Reconciling Environmental Policy with Employment, International Competitiveness and Participation Requirements.

T. Ziesemer

MERIT and Department of Economics, Rijksuniversiteit Limburg, Maastricht

October 1995

Abstract. We argue that a conventional double dividend policy - defined as reduction of greenhouse gas emissions and unemployment through taxation of energy and CO2 emissions and subsidization of wage costs - and the aim of keeping international competitiveness intact are mutually exclusive concepts. It is suggested that a double dividend policy that aims at reducing GHG emissions and unemployment without violation of international competitiveness has to tax energy use and CO2 emissions of households and should use the revenues to subsidize investment in energy-saving technologies to reduce marginal costs of firms. Reduction of energy coefficients lowers marginal costs and prices and therefore increases competitiveness and employment in an environmentally friendly way and may induce other parts of the world to participate in GHG emission reduction policies. According to this proposal the principle of causation has to be dropped nationally but not internationally.

* This paper is a slightly revised version of Chapter 4 of "Energy Technologies, Environmental Policy and Competitiveness", Final Report for JOULE II programme of the European Commission DG XII (F.1) by Paul Diederen, René Kemp, Perry Verberne, Thomas Ziesemer and Adriaan van Zon, MERIT, University of Limburg, May 1995. I would like to thank Paul Diederen, Marcel Janssen, René Kemp, Michael Kohlhaas, Hans van Meijl, Barbara Praetorius, Luc Soete, Perry Verberne and Adriaan van Zon as well as the seminar participants at the DIW Berlin and the session participants at the 'Jahrestagung des Vereins für Socialpolitik' in Linz/Austria, Sept. 1995, especially the discussant Peter Michaelis, for helpful discussions. Responsibility for views and opinions expressed is entirely mine and do not necessarily reflect those of the DG XII or the persons mentioned above. I am also grateful to Silvana de Sanctis for the very careful text and formula processing.

Reconciling Environmental Policy with Employment, International Competitiveness and Participation Requirements.

1. Introduction

The EC proposal for GHG-emission reduction suggests (among other things) the level of taxation of 10$ per barrel of oil equivalent with exemptions for energy-intensive industries. Moreover, international competitiveness of firms and unemployment should not be reduced. How taxes should be rebated, however, is an issue left open up till now. Reduction of existing distortionary taxes and subsidies for wage costs have been proposed. Here we argue that subsidies for investment into energy-saving technologies may be a superior way of revenue rebatement that supports the environmental, employment and competitiveness goals. It takes international competitiveness requirements into account right from the beginning instead of making concepts which require exemptions.

In conventional AGE (Applied General Equilibrium) analysis there is costless exogenous energy-saving technical progress and costless substitution between capital and labour in response to price changes (see Conrad and Wang 1993 for an elegant introduction). Here we undertake some first steps to replace these elements. We introduce fixed costs and induced energy savings into an economic model with environmental policy. Both are costly. We use a modification of the monopolistic competition model developed by Dixit and Stiglitz (1977). The reason is that we prefer a framework suitable for differentiated products over one for homogeneous products; the evidence (see Morrison 1989, 1990, 1992) is not in contrast with the Chamberlinian model of monopolistic competition: At the macro-level and that of highly aggregated sectors profits turn out to be approximately zero. In monopolistic competition models fixed costs limit the number of firms and there is monopolistic price setting. Environmental taxes lead to price changes induced by changes of marginal costs. We allow for many consumption goods and use of capital goods in production. Each variant is assumed to be produced by only one firm which therefore is also the only exporter in the world. The model is extended with an energy-environment part to analyze the international competitiveness of energy producers and users when environmental policy encourages energy-saving technologies and reduces distortionary taxes on wage income or subsidizes wages. As this chapter is concerned with 'what happens in the next ten years after the introduction of an environmental tax', we don't treat technology as an endogenous R&D variable because the lag from invention to marketing is typically more than ten years in many cases. This means that energy savings for the next ten years will have to be achieved with technologies that are available now. Investment in energy-saving technologies, may be of the retrofitting type, constitutes the only form of endogenous technical progress in the model. However, it is easy to imagine that an increase in demand for these technologies increases the incentive for R&D in this field.

The organisation of the chapter is as follows. In section 2 we set up a model which will guide the analysis. In section 3 we show that the impact effects of energy and C02 taxes under the EC proposal and subsidies for investment in energy-saving technologies will be rather limited in spite of the sensitivity of the results with respect to the price elasticities of demand and the

level of the tax. In section 4 we treat the dynamic decision of the firm with emphasis on endogenous technical change reducing energy coefficients through investment in energy-saving technologies which lowers energy coefficients. In section 5 we argue that a policy that leaves international competitiveness unaffected has to make sure that marginal costs are not increased by taxes. A double dividend or double benefit defined as environmental benefit cum unemployment reduction can be obtained only if the revenues from energy and C02 taxes are rebated as subsidies for investment in energy-saving technologies. In section 6 we show that prices are higher than marginal costs. Therefore a policy that speeds up the decrease in marginal costs by lowering the energy coefficients through investment in energy-saving technologies will lead to prices that may decrease more strongly than marginal costs do. This mitigates the negative income effects for households. In contrast, energy and CO2 taxes on the firm level may increase prices to a greater extent than marginal costs and reduce international competitiveness. In section 7 investment dynamics are considered. It is shown that energy and CO2 taxes have a negative impact on investment in the capital stock and on employment whereas subsidies on investment in energy-saving technologies have a positive impact on employment, the environment and international competitiveness. Section 8 briefly summarizes the argument in a self-contained manner. The reader who is not particularly interested in technical details can jump to it immediately.

2. Specification of the model

The model set up in this section serves several purposes. Firstly, it disciplines the line of thought of this chapter. Secondly, it is the basis for some quantifications in later sections. Thirdly, it makes the incentive effects from taxes and subsidies on investment in energy-saving technologies and the capital stock explicit.

Assumptions on *preferences* of households are described by the following utility function

$$u=\sum_{i=1}^{n} c_i^{\otimes_i} + \sum_{im} c_{im}^{\otimes_{im}} + f\sum_{l} \ln E_l \qquad i = 1,..., n \qquad (1)$$
$$im = n + 1,...,n^* + n$$

Consumption consists of all sectors' deliveries, c_i, as in input-output tables. Some consumer goods, c_{im} may be imported indirectly. The utility function is of the CES type with respect to the consumer goods with elasticity $\otimes_{im}$ and $\otimes_{im}$ of the ln-type with respect to the environment E and f is a parameter. The environmental part of (1) - where l is a country index and the summation over countries reflects global pollution - has marginal utility such that it moves quicker towards infinity if E goes to zero than marginal utility of c_i and c_{im} moves to infinity if c_i and c_{im} go towards zero. In Soete and Ziesemer (1992) this was a necessary assumption to make sure that the environmental tax is positive in the equilibrium and in the optimum. The positivity problem arises from the inefficiency of monopolistic prices under monopolistic competition. Monopolistic production is lower than optimum production

and therefore c.p. should be increased. However, pollution is an argument in favour of reducing output. In the present context it is widely agreed that the environmental tax, whatever its form, should be positive. To make sure that this is a result in general equilibrium and central optimum considerations it was necessary to make the environmental part steeper in marginal utility. In short, utility function (1) reflects the implicit preferences of politicians who favour environmental policy over anti-monopoly policy and material wealth. This assumption will have no impact on the issues treated in the chapter as long as optimal policy is not discussed. Export demand can either be assumed to be derived from a foreign utility function corresponding to (1) with domestic and imported goods,

$$E = \sum_i x_{iEx}^{\otimes_{iEx}} + \sum_i x_{iEx}^{*\otimes_{iEx}} \qquad i = 1,..., n \tag{2}$$

or, alternatively, from a demand function with constant price elasticities.

Production of domestically produced intermediates, x_j has labour and capital requirements

$$L_j = b_{Lj} + a_{Lj} x_j \qquad j = 1,..., n \tag{3}$$

$$K_j = b_{Kj} + a_{Kj} x_j \qquad j = 1,... n \tag{4}$$

where b-terms represent fixed costs and a-terms variable costs. a-terms could be endogenized to allow for substitution, which means that they are a function of factor prices. Because of the fixed costs it is advantageous for each firm that enters the market to produce a new variant and not to enter any other firms market. Therefore each good is produced only in one country. This is the perfect specialization result known from international trade models with differentiated goods. K_j is an abbreviation for assembled investment intermediates:

$$K_j = \int_{-\infty}^{t} [\sum_i (e^{d(\tau - t)} I_{ij}(\tau)^{\beta_{ij}}] d\tau \quad with \quad i = 1,..., e, r,..., n \tag{5}$$

β_{ij} is the elasticity of the capital stock of sector j with respect to investment goods produced

in sector i. Later vintages of investment have higher productivity at rate d. Differentiating K_j with respect to time delivers

$$\dot{K}_j = \sum_i I_{ij} (t)^{\beta_{ij}} - d\int_{-\infty}^{t} \sum_i [e^{d(\tau-t)} I_{ij}(\tau)^{\beta_{ij}}] d\tau \qquad (6)$$

To have the stock of capital, K_j at the desired level investment deliveries, I_{ij} are assembled for each j which is expressed at the first term of the right hand side of (6). At the same time, productivity of all vintages is getting more and more backward compared to that of most recent investment.

Intermediates x_{ij} are used for the production of intermediates x_j:

$$x_{ij} = a_{ij} x_j \qquad i,j = 1,..., r \qquad (7)$$

Technologies of the Energy-Environment complex

The intermediate variables i = 1, ..., n are subdivided as follows:
non-energy intermediates i = 1, ..., e
energy delivering i = e+1, ..., r and
energy-saving intermediates i = r+1, ..., n

Through investment in energy-saving technologies, i = r+1, ..., n, the firms j may reduce energy demand:

$$\dot{a}_{ij} = - \sum_{i=r+1}^{n} x_{ij}^{\beta_{ij}} \qquad i = e + 1, ..., r; \; j = 1,..., n \qquad (8)$$

The interpretation of equation (8) is that the coefficients of energy delivering sectors i = e+1, ..., r to all sectors j = 1, ..., n are reduced by using energy-saving inputs from sectors i = r+1, ..., n. Households don't change technologies with respect to energy consumption. But they may reduce energy consumption by investing in retrofitting measures. If energy becomes more expansive they invest in thermal insulation measures, which is considered to be a pure substitution of energy.

The environmental stock can be thought of as having some natural level $\bar{E}$ if there is no pollution. Pollution which diminishes environmental qualities is proportional to energy production of different sorts i = e+1, ..., r. Each energy from i = e+1, ..., r has its own way to 'contribute' to the environmental problem. This is expressed by the pollution coefficient $CO2_{e+1}$, ... , $CO2_r$, which are multiplied by the quantity of energy use of the forms i = e+1, ..., r to express the contribution to pollution (dropping the country index henceforth):

$$
\begin{aligned}
E = \bar{E} - \\
v\,[(c + x_{Ex})_{e+1} + \sum_{j=1}^{n} x_{e+1,j}, \\
(c + x_{Ex})_{e+2} + \sum_{j} x_{e+2,j}, \\
\ldots, \\
(c + x_{Ex})_{r} + \sum_{j} x_{r,j}]'(CO2_{e+1}, \ldots, CO2_r)
\end{aligned}
\qquad (9)
$$

$(c + Ex)_{e+1}$ is energy production delivered to domestic and foreign consumers. The pollution coefficient $CO2_i$ are given at constant values because there are no filters or substitutes available. The difference between the natural level $\bar{E}$ and the vector product results in the environmental stock E in (9), where v is a parameter.

Externality, policy instruments and budgets

In the sequel we discuss some desirable properties of the taxes in question:
i) a **carbon tax** combined with
ii) an inflation-protected ad valorem **energy tax for non-greenhouse externalities** of, e.g., nuclear energy with its uninsured risks; both of them are to be rebated through
iii) **subsidies** (negative taxes) for **energy-saving** investments and externality-free energy forms like **wind and solar** energy and perhaps wage subsidies.
The justification is as follows.

ad i) It is clear from the principals of tariffs and taxation that an instrument is most efficient if it goes to the roots of the problem (see Bhagwati and Srinivasan 1983 on policy ranking). To tackle carbon one should therefore have a carbon tax. This is also a quantified result in Jorgenson and Wilcoxon, 1993. If administrative costs are high, however, this result may have to be modified to a different kind of a tax.

ad ii) The advantage of ad valorem taxes is that they are less sensitive to inflation. The EC proposal of a tax at a level of 10 U.S.$ per barrel of oil equivalent, ECU .7 per Giga-Joule and ECU 35 per ton of carbon (see Koopman, Mors, Scherp, 1993) is a nominal, specific tax. After ten years of inflation at 2% from 1990 to 2000 the real value of the ten dollars is only about 8.3 dollars at 1990 prices. In contrast, an ad valorem tax is a price markup which adjusts automatically with price inflation. In case of clear deflation agreements it is of course possible to construct equivalences between the two when market prices exist. If deflation agreements are lacking, however, with ad valorem taxes it is beyond any doubt that one is talking about real effects. Of course, this only applies to the energy tax here because there are no prices for carbon and therefore there is no ad valorem tax for carbon. Undesired effects on nuclear energy could be tackled by an energy tax as a substitute for the optimal insurance contribution for nuclear accidents. However, there seems to be a principal decision that the energy tax is .7 per Giga-Joule which is a specific tax. It is as sensitive to inflation as the specific carbon tax, which cannot be an ad valorem tax. Both are eroded in case of inflation.

ad iii) The carbon tax can be at the lowest of all levels associated with alternative rebatement schemes and compatible with international CO2-emission reduction agreements if its revenues are used for subsidizing energy-saving investments and use of energy forms that have no CO2 externalities. These forms of rebatement are superior to those of reducing VATs, income taxes, or labour costs because they can be reconciled with environmental, employment and international competitiveness goals.

Exemptions to this rule could only be based on extreme, non-optimal distortions in these other taxes. In the latter case there are no net costs of CO2 mitigation because one actually can cover them by distortion reductions! There is some support for such a 'non problem' view (see Koopman, Mors, Scherp 1993, Table 2, where Spain and UK have net gains of .1 and .5 percent of GDP respectively from a VAT-rebatement scenario and Germany and Portugal have no impact on their GDP from a CO2/energy tax). However, if a countries' tax system is more distortionary than those of other countries, it could reform its tax system by making it more similar to those of other countries quite independent of any environmental policies. One way to do this is to optimize the expenditure side of the economy as Barro (1990) and Sørensen (1993) do it in order to arrive at first-best results instead of reducing excess burdens for arbitrarily given levels of public expenditure as it is done in the so called optimal taxation literature (see Lucas 1990 and Schöb 1995). Additional gains from reducing remaining tax-distortions can perhaps be obtained from an ecological tax reform if optimizing the expenditure side is impossible at the current state of knowledge or the political willingness to reconsider public expenditures is absent. But it is quite unclear how far a tax reform can go without ecological reform elements and how much necessarily has to be attributed to the ecological elements.

We will now examine the proposed energy-saving-rebatement scenario in more detail. If the rebatement is going to labour costs, given the environmental effects for reaching internationally fixed goals, the taxes have to be much higher if the advantages from subsidizing energy saving and non-externality energies are not used. If 35 ECU per ton carbon is needed for reaching the goal of international agreements, the carbon tax could be lower than 35 ECU if the revenues are used for energy-saving investments. Thus, there is a double dividend but only at a higher price per ton carbon than under an carbon reducing rebatement scheme. The dividend may go partly to the unemployment.

The modelling work takes into account the above considerations. However, the energy tax will be modelled as a specific tax in accordance with the EC proposal.

This means that the firm must pay a tax t to the government for each unit (ton of carbon) of environmental rights to pollute CO2. Tax payments are described in the following equation:

$$t(\bar{E} - E) =$$

$$t \; v \; (c + x_{Ex})_{e+1} + \sum_{j=1}^{n} x_{e+1,j}, (c + x_{Ex})_{e+2} + \sum_{j} X_{e+2,j}, \ldots, (c + x_{Ex})_{r} + \sum_{j} x_{r,j}) \quad (10)$$

$$(CO2_{e+1}, \ldots, CO2_{r})$$

If the coefficients $CO2_i$ are defined as tons of carbon per unit of energy quantity of the element in the vector to which it is multiplied, then t is the ECU price for the pollution of a ton of carbon, which is 35 ECU in the EC proposal. Taxing use of energy is an alternative that will be written as an element of the budgets with τ_i as the tax rate per GJ of energy type i.

Agents budgets

Producer k - where k = 1, ...,n is a certain value of i and j - has the following profits from revenues minus costs:

$$\pi_k =$$

$$\sum_{1}^{n} p_k x_{kj} + p_k c_k + p_k I_k^s + p_k x_{kEx} + \sum_{r+1}^{n} s_i p_i x_{ik} - \sum_{1}^{n} p_i x_{ik} - \sum_{im} p_{im} x_{im,k} - \quad (11)$$

$$t \sum_{e+1}^{r} x_{ik} CO2_i - \sum_{e+1}^{r} \tau_i x_{ik} - R \int_{-\infty}^{t} \sum_{i} p_i(\tau) I_{ik}(\tau)^d d\tau - [w_k(1 - s_{w1}) - s_{w2}] L_k$$

The first term are deliveries to other producers, the second to households, the third for investments where an upper index s indicates 'supply', the fourth for exports; the s_i -term is an investment subsidy for buying energy-saving technologies which may vary across sectors i (when different goods have different energy-saving properties); term six are costs for domestically produced intermediates, which are assumed not to be used as energy saving technologies and term seven for foreign produced intermediates; the t-term is the tax for a ton of carbon emission; the τ_i -term is a positive energy tax which can vary by energy type and it is a negative tax (subsidy) for energy use of non-externality types like wind and sun.

Energy is measured in gigajoule, GJ. Investment is financed through loans on which a nominal interest rate R has to be paid. s_{w1} is an ad valorem subsidy to wages and s_{w2} is a specific subsidy to wages.

All non-energy, energy and energy-saving-technology producers have such a profit function.

Households

$$w \sum_{j} L_j + RW + \sum_{j} \pi_j - \sum_{1}^{n} p_i c_i - \sum_{n+1}^{n+n} \tilde{p}_{im} \tilde{c}_{im} - t \sum_{e+1}^{r} c_i \; CO2_i - \sum_{e+1}^{r} \tau_i c_i + \sum_{r+1}^{n} s_i p_i c_i - \dot{W} = 0 \quad (12)$$

The first term is wage income. The second term is capital income as far as it yields a competitive capital market interest rate paid by domestic firms. The third term are monopolistic profits which may be zero if market access competes them away as in the empirical analysis of Morrison (1989, 1990, 1992). The fourth and fifth terms are consumption of domestic and imported goods. The sixth term is the carbon tax payments imposed on households. The seventh term is the energy tax which should be negative for solar energy. The eight terms are subsidies for energy-saving purchases. Households differ from firms in that they do not explicitly change energy coefficients but instead are assumed to buy energy-saving technologies instead of energy.

The *government* budget is assumed to be balanced

$$t \sum_{k} \sum_{e+1}^{r} x_{ik} \; CO2_i + \sum_{k} \sum_{e+1}^{r} \tau_i x_{ik} + t \sum_{e+1}^{r} c_i \; CO2_i + \sum_{e+1}^{r} \tau_i c_i - \sum_{k} \sum_{r+1}^{n} s_i p_i x_{ik} - \sum_{r+1}^{n} s_i p_i c_i - \sum_{k} [s_{w1} w + s_{w2}] L_k = 0 \quad (13)$$

Energy is assumed to be imported indirectly. Therefore we don't model import taxes on energy explicitly.

Current account

$\dot{D}$ + decrease in foreign reserves =

$$P_{im}\ c_{IM} + P_{im}\ I_{IM} + P_{im}\ x_{im,Ex} + \sum_{im} p_{im}\ x_{im} - \sum_{i=1}^{n} p_i\ x_{iEx} + RD \qquad (14)$$

If debt is positive also interest, RD, has to be paid. Exports need not equal imports because debt and interest payments exist. If debt is negative RD is income from foreign wealth and $\dot{D}$ is the change in foreign assets which may be either positive or negative. The current account deficit can be financed either by an increase in foreign debt or a decrease in reserves of foreign exchange.

Equilibrium

Labour market equilibrium requires that labour demand for output production, $\sum_j L_j$ including energy production and production of energy-saving intermediates, must be equal to labour supply L. Underemployment (dis)equilibria are allowed for. In that case employment is determined by demand which is smaller than supply. The labour market is therefore characterized by:

$$\sum_j L_j - L \leq O \qquad (15)$$

Investment $\sum_i \sum_j p_i I_{ij}$ can be financed by savings $\dot{W}$ or new debt $\dot{D}$:

$$\sum_i \sum_j p_i I_{ij} = \dot{W} + \dot{D} \qquad (16)$$

3. The decision of the household

The household is assumed to optimize intertemporally based on expectations and policy announcement information concerning carbon and energy taxes and related subsidies. The utility function presented above is a temporary one. Integrating the temporary utility function in equation (1) over time after multiplication by a discount term $e^{-\rho t}$ gives the intertemporal utility function. The Hamiltonian for the problem of the household is:

$$H = \sum_{i+1}^{n} c_i^{\otimes_i} + \sum_{im} \tilde{c}_{im}^{\otimes_{im}} + f\sum_{l} \ln E_l + \lambda\{w\sum_{j} L_j + RW + \sum_{j} \pi_j -$$

$$\sum_{1}^{n} p_i\, c_i - \sum_{n+1}^{n+n} \tilde{p}_{im}\, \tilde{c}_{im} - t\sum_{e+1}^{r} c_i CO2_i - \sum_{e+1}^{r} \tau_i c_i + \sum_{r+1}^{n} s_i\, p_i\, c_i\}$$

Given employment, profit income from firms, policy variables t, τ_i and s_i and initial wealth W for the short run, the household chooses consumption and savings. Due to the basic decision that the environmental problem is tackled by taxes the household can not choose the environmental variable E, which therefore will be a pure externality to the household.

The *first-order conditions* are the budget constraint and

$$-\partial H/\partial W = -\lambda R = \dot{\lambda} - \rho\lambda \; or \; \hat{\lambda} = \rho - R \; or \; \lambda = \lambda_0\, e^{(\rho - R)t} \tag{17}$$

$$\partial H/\partial c_i = \bigotimes_i c_i^{\otimes_i - 1} - \lambda p_i = 0, \quad i = 1,...,e \tag{18}$$

$$\partial H/\partial c_i = \bigotimes_i c_i^{\otimes_i - 1} - \lambda(p_i + t\, CO2_i + \tau_i) = 0, \quad i = e+1,..., r \tag{19}$$

$$\partial H/\partial c_i = \bigotimes_i c_i^{\otimes_i - 1} - \lambda[(1 - s_i)p_i] = 0, \; i = r+1,..., n \tag{20}$$

$$\partial H/\partial \tilde{c}_{im} = \bigotimes_{im} \tilde{c}_{im}^{\bigotimes_{im}-1} - \lambda \tilde{p}_{im} = 0 \qquad (21)$$

The interpretations are as follows: for non-energy products we have the usual condition that marginal utility equals the price times the value of wealth. For energy products the tax on CO_2 is also a cost element and so is the specific energy tax. For energy-saving products, a subsidy for buying energy-saving products is subtracted from the price. The transversality condition lim $\lambda e^{-\rho t} = 0$ is implied in (17).

The formal structure of the solution to the household's problem is as follows: As the initial value of W is given, the optimal initial value of λ has to be determined. The optimal path of W and λ imply values for their change. Thus the impact of a price change on quantities c_i and λ have to be derived from the budget constraint (12) and (18)-(21) for given values of W and temporary net expenditure, F. Net expenditure F can be written as:

$$F - \sum_{1}^{n} p_i c_i - \sum_{n+1}^{n+n} \tilde{p}_{im} \tilde{c}_{im} - t \sum_{e+1}^{r} c_i CO2_i - \sum_{e+1}^{r} \tau_i c_i + \sum_{r+1}^{n} s_i p_i c_i = 0 \qquad (22)$$

Impact effects of energy policy on households' energy consumption

Next we discuss the impact of energy-policy measures on households at prices that have not already adjusted to the new equilibrium, the so called 'impact effect' as it is called in macroeconomics. The reason is that most investigations in the literature present the new equilibrium solution after the introduction of the new policy. However, we don't know how long the adjustment process takes until the new equilibrium is reached and what the path to the new equilibrium will be. The impact effect tells what the first reaction of individuals is.

In (18)-(21) the consumer prices (henceforth indexed by an upper index c) are related to producer prices in the following manner:

$$p_i^c = p_i, \text{ with property } \partial p_i^c/\partial p_i = 1, \quad i = 1,..., e \qquad (23)$$

$$p_i^c = (p_i + tCO2_i + \tau_i), \text{ with } \partial p_i^c/\partial p_i = 1, \partial p_i^c/\partial \tau_i = 1, \quad \partial p_i^c/\partial t = CO2_i, \; i = e+1,..., r \qquad (24)$$

$$p_i^c = (1 - s_i)p_i, \text{ with } \partial p_i^c/\partial p_i = 1 - s_i, \partial p_i^c/\partial s_i = -p_i, \quad i = r + 1, \ldots, n \tag{25}$$

The elasticities of demand with respect to consumer prices for a given intertemporal allocation of known life-time income are (see Helpman and Krugman 1985, Chap. 6 for the derivation):

$$\varepsilon_{cp,i} = (\partial c_i/\partial p_i^c)p_i^c/c_i = -\otimes_i (1-\otimes_i)^2[\sum_1^n \otimes_i^{1/(1-\otimes_i)} p_i^{\otimes_i/(\otimes_i - 1)}]^{-1} - (1-\otimes_i)^{-1} \tag{26}$$

For an increasing number of firms the elasticity converges towards the last term.

The percentage change of the consumer demand if the ad valorem subsidy for energy saving purchases is changed can be computed as:

$$\varepsilon_{cs,i} = (\partial c_i/c_i)/(\partial s_i/s_i) = -s_i\varepsilon_{cp,i}/(1-s_i), i = r+1, \ldots, n \tag{27}$$

A percentage change in the specific tax on energy can be shown to generate a percentage change in its consumption of:

$$(\delta c_i/\delta\tau_i)(\tau_i/c_i) = \tau_i \varepsilon_{cp,i} / P_i^c, \; i = e + 1, \ldots, r \tag{28}$$

An introduction of a carbon tax starting from level zero generates a percentage change of consumption of:

$$(\delta c_i/c_i) = dt \; \varepsilon_{cp_i} CO2_i / p_i^c, \; i = e + 1, \ldots, r \tag{29}$$

To be able to compute the effects as expressed in (27)-(29) data on $\varepsilon_{cp,i}$ would be necessary on the household level. Unfortunately these are not available for energy-saving products.

Long-run price elasticities for residential aggregate energy demand in EU countries are between - o.23 and -1.40 in Brenton (1994), Kouris (1983) and Mittelstädt (1983). Short-run elasticities are much smaller. Income elasticities are between .49 and 2.43 with most of the estimates being in the neighbourhood of 1. For disaggregated fuels we have estimates by Brenton (1994) and - based on British data - from Deaton (1975). In Deaton (1975) we find income elasticities between -4 for coal and +3.7 for electricity and price elasticities between +2 for coal and -2.9 for gas. In Brenton (1994) we find compensated own price elasticities between -.65 for electricity in Denmark and -.87 in Spain and expenditure elasticities of about unity for all countries and fuels. The difference between the results of Deaton and Brenton seems to be rather extreme and supposedly stems from the different methods as discussed in footnote 3 in Brenton (1994) and more broadly in Deaton (1975). Brenton, Kouris, Mittelstädt and Deaton all provide a sophisticated discussion with respect to the reliability of these estimates.

We can only compute the effects modelled above for different values of the elasticities $\varepsilon_{cp,i}$. We use alternative values of uncompensated price elasticities $\varepsilon_{cp,i}$ = -1.1, -2, -4, -10. Sectoral elasticities on the highly aggregated level are lower because interfuel substitution vanishes in the aggregation. But even on the level of single fuels the data reflect aggregates across firms and therefore exclude the effects on price elasticities of interfirm competition. Remember that for monopoly prices to exist price elasticities have to be smaller than minus one. Otherwise monopoly profits could be infinitely high, a situation that is hardly realistic.

For a scenario on (27) we use an ad valorem investment subsidy of 10%, 25% and 50% respectively. The results for (27) are summarized in Table 1.

Table 1

The subsidy elasticity of household demand for energy-saving products $\varepsilon_{cs,i} = -s_i\varepsilon_{cp,i} / (1-s_i)$

$\varepsilon_{cp,i}^{s_i}$	10%	25%	50%
-1.1	.12	.36	1.1
-2	.22	.66	2
-4	.44	1.33	4
-10	1.1	3.33	10

The interpretation of results in Table 1 are as follows. Increasing the subsidy for energy saving purchases by 1%,e.g., from 25% to 25,25% increases the demand for energy saving products by x%, where x is the number in Table 1. If, e.g., the subsidy is 50%, a change to 50,50% increases the consumption of energy by a percentage equal to the price elasticity (see last column). With low price elasticity -1.1 and only 10% subsidy a change to a 10,1% subsidy increases the demand by .12% = 1,2 °/oo. The higher the level of the subsidy and the elasticity assumed, the stronger the effect of a 1% increase of that subsidy. The reason is that for each ECU a 1% increase in the ad valorem subsidy implies that the money value of the 10, 25, 50% subsidy is 1, 2.5 or 5 ECU cent respectively. However, the range for $\varepsilon_{cs,i}$ is rather broad: it goes from .1 to 10. Sectoral elasticities and those for household panels (see SEO 1992) are even lower than those used here for households. In that case an elasticity of

unity will only be reached for a subsidy higher than 50%.

Next we look at the effect of a carbon tax on households' demand for energy. We have price data (see Europäische Gemeinschaften 1994) and carbon emission coefficients (see IPCC Draft) for natural gas and heating gas oil. The EC average price for natural gas is 13 ECU per Gigajoule(GJ). This is also the price for Germany. The emission coefficient is .02 ton carbon per GJ (ton C/GJ). For heating gas oil (residential fuel oil) the average price is 12 ECU/GJ. This is also the price for the Netherlands, Spain and France). The emission coefficient for heating gas oil is .015 ton C/GJ. Electricity prices are 23 ECU/GJ, which is also the price for Spain and Belgium, but emission coefficients are not available. With a carbon tax of 35ECU per tonC as suggested by the EC proposal mentioned above these (all taxes included) prices become (13 + 35 0.015) ECU = 13,7ECU and (12+35.0.015) ECU =12.525ECU. The increase in the price is therefore .7 ECU per GJ natural gas and .525ECU per GJ heating gas oil which is a price increase of roughly 5% induced by the carbon tax alone. The percentage changes in consumption, $dc/c = dtCO_{2i}/p^c$, of natural gas and heating gas oil from a carbon tax, dt, of ECU 20, 35, 50 and 100 for the same elasticity as above scenarios derived from equation (29) based on price effects alone are summarized in Table 2. Income effects and cross-price elasticities from taxes on other fuels will be discussed separately below.

Table 2
Impact effects of a carbon tax on private households change in consumption, dc_i/c_i, of

Natural gas

carbon tax (ECU per ton)	20	35	50	100
$\varepsilon_{cp,i}$				
-1.1	-.034,	-.06	-.08	-.17
-2	-.06,	-.108	-.154	-.31
-4	-.12,	-.216	-.308	-.62
-10	-3.,	-.54	-.77	-1.55

Heating gas oil

carbon tax	20	35	50	100
(ECU per ton)				
$\varepsilon_{cp,i}$				
-1.1	-.028,	-.048	-.069	-.14
-2	-.05,	-.0875	-.125	-.25
-4	-.1.	-.175	-.25	-.5
-10	-.25,	-.438	-.625	-1.25

1) In Brenton (1994) and Hermes (1993) (compensted own price) elasticities for household aggregates are below unity. Elasticities in SEO (1992) for gas are also below one percent. The use of lower values will make the conclusion drawn below even stronger.

A carbon tax of 35 ECU, inducing a 5% price increase will decrease demand by 6% and 4,8% for natural gas and heating gas oil respectively under a price elasticity of -1.1 if the effect on substitutes some of which have to bear a carbon tax as well is ignored. The effect is linear in dt and in the price elasticity assumed. Price elasticities reported in the literature are at the lower end of the above scenario.

Table 3

Impact effects of an energy tax on private households percentage change in consumption, dc_i/c_i, of

		Natural gas		
energy tax (ECU per GJ)	.3	.7	1.0	1.4
$\varepsilon_{cp,i}$				
-1.1	-.025,	-.06	-.08	-.118
-2	-.048	-.1	-.15	-.22
-4	-.09,	-.21	-.3	-.43
-10	-.23	-.54	-.77	-1.07
		Heating gas oil		
energy tax (ECU per GJ)	.3	.7	1.0	1.4
$\varepsilon_{cp,i}$				
-1.1	-.028,	-.06	-.06	-.13
-2	-.05,	-.117	-.17	-.23
-4	-.1,	-.23	-.33	-.47
-10	-.25,	-.58	-.83	-1.16
		Electricity		
energy tax (ECU per GJ)	.3	.7	1.0	1.4
$d\tau$				
-1.1	-.014,	-.03	-.05	-.06
-2	-.026	-.06	-.09	-.12
-4	-.052	-.12	-.17	-.24
-10	-.13	-.3	-.43	-.61

Impact effects of an energy tax on energy consumption are considered in Table 3. Under the EC proposal there will be a change of the energy tax, $d\tau$, of .7 ECU per Gigajoule. Table 3 contains scenarios for the change in consumption $dc_i/c_i = \varepsilon_{cp,i} d\tau/p_i^c$ of formula (28) with energy tax change, $d\tau$ varying from .3 to 1.4, i.e from less than half to twice the amount contained in the EC proposal. Gigajoule prices p_i^c corresponding to that formula are 13 ECU

for natural gas, 12 ECU for heating gas oil and 23 ECU for electricity, all of which are EC average prices taken from Europaeische Gemeinschaft (1994).

Under the EC proposal the percentage change of GJ consumption of natural gas, heating gas oil and electricity will be 6%, 6% and 3% respectively if income and cross-price effects from taxes on other fuels are ignored. Again results are linear in the assumed elasticities and tax rate changes. For electricity this value has been obtained under the assumption that there is an energy tax only at the output level. These values will be different if coal and other fuels are used and taxed on the input level. In this case there can be a carbon and an energy tax on inputs for producing electricity.

The upper bound of an impact effect of an introduction of the EC proposal - still postponing discussion of income and cross-price effects generated by taxes on other fuels - can be obtained from adding up the percentage values of the 35-column of Table 2 and the .7 column of Table 3. For alternative elasticity values of demand with respect to price this yields

Table 4
Impact effect of an introduction of the EC proposal on energy consumption

$\varepsilon_{cp,i}$	-1.1	-2	-4	-10
dc/c^1	-.12	-.21	-.43	-1.1
dc/c^2	-.11	-.21	-.41	-.926

1 for natural gas
2 for heating gas oil

Deaton (1975) finds an elasticity of -2.9 for gas demand in Britain. Applying that value here the impact effect would be roughly 30% demand reduction as the starting point for analyzing the price effect of an 10% price increase from carbon and energy taxes according to Table 4 for which the following modifications are necessary:

i) These effects have been calculated using the EU average price of 13 ECU for natural gas and 12 ECU for heating gas oil when doing the division in the formula presented above. However, households pay higher prices in almost all countries. Dividing by higher prices reduces the effects of the above computations in some cases by more than one half.

ii) In Mittelstädt (1983) short-run elasticities of prices are about 1/4 of the long-run elasticities reducing this number to a 7.25% reduction of demand for natural gas and heating gas oil.

iii) Other energy forms also have to bear these taxes and therefore cross-price elasticities will soften this effect. Therefore these are upper limits for single energy forms.

iv) All results from Tables 2-4 are extremely sensitive to the values of the tax rates, the price elasticities and the price paid.

The income effect alone will be small: If a households spends as much as 1/3 of his income for housing and 20% of that on energy then the energy share in his expenditure is 6%. A price increase of 10% decreases his real income by .6%. With an income elasticity of unity the income effect will decrease demand by -.6%. Even if the income elasticity is at the highest level that can be found, 2.4, the demand decrease will be only 1.44%.

If the mixture of energy and carbon taxes keeps the structure of demand approximately constant and the price and income elasticities are at the upper value of the estimated ranges -1.4 and 2.4 respectively the price increase of 10% and the income decrease of .6% decrease energy demand by 15.5%. This is the upper level of possible demand reductions. Most estimates in Kouris (1983), Mittelstädt (1983) and Brenton (1994) are half that size leading to a **long-run effect of a 7.7 % energy demand reduction from households from the EC proposal values reached at the end of the "phasing in"**. With short-run price elasticities of -.2 and an income elasticity of 1 to be taken from the same literature the **reduction in energy demand will be 2% + .6% = 2.6% in the short run**. This is much less than the reduction in energy demand during recessions. Of course for less CO2 intensive energy forms than natural gas and heating gas oil the price increase is lower and for more CO2 intensive energy forms the price increase is higher, but this is mainly coal for which there are special rules of the game anyway. All in all reduction of competitiveness of energy in relation to other products seems to be at a minimum given the necessity to protect the environment.

4. The decision of monopolistically competitive producers

Producers choose:

i) supply quantities $x_k \equiv \sum_1^n x_{kj} + c_k + I_k^s + x_{kEx}$

ii) purchases of intermediates of all types (non-energy 1, ...,e; energy e+1, ..., r; energy saving r+1, ..., n; imported n+1,..., n+n*) where energy-saving purchases reduce the energy coefficients according to (8);

iii) the desired capital stock K_k from (4) which implies investment demand I_{ik} for a given value of the existing capital stock;

iv) labour demand L_k from (3).

The problem of the firm k then is to maximize the discounted sum of all future profits subject to the equations of motion (6) and (8) with current profits

$$\pi_k = \sum_{j=1}^{n} p_k x_{kj} + p_k c_k + p_k I_k^s + p_k x_{kEx} + \sum_{r+1}^{n} s_i p_i x_{ik} - \sum_{1}^{n} p_i x_{ik} -$$

$$\sum_{im} p_{im} x_{im,k} - t.\sum_{e+1}^{r} x_{ik} CO2_i - \sum_{e+1}^{r} \tau_i x_{ik} - R.\int_{-\infty}^{t} \sum_i P_i(\tau) I_{ik}(\tau) d\tau - \tag{11}$$

$$[w_k(1 - s_{w1}) - s_{w2}]L_k$$

and the constraints

$$L_k = b_{Lk} + a_{Lk}\, x_k,\ k = 1,\ldots,\ n \tag{3}$$

$$K_k = b_{Kk} + a_{Kk}\, x_k,\ k = 1,\ldots,\ n \tag{4}$$

$$K_k = \int_{-\infty}^{t} [\sum_i (e^{d(\tau - t)} I_{ik}\ (\tau)^{\beta_{ik}}\ ]\ d\ \tau \qquad \text{with} \quad i = 1,\ldots,\ e,\ldots,\ r,\ldots,\ n \tag{5}$$

$$\dot{K}_k = \sum_i I_{ik}\ (t)^{\beta_{ik}} - d \int_{-\infty}^{t} \sum_i [e^{d(\tau - t)}\ I_{ik}\ (\tau)^{\beta_{ik}}\ ]\ d\tau \tag{6}$$

$$x_{ik} = a_{ik}\, x_k \qquad i,\ k = 1,\ldots,\ r \tag{7}$$

Inserting (3) and (7) into the profit function (11), using (4), (6) and (8) as constraints yields the current value Hamiltonian

$$H = \sum_1^n p_k\, x_{kj} + p_k\, c_k + p_k\, I_k^s + p_k\, x_{Ex} + \sum_{r+1}^{n} s_i p_i x_{ik} - \sum_{r+1}^{n} p_i\, x_{ik} -$$

$$\sum_1^r p_i(a_{ik}\, x_k) - \sum_{im} p_{im}\, a_{im,k}\, x_k - t\sum_{e+1}^{r} (a_{ik}\, x_k)\ CO2_i - \sum_{e+1}^{r} \tau_i\, a_{ik}\, x_{ik} -$$

$$R \int_{-\infty}^{t} \sum_i p_i\, I_{ik}\, d\ \tau - [w_k(1 - s_{w1}) - s_{w2}]\ (b_{Lk} + a_{Lk}\, x_k) + \mu_{1k}\ \{K_k - b_{Kk}$$

$$- a_{Kk}\, x_k\} + \mu_{2k} \sum_{r+1}^{n} (\ x_{ik})^{\beta_{ik}} + \mu_{3k}\ \ \{\sum_i I_{ik}\ (t)^{\beta_{ik}} - d\ K_k\}$$

The first-order conditions for firms are (4),(6), (8) and (with k = 1, ..., n)

$$\delta\psi/\delta x_k = p'x_k + p_k - \sum_1^r p_i\, a_{ik} - \sum_{im} p_{im}\, a_{im,k} - t \sum_{e+1}^r a_{ik} CO2_i - \sum_{e+1}^r \tau_i\, a_{ik} - [w_k(1 - s_{w1}) - s_{w2}]a_{Lk} - \mu_{1k}\, a_{Kk} = 0,\ k = 1,..., n \quad (30)$$

$$\partial\psi/\partial x_{ik} = (s_i - 1)p_i + \mu_{2k}\beta_{ik}x_{ik}^{\beta_{ik}-1} \leq 0,\ i = r+1,..., n \quad (31)$$

$$\partial\psi/\partial I_{ik} = -Rp_i + \mu_{3k}\beta_{ik}\, I_{ik}^{\beta_{ik}-1} = 0, \quad i = 1,..., e..., r,...., n \quad (32)$$

$$-\partial\psi/\partial K_k = -\mu_{1k} + \mu_{3k}d = \dot{\mu}_{3k} - R\mu_{3k} \quad (33)$$

$$-\partial\psi/\partial a_{ik} = -x_k(-p_i - tCO2_i - \tau_i) = \dot{\mu}_{2k} - R\mu_{2k}, \quad i = e+1,..., r \quad (34)$$

The interpretation of the first-order conditions is as follows. Equation (30) states that marginal revenue equals marginal costs. CO_2 and energy taxes increase marginal costs and wage subsidies decrease marginal costs. (31) states that the value of subsidies plus the value of the reduction of the energy coefficients equal the price of the energy-saving technologies. (32) states that the interest costs of an intermediate contributing to investment equals the marginal value product of that intermediate good in the enhancement of the capital stock. (33) states that the negative value of increasing the capacity, μ_1 and depreciation valued at the shadow price of capital, μ_{3k} is equal to the undiscounted change in the discounted shadow price of capital. (34) says that the change in the shadow price of energy coefficients must equal the value of the reduction in: i) energy payments and ii) energy tax payments, all emanating from a marginal change in the energy coefficient.

5. Policy when competitiveness is guaranteed

The implications of energy and carbon taxes on firms' and households' behaviour can now be considered best by making a distinction between binding and not binding capacity constraint.

The case of a binding capacity constraint.

Capacity K_k in (4) is a state variable. If (4) is a binding constraint, it determines x_k. The

price can be read from the demand curve as expressed by consumer prices in (18)-(20) and (23)-(25) and the corresponding parts for investment, (32), and exports (not written down explicitly). This has different consequences for the three different categories of products under consideration:

For non-energy products, consumer prices are identical to producer prices because carbon and energy taxes don't appear in (18) and (23). Prices are fixed by capacity and demand. The introduction of carbon and energy taxes increases marginal and average costs and leads to lower profits. If there are zero profits without taxes there are losses and perhaps exits. However, if tax policies are announced in time these are perfectly planned exits.
For energy products, consumer prices are higher than producer prices because taxes are added to the latter. Consumer prices being fixed at the level at which capacity output can be sold, energy producers are squeezed twice: i) taxes imposed on consumers lower producer prices according to (24) because they act as a downward shift of a demand curve in the price-quantity plane; ii) marginal costs are increased in (30). Both effects reduce profits and perhaps lead to exits which may be perfectly planned if the policy is announced in advance.
For energy-saving products, a subsidy for energy-saving products to households acts like an upward shift of the demand curve in (20) and (25). It allows the firm to set higher producer prices. On the other hand, energy and carbon taxes increase marginal costs of energy producers which therefore again reduces profits. In sum, carbon and energy taxes without subsidies for energy saving make households a less profitable market segment for energy-saving technologies under a binding capacity constraint. This part of the market will shrink and makes investment less profitable. All effects are reducing profits which households receive. Income elasticities of household demand determine the general equilibrium effects of CO_2 policy. However, subsidies for investment in energy-saving technologies could make even households a profitable market segment for suppliers of energy-saving technologies.

The case of a non-binding capacity constraint.

If the capacity constraint (4) is not binding, μ_{1k} is zero. Given the real world observation of unemployment and low degrees of capacity utilisation, this may be the more realistic scenario if non-anticipated shocks (oil crises, high interest policies, financing the german unification) in connection with slow speeds of adjustment in markets and other post-war institutions have led to unemployment and lower demand than expected earlier. For the rest of this chapter we concentrate on this case. In this case marginal revenue (where x_k consists of consumption, investment, export and intermediate demand) equals marginal cost, leading to a price

$$P_k = MC /(p'x_k/p_k + 1)$$

$$with \quad MC \equiv \sum_{1}^{r} p_i a_{ik} + \sum_{im} p_{im} a_{im,k} +$$

$$t \sum_{e+1}^{r} a_{ik} CO2_i + \sum_{e+1}^{r} \tau_i a_{ik} + [w_k(1 - s_{w1}) - s_{w2}] a_{Lk}$$

The impact of carbon and energy taxes and wage subsidies on marginal cost is

$$dMC = dt \sum_{e+1}^{r} a_{ik}\, CO2_i + \sum_{e+1}^{r} d\tau_i\, a_{ik} + [w_k\,(-ds_{w1}) - ds_{w2}]\, a_{Lk}$$

Energy and carbon taxes increase marginal costs whereas wage subsidies decrease marginal costs. **Wage subsidies are** therefore **an instrument to compensate firms in a way that** potentially **leaves their marginal cost position unaffected by carbon and energy taxes**. Subsidies on energy-saving measures don't have this effect because they decrease fixed costs only upon impact and energy-saving intermediates are assumed not to be productive in the production of goods. However, if marginal costs are kept constant to insure international competitiveness and therefore prices and output don't change, pollution and unemployment are not decreased by carbon and energy taxes if the substitution between labour and energy is zero in the short run on the firm or product level by assumption (see Figure 1). The same holds empirically for the effects of exemption from a carbon tax (see Denis and Koopman 1995).

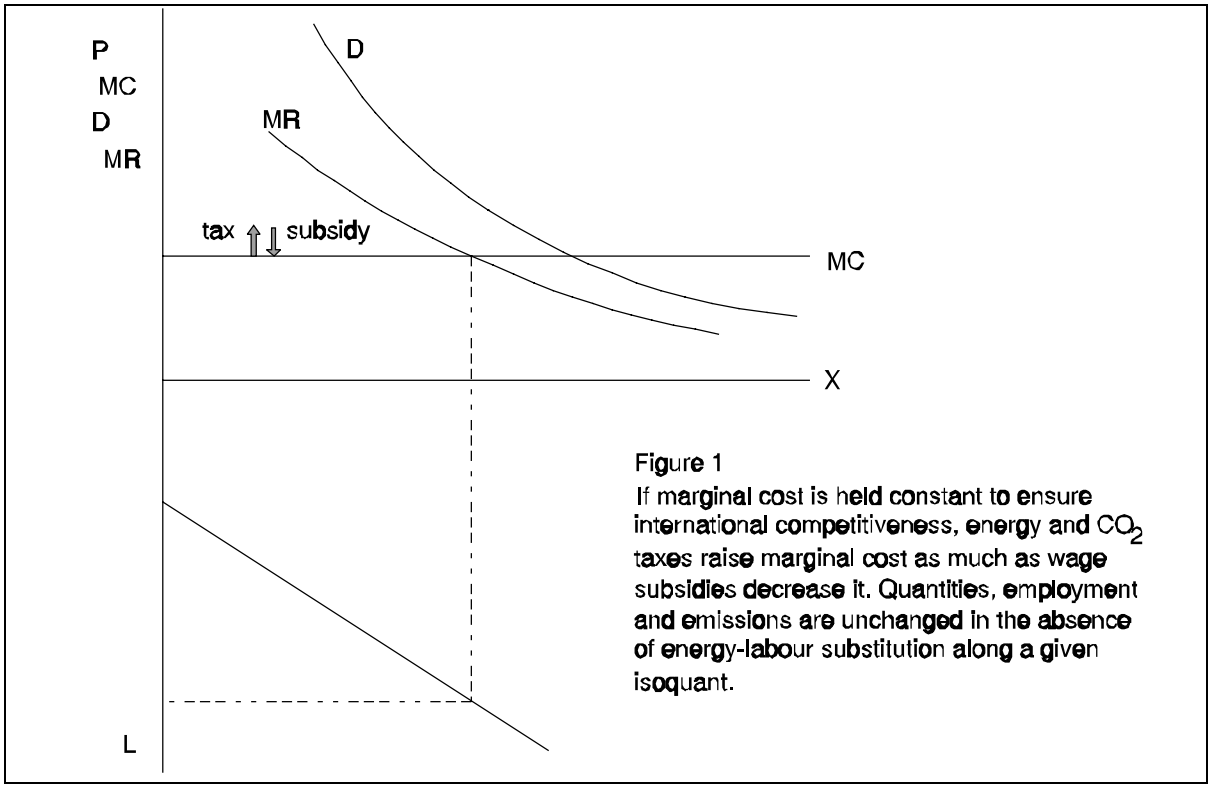

Figure 1
If marginal cost is held constant to ensure international competitiveness, energy and CO_2 taxes raise marginal cost as much as wage subsidies decrease it. Quantities, employment and emissions are unchanged in the absence of energy-labour substitution along a given isoquant.

This is clearly a critique of the double dividend idea because it does not take into account the constraint on international competitiveness. A critique of the double dividend idea by Bovenberg and van der Ploeg (1992) has been based on the treatment of leisure instead of unemployment. Bovenberg and van der Ploeg (1993) find even a triple dividend if the

initial tax system is suboptimal. However, they do not take into account the sectoral protection that is at the heart of the EC proposal.
The only way to reduce pollution if wage subsidies keep marginal costs non-increasing is to pay energy-saving subsidies as well. This raises the crucial question whether their is enough money from energy and carbon taxes to keep marginal costs constant in the short run and to pay subsidies for energy-saving investments. This question can be analyzed as follows.

All policy measures that change marginal cost in this model start at value zero, which implies $dt = t$, $d\tau_i = \tau_i$, $ds_{w1} = s_{w1}$, $ds_{w2} = s_{W2}$. Inserting this into dMC = 0 yields the short-run condition for constant marginal costs or an unchanged competitive position of a firm under a not binding capacity constraint:

$$t.\sum_{e+1}^{r} a_{ik} CO2_i + \sum_{e+1}^{r} \tau_i . a_{ik} = [w_k(-s_{w1}) - s_{w2}]a_{Lk} = 0 \qquad (35)$$

Marginal tax payments by the firm must equal marginal subsidies received for wages if the competitive position has to be unchanged.
Multiplying by x_k and summing over all firms k yields the condition for an unchanged competitive position for the economy that can be compared to the budget of the government:

$$t.\sum_{k}\sum_{e+1}^{r} a_{ik}\, x_k\, CO2_i + \sum_{k}\sum_{e+1}^{r} \tau_i .\, a_{ik}\, x_k + \sum_{k} [w_k(-s_{w1})\, s_{w2}]\, a_{Lk}\, x_k = 0 \qquad (36)$$

(36) says that to keep international competitiveness constant requires that the amount of carbon and energy taxes paid by the firm is equal to the amount of wage subsidies on variable labour cost. We look at the government budget to see what remains in the budget after these transactions are carried out. Rewriting the budget constraint of the government after replacement of L_k by (3) yields:

$$t.\sum_{k}\sum_{e+1}^{r} x_{ik}\, CO2_i + \sum_{k}\sum_{e+1}^{r} \tau_i .\, x_{ik} + t\sum_{e+1}^{r} c_i\, CO2_i + \sum_{e+1}^{r} \tau_i .\, c_i - \sum_{k} \qquad (13')$$
$$\sum_{r+1}^{n} s_i\, p_i\, x_{ik} - \sum_{r+1}^{n} s_i\, p_i\, c_i - \sum_{k} [\, s_{w1}\, w + s_{w2}](b_{Lk} + a_{LK}\, x_k) = 0$$

Cancelling terms in (13') which add up to zero according to (36) yields

$$t.\sum_{e+1}^{r} c_i CO2_i + \sum_{e+1}^{r} \tau_i . c_i$$
$$- \sum_{k} \sum_{r+1}^{n} s_i p_i x_{ik} - \sum_{r+1}^{n} s_i p_i c_i - \sum_{k} [s_{w1} w + s_{w2}] b_{Lk} = 0 \qquad (13'')$$

If the competitive position of firms has to be unaffected the sum of carbon and energy tax revenues paid by households can be used for subsidies on energy-saving investments or to subsidize fixed labour costs. If the latter is held to be undesirable from a political point of view there is a clear policy rule for C02 and competition policy: The amount of carbon and energy tax revenues paid by firms should be used to subsidize variable labour costs and the amount of carbon and energy tax revenues paid by households should be used to subsidize energy-saving measures. An important analytical implication of this rule is that under non-substitutability between labour and energy for the short run, carbon and energy taxes on firms serve the employment and competitiveness goals only by holding employment constant and carbon and energy taxes of households serve the CO_2 goal only. Subsidies for investment in energy-saving technologies help to speed up the decrease of marginal cost over time and therefore increase competitiveness and employment (see Figure 2). In sum, the only aspect where CO_2 policy, employment policy and competitiveness are not contradictory are subsidies to energy-saving investments.

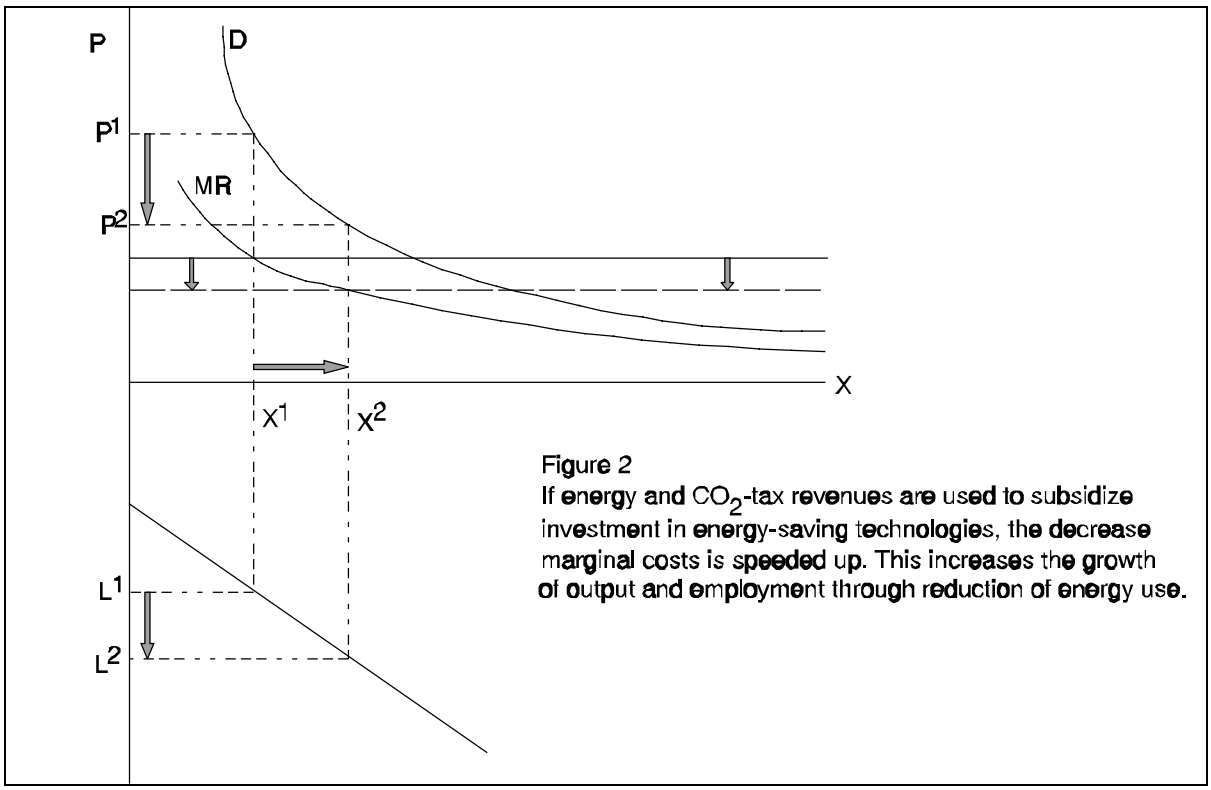

Figure 2
If energy and CO_2-tax revenues are used to subsidize investment in energy-saving technologies, the decrease marginal costs is speeded up. This increases the growth of output and employment through reduction of energy use.

Of course the assumption of zero energy-labour substitution in the short run at the

product level is not an assumption one should built policy upon. We will look in more detail at substitution. It is well known from the discussion on capital-energy substitution that the data used in empirical work are highly aggregated. Substitution is a composite effect of at least three sources: i) shifts in the structure of the activities from energy intensive to less energy-intensive activities; ii) energy-saving technical progress; iii) substitution in the narrow sense of the word, i.e. along an isoquant at the product level. With highly aggregated data it is impossible to disentangle these three effects. Therefore, not only is capital-energy substitution an unclarified issue (see J.L. Solow 1987) but so is the energy-labour substitution. A policy that holds the international competitiveness of sectors constant instead of building on sectoral shifts has to rely on the other sources. Moreover, even if energy-intensive sectors would not be protected against loss of competitiveness one should keep in mind that during the oil crises "the long-established trend of labour-intensive industries toward declining relative economic importance accelerated" (Marlay 1984, p.1279) although oil-price increases could have theoretically induced energy-labour substitution. But this didn't happen and therefore it is much less likely to occur under a CO_2 policy that increases energy prices much less than the oil crises did. Therefore, the first of the three sources of substitution is not available if sectors are protected against loosing competitiveness and substitution in the narrow sense, i.e. along an isoquant on the product level is not a reliable way in itself. The only remaining basis for CO_2 policy is energy-saving investments because "declining relative economic importance of industries intensive in their use of labour and energy, (is) suggesting a role for advanced technologies aimed at improving industrial productivity" and " to the extent that energy is an important factor in the costs of production, such technologies offer potentially significant competitive advantages" (Marlay, 1984, p.1282). Reduction of greenhouse gas emissions and unemployment therefore has to rely on investment in energy-saving technologies. Tax revenues should therefore be recycled in the form of subsidies for these investments. They speed up the decrease in marginal cost, increase production and employment in a clean way (Figure 2).

A standard objection against subsidies is that they introduce a bias against cheaper alternatives (see Proost and van Regemorter 1992). However, the question is in how far this holds if other imperfections than just the environmental ones exist. If output reduction is involved alternatives such as taxes will also have negative consequences for the employment goal and will increase the monopolistic inefficiency and induce capital movements (see Merrifield 1988 and Markusen, Morey and Olewiler 1993). The advantage of subsidies from the point of view of having three imperfections - the environmental one, unemployment and international competitiveness - is that they are all effected positively by the subsidy and suggestions for alternative instruments also will have to be evaluated with respect to all imperfections in an x-best setting. It should be kept in mind that in this proposal subsidies to firms are financed by taxing the polluting households. The principle of causation is therefore applied to households and also internationally because each country pays for its own pollution reduction. Up to the exception made for producers in order to preserve competitiveness this follows the textbook principle to tax the polluter and subsidize the clean alternative. This principle has been successfully applied to car pollution before (see Kemp 1995). Of course adding an additional restriction such as 'international competitiveness' has some costs in making an instrument a bit more costly. However,in a world with many imperfections one has to make sure that improving on one imperfection is not made at the cost of worsening on the other imperfections. The international competitiveness constraint in this chapter excludes cost increasing measures and therefore makes subsidies preferable to

taxes. Investment subsidies to preserve firms survival have also been proposed in a different setting by Carraro and Siniscalco (1992). What these proposals have in common is that subsidies are expected to induce firms to do more of what they do anyway or to do it a bit quicker. In other words, subsidies are expected to do what price changes do because this is the way in which they act in economic models. They are not expected, however, to induce totally different things (like passing thresholds) that would not have been done without subsidies. In short, one cannot expect subsidies to perform better than the price mechanism because they act as price changes and are preferable to taxes under the competitiveness constraint.

Moreover, subsidies in one country or region may induce another country to give subsidies to a close competitor to preserve his position in the competition. Thus subsidies provide an incentive to foreign countries to contribute to GHG policy by using international competition as an incentive mechanism for the participation in contributions to the solution of a global common problem.

6. Markup empirics

If policy fails to keep the competitive position of firms constant it is important to note that in models of perfect competition the impact of policies on prices and the competitive position of firms are underestimated. In perfect competition models we have marginal cost pricing and therefore dp/dMC = 1: prices increase or decrease as much as marginal costs do. However, in imperfectly competitive models with constant price elasticities we have dp/dMC = $1 / (p'x_k / p_k + 1) > 1$: prices increase or decrease more than marginal costs do. Energy and CO_2 taxes imposed on firms will lead to price increases higher than the increase in marginal costs. Similarly, decreases of marginal costs due to energy-saving investments will lead to price decreases that are stronger than those of marginal costs. This is another reason why conventional double dividend policy will underestimate the costs of CO_2 mitigation whereas the favourable effects of energy-saving measures which decrease variable costs are higher than under perfect competition. Under a linear demand function these results are turned on their head: marginal cost changes result in smaller price changes under imperfect competition because the elasticity changes drastically. However, their seems to be no evidence that linear functions are more realistic from an empirical point of view and changes of price elasticities seem to be a non-issue in the literature.

For this reason it is important to give an overview over of the literature on the relation of prices over marginal costs.

Morrison (1992) reports markups of prices on marginal costs, p/MC, which are larger than one for the US, Japan and Canada.

Markups of prices on marginal costs, p/MC,

Countries	United States	Japan	Canada
lower value	1.100 (1961)	1.06 (1960)	1.065 (1961)
upper value	1.286 (1970)	1.463 (1979)	1.221 (1977)

Most of the yearly values for the US and for Canada are between 110% and 120%, whereas for Japan they are between 106% and 146%. In Table 5 we list the results of other studies using a great diversity of methods (see references and Hairault and Portier 1993):

Table 5
Markups of prices on marginal costs p/MC

Country	sector	p/MC	Author
USA	6 one-digit sectors	>2	Hall 1988, 1990
USA	16 industries	1.2-1.4	Morrison 1990[1]
USA	industry	1.36	Domowitz et al. 1987
France	macro	1.41	Laffargue et al. 1990
France	macro	1.225	Hairault & Portier 1993

1 See Table 2 in Morrison 1990 for results on 18 industries at the two-digit level

Except for the values found by Hall these values are of the same order of magnitude as those of Morrison.

Gasiorek, Smith and Venables (1991) provide an increasing returns measure, called IRS, for European industries based on Pratten (1988) and a literature review which allows to calculate the ratio of variable to fixed costs, VC/FC, and the price/marginal-cost ratio, p/MC, under the assumption of zero profits. For an explanation of the method see the appendix. These results are listed in Table 6. Here again we find values of the same order of magnitude for variations over time and across sectors as Morrison did. The values are between 1,06 and 1,43 and most of them also are between 1,10 and 1,20.

Table 6
Markups of prices on marginal costs, p/MC,
based on increasing returns measures

Industry	IRS in %	VC/FC	p/MC
Metalliferous products	6	$7,\overline{3}$	1,14
Non-metallic mineral products	8	5,25	1,19
Chemical products	15	$2,\overline{3}$	1,43
Metal products	7	6,14	1,16
Agric. & ind. machinery	7	6,14	1,16
Office machinery & precision inst.	15	$2,\overline{3}$	1,43
Electrical goods	10	4	1,25
Transport	7	6,14	1,16
Food products	4	11,5	1,09
Textiles, clothing & leather	3	$15,\overline{6}$	1,06
Paper & printing products	13	2,85	1,35
Timber & other n.e.s.	5	9	1,11
Rubber & plastic products	5	9	1,11

The bar over a number indicates its repeated occurrence. From other studies we get only data on price elasticities of demand. These too allow to calculate values of the ratio of prices and marginal costs, p/MC. They are summarized in Table 7.

Table 7
Markups of prices over marginal costs based on price elasticities

Country	sector	p/MC[1]	author
World	220 branded prod.	2.3	Tellis 1988
Australia New Zeal.	220 branded prod.	1.93	Tellis 1988
USA	220 branded prod.	2.1	Tellis 1988
Europe[2]	220 branded prod.	2.6	Tellis 1988
Europe	pharmaceuticals	1.27	Venables 1990[3]
Europe	atr. & synth. fibres	1.13	Venables 1990
Europe	machine tools	1.08	Venables 1990
Europe	office machinery	1.10	Venables 1990
Europe	electric motors and generators	1.17	Venables 1990
Europe	domestic electrical appliances	1.15	Venables 1990
Europe	motor vehicles	1.16	Venables 1990
Europe	carpet linoleum etc.	1.06	Venables 1990
Europe (UK)	footwear	1.024	Venables 1990 (Deaton 1975)

1 We use the formula $p = MC / \otimes$ with $\otimes$ −1 as the inverse of the price elasticity.
2 Mean elasticity of 214 marketing studies for Europe (104 for the USA)
3 Venables 1990 contains calibrated results. Sectoral price elasticities are transformed into those of the firm for several market structures.

In general, no inverse price elasticity of value zero was found which would yield a price equal to marginal costs. In the case of marketing studies, the product level is used for branded products. Here the markup values are a bit higher than for non-branded products. Bresnahan (1989) reports values of the Lerner index L = (P-MC)/P. Seven of the twelve values reported imply p/MC = 1/(1-L) ratios that are larger than two. Also in the studies by Morrison where the p/MC ratio is found using estimations of cost function there is no indication that its value is unity. The only exception we could find is the statistical insignificance of the estimated mark-up for Taiwanese footwear exports to the US in Aw (1992). For Europe, the mark-up of prices on marginal costs seems to be as high as for the US with the exception of the branded-products study by Tellis (1988). This reduction can be obtained from reductions of energy coefficients obtained from speeding up investment in energy-saving technologies through investment subsidies. The marginal cost decrease enhances firm's international competitiveness and the price decrease relaxes households' burden from energy and carbon

taxes.

7. Investment dynamics

To see the impact of policy measures on investment in energy-saving technologies and capital we look at the dynamics of the firm.

Writing (32) in growth rates under a constant rate of interest given from the world market yields

$$\hat{\mu}_{3k} + (\beta_{ik} - 1)\hat{I}_{ik} = \hat{p}_i \qquad (32')$$

$\hat{\mu}_{3k}$ can be obtained from (33) as

$$- \mu_{1k} / \mu_{3k} + d + R = \hat{\mu}_{3k}$$

The shadow value of capital grows at a rate that is equal to interest and depreciation costs minus the value of reducing the capacity constraint. Insertion into (32') yields

$$- \mu_{1k} /\mu_{3k} + d + R + (\beta_{ik} - 1)\hat{I}_{ik} = \hat{p}_i \qquad (32'')$$

The growth rate of investment is

$$\hat{I}_{ik} = (\hat{p}_i + (\mu_{1k} / \mu_{3k}) - d - R) / (\beta_{ik} - 1)$$

If the percentage change in the price of investment goods is higher than the rate of depreciation and the rate of interest corrected for the value of relaxing the capacity constraint the growth rate of investment becomes negative, because investment today is less costly than investment tomorrow.

Inserting μ_{1k} from (33) and then μ_{3k} and its growth rate from (32) and (32')

respectively into (30), where marginal revenue equals marginal cost, yields

$$(p'x_k / p_k + 1)p_k - \sum_{1}^{n} p_i a_{ik} - \sum_{im} p_{im}\, a_{im,k} - t \sum_{e+1}^{r} a_{ik}\, CO2_i -$$

$$\sum_{e+1}^{r} \tau_i .\, a_{ik} - [w_k(1 - s_{w1}) - s_{w2}]\, a_{Lk} - \qquad (30')$$

$$a_{Kk} . [d + R + (\beta_{ik} - 1)\, \hat{I}_{ik} - \hat{p}_i]\, Rp_i / (\beta_{ik}\, I_{ik}^{\beta_{ik}-1}) = 0,\ k = 1,...,\ n$$

The first-order condition of marginal revenue being equal to marginal investment results in a dynamic equation for investment in the capital stock. Energy and CO_2 taxes increase marginal costs and therefore have a negative effect on the level of investment and a positive effect on the growth rate of investment which allows for a lower but increasing growth of employment because the stock of capital determines output and employment in this model when capacity is fully used. Wage subsidies have the opposite effect: the level of investment increases but grows more slowly. For all these effects the ceteris paribus assumption has been made.

A second dynamic equation for optimal firm behaviour can be derived as follows. Solving (31) for μ_{2k} and rewriting it in growth rates under the assumption of a constant ad valorem subsidy yields:

$$(1 - s_i)\, p_i/(\beta_{ik} x_{ik}^{\beta_{ik}-1}) = \mu_{2k} \quad and$$

$$\hat{\mu}_{2k} = \dot{s}_i/(1 - s_i) + \hat{p}_i + (1 - \beta_{ik})\, \hat{x}_{ik}, i = r + 1,...,n; k=1,...,n. \qquad (31')$$

The value of energy-coefficient reductions, μ_{2k} increases with an increase of the subsidy for energy-saving measures, with an increase in the cost of energy conservation and with a decrease in the quantities of these measures. The last term reflects the decreasing returns assumed for energy coefficient reductions.

Dividing (34) by μ_{2k} would in principle allow for insertion of the terms of (31'). However, the index i in (31') is for energy-saving products whereas that of (34') is that of energy products:

$$- \quad x_k \; (\; -p_i \; - \quad t \; CO2_i \; - \; \tau_i) \; / \; \mu_{2k} \; + \; R \; = \; \hat{\mu}_{2k}$$
$$i \; = \; e \; + \; 1,..., \; r \tag{34'}$$

Here the value of energy-coefficient reductions, μ_{2k}, increases with energy prices and taxes as well as carbon taxes and the interest rate.

To avoid confusion about indices we will use the index e henceforth for energy sectors, s for energy saving sectors and i for non-energy sectors. Insertion of (31') into (34') yields

$$-x_k(-p_e - tCO2_e - \tau_i)/[(1-S_s)p_s/(\beta_{sk}x_{sk}^{\beta_{sk}-1})] + R$$
$$= \dot{s}_s/(1-s_s) + \hat{p}_s + (1-\beta_{sk})\hat{x}_{sk} \tag{34''}$$

(34'') is a dynamic equation for the investment in energy-saving technologies given the prices of energy goods and energy-saving technologies. This process may be responsible for the huge decrease in energy consumption that happened to occur during history (see Ausubel 1993 for a summary). It is the basis of the policy proposal made here. A higher growth rate and a higher level of the subsidy (and of t and τ_i, the CO_2 and energy taxes) for investment in energy-saving technologies yields a higher growth of investment in energy-saving technologies because it makes it more profitable to invest. Clearly, the task of a subsidy is not to initiate investment that would not have been undertaken otherwise but it is merely to enhance the volume of investment undertaken to save energy costs. An increased demand for energy-saving technologies will allow for higher scale economies in their production given the increasing returns technology. Going beyond the model it is clear that higher demand for energy-saving technologies has a positive incentive effect for R&D in this field.

8. Conclusion

This chapter argues that a 'double dividend' is more likely to be found in a policy that subsidizes energy-saving investments out of the revenues of a carbon/energy tax than in a policy in which the revenues are used to reduce labour costs. Besides reducing emissions, such a policy thus decreases marginal costs because firms speed up the process of reducing energy use. Reduced marginal costs increase output and therefore employment.

Such a policy is superior under the condition already agreed upon that the international competitiveness of branches and firms should not suffer from CO_2 abatement policy, so that no sectoral shift occurs. In such a context, there is only substitution along an isoquant. Given the limited opportunities of substitution at least in the short run and on the productlevel we doubt that the standard double-dividend story is convincing. In contrast with that the energy-savings potentials are well known to be quite large (see Marlay 1984, Blok et al. 1990 and Velthuijsen 1993). Investment in energy-saving technologies is the road to GHG-emission reduction without endangering international competitiveness and employment of sectors.

The effects of the proposal are as follows:

i) Households pay energy and CO_2 taxes which are used for subsidies on energy-saving investments. Under the EC proposal the price level effect is roughly 10% for natural gas and heating gas oil. Substitution away from energy at the household level is likely to occur but will be very modest. Demand for energy-saving products will increase. The effects are limited. The costs of the policy are spread over the entire population, the beneficiary of GHG emission reduction.

ii) Subsidies for energy-saving investments reduce the fixed costs of production immediately because investment costs of energy-cost reduction are not part of the variable cost of production. Over time firms will speed up the process of reducing energy coefficients. As a result marginal costs decrease more quickly, which leads c.p. to lower prices and higher output, making fixed costs per unit of output lower. Consequently, greenhouse gas emissions will be reduced and employment will be higher as well. Energy-intensive sectors get a chance to become 'clean' without being the source of a new employment problem. The decrease in marginal costs will lead to a decrease in prices. A reduction of marginal costs will have a favourable impact on the competitiveness of firms. Exports going from the EC to the rest of the world will benefit most because they don't suffer from a decrease in demand induced by energy and CO_2 taxes unless the rest of the world is induced to undertake the same policy. This is another potential advantage of this proposal, that the policy deadlock of "we do nothing if they do nothing" may be broken.

iii) If politicians believe in energy-labour substitution at the product level or allow for sectoral shifts, firms can be taxed for energy use and CO_2 pollution as well and the revenues could be used for employment subsidies. This could keep marginal cost on the firm level constant only if energy consumption is not very high. Almost nothing would happen in the most energy intensive and polluting sectors when energy -labour substitution is weak whereas under subsidies for energy-saving investments they become more clean according to their energy-saving potentials.

In short, subsidies on investment in energy-saving technologies paid out of carbon and energy taxes are a better way to stimulate competitiveness and employment and achieve GHG reductions than wage subsidies are, if policy makers want to safeguard energy-intensive sectors. Moreover, subsidies may induce other countries to undertake a similar policy.

References

Ausubel, J.H., 1993, Mitigation and Adaptation for Climate Change: Answers and Questions, in: Costs, Impacts, and Benefits of CO_2 Mitigation, edited by Y.Kaya, N.Nakicenovic, W.D. Nordhaus, F.L. Toth, IIASA Laxenburg, Austria, June 1993, 557-584.

Aw, B.Y., 1992, An Empirical Model of Mark-Ups in a Quality-Differentiated Export Market, Journal of International Economics 33(3-3), November, 327-44.

Bear, R.J., 1990, Government Spending in a Simple Model of Endogenous Growth", Journal of Political Economy, vol.98, october, S103-S125.

Bhagwati, J.N. and T.N. Srinivasan, 1983, Lectures on International Trade, MIT Press, Cambridge, Massachusetts, London, England.

Blok, K., E. Worrel, R.A.W. Albers, R.F.A. Cuelenaere (1990), Data on energy conservation techniques for the Netherlands, Vakgroep Natuurwetenschap en Samenleving, Rijksuniversiteit Utrecht.

Bovenberg, A.L. and F. van der Ploeg (1992), Environmental policy, public finance and the labour market in a second-best world, Tinbergen Institute Discussion Paper 93-15, October 1992.

Bovenberg, A.L. and F. van der Ploeg (1993), Consequences of environmental Tax Reform for Involuntary Unemployment and Welfare, mimeo, September.

Brenton, P., 1994, Estimation of Cross-Country Consumption Patterns: Implications for Carbon Abatement Policies, The University of Birmingham, Department of Economics Discussion Paper No. 94-12.

Bresnahan, T. (1989), Empirical Studies of Industries with Market Power, in: Handbook of Industrial Organization, Vol. II, edited by R. Schmalensee and R.D. Willig, Elsevier Science Publishers B.V., Chap. 17, 1011-1057.

Carraro, C. and D. Siniscalco, 1992, Environmental Innovation Policy and International Competition, Environmental and Resource Economics 2: 183-200.

Conrad K. and J. Wang, 1993, Quantitative Umweltpolitik: Gesamtwirtschaftliche Auswirkungen einer CO2-Besteuerung in Deutschland(West), Jahrbuch für Nationalökonomie und Statistik, 309-324.

Deaton, A.S., 1975, The measurement of income and price elasticities, European Economic Review 6, 261-273.

Denis, C. and G.J. Koopman, 1995, Differential Treatment of Sectors and energy Products in the Design of a CO_2/Energy Tax: Consequences for Employment, Economic Welfare and CO_2 Emissions, NOTA DI LAVORO 32.95, Economics energy environment, Fondazione Eni

Enrico Mattei, Milano, Italy.

Dixit, A. and J.E. Stiglitz, 1977, Monopolistic Competition and Optimum Product Diversity, American Economic Review 67, 297-308. Domowitz, I., R. Hubbard, and B. Petersen, 1987, Market structure and cyclical fluctuations in U.S. manufacturing, Review of Economics and Statistics 70, no.1, 55-66.

Europaeische Gemeinschaften, 1994, Energiepreise 1973-1993, Luxembourg.

Gasiorek, M., A. Smith and A.J. Venables, 1991, Completing the internal market in the EC: factor demands and comparative advantage, Chapter 2 in: European Integration: Trade and Industry, edited by L.A. Winters and A.J. Venables, Cambridge University Press, Cambridge, England.

Hairault J.O. and Portier, 1993, Money, New-Keynesian macroeconomics and the business cycle, European Economic Review, Vol.37, No.8, 1533-1568.

Hall, R.E, 1988, The Relation between Price and Marginal Cost in U.S. Industry, Journal of Political Economy, Vol. 96, no.5, 921-47.

------, 1990, Invariance Properties of Solow's Productivity Residual, in: Growth/Productivity/Unemployment, edited by P.A. Diamond, MIT Press, Cambridge, Massachusetts, London, England, 71-112.

Helpman, E. and P.R. Krugman, 1985, Market Structure and Foreign Trade, Harvester Wheatsheaf, Brighton.

HERMES 1993, Harmonized Econometric Research for Modelling Economic Systems, edited by: Commission on the European Communities, North-Holland, Amsterdam.

IPCC Draft Guidelines for National Greenhouse Gas Inventories, Greenhouse Gas Inventory Reference Manual, First Draft, Volume 3.

Jorgenson and Wilcoxon, 1993, Reducing U.S. Carbon Dioxide Emissions: An Assessment of Different Instruments, Journal of Policy Modelling 15, 491-520.

Kemp, R., 1995, Environmental Policy and Technical Change, A Comparison of the Technological Impact of Policy Instruments, Universitaire Pers Maastricht.

Koopman, G.J., M. Mors and J. Scherp, 1993, The Likely Economic Impact of the Proposed Carbon/Energy Tax in the European Community, In: Costs, Impact, and Benefits of CO2 Mitigation, edited by Y. Kaya, N. Nakicenovic, W.D. Nordhaus and F.L. Toth, June, 273-290.

Kouris, G., 1983, Energy Demand Elasticities in Industrialized Countries: A Survey, The Energy Journal, Vol. 4, No.3, 73-94.

Lucas, R.B., 1990, Supply-Side Economics: An Analytical Review, Oxford Economic Papers 42, April, 293-316. Reprinted in: P.J.N. Sinclair and M.D.E. Slater, Taxation, Private

Information and Capital, Oxford University Press, Oxford, 1991.

Markusen, J.R., E.R. Morey and N.O. Olewiler, 1993, Environmental policy when market structure and plant location are endogenous, Journal of Environmental Economics and Management 24, 69-86.

Marlay, R.C., 1984, Trends in Industrial Use of Energy, Science Vol. 226, December, 1277-1283.

Merrifield, J.D., 1988, The Impact of Selected Abatement Strategies on Transnational Pollution, the Terms of Trade, and Factor Rewards: A General Equilibrium Approach, Journal of Environmental Economics and Management 15, 259-284.

Mittelstädt, A., 1983, Use of Demand Elasticities in Estimating Energy Demand, OECD, 46.p.

Morrison, C.J., 1989 , Unravelling the productivity growth slowdown in the U.S., Canada, and Japan, NBER Working Paper 2993.

--------, 1990, Market Power, Economic Profitability and Productivity Growth Measurement: An Integrated Structural Approached. NBER Working Paper 3355, May.

--------, 1992, Unravelling the Productivity Growth Slowdown in the United States, Canada and Japan: The Effects of Subequilibrium, Scale Economies and Markups, The Review of Economics and Statistics, Vol.LXXIV, August, Number 3, 381-93.

Pratten, C., 1988, A Survey of Economies of Scale, in: 'Research on the "Costs of Non-Europe", Basic Findings', Vol.2, Brussels: Commission of the European Communities.

Proost, S. and D. van Regemorter, 1992, Carbon Taxes in the European Community: Design of tax policies and their welfare impacts, European Economy, Special Edition No. 1,91-124.

Schöb, R., 1995, Zur Bedeutung des Ökosteueraufkommens: Die Double-Dividend - Hypothese. Zeitschrift für Wirtschafts- und Sozialwissenschaften 115/1, 93-117.

SEO Onderzoek, 1992, Prijselasticiteit van het huishoudelijk energieverbruik, Amsterdam.

Soete, L. and T. Ziesemer, 1992, Gains from Trade and Environmental Policy under Imperfect Competition and Pollution from Transport, MERIT Research Memorandum 92-022.

Solow, J.L., 1987, The Capital-Energy Complementarity Debate Revisited, American Economic Review, September, 605-614.

Sørensen, P.B., 1993, Human Capital Investment, Government, and Endogenous Growth, Finanzarchiv, 73 - 93.

Tellis, G.J., 1988, The Price Elasticity of Selective Demand: A Meta-Analysis of Econometric Models of Sales, Journal of Marketing Research, Vol. XXV, November, 331-41.

Venables, A.J., 1990, Trade policy under Imperfect Competition: A Numerical Assessment, CEPR Discussion Paper No.412, April 1990.

Velthuijsen, J.W., 1993, Incentives for Investment in Energy Efficiency: An Econometric Evaluation and Policy Implications, Environmental and Resource Economics 3: 153-169.

Appendix

IRS is defined as the percentage change in average costs from a 50% decrease of output. Defining average costs, AC = FC + VC, in accordance with (3) or (4) as AC = w(a +bx)/x, its derivative with respect to x is $dAC/dx = -wa/x^2 = -FC/x^2$, where FC is an abbreviation for 'fixed costs' and VC 'variable costs'. The elasticity of AC with respect to x then is $(dAC/dx)x/AC = (-wa/x^2)x/[w(a +bx)/x] = (-wa)/[w(a +bx)]$. Multiplying by dx/x yields IRS≡ dAC/AC = (dx/x)(-wa)/[w(a +bx)] = -.5(-FC)/C = -.5[-1/(1+VC/FC)]. Solving for VC/FC we find VC/FC = MCx/FC = 1/2IRS - 1. Inserting data from Gasiorek, Smith and Venables for IRS the ratio MCx/FC can be computed. Using this and the zero-profit assumption P = AC the price/marginal-cost ratio can be computed as p/MC = AC/MC = (FC + VC)/MC = (FC + MCx)/MC = FC/MCx + 1.