# Pollution, Factor Taxation and Unemployment*

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## Abstract

It has been argued that by imposing taxes on pollution one can use the additional tax revenues to replace labour taxes in order to reap a double dividend in the sense of increasing the environmental quality and alleviating unemployment. 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 in a Nash bargaining model with two factors of production and a downward sloping demand in the goods market. It is shown that such a tax reform will boost employment if it leads the trade union to accept the same or lower nominal wage. This is the case when the elasticity of substitution between labour and energy is equal to or greater than one. If the elasticity of substitution is smaller than one, the trade union succeeds in increasing nominal wages thus making the effect on employment ambiguous. In this low substitution case there exists a critical level of the elasticity of substitution for an employment-neutral green tax reform and the likelihood of success in boosting employment decreases with the bargaining power of the trade unions.



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## 1. Introduction

Europe suffers from persistently high levels of unemployment. In the first quarter of 1997, the unemployment rates in the European Union were between 3,6 % in Luxembourg and 21,1 % in Spain, with an average unemployment rate for the EU countries of 10,8 %.[1]

The dramatic situation on the labour market has limited the scope for active environmental policy. Though it is argued that green taxes are efficient in reducing damaging emissions from the usage of polluting goods, it is also argued that because of the persisting high unemployment, we cannot afford new green taxes to fight pollution as these taxes would exacerbate the problem of unemployment in Europe. Environmental policy is a luxury, we might afford in better days.

This paper tries to question the generality of this view. Focusing on green taxes on the production side, the paper shows that a green tax reform, which benefits the environment, will boost employment if it leads the trade union to accept the same or a lower nominal wage. In this case, the policy conclusion would be that there is no reason to postpone environmental policy measures to fight the ongoing pollution of the environment.

But how should green taxes help reducing 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 levels of unemployment benefits, is often made responsible for the high levels of unemployment by distorting labour supply and increasing wage pressure in labour markets. This view is supported by a recent OECD (1995) study on taxation and unemployment which found empirical evidence that taxes on labour increase wage pressure and thereby increase unemployment, at least in the medium run. A green tax reform may alleviate the tax burden on labour and hence reduce the disincentives associated with these taxes.

The early literature on the employment effects of green tax reforms was pessimistic as to whether such kind of reform would boost employment. Bovenberg and de Mooij (1994)

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[1] These are standardized unemployment rates in the definition of the OECD, cf. Main Economic Indicators, July 1997, p. 40.

and Bovenberg and van der Ploeg (1994) show that normally labour supply falls as a result of a green tax reform. Their arguments are based on a model with market clearing in the labour market and, therefore, full-employment.[2]

More recent work which has rejected the notion of full employment concludes that positive employment effects are possible. In a model with fixed after-tax wages, Bovenberg 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. Within a search theoretic framework Bovenberg and van der Ploeg (1995) identify positive employment effects for a revenue-neutral green tax reform which increases the tax on a polluting factor of production, and 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 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. Carraro, Galeotti and Gallo (1996), finally, 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 considers the introduction of green taxes on energy input in production by using 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. While

[2] See Bovenberg (1995) for a survey of the early literature on the double dividend hypothesis with particular focus on the employment effects.

Koskela and Schöb (1996) 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 imperfectly competitive 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 for the wage negotiations. Section 3 analyses the comparative static effects changes in the labour tax and the energy tax have on the negotiated wage and shows how employment and output are affected. In Section 4 the implications of a revenue-neutral green tax reform, which affects the production side by increasing the energy tax rate and reducing the labour tax accordingly, are analysed. Finally, there is a brief conclusion.

## 2. The model

### 2.1 Firm behaviour

We consider a single firm which produces output $Y$ with energy $R$ and labour $L$ as inputs. The technology is linear-homogenous and is represented by a CES production function

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

where $\sigma$ denotes the elasticity of substitution. We assume imperfect competition in the goods market, i.e. each single firm faces a downward sloping demand curve which is assumed to be isoelastic:

$$Y = D(p) = p^{-\varepsilon}, \tag{2}$$

with $\varepsilon \equiv -D_p \cdot p/Y$ denoting the output demand elasticity. To guarantee a profit maximum the output demand elasticity must exceed unity. The firm's output price is denoted by $p$.

Profit is given by

$$\pi = pY - \tilde{w}L - \tilde{q}R, \tag{3}$$

whereby the firm considers the energy price $\tilde{q}$ and the gross wage rate $\tilde{w}$ as given. The gross wage is determined by the nominal wage, which is negotiated between a trade union and the firms, and the labour tax, modelled as a payroll tax: $\tilde{w} = w(1+t_w)$. The energy price is given by the producer price of energy, i.e. the 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:

$$L = \tilde{w}^{-\sigma}\left[\tilde{w}^{1-\sigma} + \tilde{q}^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} Y \tag{4}$$

and

$$R = \tilde{q}^{-\sigma}\left[\tilde{w}^{1-\sigma} + \tilde{q}^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} Y, \tag{5}$$

respectively. Given that the second-order conditions hold, we can substitute the conditional demands into the cost function and obtain:

$$C(\tilde{w},\tilde{q},Y) = Y\left[\tilde{w}^{1-\sigma} + \tilde{q}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \equiv Yc(\tilde{w},\tilde{q}), \tag{6}$$

where $c(\tilde{w},\tilde{q})$ denotes per unit cost of production and is equal to the marginal cost of $Y$.

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

$$p\left(1 - \frac{1}{\varepsilon}\right) = c(\tilde{w},\tilde{q}), \tag{7}$$

i.e. the firm demands a price which exceeds the marginal cost by a (constant) mark-up factor of $\left[\varepsilon/(\varepsilon-1)\right]$. It is convenient to define the share of labour cost in total cost by $s \equiv \tilde{w}L/cY$ and the share of energy cost in total cost by $(1-s) \equiv 1-\tilde{w}L/cY = \tilde{q}R/cY$. Due to an iso-elastic output demand, profits are proportional to total cost, i.e. $\pi = cY/(\varepsilon-1)$.

Applying these abbreviations we can define the following factor (cross-) price elasticities analogously to the case of perfect competition [cf. Allen (1938) or Hamermesh (1993)]. The wage elasticity of labour demand $\eta_{LL}$ is given by

$$\eta_{LL} \equiv \frac{L_{\tilde{w}}\tilde{w}}{L} = -\sigma + s(\sigma-\varepsilon), \tag{8}$$

where $L_i$ denotes the partial derivative of $L$ with respect to $i$. The cross-price elasticity is given by

$$\eta_{LR} \equiv \frac{L_{\tilde{q}} \cdot \tilde{q}}{L} = (1-s)(\sigma-\varepsilon). \tag{9}$$

If the elasticity of substitution exceeds (is lower than) the output demand elasticity, factors are substitutes (complements). In the following we assume that energy and labour are complements in the sense that $\eta_{LR} < 0$.

Combining equations (8) and (9) allows an interpretation of the labour demand elasticity. First, the labour demand elasticity depends on the substitutability of factors, indicated by $\sigma$. The better 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 and it becomes stronger the larger the share of labour in total cost is (cf. Hamermesh 1993, p.24).

### 2.2 Trade union behaviour

We consider a small trade union which acts at the firm level. The objective of the trade union is to maximize the real income of its $N$ members which for a small union is equivalent to maximizing nominal income of its members. Each worker inelastically supplies one unit of labour if employed, or zero labour if unemployed. In the former case the worker receives a wage income, in the latter case the unemployed member is entitled to unemployment benefits. The nominal wage is denoted by *w*, the unemployment benefits are denoted by *b*. Unemployment benefits are assumed to be nominally fixed, which is a reasonable assumption as unemployment benefits are normally determined by the wage rate, which prevails before a tax reform takes place. The objective function of the trade union can then be written as[3]

$$V^{*} = wL + b(N - L). \tag{10}$$

## 2.3 Wage negotiations at the firm level

Usually, wages are determined in a bargaining process between the trade union and the firm then unilaterally determines employment. To model these stylized facts we apply a 'right-to manage' model which represents the outcome of the bargaining by an asymmetric Nash bargaining.[4]

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

$$\Omega = (V^{*} - V^{0})^{\beta}\pi^{1-\beta}, \tag{11}$$

with $\beta$ representing the bargaining power of the trade union. Using $V = V^{*} - V^{0}$, the first-order condition with respect to nominal wage is

$$\Omega_w = 0 \;\Leftrightarrow\; \beta\frac{V_w}{V} + (1-\beta)\frac{\pi_w}{\pi} = 0, \tag{12}$$

where variables with subscripts refer to partial derivatives (e.g. $V_w = \partial V / \partial w$). In the following we focus on changes in the tax rates only. Provided that $\Omega_{ww} < 0$, equation (12)

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[3] The use of a linear objective function is 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).

[4] This approach can be justified either axiomatically (cf. Nash 1950), or strategically (cf. Binmore, Rubinstein and Wolinsky 1986).

defines the negotiated nominal 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.

## 3. Comparative statics

In the following we will analyse how the negotiated nominal wage reacts to changes in the tax rates. From $w_{t_i} = -\Omega_{wt_i} / \Omega_{ww}$ and the fact that changes in either the labour tax or the energy tax affect both the trade union's and the firm's objective function, we can infer that for $i = w, q$

$$\text{sign}(w_{t_i}) = \text{sign}(\Omega_{wt_i}) = \text{sign}\left\{ \frac{\beta}{V^2}\left[VV_{wt_i} - V_w V_{t_i}\right] + \frac{1-\beta}{\pi^2}\left[\pi\pi_{wt_i} - \pi_w \pi_{t_i}\right] \right\}. \tag{13}$$

### 3.1 Changes in the labour tax

To understand the impact of the labour tax on the negotiated wage, we will analyse the effects on the trade union's and the firm's objective function separately. First, a labour tax affects the income of the trade union via changes in the labour demand elasticity only:

$$\text{sign}(VV_{wt_w} - V_w V_{t_w}) = \text{sign}\left( \frac{\partial \eta_{LL}}{\partial t_w} \right). \tag{14}$$

From the partial derivative of the trade union's objective function $V_w = \left(L + (w-b)L_w\right)$ it can be seen that constant labour demand elasticity implies that the benefits of a wage increase for those employed fall at the same rate (fewer workers are employed) as the losses for those fired (more workers will be fired). If the labour demand becomes less elastic the benefits fall at a lower rate. It becomes profitable to demand higher nominal wages. The partial derivative of the labour demand elasticity is given by

$$\frac{\partial \eta_{LL}}{\partial t_w} = s_{t_w}(\sigma - \varepsilon), \tag{15}$$

with

$$s_{t_w} = s_{\tilde{w}} w = \frac{s}{(1+t_w)}(1-s)(1-\sigma) \begin{cases} > \\ = \\ < \end{cases} 0 \quad \Leftrightarrow \quad \sigma \begin{cases} < \\ = \\ > \end{cases} 1. \tag{16}$$

As we assume labour and energy to be complements, i.e. $\varepsilon > \sigma$, condition (14) reduces to

$$\operatorname{sign}(VV_{wt_w} - V_w V_{t_w}) = \operatorname{sign}(\sigma - 1). \tag{14a}$$

If substitutability is low, i.e. $\sigma < 1$, the share of labour cost in total cost increases with the labour tax. A larger share *s* implies that a one percent change in the wage rate induces a larger increase in total cost and, consequently, lower output. This will lead firms to offset more workers. Hence, if *s* increases, labour demand becomes more elastic. This weakens the bargaining position of the trade union as the potential losses of a nominal wage increase go up and the other way round if *s* decreases.

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

$$\operatorname{sign}(\pi\pi_{wt_w} - \pi_w \pi_{t_w}) = \operatorname{sign}(\sigma - 1). \tag{17}$$

If substitutability is low, i.e. the labour cost share in total cost increases in nominal wages, and profits will fall at a higher rate if the nominal wage increase as a consequence of an increase in the labour tax. Therefore the firm will become more reluctant to accept nominal wage increases and demand lower wages. Hence, if substitutability is low the trade union's bargaining position becomes weaker while the firm's position becomes stronger. As a consequence, both effects of an increase in the labour tax work into the same direction. Depending on the elasticity of substitution we can summarize the total effect as:

$$w_{t_w} \begin{cases} < 0 & \text{as } \sigma < 1 \\ = 0 & \text{as } \sigma = 1. \\ > 0 & \text{as } \sigma > 1 \end{cases} \tag{18}$$

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 to the workers.[5]

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

### 3.2 Changes in the energy taxes

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. In the following we take for granted that a reduction in the energy input into production reduces the environmental damage and thus have 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

$$\mathrm{sign}(VV_{wt_q} - V_w V_{t_q}) = \mathrm{sign}\left\{\frac{\partial \eta_{LL}}{\partial t_q}\right\}, \tag{19}$$

whereby

$$\frac{\partial \eta_{LL}}{\partial t_q} = s_{t_q}(\sigma - \varepsilon), \tag{20}$$

and

$$s_{t_q} = -\frac{(1+t_w)}{(1+t_q)} s_{t_w}. \tag{21}$$

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

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

$$\mathrm{sign}(\pi\pi_{wt_q} - \pi_w \pi_{t_q}) = \mathrm{sign}\left[1 - \sigma\right]. \tag{22}$$

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

$$w_{t_q} \begin{cases} > 0 & \text{as } \sigma < 1 \\ = 0 & \text{as } \sigma = 1. \\ < 0 & \text{as } \sigma > 1 \end{cases} \tag{23}$$

### 3.3 Employment and output effects

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

$$dL = L_{\tilde{w}} d\tilde{w} + L_{\tilde{q}} q dt_q, \tag{24}$$

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

Analogously, we can determine the output effects. Having assumed that factors are complements, i.e. $\eta_{LR} < 0$, a reduction in labour due to an increase in gross wages is accompanied by a reduction in energy input and hence a reduction in output. As changes in the tax on energy also affect negotiated nominal wages, the output effects of changes in the energy tax are ambiguous if substitutability is very high as in this case trade unions will to accept lower nominal wages in the bargaining process.

## 4. Revenue-neutral green tax reform analysis

In this section we first ask 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 with a higher level of employment as the existing "labour tax system". Then we elaborate a revenue-neutral green tax reform, i.e. a tax reform which increases the energy tax and reduces the labour tax such that total tax revenues are kept constant.

### 4.1 Green tax system versus labour tax system

The government requires a fixed amount of tax revenues to finance the public good $G$. In addition, it has to finance the unemployment benefits $b$. In general, the government budget constraint is then given by

$$t_L wL + t_q qR = G + b(N - L). \tag{25}$$

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 (25) as given by

$$t_w wL + t_q qR = G. \tag{26}$$

The employment effects are not qualitatively affected by this simplification. If employment increases because of the tax reform, less tax revenues are required to meet the budget constraint and vice versa. Now, assume that initially, the tax on the negotiated wage $t_w$ is larger than the tax on energy input $t_q$. It can be shown that for given factor prices $w$ and $q$ there is an alternative tax system, which generates the same output and same tax revenues but allows for a higher level of employment.

To show this, we have to solve for the input quantities $L$ and $R$ demanded by the firm and the factor tax rates $t_w$ and $t_q$, respectively. First, both tax systems produce the same output:

$$f(L, R) = Y_0, \tag{27}$$

where $f(L, R)$ denotes the production function (1). The output level $Y_0$ is *cet. par.* 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

$$\tilde{w} f_R(L, R) - \tilde{q} f_L(L, R) = 0. \tag{28}$$

Third, marginal cost must remain constant. Otherwise the firm would not sell the same output in equilibrium as before. For linear-homogenous technologies this implies constant total costs which can be calculated from equation (6):

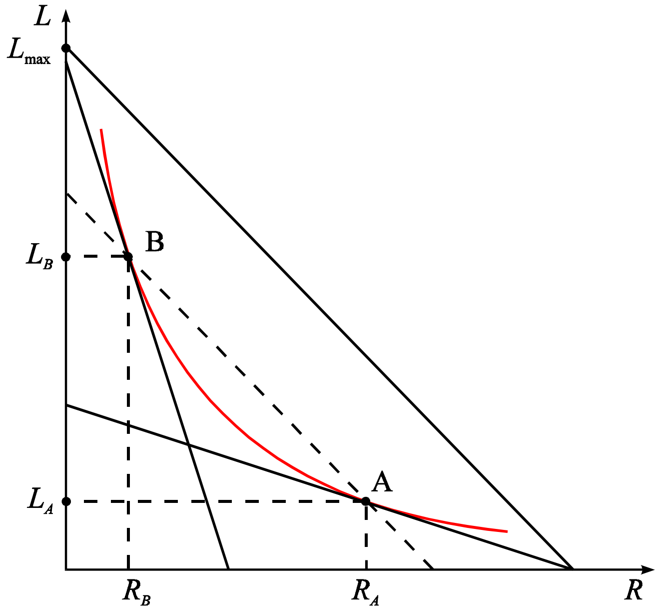
$$\tilde{w}L + \tilde{q}R = C_0, \tag{29}$$

where $C_0 = p\left[1 - (1/\varepsilon)\right]Y_0$ [cf. equations (6) and (7)]. Finally, the government budget requirement (26) must be met. Equations (26) to (29) 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 iso-cost curve and the isoquant for $Y_0$. The 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 firms or government. In addition, less energy will be used, and, consequently, the environment will improve. This result is summarized in proposition 1.

> PROPOSITION 1: Given before-tax factor prices and a linear-homogenous production technology, there exists a *green tax system* that has higher tax rates on energy and lower tax rates on labour than the existing *labour tax system* but yields the same output level and same tax revenues. The green tax system generates both a higher level of employment and a cleaner environment.

*Figure 1: Labour tax system versus green tax system*




As energy is normally imported, the domestic product will go up as domestic income, consisting of net labour income plus tax revenues is higher in B than in A. In Figure 1, the relative domestic incomes of situations A and B can be measured by the ratio of $L_A / L_{\max}$ and $L_B / L_{\max}$, respectively.

After having shown that there exists a green tax system with higher labour input, we ask whether stepwise moves towards the green tax system starting from the labour tax system A will succeed in generating higher levels of employment without imposing additional costs to either industry or government.

## 4.2 Consecutive marginal revenue-neutral green tax reforms

We continue to assume that the nominal wage negotiations are not affected by changes in the factor tax rates, i.e. $dw = 0$. Consider first a marginal green tax reform which increases the energy tax and lowers the labour tax such that the output level is kept constant, i.e. $dY = 0$. This implies a move along the isoquant, which guarantees labour input to 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 by equiproportionately reducing both taxes so that $dG = 0$ is satisfied. As an equiproportional change in tax rates reduces marginal cost this will increase output and consequently 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):

$$dY = 0 = \left[ L^{-\frac{1}{\sigma}} L_{\tilde{w}} w + R^{-\frac{1}{\sigma}} R_{\tilde{w}} w \right] dt_w + \left[ L^{-\frac{1}{\sigma}} L_{\tilde{q}} q + R^{-\frac{1}{\sigma}} R_{\tilde{q}} q \right] dt_q . \tag{30}$$

Solving for $dt_w$ yields the condition for the output-neutral tax reform:

$$\left. \frac{dt_w}{dt_q} \right|_{dY=0} = -\frac{(1-s)(1+t_w)}{s(1+t_q)} . \tag{31}$$

Next, consider the impact such an output-neutral tax reform has on the government budget:

$$dG = \left[ wL + wt_w L_{\tilde{w}} w + qt_q R_{\tilde{w}} w \right] dt_w + \left[ qR + wt_w L_{\tilde{q}} q + qt_q R_{\tilde{q}} q \right] dt_q . \tag{32}$$

Substituting condition (31) in (32) yields (after some manipulations)

$$\left. \frac{dG}{dt_q} \right|_{dY=0} = \frac{1}{s(1+t_q)} \left[ sqR - (1-s) wL \right] . \tag{33}$$

Depending on the relationship between the two tax rates we obtain

$$\left. \frac{dG}{dt_q} \right|_{dY=0} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \quad \Leftrightarrow \quad \frac{wL}{qR} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \frac{w(1+t_w) L}{q(1+t_q) R} \quad \Leftrightarrow \quad t_w \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} t_q . \tag{34}$$

Consider the case where $t_w > t_q$ so that 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 input demands. Output will rise the more the higher is the output demand elasticity $\varepsilon$.

*Figure 2: Consecutive marginal green tax reforms*

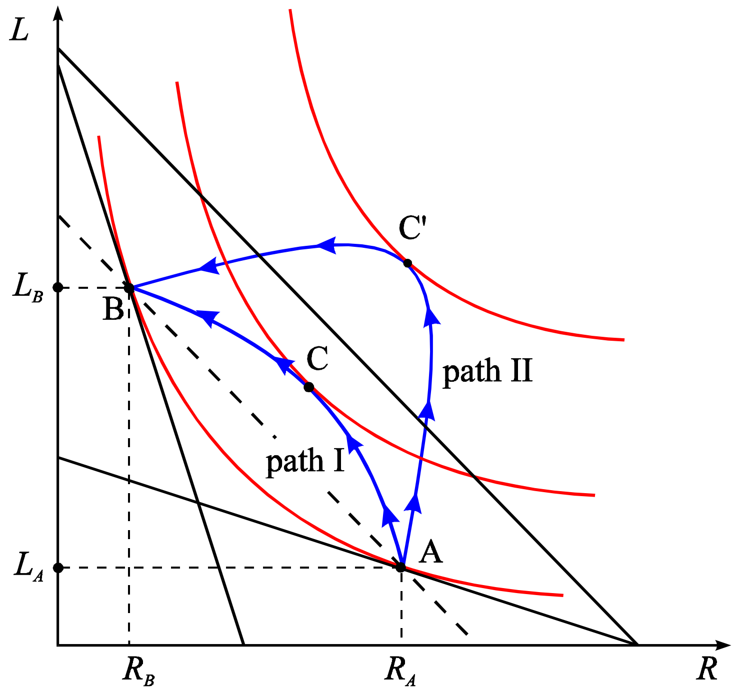



Figure 2 shows two possible paths of consecutive marginal tax reforms starting in the labour tax system A and ending in the green tax system B. Up to points C or C' where $t_w = t_q$, employment will definitely increase. A further increase in $t_q$, however, will result in output reductions. This output effect countervails the substitution effect of moving along the isoquant. If the output demand elasticity is small, the 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 both output and employment are simultaneously falling.[6] This result can be summarized in the following proposition.

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

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

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

> COROLLARY 2: If the energy tax rate exceeds the labour tax rate, a marginal revenue-neutral green tax reform, which leaves the nominal wage unaffected, will reduce the level of output.

Both Proposition 2, and Corollary 2 can be considered as direct implications 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.

### 4.3 Green tax reform and wage bargaining

As the comparative statics in Section 3 shows, the nominal wages are normally affected by changes in the factor tax rates if $\sigma \neq 1$. It is therefore necessary to take into account the effects tax rate changes have on the negotiated nominal wages, and consequently its repercussion on the factor price relation, marginal cost and tax revenues in these more general cases. The change in nominal wages due to changes in the tax rates is given by

$$dw = w_{t_w} dt_w + w_{t_q} dt_q, \tag{35}$$

which affects total tax revenues by

$$dG = \left[ t_w L + wt_w L_{\tilde{w}} (1+t_w) + qt_q R_{\tilde{w}} (1+t_w) \right] dw. \tag{36}$$

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

$$dG = G^*_{t_w} dt_w + G^*_{t_q} dt_q = 0, \tag{37}$$

with

$$G^*_{t_w} = \frac{wL}{(1+t_w)} \left\{ 1 + \left[ t_w (1+\eta_{LL}) + t_q \frac{qR}{wL} \eta_{RL} \right] (1+\omega_{t_w}) \right\} \tag{38a}$$

and

$$G^{*}_{t_q} = \frac{qR}{(1+t_q)} \left\{ t_q(1+\eta_{RR}) + t_w \frac{wL}{qR}\eta_{LR} + \omega_{t_q}\left[ t_w \frac{wL}{qR}(1+\eta_{LL}) + t_q \eta_{RL} \right] \right\}. \tag{38b}$$

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 nominal wage elasticities with respect to $t_w$ and $t_q$, respectively. The asterisk indicates that the effect on the nominal wage has been taken into account. Using the definition of the tax elasticity $\tau_{t_i} = G^{*}_{t_i}(1+t_i)/G$, reformulation of the revenue-neutrality condition (37) yields

$$\frac{\tau_{t_q}}{\tau_{t_w}} = -\frac{(1+t_q)}{(1+t_w)} \cdot \frac{dt_w}{dt_q}. \tag{39}$$

The change in employment is given by

$$dL = \left[ L_{\tilde{w}}(1+t_w) w_{t_w} + L_{\tilde{w}} w \right] dt_w + \left[ L_{\tilde{w}}(1+t_w) w_{t_q} + L_{\tilde{q}} q \right] dt_q, \tag{40a}$$

which can be rewritten as

$$dL = \frac{L}{(1+t_w)} \eta_{LL}(1+\omega_{t_w}) dt_w + \frac{L}{(1+t_q)} \left[ \eta_{LL}\omega_{t_q} + \eta_{LR} \right] dt_q. \tag{40b}$$

Substituting the condition (39) into (40b) and rearranging yields the following general condition for the change in employment:

$$\left.\frac{dL}{dt_q}\right|_{dG=0} \gtreqless 0 \quad \Leftrightarrow \quad \frac{\tau_{t_q}}{\tau_{t_w}} \gtreqless \frac{\eta_{LL}\omega_{t_q} + \eta_{LR}}{\eta_{LL}(1+\omega_{t_w})}. \tag{41}$$

The ratio of the left-hand side indicates at what percentage the labour tax has to decrease so that the public good provision $G$ remains constant. The ratio of the right-hand side denotes the percentage the wage tax 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 necessary to sustain the employment level, wage negotiations will lead to lower wages and will increase employment accordingly. As the effect of a revenue-neutral green tax reform on nominal wages depends on the size of the elasticity of substitution (see Section 3), we can distinguish 3 cases.

*Case 1: The elasticity of substitution is equal to unity, $\sigma = 1$*

The nominal wage is not affected by the green tax reform. As shown in Appendix 1, the employment effect is always positive for the Cobb-Douglas case if $t_w - t_q > 0$. Hence, the special case of condition (41) can be considered as a formal proof for proposition 2 which states that as long as the labour tax rate exceeds the energy tax rate, a marginal revenue-neutral green tax reform will increase both the level of output and employment.

*Case 2: The elasticity of substitution exceeds unity, $\sigma > 1$*

If the elasticity of substitution exceeds unity, the nominal wage elasticity with respect to $t_w$, is positive, $\omega_{t_w} > 0$. Hence, the nominal wage is reduced by a cut in the labour tax, which is *cet. par*. good for employment. However, a fall in the nominal wage also reduces the tax revenues and consequently the scope for the reduction of labour taxes.

To analyse the overall effect, we apply the condition that

$$\omega_{t_q} = -\omega_{t_w} \tag{42}$$

(see Appendix 2). The partial derivatives of equations (38a) and (38b) with respect to the nominal wage elasticity are given by:

$$\frac{\partial G^*_{t_w}}{\partial \omega_{t_w}} = \frac{wL}{(1+t_w)} \left[ t_w (1+\eta_{LL}) + t_q \frac{qR}{wL} \eta_{RL} \right] > 0 \tag{43a}$$

and

$$\frac{\partial G^*_{t_q}}{\partial \omega_{t_w}} = -\frac{\partial G^*_{t_q}}{\partial \omega_{t_q}} = -\frac{qR}{(1+t_q)} \left[ t_w \frac{wL}{qR} (1+\eta_{LL}) + t_q \eta_{RL} \right] < 0, \tag{43b}$$

where the signs are determined by the assumption of positive marginal tax revenues. Substituting equations (43a) and (43b) in the definition of the tax elasticities of condition (41), it can easily be shown that the LHS of condition (41) is increasing in $\omega_{t_w}$. Differentiating the RHS of condition (41) yields:

$$\frac{\partial}{\partial \omega_{t_w}} \frac{-\eta_{LL}\omega_{t_w} + \eta_{LR}}{\eta_{LL}(1+\omega_{t_w})} = -\frac{\eta_{LL} + \eta_{LR}}{\eta_{LL}(1+\omega_{t_w})^2} < 0. \tag{44}$$

The RHS of condition (41) is thus decreasing in $\omega_{t_w}$. These two facts establish that if employment is increasing when the nominal wage is unaffected – which has been shown to be true for $t_w > t_q$ – employment is also boosted when the negotiated wage will fall due to the revenue-neutral green tax reform. This can be summarized.

> PROPOSITION 3: 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 nominal wage will increase both the level of output and employment.

*Case 3: The elasticity of substitution is less than unity,* $\sigma < 1$

In this case trade unions will succeed in increasing the nominal wage which has a negative effect on employment. However, it also implies higher tax revenues which allows for larger tax rate cuts. It is shown in Appendix 3 that the nominal wage elasticity is an increasing function in the bargaining power of trade unions, i.e. we have

$$\left.\frac{\partial \omega_{t_w}}{\partial \beta}\right|_{\sigma<1} > 0. \tag{45}$$

According to condition (45) the stronger the bargaining power of the trade union the less elastic is the nominal wage reaction. Hence, the LHS of condition (41) is falling while the RHS is increasing in $\beta$. This result can be summarized.

> PROPOSITION 4: If the elasticity of substitution is less than one, the likelihood of a marginal revenue-neutral green tax reform to raise employment decreases with the bargaining power of the trade union.

This proposition actually reflects a general wisdom in some circles according to which strong trade unions (at the firm's level) are bad for employment.[7]

For the monopoly trade union and no energy tax one can show that a marginal revenue-neutral green tax reform increases employment when $\sigma = 1$ and that at point $\sigma = 1$ the positive employment effect is increasing with the elasticity of substitution.[8] Hence, there must be a critical elasticity of substitution $\sigma^* < 1$ for which a green tax reform is employment-neutral. Proposition 4 then allows us to immediately infer that the employment effect is positive for $\sigma \geq \sigma^*$ when the bargaining power of the trade union is less comprehensive. This finding is summarized in the following corollary.

> COROLLARY 4: If the elasticity of substitution is less than one, there exists a critical value of $\sigma^*$ for which the green tax reform is employment-neutral in the monopoly trade union case. This critical value $\sigma^*$ decreases with the bargaining power of firms.

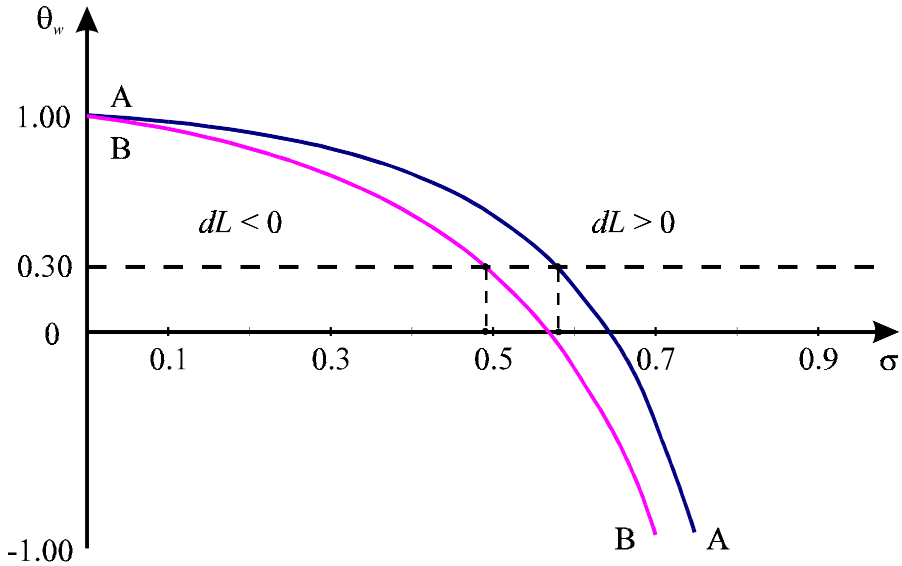
Proposition 4 implies that the "worst-case scenario" with respect to the employment effect is given when trade unions exercise monopoly power. In the following we provide some numerical results for the monopoly trade union case, remembering that the likelihood of a positive employment effect increases with the bargaining power of the firm. In Figure 3 we consider the case where there are no initial energy taxes, i.e. $t_q = 0$. The bold lines in Figure 3 show the combinations of parameter values for the elasticity of substitution $\sigma < 1$ and the initial labour tax $\theta_w = t_w/(1+t_w)$ where the employment effect is zero for two alternative values of the output demand elasticity. The line AA is calculated for the output demand elasticity of $\varepsilon = 1.5$, the curvature 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 critical value $\sigma^*$ for $\varepsilon = 2.5$ is 0.57. If the initial labour tax is 0.3, however, any elasticity of substitution above 0.58 guarantees a positive employment effect for $\varepsilon = 1.5$, and

[7] Notice that for $\sigma > 1$ the opposite conclusion that strong trade unions are good for employment applies. In the case of a Cobb-Douglas production technology, which has been usually analysed [see however Santoni (1995)] the nominal wage elasticity is independent of the bargaining power of the trade union.

[8] A proof is available upon request.

above 0.49 for $\varepsilon = 2.5$. Comparing the curvatures AA and BB shows that is the more likely that the employment effect becomes positive, the higher the output demand elasticity. It also shows that the level of the labour tax matters. The higher the labour tax, the more likely the employment effect becomes positive.

*Figure 3: The critical tax rate* $\theta_w$ *for* $t_q = 0$




## 5. 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 nominal wages which is the case if substitution between labour and energy is easy, i.e. if the elasticity of substitution is equal to or exceeds unity. This result confirms and generalizes the results from Bovenberg and van der Ploeg (1996) who analyse the case of a fixed nominal net wage.

No qualitatively unambiguous answer, though, can be given for the case where the elasticity of substitution between labour and energy is smaller than unity. The trade union succeeds in increasing nominal wages in the wage negotiations, thus making it less attractive to firms to hire new workers even though labour taxes have fallen. The effect of a green tax reform on labour demand, however, is a decreasing function of the bargaining power of the trade union and an increasing function of the elasticity of substitution. The latter allows us to determine a critical value for the elasticity of substitution.

In conclusion, our analysis presents conditions under which green tax reforms on the production side will not raise unemployment. Under these circumstances, there is no reason to postpone measures to fight pollution, which are considered to be necessary from an environmental point of view. However, in cases where the elasticity of substitution between labour and energy is low, it remains a task for empirical studies to calculate the technological relationship between labour and energy and the bargaining strength of trade unions. In particular, the lower the bargaining power of the trade union is, and the larger the labour tax rate actually is, the more likely it is that green tax reforms will boost employment.

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 that higher nominal wages increase consumer prices and hence reduce the real income of their members. In economies with *cet. par*. highly centralized wage bargaining, therefore, green tax reforms will have a more positive effect on employment than in economies with highly decentralized wage bargaining.

**Appendix 1: The Cobb-Douglas case**

In the case of $\sigma = 1$, the nominal wage is not affected by changes in the structure of factor taxes. Hence, condition (41) becomes

$$\left.\frac{dL}{dt_q}\right|_{\substack{dG=0\\ \sigma=1}} \gtreqless 0 \quad \Leftrightarrow \quad \frac{\tau_{t_q}}{\tau_{t_w}} \gtreqless \frac{\eta_{LR}}{\eta_{LL}}. \tag{41'}$$

The condition for a revenue-neutral tax reform after some calculations is then given by

$$\left.\frac{dt_w}{dt_q}\right|_{dY=0} = -\frac{(1-s)(1+t_w)}{s(1+t_q)} \cdot \frac{1-\frac{t_w}{1+t_w}\varepsilon - \gamma(1-s)(\sigma-\varepsilon)+\gamma\sigma}{1-\frac{t_w}{1+t_w}\varepsilon - \gamma(1-s)(\sigma-\varepsilon)}. \tag{A-1}$$

with $\gamma = (t_w - t_q)/(1+t_q)t_w$. As long as $t_w - t_q > 0$, the last term of the RHS exceeds unity. Hence the ratio of the tax elasticities in equation (41) exceeds the ratio $(1-s)/s$ as can be seen from condition (41). Substituting in the definitions (8) and (9), it can be easily shown that:

$$\frac{(1-s)}{s} > \frac{(1-s)(1-\varepsilon)}{-1+s(1-\varepsilon)}. \tag{A2}$$

Hence, for $\sigma = 1$ and $t_w - t_q > 0$, the employment effect is always positive.

**Appendix 2: Nominal wage elasticities**

The signs of the nominal wage elasticities $\omega_{t_i} = w_{t_i} t_i / w$ for $i = w,q$ are determined by

$$w_{t_w} = -\Omega_{ww}^{-1}\Omega_{wt_w},\; w_{t_q} = -\Omega_{ww}^{-1}\Omega_{wt_q}. \tag{A-3}$$

Furthermore, we have, using condition (14) and (17):

$$\begin{aligned}\Omega_{wt_w} &= \frac{\beta}{V^2}\left(VV_{wt_w} - V_w V_{t_w}\right) + \frac{(1-\beta)}{\pi^2}\left(\pi\pi_{wt_w} - \pi_w \pi_{t_w}\right) \\ &= -\frac{1+t_q}{1+t_w}\left[\frac{\beta}{V^2}\left(VV_{wt_q} - V_w V_{t_q}\right) + \frac{(1-\beta)}{\pi^2}\left(\pi\pi_{wt_q} - \pi_w \pi_{t_q}\right)\right] = -\frac{1+t_q}{1+t_w}\Omega_{wt_q}\end{aligned} \tag{A-4}$$

From this, it is straightforward to derive condition (42).

**Appendix 3: Bargaining power and nominal wage reaction**

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

$$w_{t_w} = -\frac{\Omega_{wt_w}}{\Omega_{ww}} = -\frac{\frac{\beta}{V^2} C + \frac{(1-\beta)}{\pi^2} D}{\frac{\beta}{V^2} A + \frac{(1-\beta)}{\pi^2} B}, \qquad \text{(A-5)}$$

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:

$$\frac{\partial w_{t_w}}{\partial \beta} = \frac{AD - CB}{V^2 \pi^2 \Omega_{ww}^2} \qquad \text{(A-6)}$$

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-6) becomes positive. To sign the impact, the bargaining power has on condition (41) we finally have to derive the impact of $\beta$ on the nominal wage elasticity. This is given by:

$$\frac{\partial \omega_{t_w}}{\partial \beta} = w^{-2}(1 + t_w) \left\{ w \frac{\partial w_{t_w}}{\partial \beta} - w_{t_w} \frac{\partial w}{\partial \beta} \right\}, \qquad \text{(A-7)}$$

as $\partial w_{t_w} / \partial \beta > 0$, (A-7) is positive for $\sigma < 1$.

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