	0	66	6	42	13	4	46
Other EU-15	0	93	8	50	23	10	58
New Members	0	52	2	13	1	0	14
United States	0	17	2	8	4	0	9
Other OECD	1	59	3	30	22	2	37
Non-OECD	1	16	2	6	6	0	9
World	0	40	4	17	7	1	20

Source: WorldScan

The table also shows the implit carbon tax associated with taxes on electricity. Again, electricity usage is taxed rather differently at different locations. Household electricity usage in the United Kingdom is subsidized when a normal VAT is deducted, while the relatively high tax on French electricity consumption is due to the relatively high share of nuclear power generation in France. Adding electricity taxes to primary energy taxation yields the ‘ Grand total’ column, which shows the sum total of energy tax receipts on primary carriers and electricity divided by total CO_2 emissions. The table suggests that energy taxation converted to implicit carbon taxes is most severe in France and Italy, both for primary carriers and when electricity is included. Within EU-25 energy taxation is lowest in the new member states.

Figure 2.1 Energy tax receipts as percentage of GDP, 2001



It should be noted that our representation of existing energy taxes as carbon taxes is not meant as a criticism of the structure of existing taxation. The conversion simply demonstrates that – whatever the motives for these taxes – they certainly are not geared to reduce carbon emissions. Energy taxation, being dominated by transport fuel taxation, may well function as a stable source of tax revenue. As a percentage of GDP the revenue raised is approximately in the 2-2.5% range (Figure 2.1). This is also the case for the new member states.

3 Cap-and-trade or energy tax harmonization or both?

In the previous section we showed that existing energy taxes, expressed as carbon tax equivalents, are quite high in the EU. On average the implicit carbon tax for EU-25 amounts to 54 euro/tCO_2 for primary energy carriers and this amount would be raised to 58 euro/tCO_2 if electricity taxes were included as well. This raises the question how tax harmonisation in terms of carbon taxation would fare as a device to curb CO_2 emissions.

As a background to the analysis of energy tax harmonization we put a cap-and-trade scenario in place, named ETSFULL, with the following characteristics

- the caps refer to all CO_2 emissions and require all agents to hold permits against emissions
- for the period 2008-2012
  - all Annex-I parties impose their Kyoto ceilings, except for Australia and the USA
  - the ceilings for individual member states of EU-25 are determined by the Burden Sharing Agreement; permits are auctioned up to a maximum of 10%; the revenues are recycled lump-sum to households
  - permits are freely tradeable within EU-25; all other Annex-I countries follow a stand-alone system without permit trade; no use is made of CDM or JI
- for the period 2013-2017
  - all Annex-I parties, except EU-25 but including Australia and the USA, put their cap equal to 99% of 2012 emissions in 2013 and decrease the cap annually by 1%
  - EU-25 takes another Kyoto-step and engages to reduce emissions with another 8% of 1990 emissions; separate ceilings for member states are absent; permit allocation to member states is in proportion to emissions of the preceding year; all permits are auctioned on a yearly basis; the revenues are recycled lump-sum to households
  - permits are freely tradeable within EU-25 only and no use is made of CDM or JI
- for the period 2018-2020
  - all Annex-I parties put their cap equal to 2017 emissions
  - permits are freely tradeable within EU-25 only and no use is made of CDM or JI

One may question the realism of the assumptions of limited permit tradeability and the non-usage of CDM and JI. These assumptions were made deliberately to enable an analysis of internal market options in a stand-alone way. The purposes of the scenario are twofold: to provide a wider international setting within which detailed rearrangements within EU-25 are analysed and to provide a background for the assessment of these rearrangements themselves.

Table 3.1 Simulation outcomes for ETSFULL, 2010 and 2020

	Emission targets in % difference from baseline		Emissions in % difference from baseline		Permit price in euro/tCO_2		Energy tax in euro/CO_2		Relative equivalent variation	
	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020
EU-25	-5	-14	-5	-14	5	19	49	41	-0.1	-0.3
Germany	-5	-12	-4	-12			54	44	-0.1	-0.3
France	-3	-9	-3	-11			71	60	-0.1	-0.2
United Kingdom	-6	-16	-5	-15			59	45	-0.1	-0.2
Italy	-3	-10	-3	-10			68	57	-0.1	-0.3
Spain	-5	-10	-4	-13			39	34	-0.1	-0.2
Other EU-15	-4	-12	-4	-12			45	36	-0.1	-0.3
New Members	-4	-24	-9	-23			13	14	-0.2	-0.6
United States	0	-10	0	-10		9	6	5	0.0	-0.1
Other OECD	-12	-18	-12	-18	18	34	30	25	-0.5	-0.7
Non-OECD			0	1			6	6	-0.0	-0.0
World			-2	-5			14	11	-0.1	-0.2

Source: WorldScan

The outcomes of this cap-and-trade system that – unlike the EU-ETS – covers the complete economy, are shown in Table 3.1. The first two columns (with digits) show the emission targets or permit allocations in percentage differences from baseline emissions. In 2010 the overall target for EU-25 is rather modest because of an excess of permits over baseline developments in the new member states. For the period 2008-2012 all member states are targeted according to the Burden Sharing Agreement, thereafter permit allocations are in proportion to last year's emissions. This change in allocation restricts emissions in the new member states rather severely because these countries are growing relatively fast in the baseline. The next two columns show emissions in percentage differences from the baseline. Member states which reduce their emissions more than their initial permit allocation, export part of their permits to other member states. In 2010 all member states of EU-15 import permits from the new member states. In contrast, in 2020 the new member states have become the largest permit importer, due to the regime switch in permit allocation. The United Kingdom also imports permits in 2020. In colums 5 and 6 the permit prices are shown. In EU-25 this price rises from 5 euro/tCO_2 in 2010 to 19 euro/tCO_2 in 2020. The USA does not participate in 2010 and meets a permit price of 9 euro/tCO_2 in 2020. The highest prices are realised in 'Other OECD' (especially in Japan and Canada), ranging from 18 euro/tCO_2 in 2010 to 34 euro/tCO_2 in 2020. Columns 7 and 8 remind us of the implicit carbon taxation via existing energy taxes. They show the level of total energy taxation of primary carriers, expressed in euro/tCO_2 (cf. the 'Total primary, Total' column of Table 2.6). The last two columns show the impacts on economic welfare in terms of relative equivalent variation. This indicator represents the change in income against baseline prices that would make consumers just as well of in the baseline as they are in the policy simulation case, expressed as a percentage of baseline consumer expenditure. Unsurprisingly, relative welfare losses tend to increase with the abatement effort and are relatively high in 'Other OECD' and, in 2020, the new member states.

With this cap-and-trade system in place we look at EU energy taxation and investigate what difference it would make if existing taxes on primary energy carriers would be harmonized in alternative ways to yield a more uniform tax on CO_2 emissions, *always maintaining energy tax revenues at baseline levels as a percentage of GPD.* Energy taxation is – to a large extent – at the jurisdiction of the member states. Assuming that the revenue raised by energy taxation is important to national governments, we keep tax revenue at baseline levels. Then, at the national level two natural alternatives present themselves: a separate harmonization of producer and consumer taxes, implying two separate carbon taxes for producers and consumers next to the ETSFULL permit price, or a complete harmonization of energy taxes, implying a single carbon tax next to the permit price. As we assumed that the EU Burden Sharing Agreement is discontinued in the post-2012 era, we can go one step further in the post-2012 period and also assess the impacts of EU-wide tax harmonization scenario's.

Hence, within the ETSFULL setting the impacts of four alternative tax harmonization scenarios are assessed:

- SEPBC: a countrywise conversion of existing primary energy taxes to a uniform carbon tax, separately for producers and consumers, for the period 2008-2020
- SEPEU: a countrywise conversion of primary existing energy taxes to a uniform carbon tax, separately for producers and consumers, for the period 2008-2012, followed by an EU-wide harmonization of existing primary energy taxes to a uniform carbon tax, separately for producers and consumers, for the period 2013-2020
- ALLBC: a countrywise conversion of existing primary energy taxes to a uniform carbon tax, for producers and consumers alike, for the period 2008-2020
- ALLEU: a countrywise conversion of existing primary energy taxes to a uniform carbon tax, for producers and consumers alike, for the period 2008-2012, followed by complete EU-wide harmonization, for the period 2013-2020

The outcomes of the tax harmonization scenarios illustrate the power that is embodied in merely rearranging existing energy taxes without giving up energy tax revenue. Three general conclusions emerge. First, conversion of existing energy taxes to more uniform emission taxes would outperform the cap-and-trade system for the next decade in terms of emissions reduction. Second, the conversion would also, in general, outperform the cap-and-trade system in terms of welfare loss. Finally, the conversion would strongly discourage the use of coal and natural gas and promote the use of petroleum, relative to the baseline.
The results are presented in more detail in Table 3.2. for EU-15, the new member states and EU-25. For each of these regions the table shows emissions and emission targets in

Table 3.2 Simulation outcomes for ETSFULL and tax harmonization alternatives, EU-15, new member states and EU-25, 2010 and 2020

	ETSFULL		SEPBC		SEPEU	ALLBC		ALLEU
	2010	2020	2010	2020	2020	2010	2020	2020
EU-15								
Emissions (% diff.)	-4	-12	-11	-14	-11	-10	-14	-10
Emission targets (% diff.)	-5	-12	-5	-12	-12	-5	-12	-12
Relative equivalent variation	-0.1	-0.2	0.0	-0.1	0.0	0.4	0.1	0.2
Labour supply (% diff.)	-0.0	-0.1	-0.0	-0.1	-0.0	0.0	-0.0	0.0
Energy tax prod. (euro/tCO_2)	39	32	41	32	28	59	47	42
Energy tax cons. (euro/tCO_2)	112	89	140	113	109	61	50	42
Energy tax tot. (euro/tCO_2)	55	45	61	48	44	60	48	42
Emissions price (euro/tCO_2)	5	19		3	0		5	2
Coal use (% diff.)	-9	-23	-34	-32	-29	-40	-38	-36
Gas use (% diff.)	-3	-12	-28	-27	-25	-23	-23	-20
Oil use (% diff.)	-2	-5	11	11	15	14	13	17
Fuel use (% diff.)	-3	-12	-11	-15	-12	-9	-13	-10
New member states								
Emissions (% diff.)	-9	-23	-8	-13	-28	-8	-15	-32
Emission targets (% diff.)	-4	-24	-4	-24	-24	-4	-24	-24
Relative equivalent variation	-0.2	-0.6	0.1	-0.1	-0.7	0.6	0.0	-0.8
Labour supply (% diff.)	-0.2	-0.4	0.0	-0.1	-0.5	0.1	-0.1	-0.7
Energy tax prod. (euro/tCO_2)	8	8	8	7	28	13	13	42
Energy tax cons. (euro/tCO_2)	56	57	78	71	109	13	13	42
Energy tax tot. (euro/tCO_2)	13	14	14	13	35	13	13	42
Emissions price (euro/tCO_2)	5	19		3	0		5	2
Coal use (% diff.)	-13	-31	-17	-22	-39	-22	-29	-47
Gas use (% diff.)	-3	-12	-12	-15	-24	-5	-10	-24
Oil use (% diff.)	-3	-10	15	12	-1	21	15	-2
Fuel use (% diff.)	-8	-21	-7	-12	-26	-6	-13	-29
EU-25								
Emissions (% diff.)	-5	-14	-11	-14	-14	-10	-14	-14
Emission targets (% diff.)	-5	-14	-5	-14	-14	-5	-14	-14
Relative equivalent variation	-0.1	-0.3	0.0	-0.1	-0.0	0.4	0.1	0.1
Labour supply (% diff.)	-0.1	-0.2	-0.0	-0.1	-0.1	0.0	-0.1	-0.1
Energy tax prod. (euro/tCO_2)	34	28	35	28	28	51	41	42
Energy tax cons. (euro/tCO_2)	108	87	135	109	109	57	46	42
Energy tax tot. (euro/tCO_2)	49	41	53	42	42	52	42	42
Emissions price (euro/tCO_2)	5	19		3	0		5	2
Coal use (% diff.)	-10	-25	-29	-29	-32	-35	-35	-39
Gas use (% diff.)	-3	-12	-26	-26	-25	-21	-22	-20
Oil use (% diff.)	-2	-6	11	11	13	15	13	14
Fuel use (% diff.)	-4	-13	-11	-14	-14	-9	-13	-13

Source: WorldScan

percentage deviations from the baseline, relative equivalent variation, labour supply in percentage deviation from the baseline, the average energy tax on primary carriers in euro/tCO_2 in production, consumption and in total, the permit price (if any), and the use of energy carriers, separately and in total, in percentage deviations from the baseline. Looking at emission reductions the tax harmonization policies generally outperform the cap-and-trade system ETSFULL. The cap does not bite before 2015 (in ALLBC, uniform tax countrywise) and when is does bite the emissions price remains quite low. The cap not only becomes restrictive at a later date, but also at lower total costs. Looking at welfare and labour supply, tax harmonization also turns out to be more attractive than cap-and-trade. The declines in welfare and labour supply are always lower than in ETSFULL, with the exception of the EU-wide tax harmonization scenarios, which hurt the new member states more than the cap-and-trade system would do. At the level of EU-25 conversion of energy taxes to a single carbon tax would even yield welfare gains, whether or not the tax is applied at member state level (ALLBC) or EU-wide (ALLEU). As these scenarios can be interpreted as replacing existing taxes for an environmental tax, this outcome does confirm the assertion of the strong double dividend hypothesis. Total carbon taxation (the sum of the emissions price and the total energy tax) in the cap-and-trade system generally exceeds taxation in the tax harmonization scenarios, taxation in the new member states under EU-wide harmonization being the notable exception. As harmonisation would increase taxes on coal and natural gas and decrease the tax on oil, the use of coal and natural gas is discouraged while the use of petroleum is fostered. Coal use is most vulnerable when a single tax is established (ALLBC), and especially if this single tax applies EU-wide (ALLEU).

Though tax harmonization thus seems to be a strong alternative to cap-and-trade, the political viability of a tax harmonisation strategy may not be large. The distributional impacts on welfare in the new member states and on employment in the coal industry (but not on consumers in the United Kingdom: they always gain) may be politically sensitive, tax harmonization is a difficult process (at the member state level, and even more so at the EU-level) and the fostered use of petroleum seems at odds with energy conservation and energy security concerns. Hence, the main lesson that remains from this section is, that existing energy taxes are quite distortive, and, by the same token, rearranging them may provide potentially very powerful instruments within the context of climate change policies.

4 EU-ETS and overall abatement efficiency

As the EU-ETS covers only part of the economy, other policy measures must ensure that the nonregulated sector reduces emissions as well. Under the Burden Sharing Agreement the

Table 4.1 ETSFULL and EU-ETS with varying allocations to regulated sectors, 2010 and 2020

	ETSFULL		ETSDIR		ETSDIR-		ETSDIR+	
EU-15	2010	2020	2010	2020	2010	2020	2010	2020
Emissions (% diff.)	-4	-12	-5	-12	-5	-12	-5	-12
Relative equivalent variation	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.2	-0.2
Labour supply (% diff.)	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Emis. price reg. (euro/tCO_2)	5	19	5	21	11	31		14
E. price nonreg.(euro/tCO_2)			8	14	3	8	15	22
Emis. price av. (euro/tCO_2)	5	19	7	18	7	19	8	18
Total tax reg. (euro/tCO2)	6	20	6	23	13	33	2	16
Tot. tax nonreg. (euro/tCO2)	-	-	111	100	103	91	119	110
Total tax av. (euro/tCO2)	61	64	62	63	63	64	63	63
Coal use (% diff.)	-9	-23	-9	-23	-13	-26	-5	-20
Gas use (% diff.)	-3	-12	-5	-11	-3	-10	-7	-13
Oil use (% diff.)	-2	-5	-2	-4	-2	-4	-3	-5
Fuel use (% diff.)	-3	-12	-4	-11	-4	-11	-5	-12
New member states								
Emissions (% diff.)	-9	-23	-4	-24	-9	-24	-4	-24
Relative equivalent variation	-0.2	-0.6	-0.1	-0.7	-0.2	-0.7	-0.1	-0.8
Labour supply (% diff.)	-0.2	-0.4	-0.1	-0.5	-0.2	-0.5	-0.1	-0.5
Emis. price reg. (euro/tCO_2)	5	19	5	21	11	31		14
E. price nonreg.(euro/tCO_2)				21		10	6	40
Emis. price av. (euro/tCO_2)	5	19	3	21	6	23	2	22
Total tax reg. (euro/tCO2)	6	19	5	22	12	31	0	14
Tot. tax nonreg. (euro/tCO2)	-	-	32	61	32	46	41	85
Total tax av. (euro/tCO2)	19	32	16	35	20	37	15	35
Coal use (% diff.)	-13	-31	-7	-33	-15	-35	-4	-31
Gas use (% diff.)	-3	-12	0	-14	-1	-11	-3	-18
Oil use (% diff.)	-3	-10	-1	-11	-2	-9	-2	-14
Fuel use (% diff.)	-8	-21	-4	-22	-8	-22	-3	-23
EU-25								
Emissions (% diff.)	-5	-14	-5	-14	-6	-14	-5	-14
Relative equivalent variation	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	-0.2	-0.3
Labour supply (% diff.)	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2
Emis. price reg. (euro/tCO_2)	5	19	5	21	11	31		14
E. price nonreg.(euro/tCO_2)			7	15	3	9	14	24
Emis. price av. (euro/tCO_2)	5	19	6	18	7	19	7	18
Total tax reg. (euro/tCO2)	6	20	6	23	13	32	1	15
Tot. tax nonreg. (euro/tCO2)	-	-	101	96	95	86	111	108
Total tax av. (euro/tCO2)	54	59	55	59	57	60	55	59
Coal use (% diff.)	-10	-25	-9	-26	-13	-29	-5	-23
Gas use (% diff.)	-3	-12	-5	-12	-3	-10	-6	-14
Oil use (% diff.)	-2	-6	-2	-5	-2	-4	-3	-6
Fuel use (% diff.)	-4	-13	-4	-13	-5	-13	-5	-13

Source: WorldScan

nonregulated sectors are implicitly capped at the national level. Without such an agreement they still are capped at the EU-level. We necessarily have to implement the EU-ETS in a rather coarse way, as a sectoral classification of plants according to the size of their combustion installations is not available. Thus, we assume that the following sectors are covered by the EU-ETS: electricity, energy intensive products, chemical products and capital goods and durables. Taken together, these sectors emit somewhat less than half of EU-25 fossil CO_2 emissions.

Households and the remaining production sectors belong to the nonregulated sector. Given the cap on the regulated sector and the overall caps taken from ETSFULL the impact that the various policy measures should have on the nonregulated sector can be measured. We represent this impact with a separate carbon tax for the nonregulated sector.

First, we address the question of the overall efficiency of the EU system, by comparing it with the outcomes of ETSFULL. We also assess the impacts of over- and underallocations of permits to the regulated sector. For the ETSDIR scenario permits are allocated to the regulated sector in the member states as follows. We take the national ceiling from ETSFULL and reduce this ceiling by multiplying it by the baseline share of the regulated emissions in total emissions. Underallocation (ETSDIR-) is represented by reducing the ceilings thus arrived at by 5%. Conversely, overallocation (ETSDIR+) is represented by increasing the caps by 5%. Especially in the case of overallocation, the situation may arise that the ceiling for the regulated sector is not binding. In that case the permit slack is added to the cap of the nonregulated sector, provided that the permit price is zero and the slack is not needed as a permit export to other member states. Conversely, in the case of underallocation it may occur that the ceiling for the nonregulated sector is not binding. In that case the slack is left idle.

Detailed results are given in Table 4.1. This table shows emissions, relative equivalent variation, labour supply in percentage deviation from the baseline, the permit price of the regulated sector, the carbon tax of the nonregulated sector and the average of these in euro/tCO_2. To these we add existing energy taxes, thus arriving at total taxes for the regulated and the nonregulated sector and the average of these two. The final entries of Table 4.1 represent the use of energy carriers, separately and in total, in percentage deviations from the baseline.

The general conclusion that can be drawn from the table, is that – *given existing energy taxes* – the EU system has an efficiency that is more or less comparable with a complete cap-and-trade system, covering all sectors simultaneously (as in ETSFULL). Moreover, though under- or overallocation of permits to the regulated sector decreases efficiency somewhat, the differences are relatively minor. Though the carbon taxes for both sectors will generally differ, the differences are small in comparison to the difference in existing taxes. These are predominantly present in the nonregulated sector. In terms of economic welfare ETSDIR performs slightly worse than ETSFULL in 2010 and slightly better in 2020 at the level of EU-15. The converse is true for the new member states (slightly better in 2010, slightly worse in 2020). As the differences are very small and EU-15 is the dominating economy, EU-25 shows the same picture as EU-15. Under- and overallocation of permits to the regulated sector has noticeable impacts on relative differences in carbon taxation between the two sectors. In the case of overallocation this tax would amount at the level of EU-25 to 14 euro/tCO_2 for the regulated sector in 2020 and to 24 euro/tCO_2 for the nonregulated sector. Here it is worth mentioning that in this case it takes until 2011 before a positive permit price emerges.

Conversely, in the case of underallocation, the permit price would rise to 31 euro while the nonregulated sector would face a carbon tax of 9 euro. Here we note that in this case in 2010 emissions reduction is larger than needed at the level of EU-25 due to a slack of the new member states and ‘ Rest of EU-15’ in the nonregulated sector. These slacks cannot be used elsewhere in EU-25. Under- or overallocation of permits is always costly, but the welfare losses are generally rather small. The largest negative impacts on economic welfare would occur in 2020 in the new member states when permits would have been overallocated, enforcing a rather drastic increase of taxation of the nonregulated sector in these countries.

Table 4.2 ETSFULL and EU-ETS with and without extension of sectors and harmonized treatment of nonregulated sectors, 2010 and 2020

	ETSFULL		ETSDIR		ETSDIRU	ETSEXT		ETSEXTU
EU-15	2010	2020	2010	2020	2020	2010	2020	2020
Emissions (% diff.)	-4	-12	-5	-12	-12	-5	-12	-12
Relative equivalent variation	-0.1	-0.2	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2
Labour supply (% diff.)	-0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Emis. price reg. (euro/tCO_2)	5	19	5	21	21	4	19	18
E. price nonreg.(euro/tCO_2)	-	-	8	14	16	14	16	20
Emis. price av. (euro/tCO_2)	5	19	7	18	19	8	18	19
Total tax reg. (euro/tCO2)	6	20	6	23	23	14	27	27
Tot. tax nonreg. (euro/tCO2)	-	-	111	100	102	144	124	128
Total tax av. (euro/tCO2)	61	64	62	63	64	63	63	64
Coal use (% diff.)	-9	-23	-9	-23	-24	-8	-22	-23
Gas use (% diff.)	-3	-12	-5	-11	-11	-6	-12	-12
Oil use (% diff.)	-2	-5	-2	-4	-5	-2	-4	-5
Fuel use (% diff.)	-3	-12	-4	-11	-11	-5	-11	-12
New member states								
Emissions (% diff.)	-9	-23	-4	-24	-23	-6	-24	-22
Relative equivalent variation	-0.2	-0.6	-0.1	-0.7	-0.6	-0.1	-0.8	-0.6
Labour supply (% diff.)	-0.2	-0.4	-0.1	-0.5	-0.4	-0.1	-0.5	-0.4
Emis. price reg. (euro/tCO_2)	5	19	5	21	21	4	19	18
E. price nonreg.(euro/tCO_2)	-	-		21	16		42	20
Emis. price av. (euro/tCO_2)	5	19	3	21	20	4	22	19
Total tax reg. (euro/tCO2)	6	19	5	22	22	7	21	21
Tot. tax nonreg. (euro/tCO2)	-	-	32	61	54	59	110	82
Total tax av. (euro/tCO2)	19	32	16	35	33	17	36	32
Coal use (% diff.)	-13	-31	-7	-33	-32	-10	-32	-31
Gas use (% diff.)	-3	-12	0	-14	-12	-1	-16	-12
Oil use (% diff.)	-3	-10	-1	-11	-10	-2	-12	-10
Fuel use (% diff.)	-8	-21	-4	-22	-21	-6	-23	-20
EU-25								
Emissions (% diff.)	-5	-14	-5	-14	-14	-5	-14	-14
Relative equivalent variation	-0.1	-0.3	-0.1	-0.2	-0.3	-0.2	-0.3	-0.3
Labour supply (% diff.)	-0.1	-0.2	-0.1	-0.2	-0.2	-0.1	-0.2	-0.2
Emis. price reg. (euro/tCO_2)	5	19	5	21	21	4	19	18
E. price nonreg.(euro/tCO_2)	-	-	7	15	16	12	18	20
Emis. price av. (euro/tCO_2)	5	19	6	18	19	7	18	19
Total tax reg. (euro/tCO2)	6	20	6	23	23	13	26	26
Tot. tax nonreg. (euro/tCO2)	-	-	101	96	97	137	123	124
Total tax av. (euro/tCO2)	54	59	55	59	60	56	59	59
Coal use (% diff.)	-10	-25	-9	-26	-26	-9	-25	-25
Gas use (% diff.)	-3	-12	-5	-12	-11	-5	-12	-12
Oil use (% diff.)	-2	-6	-2	-5	-5	-2	-5	-6
Fuel use (% diff.)	-4	-13	-4	-13	-13	-5	-13	-13

Source: WorldScan

Could the efficiency of the EU-system be increased by an EU-wide harmonization of the policy efforts aimed to curb nonregulated emissions when the Burden Sharing Agreement would expire after the year 2012? And could the efficiency be increased when more sectors would be brought within the EU-ETS? These questions are addressed with additional scenarios of which the outcomes are shown in Table 4.2. Limiting the extension of the EU-ETS to producing sectors that are taxed for energy use at a degree that is comparable to the sectors that currently are ruled by the EU-ETS, would imply an extension to all firms, except for those engaged in transportation. Hence**,** the ETSEXT scenario extends the EU-ETS to all sectors except transport. The scenario's ETSDIRU and ETSEXTU deviate from ETSDIR and ETSEXT in only one respect: after 2012 a uniform, EU-wide tax is imposed on the nonregulated sectors as a stylized representation of EU-policy coordination and harmonization in addressing the nonregulated sectors.

Given existing energy taxes, the general conclusions are that neither harmonization nor extension would increase economic welfare. Extension of the EU-ETS with other production sectors will lower the permit price and raise the carbon tax for the nonregulated sectors. The reasons are twofold. First, more reduction opportunities are now available in the regulated sector while fewer options are left in the nonregulated sector. Second, existing energy taxes are now even more concentrated in the nonregulated sector. This implies that the carbon tax must rise considerably to have an impact on emissions. Abatement is the result of relative price changes. Hence the carbon tax must be relatively high when pre-existing taxes are high. Paraphrasing Ricardo: (pre-existing) tax is not high because abatement costs are high, but abatement is costly because the tax is high. As the taxation level in the nonregulated sector is no longer diluted by the inclusion of mildly taxed sectors the control of this sector by carbon taxation becomes more costly. Hence, the overall welfare impacts of extending the EU-ETS are slightly negative. This assessment does not take into account possible differences in administrative costs. These costs may be lower for an extended system. If permits can be efficiently auctioned (and the cumbersome grandfathering process skipped), it may be less costly to include a large number of firms in the EU-ETS than monitoring them separately to check compliance with a large variety of other policy measures. EU-wide harmonization of policies addressing the nonregulated sectors, represented by a common EU-wide carbon tax for these sectors, turns out to be welfare decreasing at EU-level. This applies to both the EU-ETS in its current form and its extension. The new member states would gain in 2020 in both settings, because harmonization would lower nonregulated carbon taxation in these countries. This gain is insufficient to compensate the losses of the oher member states. Existing taxes of the nonregulated sectors vary considerably over member states. Apparently it is more efficient to address these sectors with dedicated, national policy measures than by a common carbon tax.

The lesson from this section is – again – that existing energy taxes interact in important ways with cap-and-trade systems (see also Böhringer *et al.*, 2006, for the impacts of introducing an energy tax within cap-and-trade). The higher these taxes are, the higher the costs will be of further emission reductions. As existing taxes are very skewly distributed over sectors and households and quite divergent over member states, is seems sensible to limit the EU-wide cap-and-trade system to those sectors that are taxed rather mildly. This limited coverage characterizes the EU-ETS in its current form. Extension of the EU-ETS with other sectors that are also mildly taxed may not enhance overall economic welfare. Unless there are other benefits, that is.

5 EU-ETS and the potential benefits of revenue recycling

Thusfar, in our policy simulations, all revenue from permit auctions (by assumption up to 10 percent in the Kyoto-period and 100 percent thereafter) has been transferred lump-sum to households. In this section we indicate the potential benefits implied by alternative recycling methods.

Bovenberg (1999) and Bovenberg and Goulder (2002) have shown that, in general and in empirically based general equilibrium models, the strong double dividend proposition does not seem to hold. The overall impact of a green tax reform depends on three components. The first component is the *primary cost* of the environmental tax: this is the direct cost to the regulated sector associated with the need to reduce pollution through changes in production methods. The second component, which requires a general equilibrium analysis, is the *revenue-recycling effect* that serves to lower the costs of the green tax reform. The third component, again a general equilibrium phenomenon, is called the *tax interaction effect*, which counters the revenue-recycling effect. To the extent that environmental taxes raise producers' costs, they imply higher commodity prices. This effectively reduces real factor returns, as the purchasing power of nominal wages or nominal returns on capital is reduced. When there are pre-existing taxes on these factors, the environmental tax functions like an increase in factor taxes, reinforcing the distortions in factor markets from prior taxes. This adverse factor-market impact is the tax-interaction effect. To get the double dividend the cost-reducing revenue recycling effect should outweigh both the primary cost and the costly tax-interaction effect. Under neutral conditions and in numerical simulations the revenue recycling effect is in general not strong enough to do this and the double dividend thus does not arise. The analysis does lead to the conclusion though, that auctioning of emission permits is to be preferred over grandfathering. In both cases we have increases in primary costs and the tax interaction effect. But only under auctioning the countervailing revenue recycling effect occurs, whereas under grandfathering the rents of the grandfathered permits accrue to the polluters that received them.

We show the potential benefits of two alternatives of recycling permit revenue in the extended EU-ETS. The choice for the extended system as the reference case is deliberate, as it provides more revenue to be recycled than the EU-ETS in its current delineation. First, we use the permit revenue to reduce taxes on labour. Here, WorldScan closely follows the accounting structure of the GTAP-6 database, in which factor taxes are represented as *ad valorem* input taxes incurred by producers. Hence, reducing these taxes on labour will lower producer prices, raise the real net wage and foster labour supply. The implementation is such that labour taxes are reduced as soon as permit revenue raises energy tax revenue above baseline levels as a percentage of GDP. Second, we use permit revenue to reduce both taxes on electricity and existing energy taxation for the regulated sector. The basic idea behind this set-up is as follows. Taxation levels are relatively low for the regulated sector and relatively high for the nonregulated sectors. We have seen in section 2 that harmonization of energy taxation is a powerful and efficient instrument for emissions reduction. Instead of lowering the high taxes in the nonregulated sectors a step towards harmonization could also be made by raising the permit price of the regulated sector. This is precisely what this policy scenario will do. Given the cap both the decreased taxation of energy carriers in the regulated sector and the increased demand for electricity will raise the price of permits. The rise, when large enough, might foster the adoption of cleaner technologies in power generation (such as increased use of renewables or carbon capture and storage in coal-fired power stations). In addition, reduced taxation of electricity would lower the extent of 'double taxation'. Electricity generation is taxed already via the permit price. Hence, from the emission reduction point of view, there does not seem to be need to tax the use of electricity as well, which in itself is non-polluting. Again, the taxes are reduced as soon as permit revenue raises energy tax revenue above baseline levels.

Table 5.1 Impacts of revenue recycling through a reduction of employer contributions on labour, ETSEXTLAB, or a reduction of energy taxation on electricity and primary energy used by the regulated sector, ETSEXTELY, versus lump-sum transfers, ETSEXT, 2010 and 2020

	ETSEXT		ETSEXTLAB		ETSEXTELY	
EU-15	2010	2020	2010	2020	2010	2020
Emissions (% diff.)	-5	-12	-5	-12	-5	-12
Relative equivalent variation	-0.15	-0.23	-0.15	-0.10	-0.15	-0.22
Labour supply (% diff.)	-0.06	-0.10	-0.05	0.09	-0.05	-0.08
Emis. price reg. (euro/tCO_2)	4	19	4	19	5	23
E. price nonreg.(euro/tCO_2)	14	16	14	16	14	18
Emis. price av. (euro/tCO_2)	8	18	8	18	8	21
Total tax reg. (euro/tCO2)	14	27	14	27	14	25
Tot. tax nonreg. (euro/tCO2)	144	124	144	124	145	127
Total tax av. (euro/tCO2)	63	63	63	63	63	62
New member states						
Emissions (% diff.)	-6	-24	-6	-24	-7	-24
Relative equivalent variation	-0.14	-0.77	-0.14	-0.29	-0.14	-0.66
Labour supply (% diff.)	-0.12	-0.50	-0.12	0.37	-0.12	-0.46
Emis. price reg. (euro/tCO_2)	4	19	4	19	5	23
E. price nonreg.(euro/tCO_2)		42		45		18
Emis. price av. (euro/tCO_2)	4	22	4	23	4	22
Total tax reg. (euro/tCO2)	7	21	7	21	7	23
Tot. tax nonreg. (euro/tCO2)	59	110	59	113	59	80
Total tax av. (euro/tCO2)	17	36	17	36	17	35
EU-25						
Emissions (% diff.)	-5	-14	-5	-14	-5	-14
Relative equivalent variation	-0.15	-0.26	-0.15	-0.11	-0.15	-0.24
Labour supply (% diff.)	-0.07	-0.18	-0.07	0.14	-0.07	-0.16
Emis. price reg. (euro/tCO_2)	4	19	4	19	5	23
E. price nonreg.(euro/tCO_2)	12	18	12	18	13	18
Emis. price av. (euro/tCO_2)	7	18	7	19	7	21
Total tax reg. (euro/tCO2)	13	26	13	26	13	24
Tot. tax nonreg. (euro/tCO2)	137	123	137	123	137	123
Total tax av. (euro/tCO2)	56	59	56	59	56	58

The general conclusion that can be drawn from these revenue recycling policies is that the impacts belong to the weak double dividend category (see Table 5.1). The impacts on economic welfare are less negative than for the case of lump-sum recycling. Yet, welfare is not *raised* above baseline levels. The impacts of reduced labour taxation appear to be most beneficial. This presumably is due to the induced increase in labour participation. This increase is relatively large in the new member states. The welfare impacts of reduced electricity taxation and reduced taxation of energy use by the regulated sector are relatively minor, but not negligible, especially not in the new member states. The impacts on the permit price are as expected and considerable both in absolute terms as relative to the nonregulated emissions price. The permit price rises from 19 euro/tCO_2 (ETSEXT) to 23 euro/tCO_2 (ETSEXTELY) in 2020. The carbon tax remains stable at EU level (at 18 euro/tCO_2 in 2020) and shows a fall in the new member states (from 42 to 18 euro/tCO_2 in 2020).

6 Conclusions

The interactions of existing EU energy taxes with cap-and-trade systems are important.

The fact that double dividends would occur if these taxes were converted to a single carbon tax, either at member state level or EU-wide, indicates that these taxes are highly distortive. Restructuring energy taxes in the direction of a carbon tax may outperform cap-and-trade both in terms of emissions reduction and in terms of economic welfare. Yet, such a restructuring is unlikely to be a viable political strategy, as it would foster the use of oil at the expense of coal and natural gas which seems at odds with energy conservation and energy security concerns.

The overall EU system aiming at emission reductions imposes caps in many quarters due to the combined effects of limited EU-ETS sectoral coverage and the Burden Sharing Agreement. Yet, given existing energy taxes, there is no clear evidence that the overall efficiency of this system is lower than the efficiency of a cap-and-trade system that would completely cover all emitters.

Extension of the EU-ETS with other sectors that are mildly taxed may not be welfare-improving. The cap would then cover all emitters, except the transport sector and households which face relatively high energy taxes. Additional measures to curb emissions in the nonregulated sector are relatively costly, because taxation is already high. Yet, other benefits, such as reduced administrative costs or a larger taxbase for revenue recycling, may nevertheless make an extension of the EU-ETS beneficial.

Auctioning of permits is to be preferred to grandfathering because of the positive impacts on economic welfare when revenues are recycled appropriately. Positive welfare impacts over and above the recycling of permit revenue in a lump-sum fashion are to be expected from reductions of employer contributions on labour and from reduced taxation of taxes on electricity and on the energy inputs of the regulated sector.

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Appendix

Table A.1 Percentage tax rates on energy carriers delivered to firms, applicable on pre-tax values, by country, 2001

	Coal	Petroleum and coal products				Natural gas	Electricity
		to electricity	to transport	to other sectors	total		
Germany	0.0	12.7	136.4	11.9	50.2	14.2	0.0
France	0.0	12.7	69.8	10.9	36.9	11.0	0.0
United Kingdom	13.8	31.9	232.2	28.2	105.9	4.5	5.7
Netherlands	0.0	12.7	43.3	16.6	20.6	6.5	10.5
Italy	0.0	12.7	89.0	18.5	49.6	11.1	20.0
Spain	0.0	6.4	65.0	6.4	31.3	11.1	5.0
Rest of EU-15	0.0	11.1	71.8	17.6	34.0	13.9	8.7
New member states	0.0	11.1	86.9	9.9	28.8	5.3	1.0
Other Europe	25.0	12.7	102.8	17.6	39.0	0.8	11.1
Canada	0.0	4.9	47.9	5.2	19.7	9.1	11.4
Other OECD	5.0	5.0	100.0	5.0	25.5	4.9	8.1
Former Soviet Union	20.5	5.3	8.6	8.6	6.4	5.1	20.5
Turkey	17.8	38.3	80.2	38.3	46.2	17.6	18.9
United States	0.0	4.9	46.6	5.2	25.0	5.1	5.3
Australia	0.0	5.3	81.8	5.2	44.4	4.5	5.3
Brazil	0.0	5.3	42.9	11.1	18.6	4.8	5.3
Other Latin America	0.0	5.3	42.9	11.1	19.8	4.4	5.3
Middle East	0.0	5.3	42.9	5.3	14.1	4.7	5.3
China	0.0	5.3	42.9	5.3	9.5	4.1	5.3
India	18.2	5.3	52.0	30.0	31.9	5.3	5.3
Rest of world	5.3	5.3	38.9	3.1	12.7	4.8	5.3

Source: Van Leeuwen, 2006

Table A.2 Percentage tax rates on energy carriers delivered to households, applicable on pre-tax values, by country, 2001

	Coal		Petroleum		Natural gas		Electricity	
	Total	of which VAT	Total	of which VAT	Total	of which VAT	Total	of which VAT
Germany	16.0	16.0	253.4	16.0	31.2	16.0	15.9	15.9
France	19.6	19.6	142.1	19.6	17.4	17.4	26.7	17.0
United Kingdom	5.0	5.0	318.4	17.5	5.0	5.0	4.9	4.9
Netherlands	19.0	19.0	99.6	19.0	61.0	19.0	74.5	19.0
Italy	20.0	20.0	164.6	20.0	86.9	19.4	37.6	10.0
Spain	16.0	16.0	112.8	16.0	16.0	16.0	22.0	16.0
Rest of EU-15	20.0	20.0	144.5	20.0	25.0	15.0	25.0	14.0
New member states	22.0	22.0	263.6	22.0	22.0	20.0	22.0	20.0
Other Europe	15.0	15.0	91.9	15.0	14.9	14.0	14.9	14.0
Canada	7.0	7.0	64.7	7.0	6.5	6.5	11.2	11.2
Other OECD	4.0	4.0	104.1	4.0	6.0	6.0	7.1	6.0
Former Soviet Union	20.0	20.0	62.9	20.0	22.0	20.0	22.0	20.0
Turkey	17.7	17.7	103.7	17.7	17.6	17.6	23.6	17.7
United States	6.0	6.0	30.0	6.0	6.0	6.0	6.4	6.0
Australia	10.0	10.0	111.9	10.0	9.9	9.1	10.0	9.1
Brazil	10.0	10.0	53.8	10.0	11.1	10.0	11.1	10.0
Other Latin America	10.0	10.0	53.8	10.0	11.1	10.0	11.1	10.0
Middle East	10.0	10.0	53.8	10.0	11.1	10.0	11.1	10.0
China	13.0	13.0	53.8	17.0	13.6	13.0	13.6	13.0
India	11.3	11.3	43.5	11.3	11.4	11.3	11.4	11.3
Rest of world	10.0	10.0	53.8	10.0	11.1	10.0	11.1	10.0

Source: Van Leeuwen, 2006