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Energy Tax Reform with Excemptions for the Energy-Intensive Export Sector

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Abstract

The present paper applies a theoretical two-sector three-factor model to analyze a variety of energy tax reforms with the common feature of at least partly exempting the energy-intensive export sector from the tax. As a result, all scenarios with exemptions reduce energy less than the non-discriminating textbook version of the energy tax. Moreover, in the two scenarios that exemplify typical attributes of the tax reforms in Germany and Denmark, an increase in total energy use is possible. This is due to a positive output effect resulting from a substitution of the energy-intensive for the labor-intensive commodity.

Keywords: Environmental tax reform, general equilibrium model

JEL classification: D50, H20, Q40

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1. Introduction

In Europe, several countries have introduced energy taxes that are environmentally motivated. The Scandinavian countries and the Netherlands already implemented CO_2 taxes at the beginning of the nineties[1] and most recently, Germany followed by introducing an ecological tax reform in 1999[2]. Other European countries like Italy and the U.K. have a tradition of high energy taxes that are fiscally motivated. With respect to its effect on energy demand, such a distinction, however, is irrelevant.

It is typical of most of these tax systems that energy- and/or export-intensive sectors are at least partly exempted from the tax. In Sweden, for example, the tax rate for the industrial sector is only 25 percent of the general tax rate[3]. In Denmark, energy-intensive firms have the option of committing themselves to reducing their emissions to a negotiated level, in which case the tax on remaining emissions is substantially reduced. Switzerland intends to fully exempt major emittents from carbon dioxide taxes provided they implement energy-saving measures[4]. As an exception to the rule, the Netherlands does not provide such tax reliefs on the use of carbon dioxide. However, the tax rate in this country is so moderate that the resulting commodity price increases only amount to a few percent[5].

From an efficiency point of view, such tax exemptions have no rationale, since marginal abatement costs among emittents will not be equalized and, therefore, total costs to attain a given standard are not minimized. The motivation behind such tax reliefs is political. If a country unilaterally introduces environmental taxes such as an energy tax, its export industry fears losing international competitiveness and market share. Hence, if this sector has a strong political influence, it is granted a tax reduction or is even exempted from paying the new energy tax [6].

The additional revenue from environmental taxes is typically used in order to reduce – or not to raise - other existing taxes. It is noteworthy that such a general reduction in existing taxes

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[1] For a survey of existing air pollutant taxes in Europe and Japan, see Cansier and Krumm (1997). For a more general overview on environmental taxes in OECD countries, see OECD (1995).
[2] German bill on the introduction of an ecological tax reform (March, 1999).
[3] Cansier and Krumm (1997), p. 66.
[4] Art. 9, Swiss federal bill on the reduction of CO_2 emissions.
[5] Cansier and Krumm (1997), p.65.
[6] The political economy of environmental politics goes back to the famous paper by Buchanan and Tullock (1975). For an overview of the political economy of environmental regulation, see Hahn (1990) and Keohane, Revesz and Stavins (1997).

does not exclude the energy-intensive sectors. Such a reimbursement scheme is realized in Germany, where the tax yield is used to uniformly cut social insurance contributions in all sectors[7]. In Denmark, the tax burden in the industrial sector is further reduced by redistributing the revenue back to this sector. In all these cases, it can be expected that the tax reform favors the exempted sector, which will expand at the cost of the other sectors. Furthermore, since the exempted sector is energy-intensive, the possibility arises that due to structural changes the tax reform will lead to increased total energy consumption. This paper seeks to analyze the effects of such exemption rules on total energy use and to identify conditions under which energy use is raised.

The general equilibrium model used in the paper is a two-sector three-factor open economy model. This type of model has often been applied since it was introduced by Harberger in 1962. Interestingly though, it has not yet been used to analyze environmental tax reforms. While Bovenberg and de Mooij (1994a), in their well-known paper on the double dividend, and Bovenberg and van der Ploeg (1994a) introduce only one factor, Bovenberg and de Mooij (1994b) as well as Bovenberg and van der Ploeg (1994b) use only one sector.

In addition, there is a large number of models that analyze environmental tax reforms within a computable general equilibrium. Ballard and Medema (1993), Goulder (1995a), Bovenberg and Goulder (1996) as well as Parry, Williams and Goulder (1999) all emphasise the role of existing taxes and the double dividend that might occur when the energy tax yield is used to cut distortionary taxes. Boyd, Krutilla and Viscusi (1995), on the other hand, calculate the welfare consequences of a unilateral CO_2 emission reduction including local benefits such as improved ambient air quality. All these models incorporate many sectors and several factors, but they do not address the topic of discriminating factor taxes. A noteworthy exception is Böhringer and Rutherford (1997), who calculate the welfare cost of exemptions in Germany's energy policy. They also reveal that direct wage subsidies constitute a more cost-effective measure to maintain jobs in the export sector while still reducing total energy consumption to a given level.

The present paper shifts the focus from welfare analysis to the investigation of structural changes due to discriminating energy taxes. It isolates the effects that raise or reduce total energy use and compares the size of these effects within a theoretically tractable model.

The paper is structured as follows: Section 2 introduces the model and derives a general result as a function of relative factor and commodity prices. Section 3 introduces four scenarios and

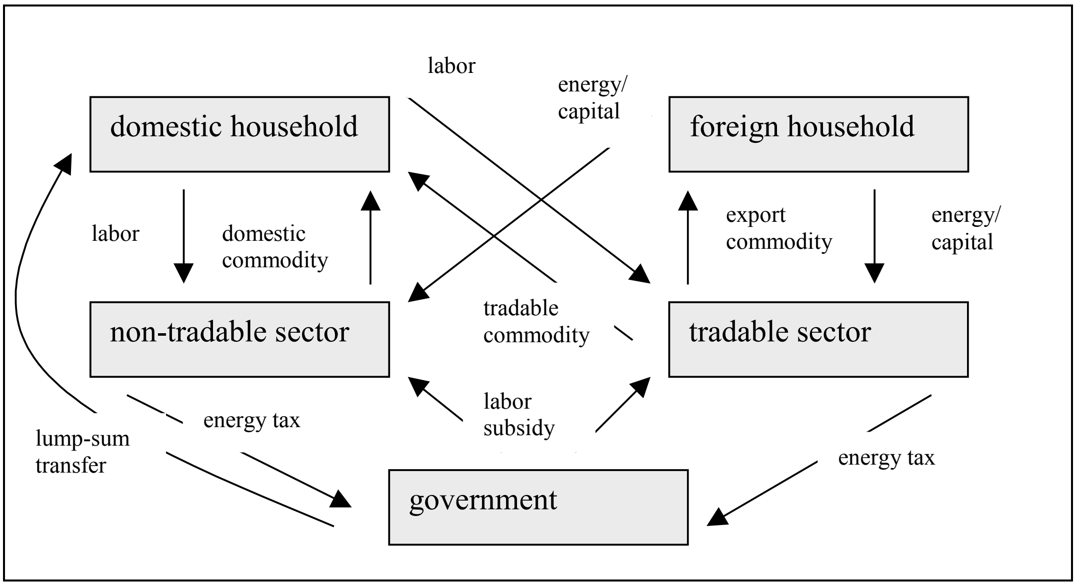
[7] Center for European Economic Research (1999).

discusses the results with respect to total energy use. Finally, section 4 summarizes and concludes.

2. The Model

In order to analyze the effects of energy taxes with exemptions, a model is chosen comprising a mixture of the traditional Harberger model and the model used in Bovenberg and De Mooij (1994b). While the former depicts two sectors with different factor intensities, the latter introduces three factors, of which labor is immobile and capital as well as energy are traded internationally. Figure 1 illustrates the structure of the model. One sector produces a tradable merchandise and is assumed to be energy-intensive. The other sector supplies a non-tradable commodity such as services and is assumed to be labor-intensive[8].

Figure 1: The structure of the model



On the factor level, the domestic household trades energy and capital (in the domestically consumed good) with labor (in the exported good). Government transfers the energy tax yield back to the household or to labor. Table 1 gives a mathematical description of the model.

[8] Since there are three factors of production, the reciprocity between energy- and labor intensity does not necessarily hold. To be precise, it is assumed that the cost share of energy is higher in the tradable sector and the cost share of labor is higher in the non-tradable sector.

Production:

Two representative firms in the sectors s (services) and m (merchandise) produce at constant returns to scale (I.1). The implicit factor demand functions in (I.2) follow from cost minimization. The non-profit condition (I.3) is guaranteed by the assumption of perfect competition. The producer prices of labor and energy (I.4) may each include a specific tax rate[9].

Table 1: The Model in Levels

Production:		
Output in sectors i = m, s	$Y_i = Y_i\left[L_i, N_i\left(K_i, E_i\right)\right]$	(I.1)
First order conditions	$P_{Y_i}\dfrac{\partial Y_i}{\partial L_i} = P_{L_i}^p$	(I.2)
	$P_{Y_i}\dfrac{\partial Y_i}{\partial N_i}\dfrac{\partial N_i}{\partial K_i} = \overline{P}_K\,;\; P_{Y_i}\dfrac{\partial Y_i}{\partial N_i}\dfrac{\partial N_i}{\partial E_i} = P_{E_i}^p$	
Non profit condition	$P_{Y_i}Y_i = P_{L_i}^p L_i + \overline{P}_K K_i + P_{E_i}^p E_i$	(I.3)
Producer prices	$P_{L_i}^p = P_L + t_{L_i}\,;\; P_{E_i}^p = \overline{P}_E + t_{E_i}$	(I.4)
Household:		
Utility function	$U = U\left(Y_s, Y_m^d\right)$	(I.5)
Marginal rate of substitution	$\dfrac{\partial U}{\partial Y_s}\dfrac{\partial Y_m^d}{\partial U} = \dfrac{P_{Y_s}}{P_{Y_m^d}}$	(1.6)
Budget constraint	$P_{Y_m^d}Y_m^d + P_{Y_s}Y_s = P_L\overline{L} + H$	(I.7)
Government budget	$\sum_i t_{E_i}E_i + \sum_i t_{L_i}L_i = H$	(I.8)
Tradable good market	$Y_m^d + Y_m^x = Y_m$	(I.9)
Factor markets	$\sum_i L_i = \overline{L}\,;\; \sum_i K_i = K\,;\; \sum_i E_i = E$	(I.10)
Trade balance	$\overline{P}_K K + \overline{P}_E E = \overline{P}_{Y_m}Y_m^x$	(I.11)

Notation:

Y_i :	supply of commodity i
Y_m^d :	domestic demand for tradable commodity
Y_m^x :	export of tradable commodity
$\overline{L}$:	total labor supply
E :	total energy use
L_i :	labor use in sector i
K_i :	capital use in sector i
E_i :	energy use in sector i
P_{Y_i} :	price of commodity in sector i
P_L :	after-tax wage rate
$P_{L_i}^p$:	producer price of labor in sector i
$\overline{P}_K$:	world market price of capital
$\overline{P}_E$:	world market price of energy
$P_{E_i}^p$:	producer price of energy in sector i
t_{L_i} :	tax rate on labor in sector i
t_{E_i} :	tax rate on energy in sector i
H :	lump-sum transfer to household

[9] Where applied, the labor tax rate is negative, i.e. labor is subsidized.

Household:

The household's utility is homothetic and depends on the consumption of the non-tradable and the domestically consumed tradable good (I.5 and I.6). Environmental quality is not included in the utility function, since the focus of the paper is on energy input but not on welfare[10]. For the same reason, labor is supplied at a given quantity, which gives rise to the budget constraint (I.7).

Government:

The government collects energy taxes that are redistributed as a lump-sum to the household or used to subsidize labor (I.8). There is no public good supplied. This simplification does not affect the results as long as the supply of the public good is fixed exogenously and it is weakly separable from the privately consumed goods.

International trade:

With the tradable good market (I.9) and the factor markets (I.10) in equilibrium, the trade balance (I.11) follows from Walras' law. It is assumed that the prices of the traded commodity and factors are given by world market prices.

In order to derive the reduced forms for a marginal change in energy taxes, the model is log-linearized. Table 2 presents the model in relative changes (denoted by a tilde unless indicated otherwise) around an initial equilibrium. In the benchmark, there is a uniform energy tax across both sectors, its revenue being reimbursed lump-sum. The two formulations of the government budget (II.8a and II.8b) refer to different tax reform scenarios to be explained later on. Since the same parameters apply to the production of Y_m^d and Y_m^x, factor demand in sector m is not further disaggregated.

[10] Moreover, if the reduction in energy use contributes to a global public good, its impact on domestic utility can be igmored.

Table 2: The Model in Relative Changes

Output	$\tilde{Y}_i = \alpha_{L_i}\tilde{L}_i + \alpha_{K_i}\tilde{K}_i + \alpha_{E_i}\tilde{E}_i$	(II.1)
Demand for labor	$\tilde{L}_i = \tilde{Y}_i + \left(\alpha_{K_i} + \alpha_{E_i}\right)\sigma_{L_i}\left(\phi_{E_i}\tilde{P}^p_{E_i} - \tilde{P}^p_{L_i}\right)$	(II.2a)
Demand for capital	$\tilde{K}_i = \tilde{Y}_i - \alpha_{L_i}\sigma_{L_i}\left(\phi_{E_i}\tilde{P}^p_{E_i} - \tilde{P}^p_{L_i}\right) + \phi_{E_i}E_i\sigma_{N_i}P^p_{E_i}$	(II.2b)
Demand for energy	$\tilde{E}_i = \tilde{Y}_i - \alpha_{L_i}\sigma_{L_i}\left(\phi_{E_i}\tilde{P}^p_{E_i} - \tilde{P}^p_{L_i}\right) - \phi_{K_i}\sigma_{N_i}P^p_{E_i}$	(II.2c)
Non-profit condition	$\tilde{P}_{Y_i} = \alpha_{L_i}\tilde{P}^p_{L_i} + \alpha_{E_i}\tilde{P}^p_{E_i}$	(II.3)
Producer prices	$\tilde{P}^p_{L_i} = \tilde{P}_L + \tilde{t}_{L_i}$	(II.4)
	$\tilde{P}^p_{E_i} = \tilde{t}_{E_i}$	(II.5)
Commodity demand	$\tilde{Y}_s - \tilde{Y}^d_m = -\sigma_U\left(\tilde{P}_{Y_s} - \tilde{P}_{Y^d_m}\right)$	(II.6)
Budget constraint	$\beta_s\left(\tilde{P}_{Y_s} + \tilde{Y}_s\right) + \beta^d_m\left(\tilde{P}_{Y^d_m} + \tilde{Y}^d_m\right) = \beta_L\tilde{P}_L + \beta_H\tilde{H}$	(II.7)
Government budget	$\sum_i \frac{t_E E_i}{H}\tilde{t}_{E_i} + \tilde{E} = \tilde{H}$	(II.8a)
	$\tilde{E} = \tilde{H}\ ;\ \tilde{t}_{L_i} = -\frac{\alpha_{E_i}}{\alpha_{L_i}}\tilde{t}_{E_i}$	(II.8b)
Factor markets	$\gamma_{L_s}\tilde{L}_s + \gamma_{L^d_m}\tilde{L}^d_m + \gamma_{L^x_m}\tilde{L}^x_m = 0$	(II.9a)
	$\gamma_{K_s}\tilde{K}_s + \gamma_{K^d_m}\tilde{K}^d_m + \gamma_{K^x_m}\tilde{K}^x_m = 0$	(II.9b)
	$\gamma_{E_s}\tilde{E}_s + \gamma_{E^d_m}\tilde{E}^d_m + \gamma_{E^x_m}\tilde{E}^x_m = 0$	(II.9c)
Trade balance	$\delta_K\tilde{K} + \delta_E\tilde{E} = \tilde{Y}^x_m$	(II.10)

Notation:

Parameters:

σ_{L_i}: substitution elasticity between labor and composite factor N in sector i

σ_{N_i}: substitution elasticity between capital and energy in sector i

σ_U: substitution elasticity of commodity demand

Taxes:

$\tilde{t}_{E_i} \equiv \frac{dt_{E_i}}{P^p_E}\ ;\ \tilde{t}_{L_i} \equiv \frac{dt_{L_i}}{P^p_L}$

Endogenous variables:

$\tilde{Y}_s, \tilde{Y}^d_m, \tilde{Y}^x_m, \tilde{L}_i, \tilde{E}_i, \tilde{E}, \tilde{K}_i, \tilde{K}, \tilde{P}_{Y_s}, \tilde{P}_{Y^d_m}, \tilde{P}^p_{L_i}, \tilde{P}^p_{E_i}, \tilde{P}_L, \tilde{t}_{L_i}$

Exogenous variables:

$\tilde{t}_{E_i}$

Shares:

$\alpha_{L_i} = \frac{P^p_L L_i}{P_{Y_i}Y_i}\ ;\ \alpha_{K_i} = \frac{\overline{P}_K K_i}{P_{Y_i}Y_i}\ ;\ \alpha_{E_i} = \frac{P^p_E E_i}{P_{Y_i}Y_i}$

$\phi_{E_i} = \frac{\alpha_{E_i}}{\alpha_{K_i} + \alpha_{E_i}}\ ;\ \phi_{K_i} = \frac{\alpha_{K_i}}{\alpha_{K_i} + \alpha_{E_i}}$

$\beta_s = \frac{P_{Y_s}Y_s}{P_{Y_s}Y_s + P_{Y^d_m}Y^d_m}\ ;\ \beta^d_m = \frac{P_{Y^d_m}Y^d_m}{P_{Y_s}Y_s + P_{Y^d_m}Y^d_m}$

$\beta_L = \frac{P^p_L\overline{L}}{P^p_L\overline{L} + H}\ ;\ \beta_H = \frac{H}{P^p_L\overline{L} + H}$

$\gamma_{L_s} = \frac{L_s}{\overline{L}};\ \gamma_{L^d_m} = \frac{L^d_m}{\overline{L}};\ \gamma_{L^x_m} = \frac{L^x_m}{\overline{L}}$

$\gamma_{K_s} = \frac{K_s}{K};\ \gamma_{K^d_m} = \frac{K^d_m}{K};\ \gamma_{K^x_m} = \frac{K^x_m}{K}$

$\gamma_{E_s} = \frac{E_s}{E};\ \gamma_{E^d_m} = \frac{E^d_m}{E};\ \gamma_{E^x_m} = \frac{E^x_m}{E}$

$\delta_K = \frac{\overline{P}_K K}{\overline{P}_K K + \overline{P}_E E}\ ;\ \delta_E = \frac{\overline{P}_E E}{\overline{P}_K K + \overline{P}_E E}$

With the model as represented in table 2, we first derive a semi-reduced form of total energy use as a function of relative commodity and factor prices. This general result can then be used to calculate the result of different tax reform scenarios.

Because labor input is exogenous, total energy use is expressed conditional on labor. Equations II.9c and II.2 yield:

$$\begin{aligned}\widetilde{E} &= \gamma_{E_s}\left[\widetilde{L}_s - \sigma_{L_s}\left(\phi_{E_s}\widetilde{P}^p_{E_s} - \widetilde{P}^p_{L_s}\right) - \phi_{K_s}\sigma_{N_s}\widetilde{P}^p_{E_s}\right] \\ &+ \gamma_{E^d_m}\left[\widetilde{L}^d_m - \sigma_{L_m}\left(\phi_{E_m}\widetilde{P}^p_{E^d_m} - \widetilde{P}^p_{L^d_m}\right) - \phi_{K_m}\sigma_{N_m}\widetilde{P}^p_{E^d_m}\right]. \\ &+ \gamma_{E^x_m}\left[\widetilde{L}^x_m - \sigma_{L_m}\left(\phi_{E_m}\widetilde{P}^p_{E^x_m} - \widetilde{P}^p_{L^x_m}\right) - \phi_{K_m}\sigma_{N_m}\widetilde{P}^p_{E^x_m}\right]\end{aligned} \tag{1}$$

Next, $\widetilde{L}^x_m$ is eliminated, using II.9a. Note that this procedure, at the same time, eliminates $\widetilde{L}^d_m$, since a shift of production within sector m changes neither total labor nor total energy use. Therefore, energy use can be calculated as a function of labor input in sector s and relative prices only:

$$\begin{aligned}\widetilde{E} &= \frac{\gamma_{E_s}\gamma_{L^x_m} - \gamma_{E^x_m}\gamma_{L_s}}{\gamma_{L^x_m}}\widetilde{L}_s \\ &- \gamma_{E_s}\left[\sigma_{L_s}\left(\phi_{E_s}\widetilde{P}^p_{E_s} - \widetilde{P}^p_{L_s}\right) + \phi_{K_s}\sigma_{N_s}\widetilde{P}^p_{E_s}\right] \\ &- \gamma_{E^d_m}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}^p_{E^d_m} - \widetilde{P}^p_{L^d_m}\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}^p_{E^d_m}\right] \\ &- \gamma_{E^x_m}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}^p_{E^x_m} - \widetilde{P}^p_{L^x_m}\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}^p_{E^x_m}\right]\end{aligned}. \tag{2}$$

The first line in equation 2 represents an output effect, stemming from a shift of production between the labor-intensive sector s and the energy-intensive sector m – or mx respectively. If production is shifted from sector m to s, energy use decreases and vice versa. The remaining terms in equation 2 stand for the substitution of labor and capital for energy in the production of Y_s, Y^d_m and Y^x_m respectively[11]. Note that the inclusion of capital as a third factor reinforces the negative substitution effect on energy. The energy price increase causes both a substitution of capital for energy as well as a substitution of labor for the composite factor including energy.

Turning to consumption, $\widetilde{Y}_s$ is derived, using budget constraint II.7, commodity demand II.6 and the government budget II.8:

$$\widetilde{Y}_s = \beta_H\widetilde{E} - \beta^d_m\sigma_U\left(\widetilde{P}_{Y_s} - \widetilde{P}_{Y^d_m}\right). \tag{3}$$

[11] The distinction between output and factor substitution effect goes back to Mieszkowski. Cited in Atkinson, Stiglitz (1980), p. 173.

Since revenue from the additional energy tax is fully redistributed to the household, real income remains unaltered in a situation without existing taxes. Starting from positive tax rates, however, a tax increase changes the existing energy tax base and, as a consequence, real income. With existing energy taxes, a decrease in energy use further distorts the energy market and real income falls. If, on the other hand, energy use expands, the distortion is reduced and real income increases (see the first term on the r.h.s. of equation 3).

Using equations 3 and II.2, we substitute $\widetilde{L}_s$ in equation 2 for $\widetilde{Y}_s$:

$$\begin{aligned}\widetilde{E} &= \frac{\gamma_{E_s}\gamma_{L_m^x} - \gamma_{E_m^x}\gamma_{L_s}}{\gamma_{L_m^x}}\left[\beta_H \widetilde{E} - \beta_m^d \sigma_U \left(\widetilde{P}_{Y_s} - \widetilde{P}_{Y_m^d}\right)\right] \\ &+ \frac{\gamma_{E_s}\gamma_{L_m^x} - \gamma_{E_m^x}\gamma_{L_s}}{\gamma_{L_m^x}}\left(\alpha_{K_s} + \alpha_{E_s}\right)\sigma_{L_s}\left(\phi_{E_s}\widetilde{P}_{E_s}^p - \widetilde{P}_{L_s}^p\right) \\ &- \gamma_{E_s}\left[\sigma_{L_s}\left(\phi_{E_s}\widetilde{P}_{E_s}^p - \widetilde{P}_{L_s}^p\right) + \phi_{K_s}\sigma_{N_s}\widetilde{P}_{E_s}^p\right] \\ &- \gamma_{E_m^d}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}_{E_m^d}^p - \widetilde{P}_{L_m^d}^p\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}_{E_m^d}^p\right] \\ &- \gamma_{E_m^x}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}_{E_m^x}^p - \widetilde{P}_{L_m^x}^p\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}_{E_m^x}^p\right]\end{aligned} \quad . \qquad (4)$$

The first line in (4) represents an income and an output effect (the first and the second term in brackets). The second line describes the substitution of $\widetilde{L}_m^x$ for $\widetilde{Y}_s$. This substitution effect can be added to the substitution of $\widetilde{E}_s$ for $\widetilde{L}_s$ to arrive at:

$$\begin{aligned}\widetilde{E} &= \frac{\gamma_{E_s}\gamma_{L_m^x} - \gamma_{E_m^x}\gamma_{L_s}}{\gamma_{L_m^x}}\left[\beta_H \widetilde{E} - \beta_m^d \sigma_U \left(\widetilde{P}_{Y_s} - \widetilde{P}_{Y_m^d}\right)\right] \\ &- \frac{\gamma_{E_s}\gamma_{L_m^x}\alpha_{L_s} + \gamma_{E_m^x}\gamma_{L_s}\left(\alpha_{K_s} + \alpha_{E_s}\right)}{\gamma_{L_m^x}}\sigma_{L_s}\left(\phi_{E_s}\widetilde{P}_{E_s}^p - \widetilde{P}_{L_s}^p\right) - \gamma_{E_s}\phi_{K_s}\sigma_{N_s}\widetilde{P}_{E_s}^p \\ &- \gamma_{E_m^d}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}_{E_m^d}^p - \widetilde{P}_{L_m^d}^p\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}_{E_m^d}^p\right] \\ &- \gamma_{E_m^x}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}_{E_m^x}^p - \widetilde{P}_{L_m^x}^p\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}_{E_m^x}^p\right]\end{aligned} \quad . \qquad (5)$$

Solving for $\widetilde{E}$, the semi-reduced result as a function of relative price changes is derived:

$$\widetilde{E} = \frac{\gamma_{L_m^x}}{\gamma_{L_m^x} - \left(\gamma_{E_s}\gamma_{L_m^x} - \gamma_{E_m^x}\gamma_{L_s}\right)\beta_H}$$

$$\begin{aligned}
\Big\{ & -\frac{\gamma_{E_s}\gamma_{L_m^x} - \gamma_{E_m^x}\gamma_{L_s}}{\gamma_{L_m^x}}\beta_m^d \sigma_U \left(\widetilde{P}_{Y_s} - \widetilde{P}_{Y_m^d}\right) \\
& - \frac{\gamma_{E_s}\gamma_{L_m^x}\alpha_{L_s} + \gamma_{E_m^x}\gamma_{L_s}\left(\alpha_{K_s} + \alpha_{E_s}\right)}{\gamma_{L_m^x}}\sigma_{L_s}\left(\phi_{E_s}\widetilde{P}_{E_s}^p - \widetilde{P}_{L_s}^p\right) \\
& - \gamma_{E_s}\phi_{K_s}\sigma_{N_s}\widetilde{P}_{E_s}^p \\
& - \gamma_{E_m^d}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}_{E_m^d}^p - \widetilde{P}_{L_m^d}^p\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}_{E_m^d}^p\right] \\
& - \gamma_{E_m^x}\left[\sigma_{L_m}\left(\phi_{E_m}\widetilde{P}_{E_m^x}^p - \widetilde{P}_{L_m^x}^p\right) + \phi_{K_m}\sigma_{N_m}\widetilde{P}_{E_m^x}^p\right]\Big\}
\end{aligned} \tag{6}$$

With sector s labor-intensive and sector m energy-intensive, the term in front of the braces in equation (6) is between zero and one. Without existing taxes, β_H vanishes and the term is equal to one. With existing taxes, however, the income effect reduces the absolute value of $\widetilde{E}$. If total energy use decreases, real income and consumption of both Y_s and Y_m^d are reduced. At the same time, export Y_m^x goes up. While such a shift between Y_m^d and Y_m^x does not affect factor use, the shift from the labor-intensive Y_s to the energy-intensive Y_m^x increases energy demand. As a consequence, the initial reduction in energy is smaller. If, on the other hand, total energy demand rises, income and consumption increase. In this case, a shift from energy-intensive exports to labor-intensive non-tradables takes place, and the initial energy increase is reduced. Note that the income effect does not change the sign of the result, which is determined by the terms in the braces of (6) alone.

3. Results of four scenarios

Four scenarios are evaluated. The first scenario (*REF*) corresponds to the textbook version of the energy tax and serves as a reference point. Two other scenarios, labeled *GER* and *DEN*, represent a stylized version of the tax reform in Germany and Denmark. Of course, these two scenarios do not precisely describe all the features of the rather complicated tax schemes in these countries. Rather, they focus on special regulations to reduce the tax burden of the energy-intensive sector. Finally, the scenario *GER** is a refinement of the basic scenario *GER*. The relative commodity and factor prices of the four scenarios are presented in table 3.

Table 3: Relative price changes

	REF	*GER*	*GER**	*DEN*
$\left(\tilde{P}_{Y_s} - \tilde{P}_{Y_m^d}\right)/\tilde{t}_E$	$\frac{-\alpha_{L_s}\alpha_{E_m} + \alpha_{L_m}\alpha_{E_s}}{\alpha_{L_m}} < 0$	α_{E_s}	$\alpha_{E_s} - \alpha_{E_m} < 0$	α_{E_s}
$\left(\phi_{E_s}\tilde{P}^p_{E_s} - \tilde{P}^p_{L_s}\right)/\tilde{t}_E$	$\phi_{E_s} + \frac{\alpha_{E_m}}{\alpha_{L_m}}$	ϕ_{E_s}	ϕ_{E_s}	ϕ_{E_s}
$\left(\phi_{E_m}\tilde{P}^p_{E_m^d} - \tilde{P}^p_{L_m^d}\right)/\tilde{t}_E$	$\phi_{E_m} + \frac{\alpha_{E_m}}{\alpha_{L_m}}$	0	ϕ_{E_m}	$\phi_{E_m} + \frac{\alpha_{E_m}}{\alpha_{L_m}}$
$\left(\phi_{E_m}\tilde{P}^p_{E_m^x} - \tilde{P}^p_{L_m^x}\right)/\tilde{t}_E$	$\phi_{E_m} + \frac{\alpha_{E_m}}{\alpha_{L_m}}$	0	0	$\phi_{E_m} + \frac{\alpha_{E_m}}{\alpha_{L_m}}$
$\tilde{P}^p_{E_s}/\tilde{t}_E$	1	1	1	1
$\tilde{P}^p_{E_m^d}/\tilde{t}_E$	1	0	1	1
$\tilde{P}^p_{E_m^x}/\tilde{t}_E$	1	0	0	1

Scenario *REF*:

In this scenario, a uniform energy tax rate without exemption is applied. The tax revenue is redistributed lump-sum to the household according to (II.8a).

With the given world market price of the exported good, an increase in the energy price must be compensated for by a fall in the producer price of labor. The price of energy as well as the price of the composite factor N, therefore, rise relative to labor. As a consequence, all the substitution effects are negative.

The factor price changes do not alter the price of the tradable commodity. The price of the non-tradable commodity, however, decreases due to the different factor intensities. The household substitutes the non-tradable for the energy-intensive tradable good, which reduces energy use.

Thus, in the reference scenario, all the substitution effects as well as the output effect on energy are negative. Moreover, the reduction in energy use erodes the base of the existing energy tax and additionally distorts the energy market from a purely fiscal point of view. Real income falls, which, in the case of homothetic utility, leads to an equal reduction in demand for the non-tradable and the tradable commodity. With labor supply given, production is shifted to the exported commodity, which causes energy input to rise again. As mentioned above, the income effect, therefore, lessens the initial effect on total energy use.

Scenario *GER*:

In this scenario the energy-intensive export sector is exempted from the energy tax but the revenue recycling does not discriminate between the two sectors.

Since the export sector is not taxed, the non-profit condition requires that the producer price of labor remains unchanged. Thus, there is no factor substitution in the export sector. In the domestic sector, on the other hand, the energy price and the price of the composite factor increase relative to labor and give rise to a negative substitution effect on energy.

The energy tax increase in the domestic sector raises the relative commodity price of non-tradables. The household substitutes energy-intensive tradables for labor-intensive non-tradables, which increases total energy input. The effect on total energy use thus depends on the relative size of the negative substitution and the positive output effect. Equation 7 presents the reduced form of total energy use. For simplicity, the income effect is ignored.

$$\left.\frac{\tilde{E}}{\tilde{t}_E}\right|_{H=0} = \frac{-\gamma_{E_s}\gamma_{L_m^x} + \gamma_{E_m^x}\gamma_{L_s}}{\gamma_{L_m^x}}\beta_m^d\sigma_U\alpha_{E_s} - \frac{\gamma_{E_s}\gamma_{L_m^x}\alpha_{L_s} + \gamma_{E_m^x}\gamma_{L_s}\left(\alpha_{K_s} + \alpha_{E_s}\right)}{\gamma_{L_m^x}}\sigma_{L_s}\phi_{E_s} - \gamma_{E_s}\phi_{K_s}\sigma_{N_s} \qquad (7)$$

From equation 7, we can deduce that the possibility of an energy increase rises with (a) the substitution elasticity in utility relative to the substitution elasticities in production, (b) the difference in factor intensities and (c) the expenditure share of the domestically consumed tradable good.

It can be shown that a necessary condition for energy use to rise is that the substitution elasticity in utility is larger than a weighted average of the substitution elasticities in production. A sufficient condition for energy use to rise, on the other hand, is that the elasticities in production vanish. Such a limitational production function in the domestic sector might prevail in the short run. Therefore, an increase in total energy use due to the exemption of the export sector is more plausible in the short run.

Scenario *GER**:

Instead of exempting the whole export sector from paying the energy tax, it is conceivable to restrict the exemption on the exported goods only. In Switzerland, such a tax scheme is applied with respect to volatile organic compounds (VOC) – a substance that is used, for example, as a component of varnish and paint. The VOC charge is refunded to firms that use the substance in the production of goods to be exported.

With such a tax, the producer price of labor is still unchanged. However, since the tradable sector now pays taxes on energy in domestically sold products, a factor substitution in the production of these goods takes place[12]. The factor substitution in the non-tradable sector remains unaltered when compared with the scenario *GER*. However, the output effect in the scenario *GER** is negative. Since both domestically consumed commodities are subject to the energy tax and since the tradable good is energy-intensive, the relative consumer price of the tradable good rises, and the substitution of the non-tradable good reduces total energy demand. With all the effects being negative, the scenario *GER** unambiguously reduces total energy use. Moreover, the reduction is always stronger than in the scenario *GER*.

Scenario *DEN*:

It is a special feature of the Danish tax system that the tax paid by the industrial sector is used to lower the employers' contribution to social insurance in this sector[13]. Therefore, in the scenario *DEN*, a uniform tax rate across all sectors is applied and the tax yield of the non-tradable sector is used to reduce the producer price of labor in that sector. The revenue from the non-tradable sector, on the other hand, is redistributed lump-sum to the household. While in the scenario *GER* the exemption refers to the energy tax, the scenario *DEN* discriminates with respect to the reimbursement scheme. In both scenarios, the price of the tradable good does not vary while the price of the non-tradable increases due to the higher energy tax. Thus, an equivalent change of relative commodity prices results. The equivalence also holds for the relative factor prices in the non-tradable sector. This is due to the fact that in both scenarios the producer price of labor remains unchanged in this sector. In contrast to *GER*, however, the relative factor prices in the industrial sector vary in *DEN* because the energy price rises while the producer price of labor is reduced. Hence, there is an additional negative substitution

[12] Note that with such a discriminating tax structure, the factor intensities in the tradable sector drift apart. Domestically sold products are produced with less energy than exported goods.

[13] Cansier and Krumm, p. 67.

effect in the scenario *DEN*, which makes an increase in total energy use less likely than in the scenario *GER*. In any case, the tax reform in *DEN* results in a smaller change of energy than in *GER*[14].

Comparing *DEN* and *GER**, the results with respect to total energy use are ambiguous. While the output effect is positive in *DEN* and negative in *GER**, *DEN* causes stronger substitution effects. The size of these two countervailing effects depends on the model parameters.

4. Summary and Conclusions

This paper is based on the observation that in most European countries which implemented environmentally motivated energy taxes, energy-intensive and export-oriented sectors are at least partly exempted from paying the tax. The paper is intended to analyze the effects of these special regulations on total energy use. For this purpose a model with an energy-intensive tradable and a labor-intensive non-tradable commodity is applied. Furthermore, the model consists of three factors, of which energy and capital are traded at world market prices while labor is immobile and supplied exogenously.

Two scenarios are identified in which tax reform may increase total energy use. Such a result, obviously unintended by the policy maker, is always possible if an exemption of the energy-intensive export sector reduces the relative commodity price of this sector. In this case, a substitution of the energy-intensive for the labor-intensive good causes a positive output effect on total energy use. In the scenario labeled *GER*, such a positive output effect is due to the tax exemption of the energy-intensive sector. In the scenario labeled *DEN*, on the other hand, the positive output effect originates from a discriminating redistribution of the tax revenue. In this scenario, both sectors are subject to a uniform energy tax, but while the tax yield of the energy-intensive sector is used to subsidize labor in this sector, the tax paid by the labor-intensive sector is redistributed lump-sum to the household.

If the exemption of the energy tax is restricted to the exported goods (as shown in scenario *GER**), the relative price of domestically consumed goods does not change and, as a consequence, no output effect on total energy use occurs. The same applies if, in contrast to scenario *DEN*, the tax yield in both sectors is used to reduce the producer price of labor in the respective sectors.

[14] If the energy change is negative, *Denmark* reduces energy more than *Germany*.

With respect to factor substitution, it is derived that, in the textbook scenario which does not discriminate between sectors, the effect on energy is the strongest. In the exemption scenarios, the factor substitution effects are reduced or even eliminated. Not surprisingly, the textbook scenario, therefore, yields the largest reduction in energy.

Finally, starting from a benchmark with existing energy taxes, there is an income effect on energy caused by a change of the energy tax base. If, for example, energy use decreases, the distortion in the energy market is reinforced from a purely fiscal point of view and real income is reduced. With labor supply given exogenously, such a reduction in real income is reflected in a shift between domestically consumed and exported goods, which lessens the initial decrease in energy input.

Because of exogenous labor supply, no labor tax is modeled in the benchmark. By the same token, the additional revenue from the energy tax raise is redistributed lump-sum to the household in all the scenarios except in the discriminating scenario *DEN*. If, on the other hand, labor supply were modeled endogenously, it would be sensible to introduce labor taxes in the benchmark and to use the additional revenue from the energy tax to cut labor taxes. Bovenberg and De Mooij (1994a and 1994b) have shown that in such a model the erosion of the energy tax base is equivalent to a reduction in real after-tax wages. With positive – uncompensated – wage elasticity, labor supply would fall and the overall production level as well as energy input would be reduced. The same argumentation with reversed signs would apply to a situation where the energy tax base is enlarged. The size of this additional effect crucially depends on the uncompensated elasticity of labor supply, which in most empirical studies, however, is rather small[15].

[15] See, for example, Hausman (1985)

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