Carbon Taxes with Exemptions in an Open Economy: A General Equilibrium Analysis of the German Tax Initiative*

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Sectoral exemptions from environmental regulation are applied in many countries to avoid adverse adjustment effects in specific industries. The problem with exemptions is that they can make environmental policy more costly. Our paper analyzes the welfare costs of exemptions in environmental policy together with the issue of unilateral carbon taxes in an open economy. Several countries within the EU have introduced or contemplated unilateral taxes to reduce anthropogenic CO_2 emissions. Taxes which are unilaterally imposed in an open economy can have significant impacts on production and employment of energy- and export-intensive industries. To save jobs by maintaining "international competitiveness" most CO_2 taxation schemes include exemptions for energy- and export-intensive industries as a compromise between environmental objectives and employment in these sectors. This paper shows that such compromises are costly: as the tax base narrows, the dead-weight loss increases. Our calculations illustrate this point in the framework of a static general equilibrium model for West Germany calibrated to 1990 data. We evaluate the excess costs of exemptions as a means of saving jobs in specific industries relative to an alternative instrument, a uniform carbon tax cum wage subsidy which achieves an identical level of national emissions and employment at a fraction of the cost.

1. INTRODUCTION

Unilateral environmental taxes can have significant implications for the international competitiveness of industries. As the relative production costs of environment-intensive goods rise in comparison to the relative costs of producing the same goods elsewhere, unilateral taxation implies a loss of comparative advantage. A loss in comparative advantage, i.e., international competitiveness, will be most severe

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for export-intensive sectors in which environment-intensive inputs represent a significant share of direct and indirect costs. To avoid adverse production and employment shocks in these industries sectoral exemptions from environmental taxes are common in many countries. (For a recent survey on the structure and administration of environmental taxes in OECD countries, see OECD [18].) The problem with exemptions is that they can induce significant excess costs for achieving environmental objectives.

This paper investigates the welfare implications of exemptions together with the issue of unilateral carbon taxes in an open economy. In our analysis we calculate the costs of environmental policies with respect to national CO_2 emission reduction, operating on the premise that trade-induced changes in CO_2 emissions of nonparticipating countries may be of second-order magnitude.[1] The empirical analysis in this paper focuses on three questions:

(i) To what extent do exemptions magnify the costs of carbon taxes?

(ii) How much more costly are exemptions than direct wage subsidies as a means of saving jobs?

(iii) How do exemptions affect sectoral employment and exports?

We address these questions in the context of a static general equilibrium model for West Germany with 58 sectors based on the most recently available consistent economic and energy data for 1990 [24].

The results presented here confirm standard intuition from the public finance and taxation literature: exemptions can significantly increase the welfare cost of taxes (see, for example, Ballard and Shoven [2] and Wiegard [28]). The welfare costs of exemptions increase with the target level of emission reductions and the share of the exempted sectors in economic activity and total emissions. Exemptions may retain jobs in subsidized sectors, but these jobs are expensive for society as a whole. Our calculations suggest that there may be far less costly methods of retaining employment in specific industries. Sector-specific wage subsidies applied in concert with a uniform environmental tax produce a Pareto-superior policy.

The economic effects of CO_2 reduction measures have been widely assessed over the past years. (For comprehensive surveys of studies see Grubb *et al.* [15] and UNEP, 1995.) Although several authors have addressed the issue of competitiveness [19, 20], we are aware of no previous work which has focused on the efficiency implications of carbon taxes with exemptions. There are only a few "top-down" macroeconomic analyses of carbon taxation in Germany, and these assess either uniform taxation [7, 8] or carbon taxes with exemptions [27]. None of these studies analyzes the economic costs of exemptions subject to economy-wide reduction targets. In a footnote, Welsch states:

> The tax exemption for sectors is not relevant for explaining the reduced effectiveness of the national tax... {as compared with an EU-wide energy/carbon tax}... because these sectors only account for 10% of gross output value. [27, p. 23, footnote 5]

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[1] An increase in emissions by nonparticipating countries due to the relocation of energy-intensive production or reductions in the international oil price has been referred to as "carbon leakage" [21]. If leakage rates are high, this can justify a tax rate differentiation across sectors to avoid the problem of carbon leakage and to increase efficiency of (global) CO_2 reduction [16]; however, this depends crucially on model structure (see [3]). The magnitude of leakage rates is an open research topic with considerable disagreement on empirical values. For an overview and interpretation of different calculations, see Rutherford [23].

The results presented here dispute this conclusion. Welfare losses associated with exemptions are significant even though the share of exempted sectors in overall economic activity and carbon emission might be small.

The results presented in this paper are subject to some important caveats. First, we recognize that our open economy model fails to account for potentially important trade-related impacts on global emissions. The German economy is closely linked to other European economies and therefore the *global* environmental impacts of unilateral policies cannot be assessed in isolation. On the other hand, if Germany contemplates unilat eral cutbacks in order to signal a willingness to take action and encourage other EU member states to take similar steps, the key issue is the cost of reducing German emissions and not EU-wide emissions. A second limitation of our analysis is the treatment of adjustment and intertemporal linkages. Adjustment costs relate to the speed with which policies are adopted and the ability of the human and physical capital stock to accommodate these policies. We believe that the economic links identified in our static framework can provide a useful starting point for subsequent analysis of the adjustment process.

The remainder of this paper is organized as follows: Section 2 introduces the policy background of carbon taxation in Europe and lays out the specifics of the German carbon tax proposal which provides the policy framework for our empirical analysis. Section 3 gives an overview of the basic model structure and the model specification (benchmark data and elasticities). Section 4 describes the policy scenarios and reports the computational results. Section 5 provides a sensitivity analysis of our results with respect to changes in the underlying model structure and elasticities. Section 6 concludes.

2. POLICY BACKGROUND

To combat global warming several international conferences (Toronto 1988, Cairo 1990, Rio 1992, Berlin 1995) have called for significant reductions in the combustion of fossil fuels. Due to the difficulties of identifying and implementing a "fair" world-wide CO_2-reduction schedule for all countries, no concerted policy action has yet been undertaken. The European Union which forcefully advocated taxes on carbon emissions as an effective instrument to reduce global carbon-dioxide emissions put EU-wide CO_2-reduction measures under the condition that other important developed economies (i.e., the United States and Japan) would take similar steps [4, 5]. The "conditionality" clause was introduced in the EU policy platform in part due to the political pressure of energy- and export-intensive industries which feared negative impacts on their international competitiveness. Given the lack of concrete EU-wide action there is increasing political pressure for unilateral action in single EU member countries where domestic voters stress the need for taking a leading role. Five countries—Denmark, Finland, the Netherlands, Sweden, and Norway—have already implemented some kind of carbon tax [18, pp. 32–36]. Other Eu member states such as Germany are contemplating a unilateral carbon tax [12]. Policymakers at the national level must take account of impacts on energy- and export-intensive industries which face severe production and employment cutbacks as a consequence of the loss in international competitiveness. Moreover, many of the energy- and export-intensive industries (such as iron and steel or chemical products) have long been protected and treated as

TABLE 1

Sectors Qualifying for Exemptions under Enquete-Kommission Plan

Sector (SIO)	Energy share	Export share	Output[a]
Chemical products (CHM, 9)	3.8%	40.5%	198.3
Ceramic goods (CER, 14)	4.9%	30.7%	5.2
Glass (GLA, 15)	6.2%	27.5%	13.6
Iron and steel (ORE, 16)	10.1%	33.0%	52.1
Nonferrous metals (NFM, 17)	5.1%	29.8%	30.2
Casting (CAS, 18)	5.2%	15.9%	16.1
Paper products (PAP, 33)	8.6%	37.5%	20.3

Note. SIO, System of production sectors for Input–Output computations; (CHM, 9), (model-specific acronym, IO table index); Energy share, share of gross production value, 1990; Export share, export share of turnover, 1991.

Source. Enquete-Kommission [11].

[a] In Billion DM_{1990}.

strategically important for economic development. Given the threat of high sectoral unemployment and facing the traditional strong lobby of these sectors, nearly every tax scheme which has been proposed involves tax exemptions to energy- and export-intensive industries in order to maintain comparative advantage and sectoral employment.[2]

As the main emitter of CO_2 within the EU,[3] Germany continues to affirm its objective of reducing CO_2 emissions by 25–30% by the year 2005, taking 1990 as the base year for the whole of Germany including the Five New Laender. In order to achieve these quantitative reduction targets a carbon tax is considered to be an appropriate instrument by policymakers. Exemptions are proposed for sectors whose energy cost share of gross production value is greater than 3.75% and whose export share of turnover is greater than 15%.[4] Table 1 specifies the seven industrial sectors which are potentially exempted from paying carbon taxes [11].

3. MODEL STRUCTURE AND PARAMETRIC FRAMEWORK

Our model is a static open general equilibrium model designed to investigate the economic implications of CO_2 tax exemptions for energy- and export-intensive industries in the West German economy.[5] It has a disaggregate representation of 58 industries corresponding to the standard structure of German input–output tables [25]. The energy goods identified in the model include coal and coal products

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[2] In Sweden the total amount of CO_2 tax paid by energy-intensive industries is limited to 1.7% of the sales values of the goods produced [6, p. 84]. In other Nordic countries (Denmark, Norway) the tax rates for industries are very low compared to the final demand sector with some sectors (e.g., shipping, aviation) being fully exempted [26, pp. 32–36].

[3] At 1990 levels, West Germany accounted for 25% of overall EU emissions (EU without East Germany). East Germany's emission amounted to an additional 11% of the EU emissions.

[4] Export-intensity of sectors according to the policy proposal does not imply that these sectors are net exporters. In the benchmark 10 table of 1990 some sectors are actually net importers (ceramic goods, nonferrous metals, paper).

[5] An appendix containing the algebraic formulation of the model is available upon request from the authors.

(COA), crude oil (CRU), electric power, steam and warm water (ELE), natural gas (GAS), and refined oil products (OIL). This disaggregation is essential in order to distinguish energy goods by carbon intensity.

The costs of carbon taxes can significantly change in a second-best situation when the interaction of carbon taxes with existing taxes and the method of carbon tax recycling alter the marginal excess burden for public goods provision (see, e.g., Goulder [14]). To account for second-best effects the model incorporates the main features of the German tax system: labor taxes (including social insurance contributions), capital taxes (corporate and trade taxes), other indirect taxes (e.g., mineral oil tax), and value-added taxes.

In international trade Germany is treated as small relative to the world market. That is, we assume that changes in German import and export volumes have no effect on its terms of trade. Domestic and foreign energy goods are regarded as perfect substitutes. In other sectors domestic and foreign products are distinguished by the Armington assumption.[6] We impose trade balance with respect to the rest of the world accounting for an exogenously specified net trade surplus and international capital flows.

Factor Markets

Primary factors of production are capital and labor, which are employed together with energy and materials inputs to produce the domestic output. The labor supply is responsive to the real wage through a labor leisure choice, with preferences calibrated to a target elasticity of labor supply. For our baseline computations, we assume perfectly competitive factor markets in which the prices on factors adjust so that supply equals demand. Also, both factors are assumed to be homogeneous and perfectly mobile between sectors. Labor is only mobile domestically, whereas capital is mobile also at the international level; i.e., the return to capital is treated as exogenous in the model.

Production

Nested, separable constant elasticity of substitution production functions are employed to specify the substitution possibilities in domestic production between capital, labor, energy, and material inputs (KLEM).

The material aggregate in each sector is composed of nonenergy inputs between which there is a zero elasticity of substitution. Within the energy aggregate nonelectric and electric energy inputs trade off with elasticities of substitution characterized by a separable nested CES function.[7]

The above specification of technologies allows the comprehensive representation of the substitution possibilities in production, with interfuel substitution within the

[6] The Armington goods are aggregated with identical import shares for a given import good across all components of final and intermediate demand. On the export side, products of the Armington sectors destined for domestic and international markets are treated as imperfect substitutes, produced subject to a constant elasticity of transformation.

[7] Nonelectric fossil inputs (gas, refined oil, and crude oil) excluding coal enter at the bottom nest with a constant substitution elasticity. At the next level nonelectric (noncoal) inputs and electricity combine with a constant elasticity of substitution. In the top nest, coal and the nonelectric–electric energy aggregate trade off with a constant elasticity of substitution.

energy aggregate as well as substitution between energy and other production factors.

Intermediate energy demand is distinguished between feedstocks, i.e., intermediate energy goods which enter the material aggregate, and fuels, i.e., intermediate energy goods which enter the energy aggregate. This distinction between different types of energy inputs is important because only (fossil) fuel consumption leads to carbon emissions. We combine monetary flows of the German national input–output table with consistent physical flow data on the emission-relevant fuel use in production (and final demand) to produce sector- and energy-specific CO_2 emission coefficients. The CO_2 emission coefficients indicate tons of CO_2 per unit DM of fuel use in a specific sector and are the base for the application of carbon taxes.

Taxation and Public Expenditure

Government provides a public good which is produced with commodities purchased at market prices. These expenditures are financed with tax revenues. All of our simulations are based on revenue-neutral tax reforms. This is done by keeping the amount of the public good provision fixed and recycling any residual revenue lump-sum or through a reduction in labor or capital taxes.

Investment Demand

Investment is determined by the savings decisions of private households. This decision in turn depends on the expected rate of return. In our model with static expectations the rate of return is represented by the ratio of the quasi-rent on capital to the cost of a unit of new capital, both evaluated at equilibrium prices. We specify preferences to match a target benchmark elasticity of savings with respect to the rate of return.

Final Demand

In order to focus on efficiency issues we use a representative consumer to model demand side. The consumer's welfare is determined by a nested separable CES function which describes the trade-offs between savings (future consumption), leisure, and consumption. At the top level savings enter with a composite of leisure and aggregate consumption at a constant elasticity of substitution, which is calibrated to produce an exogenous price elasticity of savings with respect to the rate of return. At the second level leisure and aggregate consumption combine with a constant elasticity of substitution, which is calibrated to be consistent to an exogenous elasticity of labor supply with respect to the real wage. Expenditures on the aggregate consumption bundle are allocated between an aggregate energy commodity and an aggregate nonenergy commodity according to a CES function. At the bottom level the aggregate energy commodity is composed of different energy goods which trade off with a constant elasticity of substitution, whereas the aggregate nonenergy commodity consists of nonenergy goods whose substitution patterns are described by a Cobb–Douglas function.

TABLE 2
Key Elasticities Used in the Model

Index[a]	Description	Value
σ_{KLEM}	Elasticity of substitution between the material inputs and the composite of capital, labor, and energy inputs	0
σ_{KLE}	Elasticity of substitution between energy inputs and value added	0.5
σ_{KL}	Elasticity of substitution between labor and capital	1
σ_{COA}	Elasticity of substitution between coal and the aggregate of electricity and different fossil inputs (excluding coal) in the energy aggregate of sectoral production	0.25[b]
σ_{ELE}	Elasticity of substitution between electricity and the aggregate of different fossil inputs (excluding coal) in the (non-coal) energy input of sectoral production	1
σ_{FOS}	Elasticity of substitution between different fossil inputs (excluding coal) in the energy aggregate of sectoral production	2
σ_{NEC}	Elasticity of substitution between the energy aggregate and the non-energy aggregate of household demand	0.3
σ_{NC}	Elasticity of substitution between different non-energy inputs into the non-energy bundle of household demand	1
σ_{EC}	Elasticity of substitution between different energy inputs into the energy aggregate of household demand	2
σ_{DM}	Elasticity of substitution between domestic goods and imports (Armington)[c]	4
σ_{DX}	Elasticity of substitution between domestic goods and exports (Armington)[c]	4
σ_{LS}	Uncompensated labor supply elasticity	0.1
σ_{S}	Elasticity of savings with respect to the rate of return	0.4

[a] See Appendix for related notations.
[b] Except for electricity where the value is set equal to 3.
[c] The elasticity of substitution is set to infinite for Heckscher–Ohlin goods.

Benchmark Equilibrium

As is customary in applied general equilibrium analysis, the model is based on economic transactions in a particular benchmark year (1990 in this case). Benchmark data determine parameters of the functional forms from a given set of benchmark quantities, prices, and elasticities. Table 2 shows the key elasticity values employed in the model. These values are similar to empirical estimates used in comparable studies.[8]

Table 3 presents total tax payments as well as the marginal excess burden (MEB) of Germany's major taxes in the benchmark equilibrium. The MEB represents the excess cost to society of raising an additional DM of government revenue using a particular tax. In our model, the cost of raising one additional DM of public funds using the capital tax thus costs 1.73 DM in terms of forgone consumer welfare. Our numbers for the marginal excess burden of taxation are in line with recent estimates in the literature [13]. Due to assumed international capital mobility within the EU, the excess burden of capital taxation is highest, followed by labor

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[8] For the nesting structure and the substitution elasticities in production see Manne and Richels [17]. The substitution patterns in final demand between savings, leisure, and consumption are taken from Ballard *et al.* [1].

TABLE 3

Tax Revenues and Marginal Excess Burden in the Benchmark

	Tax revenue[a] (billion DM_{1990})	Marginal excess[b] burden (%)
Capital tax[c]	129	72.8
Labor tax[d]	585	36.4
VAT	158	23.4

[a] Statistisches Bundesamt [25].

[b] Authors' calculation.

[c] Capital taxes in the model represent all corporate and trade taxes.

[d] Labor taxes in the model represent income taxes on labor as well as total payments of employers and employees to social insurances.

taxation and VAT. This suggests that the costs of carbon taxes might be significantly lowered by revenue-neutral swaps of carbon taxes against distortionary capital and labor taxes compared to a revenue-neutral lump-sum rebate of taxes or an increase in government expenditures.

Table 4 provides an overview of the structure of economic activity and the pattern of emissions by energy good and sector in the benchmark year. We have grouped sectors from the model into energy sectors (ES), exempted sectors (XEM), rest of industry (ROI), and final demand (FD).

Potentially exempt sectors amount to roughly 8% of gross output, 6% of employment, 19% of exports, and 12% of carbon emissions. The small share of exempt sectors in gross output and carbon emissions suggests that overall welfare losses due to exemptions will be moderate. The ratio between emissions and gross

TABLE 4

Benchmark Data for 1990

	XEM	ES	ROI	FD	Total
		Economic data in billion DM_{1990}			
Output	386	188	4078		4652
	(8%)	(4%)	(88%)		(100%)
Wages	79	28	1199		1306
	(6%)	(2%)	(92%)		(100%)
Exports	133	8	567		708
	(19%)	(1%)	(80%)		(100%)
	Carbon emissions in million tons CO_2 (Total: 699 million tons)				
Coal	50	228	13	5	297
	(17%)	(77%)	(4%)	(2%)	(100%)
Oil	13	23	119	138	293
	(4%)	(8%)	(41%)	(47%)	(100%)
Gas	23	24	31	32	110
	(21%)	(22%)	(29%)	(29%)	(100%)
Total	86	275	163	175	699
	(12%)	(40%)	(23%)	(25%)	(100%)

Note. XEM, potentially exempt energy-intensive; ES, energy producing and processing sectors; ROI, other industrial and service sectors; FD, final demand.

Source. Statistisches Bundesamt [24].

output is significantly higher for exempted sectors than for the rest of industry, which indicates a potentially higher scope of CO_2-substitution possibilities in exempted sectors. Given exogenous reduction targets, exemptions for those sectors with high carbon intensity can significantly increase the burden of cutbacks to nonexempted sectors with low carbon mitigation possibilities.

4. SCENARIOS AND RESULTS

Policy Scenarios

In our simulations we consider three tax policies. The first of these ("uniform") considers an economy-wide tax on carbon dioxide emissions stemming from fossil fuel combustion in domestic production and consumption. Carbon taxes do not apply to embodied carbon in imported goods. Similarly, carbon taxes do not apply to exports of any kind, and there are no rebates of carbon taxes paid on inputs to exported goods. Given technical and political constraints for an increase of inter-European electricity trade, we fix trade in electricity at the benchmark level. This setting avoids an extreme increase in electricity imports which are not subject to the carbon tax.

The second policy scenario ("exempt") involves a carbon tax with exemptions for selected industries. The basis for qualification as an exempted sector is taken as given; i.e., we do not model the endogenous response of firms which could conceivably modify their cost or sales shares in order to qualify for exemption.

The third policy scenario ("subsidies") involves a uniform carbon tax with the addition of a wage subsidy for the industries exempted in the previous scenario. The subsidy rate is set so that there is no decrease in the aggregate employment of potentially exempted sectors relative to the benchmark.

We generate results for each of these three policy scenarios using three different assumptions regarding the compensating adjustments in other taxes. The government is assumed to keep tax changes revenue-neutral by recycling carbon tax income either lump-sum or through a reduction in labor or capital taxes.

In our counterfactuals we compute equilibria with and without exemptions for target reductions of 10, 20, and 30% from the benchmark carbon emission level. Exemptions imply that carbon taxes for the remaining sectors must increase.

Tables 5 and 6 summarize the results for the three policy scenarios (uniform taxes, tax exemptions, and uniform taxes with wage subsidies) and the different assumptions about revenue recycling (lump-sum, labor taxes, and capital taxes).

Employment Effects and the Welfare Costs of Exemptions

Table 5A reports Hicksian-equivalent variations in income as a measure of the welfare effects resulting from the imposition of different policy instruments to meet the given emission targets. Our most significant and robust finding is that exemptions significantly magnify the costs of emission reduction when compared to uniform taxes. The excess burden of exemptions increases with the target level of emission reduction. For a 30% reduction in carbon emissions, exemptions raise the total costs of emission abatement by roughly one-fifth. Tax exemptions for energy- and export-intensive sectors responsible for 12% of the benchmark emissions cause

TABLE 5

Model Results of the Effects on Welfare, Employment, and Exports

	Uniform			Exemption			Wage Subsidy		
	10	20	30	10	20	30	10	20	30
	A. Welfare in money-metric benchmark utility (billion DM_{90})								
Lump_sum	−6.1	−16.0	−31.7	−6.5	−18.3	−38.7	−5.6	−15.0	−30.5
L Tax	−4.4	−12.2	−25.5	−4.5	−13.4	−30.1	−3.8	−11.0	−23.8
K Tax	−2.9	−9.4	−21.5	−2.8	−10.2	−26.7	−2.4	−8.2	−20.0
	B. Wage premium (1000 DM_{90} per job saved)								
Lump_sum	0.0	0.0	0.0	19.1	46.2	86.9	−18.3	−14.5	−10.0
L Tax	0.0	0.0	0.0	1.9	21.4	52.6	−22.8	−18.9	−13.9
K Tax	0.0	0.0	0.0	−6.2	13.4	45.6	−26.9	−22.3	−15.7
	C. Employment in energy- and export-intensive sectors (% change from benchmark)								
Lump_sum	−4.2	−10.0	−17.3	−2.0	−5.2	−9.8	0.0	0.0	0.0
L Tax	−3.9	−9.5	−16.6	−1.6	−4.4	−8.4	0.0	0.0	0.0
K Tax	−3.2	−8.0	−14.4	−0.5	−1.8	−3.6	0.0	0.0	0.0
	D. Exports of energy- and export-intensive sectors (% change from benchmark)								
Lump_sum	−8.4	−19.1	−31.8	−3.9	−10.0	−18.2	−2.6	−5.8	−9.7
L Tax	−8.2	−18.8	−31.4	−3.6	−9.2	−17.0	−2.8	−6.2	−10.3
K Tax	−6.7	−15.7	−27.2	−1.3	−3.9	−7.5	−2.2	−4.9	−8.2

fossil energy consumption of these sectors to decline less and shifts the burden of emission reduction to other sectors with lower carbon substitution possibilities. As a consequence marginal tax rates and induced welfare losses are higher to achieve a given economy-wide target of emission reduction.

The excess burden of exemptions becomes more evident when we measure the specific welfare costs related to the use of exemptions for retaining jobs in energy-intensive sectors. In order to provide a meaningful measure for the specific costs of employment policy we compute an effective general equilibrium wage premium in DM per worker by dividing the Hicksian equivalent variation by the number of workers whose jobs are "saved." For the 20% reduction target, these

TABLE 6

Model Results of Carbon Tax Rates and Replacement Tax Rates

	Uniform			Exemption			Wage subsidy		
	10	20	30	10	20	30	10	20	30
	A. Carbon tax rates (DM_{90} per tonne of carbon)								
Lump_sum	23.0	59.0	119.0	29.0	82.0	178.0	24.0	63.0	129.0
L Tax	23.0	61.0	124.0	30.0	86.0	190.0	24.0	65.0	134.0
K Tax	25.0	65.0	134.0	33.0	96.0	223.0	26.0	69.0	144.0
	B. Carbon tax revenue (% of benchmark labor and capital tax revenue)								
Lump_sum	2.0	4.6	8.2	2.2	5.5	10.2	2.1	5.0	9.0
L Tax	2.0	4.8	8.6	2.3	5.8	10.9	2.1	5.1	9.3
K Tax	2.2	5.2	9.3	2.5	6.4	12.5	2.2	5.4	9.8
	C. Replacement tax rates (change relative to benchmark index (= 100))								
Lump_sum	−0.7	−1.6	−2.7	−0.9	−2.1	−3.9	−0.7	−1.7	−2.9
L Tax	−1.8	−4.1	−7.1	−2.2	−5.6	−10.5	−1.9	−4.4	−7.7
K Tax	−8.9	−20.2	−34.3	−11.1	−27.5	−52.6	−9.3	−21.5	−36.9

wage premia range between annual 13,400 and 46,200 DM per worker depending on the recycling strategy of carbon taxes. For a 30% reduction target, the premia increase to values between 45,600 and 86,900 DM per worker and year (see Table 5B).

If jobs are the sole justification for exemptions, Tables 5A–5C show that a uniform carbon tax combined with wage subsidies to potentially exempted sectors retains more jobs than an exemption policy and costs far less. As pointed out by Dixit [10], we find that *targeted instruments* (carbon taxes together with wage subsidies) are clearly superior to *blunt instruments* (a CO_2 tax with exemptions).

In a model with a variety of benchmark taxes, uniform carbon taxes are not always optimal. Given our representation of the German economy and tax system, we find that a policy which combines uniform carbon taxes with wage subsidies to potentially exempted sectors is Pareto-superior due to second-best effects.[9] First, direct wage subsidies lower the distortionary effects of labor taxes.[10] Second, wage subsidies for potentially exempted sectors which are labor-intensive relative to the rest of the economy cause an increase in capital use in the rest of the economy, thereby indirectly offsetting some of the excess burden of capital taxes.[11]

The comparison of carbon tax recycling across different instruments indicates that the costs of emission reduction are significantly reduced by a revenue-neutral cut of existing distortionary taxes. Given the higher marginal excess burden on (internationally mobile) capital in this model, a compensating reduction in capital axes is superior to reductions in labor taxes from an efficiency standpoint.

Export Performance

Next, we turn to the analysis of changes in exports for energy- and export-intensive sectors as given in Table 5D. As with sectoral employment, exports decrease in spite of the exemptions, although less than with a uniform tax. Comparing with the third policy package, however, we see that wage subsidies in fact cause exports to fall less precipitously than uniform taxes or exemptions. Tables 5C and 5D suggest that energy- and export-intensive sectors will face serious adjustment problems with increasing targets of emission reduction.

Marginal Costs of Abatement

Table 6A shows the marginal costs of carbon emission reductions. The marginal costs of emission reduction, i.e., the implicit carbon tax rates, range between 119 and 184 DM per tonne of carbon for a 30% reduction ($74–$140 per tonne at DM 1.6 per U.S.$). This is roughly consistent with values obtained in other studies. The high inframarginal welfare cost of exemptions are reflected in higher tax rates for the exemption scenario.

[9] As reported in an earlier version of this paper, the ranking between uniform taxation and uniform taxation cum wage subsidies is reversed for the case of a first-best economy without prior tax distortions while the exemption policy clearly remains most inefficient.

[10] The endogenous wage subsidy rates are small relative to the tax rates imposed on labor. The cut-back in producers' labor costs due to subsidies are on the order of magnitude of 10% of the labor taxes.

[11] Similar second-best mechanisms apply for the exemption policy. Carbon tax exemptions work, however, only as an indirect wage subsidy and generally do not offset the distortions induced by shifting away the burden of carbon reduction mainly on labor.

Carbon Tax Revenue and Replace Tax Rates

Revenues from carbon taxation reflect carbon tax rates at different reduction targets. Tables 6B–6C show that high carbon tax revenues in the exemption case allow for high cutbacks of existing distortionary taxes. As evident from Table 5A this policy is less effective because the strong negative tax interaction effect (due to the high marginal tax rates) dominates the positive revenue recycling effect. The differences in welfare costs across alternative carbon tax recycling strategies (see Table 5A) are reflected in the magnitudes of cutbacks in distortionary taxes: high cutbacks in relatively distortionary taxes are most beneficial.

5. SENSITIVITY ANALYSIS

We have done a number of additional calculations to better understand how different economic assumptions affect our conclusions. This section summarizes our findings.

Capital Mobility and Labor Supply Elasticity

We have repeated our basic calculations in a model with restricted international capital mobility. This framework greatly reduces the marginal excess burden of capital taxes in the benchmark and reverses the ranking of tax recycling strategies. Labor taxes are relatively more distortionary with an excess burden of 16%, and carbon tax recycling through cuts in labor taxes are superior to capital tax cuts. This model illustrates the theoretical point often made in public finance literature (see, e.g., Goulder [14]), namely, that the cost of achieving a given level of reduction depends on both the revenue recycling and the tax interaction effect. The welfare costs are reduced for all policies because the benchmark tax system is less distorted and thus the negative tax interaction effects with additional carbon taxes are significantly lower than in the baseline model. The excess burden of exemptions over uniform carbon taxation stays in the same order of magnitude with a wage premia in the range of 69 to 92 thousand DM per worker at a 30% reduction target for labor and capital tax recycling.

If we make capital sector-specific in order to account for short-run adjustment costs, the marginal excess burden of the benchmark tax system further decreases. Decreased intersectoral capital mobility, however, increases the cost of achieving any reduction target by reducing the size of the production possibility frontier. As the overall cost increases, so does the excess cost of exemptions relative to uniform taxation. The wage premium of exemptions increases to between 91 and 118 thousand DM per job.

Augmenting the elasticity of labor supply with respect to real wages (from 0.1 to 0.15) increases the benchmark excess burden of taxes and leads to slightly higher welfare costs in all scenarios compared to the baseline results. The quantitative and qualitative ranking of different tax policies and recycling options remains unchanged.

Number of Exempted Sectors

The baseline computations suggest that the exemption of energy- and export-intensive sectors creates a large excess of costs even though the exempted sectors have only a small share of overall economic activity and carbon emissions. In order to see how the excess costs change as the number of exempted sectors increases, we vary the qualification requirements for exemptions. Not surprisingly we find that the welfare costs of tax exemptions rise with the number of exempted industries.

Base Year

A well-recognized shortcoming of calibrated equilibrium modeling is that temporary fluctuations over the business cycle are always present in input–output tables. When these data are subsequently used to calibrate utility and cost functions, temporary disequilibria may distort the behavioral models for consumers and producers. In order to establish that our results were not unduly affected by extraordinary features of the 1990 input–output table, we have repeated our calculations using two alternative base years for which comparable input–output data are available, 1986 and 1988. We find that changing the base year does not alter our qualitative results.

6. SUMMARY AND CONCLUSION

In this study, we have considered the economic implications of sectoral exemptions from environmental regulation with specific reference to carbon taxation with exemptions for energy- and export-intensive industries. We have analyzed this issue in the context of a static general equilibrium model calibrated to 1990 data for West Germany. The insights which emerge from the simulations are as follows:

(1) Welfare losses associated with exemptions can be substantial even when the share of exempted sectors in overall economic activity and carbon emission is small. Holding emissions constant, exemptions for some sectors imply increased tax rates for others and higher costs for the economy as a whole.

(2) Results from our simulation of a uniform carbon tax suggest that political pressure from labor unions and industries is likely because many of these sectors decline in employment, output, and exports as a result of carbon taxes. Our model gives insights into trade-offs between sector-specific concessions for energy- and export-intensive industries and the impacts of exemptions on economy-wide efficiency.

(3) Our comparison of a "tax expenditure" (i.e., a carbon tax exemption) with a direct wage subsidy revealed that the first of these is extraordinarily costly if it is viewed solely as a means of maintaining jobs in the affected industries.

Carbon emissions are a global externality, so the results and conclusions presented here are predicated on the assumption that unilateral carbon reduction in a single country does not induce significant changes of carbon emissions elsewhere. If leakage rates are low, tax exemptions of energy- and export-intensive industries do not provide an efficient policy for unilateral action. In the case of high leakage rates partial tax exemptions of industries might increase efficiency of (global) CO_2 reduction [16, 3]. As leakage rates are crucial for the efficient design of a unilateral abatement policy, future research should be directed toward the measurement of these values in a multiregional framework.

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