CENTER FOR ECONOMIC STUDIES

POLLUTION, FACTOR TAXATION AND UNEMPLOYMENT

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Working Paper No. 151

UNIVERSITY OF MUNICH

CES

Working Paper Series

CES Working Paper No. 151
January 1998

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Abstract

When consumers choose between clean and dirty goods and the labour market clears, a green tax reform may not bring about a double dividend in the sense of increasing environmental quality and increasing employment. However, when firms choose between clean and dirty factors of production, and when there is unemployment, such a result is very likely to occur. The paper investigates a model of a monopolistic firm where labour and energy are factors of production and trade unions negotiate the wage rate, accepting some unemployment as a result of aggressive wage demands. It is shown that, in such a framework, a green tax reform will boost employment provided it does not increase the net-of-tax wage rate by too much. This is the case when the elasticity of substitution between labour and energy is greater than one, equal to one or not too far below one.

Keywords: factor taxation, green tax reform, trade unions

JEL Code: H20, J51

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1. Introduction

Europe is suffering from persistently high levels of unemployment. In the third quarter of 1997, the average unemployment rate in the European Union was nearly 11%.[1] The high level of unemployment has limited the scope for active environmental policies. Although it is generally agreed that green taxes will reduce environmental pollution, the fear that these taxes would exacerbate the problem of unemployment is widespread. Environmental policy is seen as a luxury that should be postponed until better days.

This paper questions the generality of this view. Focusing on green taxes on the production side, we show that a green tax reform which benefits the environment will boost employment if it results in the trade unions accepting the same, a lower, or a not too much higher net-of-tax wage. Thus there is little reason to postpone environmental policy measures in order to fight the ongoing pollution of the environment.

But how can green taxes reduce unemployment? One obvious answer is by rebating tax revenues from green taxes through cuts in labour taxes. The high level of taxes on labour income, combined with the high level of unemployment benefits, is often made responsible for unemployment since it distorts labour supply and increases wage pressure in labour markets (see OECD 1995). A green tax reform may alleviate the tax burden on labour and hence reduce the resulting disincentives.

The early literature on the employment effects of green tax reforms was pessimistic with regard to whether such reforms would boost employment. Bovenberg and de Mooij (1994) and Bovenberg and van der Ploeg (1994) have argued that labour supply will normally fall as a result of a green tax reform. However, their arguments are based on models with market clearing in the labour market and, therefore, full employment.[2]

More recent work has given up the assumption of full employment and concludes that positive employment effects are possible. In a model with fixed net-of-tax wages, Bovenberg

[1] OECD, cf. Main Economic Indicators, December 1997, p. 40.
[2] See Bovenberg (1995) for a survey of the early literature on the double dividend hypothesis with particular focus on the employment effects.

and van der Ploeg (1996) show that if green taxes are low initially, employment may increase if substitution between labour and resources within the production sector is easy. Bovenberg and van der Ploeg (1995) identify within a search theoretic framework positive employment effects for a revenue-neutral green tax reform which increases the tax on a polluting factor of production and which succeeds in shifting the tax burden away from labour income to transfer income. Using an efficiency wage model, Schneider (1997) also shows that employment may increase due to an increase in green taxes.

Koskela and Schöb (1996) apply a model with endogenous wage negotiations. They show that, if unemployment benefits are nominally fixed and are taxed at a lower rate than wage income, a revenue-neutral green tax reform which increases green taxes on the consumption of a polluting good alleviates unemployment. Holmlund and Kolm (1997) examine the role of an environmental tax reform for a small open economy with monopolistic competition. Assuming a Cobb-Douglas technology, they show for a two sector economy that a revenue-neutral tax reform which increases the energy tax and reduces the labour tax increases employment if wages in the tradable sector are higher than in the non-traded sector. Finally, Carraro, Galeotti and Gallo (1996), provide numerical simulations of the effects of a carbon tax reform in a bargaining model, which indicate some evidence in favour of a short-run employment dividend.

This paper analyses the effects of green tax reforms on unemployment. Throughout the analysis we assume that full employment has not yet been reached and that the government policy objective is to further reduce unemployment. We therefore apply a model similar to, but more general than, Koskela and Schöb (1996), where the wage is endogenously determined in a bargaining process between trade unions and firms. However, while Koskela and Schöb analyse green tax reforms in a model with consumption externalities, a single factor of production, and exogenous goods prices, we study green tax reforms with production externalities, two factors of production, and monopolistic firms. The main focus is on the impact the revenue-recycling effect has on the wage negotiations and employment. The wage negotiations are analysed using a 'right-to-manage' model by allowing non-constant elasticities of factor demands. Trade unions and firms bargain over wages and firms then choose the employment level that maximizes profits. Thus, our analysis can be regarded as a partial synthesis of Holmlund and Kolm (1997) on the one hand and Bovenberg and van der Ploeg (1996) on the other hand.

The paper is organized as follows. Section 2 presents the basic model. In Section 3 the implications of a revenue-neutral green tax reform are analysed when the net-of-tax wage is kept constant. Section 4 derives conditions which guarantee positive employment effects for consecutive marginal revenue-neutral green tax reforms. Section 5 extends the analysis to the case where the net-of-tax wage is negotiated between a trade union and the firm and analyses how the possible changes in the net-of-tax wage modify the picture. Finally, there is a brief conclusion.

2. The model

We consider a monopolistic firm which produces output Y using imported energy R and domestic labour L as inputs. The use of energy in production is dirty in the sense that it produces a negatives externality on households or other sectors of the economy. The technology is linear-homogenous and is represented by a CES production function

$$Y = f(L,R) = \left[L^{\frac{\sigma-1}{\sigma}} + R^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where σ denotes the elasticity of substitution. The firm faces a downward sloping demand curve which is assumed to be isoelastic. Denoting the output price with p and the output demand elasticity with $\varepsilon \equiv -D_p \cdot p \;\, Y$ we have:[3]

$$Y = D(p) = p^{-\varepsilon}.$$

[3] The elasticity of demand depends on the consumer's elasticity of substitution between good Y and its substitutes. See Dixit and Stiglitz (1977) for a formal analysis of the relationship between substitutability and pricing.

To guarantee a profit maximum the output demand elasticity must exceed unity. Profit is given by

$$\pi = pY - \tilde{w}L - \tilde{q}R,$$

where the firm considers the energy price $\tilde{q}$ and the gross wage rate $\tilde{w}$ as given. The gross wage is the net-of-tax wage, which is negotiated between a trade union and the firms, plus the labour tax, modelled as a payroll tax: $\tilde{w} = w(1+t_w)$. The energy price is the foreign resource price plus a green tax levied on the use of energy in production: $\tilde{q} = q(1+t_q)$. Profit maximization with respect to inputs yields the conditional labour and energy demand functions:

$$L = \tilde{w}^{-\sigma}\left[\tilde{w}^{1-\sigma} + \tilde{q}^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} Y$$

and

$$R = \tilde{q}^{-\sigma}\left[\tilde{w}^{1-\sigma} + \tilde{q}^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} Y,$$

respectively. Substituting the conditional demands into the cost function we obtain

$$C(\tilde{w},\tilde{q},Y) = Y\left[\tilde{w}^{1-\sigma} + \tilde{q}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \equiv Yc(\tilde{w},\tilde{q}), \tag{2}$$

where $c(\tilde{w},\tilde{q})$ denotes average and marginal cost of production.

Profit maximization with respect to output yields the first-order condition

$$p\left(1 - \frac{1}{\varepsilon}\right) = c(\tilde{w},\tilde{q}), \tag{3}$$

i.e. the domestic firm demands a price which exceeds the marginal cost by a (constant) mark-up factor of $[\varepsilon/(\varepsilon-1)]$. Due to the iso-elastic output demand, profit is proportional to total cost, i.e. $\pi = cY/(\varepsilon-1)$.

The government requires a fixed amount of tax revenues to finance the public good G. In addition, it has to finance the unemployment benefit b. The only tax instruments available are taxes on labour and energy. In general, the government budget constraint is then given by

$t_w wL + t_q qR = G + b(N - L)$. In the following, however, we abstract from changes in the government budget due to changes in the unemployment benefit payments and focus on a reduced form of the government budget constraint given by

$$t_w wL + t_q qR = G. \tag{4}$$

The employment effects are not qualitatively affected by this simplification. If employment increases because of the tax reform, fewer tax revenues are required to meet the budget constraint and vice versa.

3. Labour tax system vs green tax system

We start our analysis by asking whether there exists a "green tax system", characterized by relatively high tax rates on energy and relatively low labour taxes, which yields the same output as the existing "labour tax system" where the labour tax rate exceeds the energy tax rate, but generates a higher level of employment. For the time being it is assumed that the net-of-tax wage w is fixed. This assumption will be relaxed in Section 5.

The initial tax system is characterized by a tax on labour income, t_w, which is larger than the (ad-valorem) tax on energy input, t_q. It can be shown that, for given net-of-tax factor prices w and q, there is an alternative tax system, which generates the same output and tax revenue but allows for a higher level of employment.

There are a few conditions that must be satisfied for the green and labour tax systems. First, both tax systems produce the same output,

$$f(L, R) = Y_0, \tag{5}$$

where the output level Y_0 is *ceteris paribus* determined by the initial tax rates t_w^A and t_q^A. Second, profit maximization requires that output is produced with minimum cost. The first-order condition for cost-minimization can be represented by

$$\tilde{w} f_R(L, R) - \tilde{q} f_L(L, R) = 0, \tag{6}$$

where f_i denotes the partial derivative of $f(L,R)$ with respect to $i = L, R$ (e.g. $f_R = \partial f \ \partial R$). Third, the marginal cost is equal in the two systems for otherwise the firm would not sell the same output in equilibrium as before. With linear-homogenous technologies this implies constant total cost,

$$\tilde{w}L + \tilde{q}R = C_0. \tag{7}$$

In the special case of a CES production function, this cost could even be explicitly calculated from equations (2) and (3): $C_0 = p\left[1-(1\ \varepsilon)\right]Y_0$. Fourth, the government budget constraint (4) must be met.

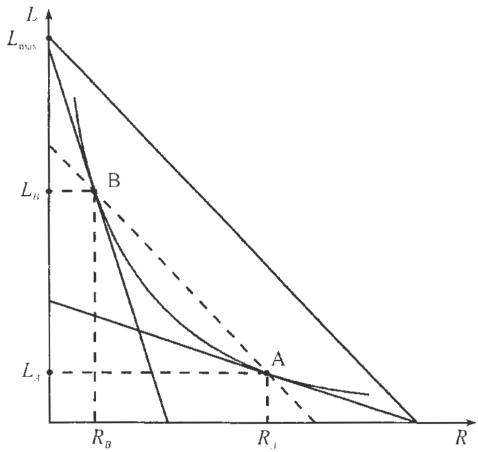
Equations (4) through (7) provide an equation system which can be solved with respect to the optimal inputs and the necessary tax rates, respectively. As the initial labour tax system (t_w^A, t_q^A) provides a first solution with a higher tax rate on labour than on energy, the second solution will yield an equilibrium with higher taxes on energy and a higher labour demand.

The solution is represented in Figure 1 where point A indicates the initial labour tax system (t_w^A, t_q^A) with $t_w^A > t_q^A$, which is given by the tangency of the iso-cost curve and the isoquant for Y_0. Point B indicates a green tax system (t_w^B, t_q^B) with $t_q^B > t_w^B$ which yields the same output at the same total cost. The latter is the case as B lies on the dotted iso-revenue line which is parallel to the before-tax iso-cost curve (starting in $L_{\max}$). Moving directly from A to B will instantaneously increase employment without imposing any additional cost on either firm or government. In addition, less energy will be used, and, consequently, the environment will improve. This result is summarized in proposition 1.

PROPOSITION 1: With given net-of-tax factor prices and a linear-homogenous production technology, there exists a *green tax system* with higher tax rates on energy than on labour which yields the same output level and same tax revenues as the existing *labour tax system* where the labour tax rate exceeds the energy tax rate. The green tax system generates both a higher level of employment and a cleaner environment.

Note that Proposition 1 refers to linear-homogenous production functions in general. The CES production function introduced in (1) has not yet been used in the derivation.

Figure 1: Labour tax system versus green tax system



4. Marginal revenue-neutral green tax reforms

Section 3 considered a jump from a labour tax system to a green tax system. One may ask, however, under what condition do consecutive revenue-neutral green tax reforms also guarantee positive employment effects.

To analyse the employment and output effects of a marginal revenue-neutral green tax reform, we split the tax reform into two separate steps. First, we consider a marginal green tax reform which increases the energy tax and lowers the labour tax so that the output level is kept constant, i.e. $dY = 0$. This implies a movement along the isoquant, which guarantees that labour input will increase, while leaving marginal cost constant as a direct implication of Euler's theorem.

If such a tax reform generates excess tax revenues, $dG > 0$, the surplus in tax revenues will be rebated in a second step by equiproportionally reducing both taxes so that $dG = 0$. Since an equiproportional change in tax rates reduces marginal cost, this will increase output and consequently the demand for both inputs. Hence, such a green tax reform will unambiguously increase employment while the effect on energy input remains *a priori* ambiguous.

The output-neutral tax reform can be derived by totally differentiating the production function (1):

$$dY = 0 = \left[L^{-\frac{1}{\sigma}} L_{\tilde{w}} w + R^{-\frac{1}{\sigma}} R_{\tilde{w}} w \right] dt_w + \left[L^{-\frac{1}{\sigma}} L_{\tilde{q}} q + R^{-\frac{1}{\sigma}} R_{\tilde{q}} q \right] dt_q . \tag{8}$$

Solving for dt_w one gets

$$\left. \frac{dt_w}{dt_q} \right|_{dY=0} = -\frac{(1-s)(1+t_w)}{s(1+t_q)}, \tag{9}$$

where $s \equiv \tilde{w}L / cY$ denotes the cost share of labour and $(1-s) \equiv 1 - \tilde{w}L / cY = \tilde{q}R / cY$ the cost share of energy. Next, consider the impact such an output-neutral tax reform has on the government budget:

$$dG = \left[wL + wt_w L_{\tilde{w}} w + qt_q R_{\tilde{w}} w \right] dt_w + \left[qR + wt_w L_{\tilde{q}} q + qt_q R_{\tilde{q}} q \right] dt_q . \tag{10}$$

Substituting conditions (8) and (9) in (10) yields (after some manipulations)

$$\left. \frac{dG}{dt_q} \right|_{dY=0} = \frac{1}{s(1+t_q)} \left[sqR(\sigma(1+t_q) - t_q) - (1-s)wL(\sigma(1+t_w) - t_w) \right].$$

Depending on the relationship between the two tax rates we obtain

$$\left. \frac{dG}{dt_q} \right|_{dY=0} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \quad \Leftrightarrow \quad t_w \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} t_q .$$

Suppose labour is taxed more heavily than energy, i.e. $t_w > t_q$. In this case, the output-neutral tax reform leads to a surplus in tax revenues, i.e. $dG / dt_q |_{dY=0} > 0$. Rebating this budget surplus reduces the marginal cost and consequently increases output and therefore factor demands. Output will rise more the higher is the output demand elasticity ε.

Figure 2: Consecutive marginal green tax reforms

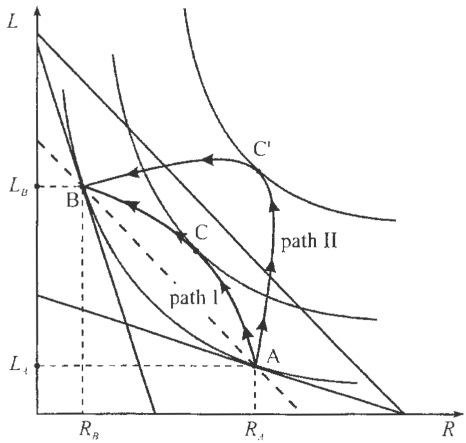


Figure 2 shows two conceivable paths of consecutive marginal tax reforms starting in the labour tax system A and ending in the green tax system B. Up to points C or C' where $t_w = t_q$, employment will definitely increase. A further increase in t_q, however, will result in output reductions. This output effect countervails the substitution effect of moving along the isoquant. If the output demand elasticity is small, the initial rise and subsequent fall in output will be small and the substitution effect will dominate the output effect. This case is represented by path I in Figure 2. Moving from C to B further increases employment while output is falling. If output demand is very elastic, however, as represented by path II there will be an interval on the path II from C' to B where output and employment are falling simultaneously.[4] This result can be summarized in the following proposition.

[4] For the same reason, moving from A to C' increases energy demand and hence worsens environmental quality.

PROPOSITION 2: As long as the labour tax rate exceeds the energy tax rate, a marginal revenue-neutral green tax reform, which leaves the net-of-tax wage unaffected, will increase output and employment.

Going beyond C or C', we can add the following corollary.

COROLLARY 1: If the energy tax rate exceeds the labour tax rate, a marginal revenue-neutral green tax reform, which leaves the net-of-tax wage unaffected, will reduce the level of output.

The corollary can be considered as a direct implication of the Diamond and Mirrlees (1971) production efficiency theorem. For given total cost and tax revenue requirement, an equiproportional factor taxation, which is equivalent to an output tax, maximizes output.[5]

5. Green tax reform and wage negotiations

It is time now to relax the assumption of exogenously given wages, as promised. We assume that the wage level is determined in wage negotations which take place between a small trade union and the firm. The objective of the trade union is to maximize the income of its N members. Each member works one unit of time and receives a wage income. Unemployed members are entitled to unemployment benefits. The net-of-tax wage is again denoted by w. The unemployment benefit is fixed at the level b. The objective function of the trade union can be written as[6]

$$V^{*} = wL + b(N - L).$$

[5] Notice that an equiproportional factor taxation need not be welfare-maximizing in our framework of imperfectly competitive labour markets, though it is in the Diamond-Mirrlees framework.
[6] A linear objective function is used for analytical convenience. It is often claimed that trade unions do not care about the level of employment if lay-offs follow an inverse seniority rule. In this case the objective function of the trade union would reduce to $V^{*} = w$ (cf. Oswald 1993). In the following, we abstract from wage taxes, taxes on unemployment benefits and different types of tax allowances. The effects these parameters have on trade union's behaviour are elaborated in detail by Koskela and Schöb (1996).

Wages are usually determined in a bargaining process between the trade union and the firm, and the firm then unilaterally determines employment. To model this, we apply a 'right-to manage' model which represents the outcome of the bargaining by asymmetric Nash bargaining.[7]

The fall-back position of the trade union is given by $V^0 = bN$, i.e. all members receive their reservation wage equal to the unemployment benefit. The fall-back position for the firm is given by zero profits, i.e. $\pi^0 = 0$. The Nash bargaining maximand can then be written as

$$\Omega = (V^* - V^0)^\beta \pi^{1-\beta},$$

with β representing the bargaining power of the trade union. Using $V \equiv V^* - V^0$, the first-order condition with respect to the net-of-tax wage is

$$\Omega_w = 0 \iff \beta \frac{V_w}{V} + (1-\beta)\frac{\pi_w}{\pi} = 0, \tag{11}$$

where the subscripts denote partial derivatives (e.g. $V_w = \partial V / \partial w$). In the following we focus on changes in tax rates only. Provided that the second derivative is negative, i.e. $\Omega_{ww} < 0$, equation (11) defines the negotiated wage from Nash bargaining as a function of the tax rates t_w, t_q so that $w = w(t_w, t_q)$. The next section provides the comparative statics necessary to analyse revenue-neutral green tax reforms affecting the production side.

5.1 Comparative statics

The question is how the negotiated wage will react to changes in the tax rates. From implicit differentiation of condition (11) we can infer that $\partial w / \partial t_i = w_{t_i} = -\Omega_{wt_i} / \Omega_{ww}$, $i = w, q$. This allows us to sign the net-of-tax wage change due to a change in either the labour tax or the energy tax:

[7] This approach can be justified either axiomatically (cf. Nash 1950), or strategically (cf. Binmore, Rubinstein and Wolinsky 1986). Alternatively, one could apply an efficient bargaining model where the trade union and the firm negotiate over both wages and employment. Our approach here is in line with Oswald (1993) who has shown that empirically, in almost all contracts, firms explicitly obtain the right to unilaterally determine employment.

$$\operatorname{sign}(w_{t_i}) = \operatorname{sign}(\Omega_{wt_i}) = \operatorname{sign}\left(\frac{\beta}{V^2}\left[VV_{wt_i} - V_w V_{t_i}\right] + \frac{1-\beta}{\pi^2}\left[\pi\pi_{wt_i} - \pi_w \pi_{t_i}\right]\right). \tag{12}$$

To interpret this expression we make use of the explicit form of the following factor (cross-) price elasticities, which can be derived analogously to the case of perfect competition [cf. Allen (1938) or Hamermesh (1993)]. The wage elasticity of labour demand $\eta_{L,\tilde{w}}$ is given by

$$\eta_{L,\tilde{w}} \equiv \frac{L_{\tilde{w}}\tilde{w}}{L} = -\sigma + s(\sigma - \varepsilon), \tag{13}$$

and the cross-price elasticity is

$$\eta_{L,\tilde{q}} \equiv \frac{L_{\tilde{q}} \cdot \tilde{q}}{L} = (1-s)(\sigma - \varepsilon). \tag{14}$$

If $\eta_{L,\tilde{q}} > 0$ factors are factor price substitutes and they are factor price complements if the reverse is true (cf Hamermesh 1993, p.37). In the following we assume that energy and labour are complements in the sense that $\eta_{L,\tilde{q}} < 0$. Obviously, this is the case if the output demand elasticity falls short of the elasticity of substitution.

Combining equations (13) and (14) allows an interpretation of the labour demand elasticity. First, the labour demand elasticity depends on the substitutability of factors, indicated by σ. The more easily energy can be substituted for labour the more elastic labour demand is. The size of the labour demand elasticity also depends on whether factors are substitutes or complements. If factors are complements, the marginal productivity of labour declines as an increase in wages reduces energy demand. This has a negative effect on labour demand which becomes stronger the larger the share of labour in total cost is (cf. Hamermesh 1993, p.24).

To understand the impact that changes in the labour tax have on the negotiated wage, we will analyse the effects on the trade union's and the firm's objective functions separately. First, a labour tax affects the income of the trade union only to the extent that the labour demand elasticity is not constant but reacts to a change in the labour tax rate:

$$\operatorname{sign}(VV_{wt_w} - V_w V_{t_w}) = \operatorname{sign}\left(\frac{\partial \eta_{L,\tilde{w}}}{\partial t_w}\right). \tag{15}$$

From the partial derivative of the trade union's objective function $V_w = \{L + (w-b)L_w\}$ it can be seen that a constant labour demand elasticity implies that if the labour tax rate increases and the trade union fights for higher wages, the benefits of a wage increase for those employed fall in proportion to the losses which occur because more workers are fired. If the labour demand becomes less elastic, however, the benefits fall at a lower rate and it becomes profitable to demand higher wages. The partial derivative of the labour demand elasticity with respect to the labour tax rate is given by

$$\frac{\partial \eta_{L,\bar{w}}}{\partial t_w} = s_{t_w}(\sigma - \varepsilon),$$

with

$$s_{t_w} = s_{\bar{w}} w = \frac{s}{(1+t_w)}(1-s)(1-\sigma)\begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \quad \Leftrightarrow \quad \sigma \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 1.$$

As we assume labour and energy to be complements, i.e. $\varepsilon > \sigma$, condition (15) reduces to

$$\text{sign}(VV_{wt_w} - V_w V_{t_w}) = \text{sign}(\sigma - 1).$$

If substitutability is low, i.e. $\sigma < 1$, the cost share of labour increases with the labour tax rate. A larger share s implies that a one percent increase in the wage rate induces a larger increase in total cost and, consequently, a larger fall in output. This will lead firms to lay off more workers. Hence, if s increases, labour demand becomes more elastic. This weakens the bargaining position of the trade union since the potential losses in terms of lay-offs that result from a wage increase go up. The situation is reversed if s decreases.

With respect to the firm's bargaining position, it can be shown that

$$\text{sign}(\pi\pi_{wt_w} - \pi_w \pi_{t_w}) = \text{sign}(\sigma - 1).$$

If substitutability is low, the cost share of labour is an increasing function of the wage rate. In this case, a rise in the net-of-tax wage rate will induce a fall of profits. Therefore the firm will become more reluctant to accept wage increases and demand lower wages. Hence, if substitutability is low, an increase of the labour tax rate will weaken the trade union's bargaining position and strengthen that of the firm. As a consequence, the two effects of an increase in the labour tax rate work in the same direction. Depending on the elasticity of substitution we can summarize the total effect as:

$$w_{t_w} \begin{cases} < 0 & \text{as } \sigma < 1 \\ = 0 & \text{as } \sigma = 1. \\ > 0 & \text{as } \sigma > 1 \end{cases} \tag{16}$$

In what follows we assume that the total effect on gross wages, $d\tilde{w}\ dt_w = w + (1+t_w)w_{t_w}$, is always positive, i.e. a labour tax will not be fully shifted onto the workers.[8]

Next consider a change in the green tax levied on energy input. The rationale for such a tax is to reduce emissions connected with the use of oil, gas or coal which damage the environment. Thus, we take it for granted that a reduction in the energy input into production has a positive impact on the environment. Given this assumption, we are then interested in the impact such a green tax has on wage negotiations. Analytically, the impact on the trade union's bargaining position is given by

$$\operatorname{sign}(VV_{wt_q} - V_w V_{t_q}) = \operatorname{sign}\left(\frac{\partial \eta_{L,\tilde{w}}}{\partial t_q}\right),$$

where

$$\frac{\partial \eta_{L,\tilde{w}}}{\partial t_q} = s_{t_q}(\sigma - \varepsilon),$$

and

$$s_{t_q} = -\frac{(1+t_w)}{(1+t_q)} s_{t_w}.$$

[8] This is also in line with empirical evidence. See e.g. Lockwood and Manning (1993) and Holm, Honkapohja and Koskela (1994).

The energy tax has the opposite effect on the labour demand elasticity to an increase in the labour tax. If substitutability is low, an increase in t_q reduces the cost share of labour. Since factors are complements, a lower share implies that labour demand becomes less elastic.

A similar analogy can be made for the effect on firm's profit. In this case we have

$$\operatorname{sign}(\pi\pi_{wt_q} - \pi_w \pi_{t_q}) = \operatorname{sign}(1-\sigma).$$

With respect to the firm's bargaining position, the energy tax has the opposite effect to the labour tax. Again both effects work in the same direction. If substitutability is high, the trade union's bargaining position becomes weaker while the firm's position becomes stronger, and vice versa. Depending on the elasticity of substitution we can summarize the total effect of an increase in t_q as:

$$w_{t_q} \begin{cases} >0 & \text{as } \sigma < 1 \\ =0 & \text{as } \sigma = 1. \\ <0 & \text{as } \sigma > 1 \end{cases} \tag{17}$$

As in the case of labour taxes, the net-of-tax wage effect of a green tax rate increase depends solely on the size of the elasticity of substitution, but with opposite sign.

Given the assumption that $d\tilde{w}\ dt_w > 0$, even if $w_{t_w} < 0$, the firm will never shift a labour tax increase completely to the trade union. Hence, employment always falls as a result of an increase in the labour tax. The employment effect in the case of the energy tax rate is given by

$$dL = L_{\tilde{w}} d\tilde{w} + L_{\tilde{q}} q dt_q,$$

with $L_{\tilde{w}} < 0$ and $L_{\tilde{q}} < 0$, respectively. The employment effect is ambiguous for $\sigma > 1$ because there are of two opposing effects. As factors are complements, an increase in one factor price always reduces the demand for the other factor. However, if in addition $\sigma > 1$, an increase in the energy price will also reduce the negotiated wage. The total effect is therefore *a priori* ambiguous.

Analogously, we can determine the output effects. As $\eta_{L,\tilde{q}} < 0$, a reduction in labour demand due to an increase in the gross wage rate is accompanied by a reduction in energy input and hence a reduction in output. As a change in the green tax rate also affects the negotiated wage, the output effect of this change is ambiguous if substitutability is very high since in this case trade unions will accept a lower wage in the bargaining process.

5.2 Green tax reform with net-of-tax wage reactions

In general it is to be expected that net-of-wage rates will not stay constant after a green tax reform. However, there is an interesting special case of a Cobb-Douglas production technology with $\sigma = 1$. In this case, as the conditions (16) and (17) show, the net-of-tax wage rate is not affected from changes in the tax rates and the analysis of Section 3 and 4 applies. Propositions 1 and 2 carry over to the case of a Cobb-Douglas production technology when wages are negotiated between the trade union and the firm. The following proposition is readily available from this consideration.

PROPOSITION 3: If there are wage negotiations between the trade union and the firm and the technology is Cobb-Douglas, a marginal revenue-neutral green tax reform will increase output and employment as long as the labour tax rate exceeds the energy tax rate.

Changes in the net-of-tax wage rate will occur if $\sigma \neq 1$. The government then has to take into account the effects tax rate changes have on the negotiated wage, and consequently its repercussion on the factor price ratio, the marginal cost and the tax revenue. The change in the net-of-tax wage rate due to changes in the tax rates is given by

$$dw = w_{t_w} dt_w + w_{t_q} dt_q,$$

which affects total tax revenues (4) by

$$dG = \left[t_w L + w t_w L_{\tilde{w}} (1 + t_w) + q t_q R_{\tilde{w}} (1 + t_w) \right] dw.$$

The condition for a revenue-neutral change in the structure of factor taxation is given by

$$dG = G^*_{t_w} dt_w + G^*_{t_q} dt_q = 0, \tag{18}$$

with

$$G^{*}_{t_w} = \frac{wL}{(1+t_w)}\left[1+\left(t_w(1+\eta_{L,\tilde{w}})+t_q\frac{qR}{wL}\eta_{R,\tilde{w}}\right)(1+\omega_{t_w})\right] \tag{19}$$

and

$$G^{*}_{t_q} = \frac{qR}{(1+t_q)}\left[1+t_q(1+\eta_{R,\tilde{q}})+t_w\frac{wL}{qR}\eta_{L,\tilde{q}}+\omega_{t_q}\left(t_w\frac{wL}{qR}(1+\eta_{L,\tilde{w}})+t_q\eta_{R,\tilde{w}}\right)\right]. \tag{20}$$

The terms $\omega_{t_w} = (1+t_w)w_{t_w}\ w$ and $\omega_{t_q} = (1+t_q)w_{t_q}\ w$ describe the net-of-tax wage elasticities with respect to t_w and t_q, respectively. The asterisks in equations (18) through (20) indicate that the effect on the net-of-tax wage rate has been taken into account. Using the definition of the tax revenue elasticity with respect to the tax rate t_i $\tau_{t_i} = G^{*}_{t_i}(1+t_i)/G$, reformulation of the revenue-neutrality condition (18) yields

$$\frac{\tau_{t_q}}{\tau_{t_w}} = -\frac{(1+t_q)}{(1+t_w)}\cdot\frac{dt_w}{dt_q}. \tag{21}$$

The change in employment is given by

$$dL = \left[L_{\tilde{w}}(1+t_w)w_{t_w} + L_{\tilde{w}}w\right]dt_w + \left[L_{\tilde{w}}(1+t_w)w_{t_q} + L_{\tilde{q}}q\right]dt_q,$$

which can be rewritten as

$$dL = \frac{L}{(1+t_w)}\eta_{L,\tilde{w}}(1+\omega_{t_w})dt_w + \frac{L}{(1+t_q)}\left[\eta_{L,\tilde{w}}\omega_{t_q} + \eta_{L,\tilde{q}}\right]dt_q. \tag{22}$$

Substituting the condition (21) into (22) and rearranging, yields the following general condition for the change in employment:

$$\left.\frac{dL}{dt_q}\right|_{dG=0} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \quad \Leftrightarrow \quad \frac{\tau_{t_q}}{\tau_{t_w}} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \frac{\eta_{L,\tilde{w}}\omega_{t_q} + \eta_{L,\tilde{q}}}{\eta_{L,\tilde{w}}(1+\omega_{t_w})}. \tag{23}$$

If a tax reform increases the gross energy price by one percent, the ratio of the left-hand side indicates the percentage by which the gross wage has to decrease because of a cut in the labour tax in order to keep the public good provision G constant. The ratio of the right-hand side denotes the percentage the gross wage has to decline to keep the employment level constant. If the revenue-neutrality requirement allows the government to cut the wage tax at a higher rate than is necessary to sustain the employment level, wage negotiations will lead to lower wages and will increase employment accordingly.

Now if the elasticity of substitution exceeds unity, the net-of-tax wage elasticity with respect to t_w, is positive, $\omega_{t_w} > 0$. Hence, the net-of-tax wage is reduced by a cut in the labour tax rate, which is *ceteris paribus* good for employment. However, a fall in the net-of-tax wage rate also reduces the tax revenues and consequently the scope for the reduction of labour taxes. It follows from condition (12) that

$$\omega_{t_q} = -\omega_{t_w} \tag{24}$$

(see Appendix 1). The partial derivatives of equations (19) and (20) with respect to the net-of-tax wage elasticity are given by:

$$\frac{\partial G^*_{t_w}}{\partial \omega_{t_w}} = \frac{wL}{(1+t_w)}\left(t_w(1+\eta_{L,\tilde{w}}) + t_q \frac{qR}{wL}\eta_{R,\tilde{w}}\right) < 0 \tag{25}$$

and

$$\frac{\partial G^*_{t_q}}{\partial \omega_{t_w}} = -\frac{\partial G^*_{t_q}}{\partial \omega_{t_q}} = -\frac{qR}{(1+t_q)}\left(t_w \frac{wL}{qR}(1+\eta_{L,\tilde{w}}) + t_q \eta_{R,\tilde{w}}\right) > 0, \tag{26}$$

where the signs are determined by the assumption of positive marginal tax revenues. Substituting equations (25) and (26) for the definition of the tax elasticities in condition (23), it can easily be shown that the left-hand side of condition (23) is increasing in ω_{t_w}. Differentiating the right-hand side of condition (23) yields:

$$\frac{\partial}{\partial \omega_{t_w}} \frac{-\eta_{L,\tilde{w}}\omega_{t_w} + \eta_{L,\tilde{q}}}{\eta_{L,\tilde{w}}(1+\omega_{t_w})} = -\frac{\eta_{L,\tilde{w}} + \eta_{L,\tilde{q}}}{\eta_{L,\tilde{w}}(1+\omega_{t_w})^2} < 0.$$

The right-hand side of condition (23) is thus decreasing in ω_{t_w}. These two facts establish that if employment is increasing when the net-of-tax wage is unaffected – which has been shown to be true for $t_w > t_q$ – employment will also increase when the negotiated wage falls due to the revenue-neutral green tax reform. This yields Proposition 4.

PROPOSITION 4: As long as the labour tax rate exceeds the energy tax rate, a marginal revenue-neutral green tax reform which induces a reduction in the net-of-tax wage rate will increase both the level of output and employment.

If, on the contrary, the elasticity of substitution is less than unity, $\sigma < 1$, so that the trade union succeeds in increasing the wage rate, a negative effect on employment results. However, such an increase in the net-of-tax wage rate also implies a higher tax revenue which allows for larger tax cuts. It is shown in Appendix 2 that the net-of-tax wage elasticity is an increasing function of the bargaining power of the trade union:

$$\left.\frac{\partial \omega_{t_w}}{\partial \beta}\right|_{\sigma<1} > 0. \tag{27}$$

According to condition (27) the stronger the bargaining power of the trade union the less elastic is the net-of-tax wage reaction. Hence, the left-hand side of condition (23) is falling while the right-hand side is increasing in β. This result can be summarized in

PROPOSITION 5: If the elasticity of substitution is below a critical value σ^* which is itself less than one, a marginal revenue-neutral green tax reform will reduce employment. The critical value is an inverse function of the bargaining power of the trade union, as measured by β.

This proposition confirms the wisdom that strong trade unions (at the firm's level) are bad for employment.[9]

In the case where the trade union exercises monopoly power and there is no energy tax we know that a marginal revenue-neutral green tax reform increases employment when $\sigma = 1$. Furthermore, it can be shown that, with $\sigma = 1$, the positive employment effect is increasing

[9] Notice that for $\sigma > 1$ the opposite conclusion, that strong trade unions are good for employment, applies.

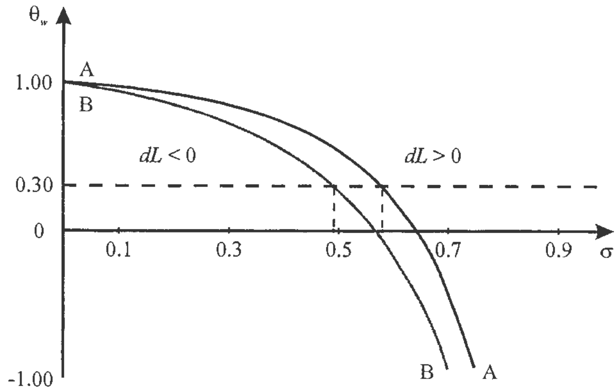
with the elasticity of substitution.[10] Proposition 5 allows us to infer that the employment effect is positive for $\sigma \geq \sigma^*$ when the bargaining power of the trade union is limited.

Proposition 5 implies that the "worst-case scenario" with respect to the employment effect occurs when trade unions exercise monopoly power. In the following we provide some numerical results for the case of a monopoly trade union, remembering that the range for a positive employment effects increases with the bargaining power of the firm. In Figure 3 we consider the case where there is no initial energy tax rate, i.e. $t_e = 0$. The bold lines in Figure 3 show the geometric locus of the combinations of the elasticity of substitution and the initial labour tax, $\theta_w = t_w/(1+t_w)$, where the employment effect is zero. The line AA is calculated for the output demand elasticity of $\varepsilon = 1.5$ and the line BB for $\varepsilon = 2.5$. In the case of $\varepsilon = 1.5$, any elasticity of substitution above 0.64 guarantees a positive employment effect for any positive initial labour tax rate. The corresponding critical value σ^* for $\varepsilon = 2.5$ is 0.57. However, if the initial labour tax is 0.3, any elasticity of substitution above 0.58 (0.49) guarantees a positive employment effect when $\varepsilon = 1.5$ ($\varepsilon = 2.5$). A comparison of the lines AA and BB shows that a positive employment effect becomes more likely, the higher the output demand elasticity, and that the higher the initial labour tax rate, the more likely the employment effect becomes positive.[11]

[10] A proof is available upon request.

[11] Alternatively, one could ask what happens if an increase in the energy tax is compensated, not by a decrease in the labour tax rate, but by an increase in lump-sum transfers? The answer depends not only on the elasticity of substitution, but also on who receives the lump-sum transfers. Consider for simplicity the case of the Cobb-Douglas production function. An increase in the energy tax rate compensated by a rise in lump-sum transfers to the firm would increase the net-of-tax wage rate. Hence unemployment would go up. On the other hand if a lump-sum transfer is given to the members of the trade union, the net-of-tax wage rate would decrease so that the unemployment effect would remain indeterminate. A complete set of results is available from the authors upon request.

Figure 3: The critical tax rate θ_w for $t_q = 0$



6. Concluding remarks

This paper elaborates the employment effect of a revenue-neutral green tax reform which raises taxes on energy input and reduces the tax rate on labour input accordingly. If such a tax reform does not affect wage negotiations between trade unions and firms, labour demand will increase -- at least as long as the tax rate on energy does not exceed the tax rate on labour. The same result applies to the case where the green tax reform leads the trade union to accept lower wage rate which is the case if the elasticity of substitution between labour and energy exceeds unity.

No qualitatively unambiguous answer can be given for the case where the elasticity of substitution between labour and energy is smaller than unity, for in this case the green tax reform implies an increasing net-of-tax wage rate. However, if the elasticity of substitution is not too far below one, it will still be true that unemployment is reduced. In addition, our analysis shows that the lower the bargaining power of the trade union, and the larger the actual labour tax rate, the more likely it is that a green tax reform will boost employment.

In conclusion, our analysis presents conditions under which green tax reforms on the production side will reduce rather than increase unemployment. Thus, there seems to be little reason to postpone the implementation of environmental policies.

This paper considers the case of a small trade union only. Following Calmfors and Driffill (1988), however, we can expect that more centralized wage negotiations will lead trade unions to take into account the fact that higher wages increase consumer prices and hence reduce the real income of their members. In economies with *ceteris paribus* highly centralized wage bargaining, therefore, green tax reforms will have a more positive effect on employment than in economies with highly decentralized wage bargaining. Assuming centralized bargaining would therefore strengthen our results.

Appendix 1: Net-of-tax wage elasticities

The signs of the net-of-tax wage elasticities $\omega_{t_i} = w_{t_i} t_i \; w$ for $i = w, q$ are determined by

$$w_{t_w} = -\Omega_{ww}^{-1}\Omega_{wt_w},\; w_{t_q} = -\Omega_{ww}^{-1}\Omega_{wt_q}.$$

Furthermore, we have, using condition (12):

$$\Omega_{wt_w} = \frac{\beta}{V^2}\left(VV_{wt_w} - V_w V_{t_w}\right) + \frac{(1-\beta)}{\pi^2}\left(\pi\pi_{wt_w} - \pi_w \pi_{t_w}\right)$$

$$= -\frac{1+t_q}{1+t_w}\left[\frac{\beta}{V^2}\left(VV_{wt_q} - V_w V_{t_q}\right) + \frac{(1-\beta)}{\pi^2}\left(\pi\pi_{wt_q} - \pi_w \pi_{t_q}\right)\right] = -\frac{1+t_q}{1+t_w}\Omega_{wt_q}$$

From this, it is straightforward to derive condition (24).

Appendix 2: Bargaining power and net-of-tax wage reactions

The marginal change in the negotiated wage because of an increase in the labour tax rate is given by

$$w_{t_w} = -\frac{\Omega_{wt_w}}{\Omega_{ww}} = -\frac{\frac{\beta}{V^2}C + \frac{(1-\beta)}{\pi^2}D}{\frac{\beta}{V^2}A + \frac{(1-\beta)}{\pi^2}B},$$

where $A = VV_{ww} - V_w^2$, $B = \pi\pi_{ww} - \pi_w^2$, $C = VV_{wt_w} - V_w V_{t_w}$, $D = \pi\pi_{wt_w} - \pi_w \pi_{t_w}$. Taking the partial derivative with respect to the bargaining position of the trade union yields:

$$\frac{\partial w_{t_w}}{\partial \beta} = \frac{AD - CB}{V^2 \pi^2 \Omega_{ww}^2} \tag{A-1}$$

Using the facts that $A < 0$, $B > 0$ and sign (C) = sign (D) [from the comparative statics result] with $C, D < 0$ for $\sigma < 1$, equation (A-1) becomes positive. To sign the impact, the bargaining power has on condition (23) we finally have to derive the impact of β on the net-of-tax wage elasticity. This is given by:

$$\frac{\partial \omega_{t_w}}{\partial \beta} = w^{-2}(1+t_w)\left[w\frac{\partial w_{t_w}}{\partial \beta} - w_{t_w}\frac{\partial w}{\partial \beta}\right]. \tag{A-2}$$

As $\partial w_{t_w} \; \partial \beta > 0$, (A-2) is positive for $\sigma < 1$.

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