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OPTIMAL TAXATION, PUBLIC GOODS AND ENVIRONMENTAL POLICY WITH INVOLUNTARY UNEMPLOYMENT

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ABSTRACT

The implications of more environmental concern for the optimal provision of public goods, tax structure, environmental policy, and involuntary unemployment are derived within a second-best framework in which lump-sum taxes and subsidies are not available and labour supply is rationed due to a rigid consumer wage. A shift towards greener preferences boosts employment if labour is a better substitute for polluting resources than the fixed factor, the profit tax is low, and the production share of the fixed factor is large. If initial environmental concern is small, public consumption may rise as well.

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1 Introduction

The rapid deterioration of the natural environment and the persistent high levels of involuntary unemployment are the two main problems facing many western democracies today. Moreover, falling labour market participation is eroding the financial base of the welfare state in many countries, thereby threatening the provision of public goods. In order to address these issues, various politicians have argued in favour of raising pollution taxes and using the receipts to cut labour taxes. In this way, they expect to kill three birds with one stone: a cleaner environment, a reduction in involuntary unemployment, and a cut in the cost of public funds, thereby creating more room for public spending.

In previous work we have explored these issues with a clearing labour market (Bovenberg and van der Ploeg, 1992; 1993). We found that a shift towards greener preferences reduces rather than expands employment. Employment falls even though households and the government switch from dirty to clean consumption commodities and firms substitute clean factors of production (including labour) for dirty inputs. The reason is that labour bears the incidence of environmental taxes. Hence, environmental taxes are implicit taxes on labour. The optimal response to more environmental concern involves a rise in public abatement and the dirt tax, and a fall in the labour tax. If substitution effects dominate income effects in labour supply, the switch from distortionary to non-distortionary taxation reduces the marginal cost of public funds. This creates more room for public priorities, i.e. a clean environment and provision of traditional public goods.

This paper investigates the robustness of these results to the introduction of involuntary unemployment. We assume that involuntary unemployment is caused by a rigid and too high consumer wage, which is a standard assumption in much of macroeconomic analysis (e.g., Bruno and Sachs, 1985). Within this framework, the distortion in the labour market is measured by a virtual tax on labour, which is proportional to the gap between the consumer wage and the marginal rate of substitution between private consumption and leisure at the rationed level of labour supply. The environmental distortion is given by marginal environmental damages due to the use of polluting inputs.

We extend the literature on optimal taxation in a number of directions. First, we examine optimal distortionary taxation in the presence of two non-tax distortions, namely wage rigidities and environmental externalities. Sandmo (1975) investigates optimal taxation with environmental externalities in the context of a clearing labour market and an exogenous revenue target. Marchand, Pestieau and Wibaut (1989) analyse optimal taxation in the presence of rationing on the labour market. We examine how the interaction between environmental externalities and rationed labour supply affects optimal tax structures. Indeed, the tax system faces the threefold task of raising public revenue, internalising environmental externalities, and
combatting involuntary unemployment. Second, we explore the impact of these market failures on not only the optimal tax structure but also on the marginal cost of public funds and the optimal level of public spending. In doing so, we integrate wage rigidities and environmental externalities in the literature on the optimal provision of public goods in the presence of distortionary taxation (for a recent survey, see Ballard and Fullerton (1992)). Third, most of the literature on optimal taxation and public goods merely derives and interpret the first-order conditions for optimal government policy. We go beyond the characterisation of first-order conditions by investigating the comparative statics of a shift towards greater environmental concern.

Overall welfare is affected by the quality of the natural environment, public consumption, and private consumption of both produced commodities and leisure. More environmental concern yields a 'green' dividend in the sense that the quality of the natural environment improves. If, in addition, the level of public consumption rises, we speak of a 'red' dividend. In that case, the overall supply of the public goods (i.e. public consumption and the quality of the natural environment) increases. Hence, there is a 'social' double dividend. The impact on private welfare can be decomposed into effects on income from the fixed factor ('profits') and employment. We define a blue dividend as a rise in profits. An increase in employment yields a first-order effect on private welfare because of the gap between the actual wage and the reservation wage. The welfare gain associated with an increase in employment is defined as a 'pink' dividend. If both environmental quality and employment rise, we speak about an 'employment' double dividend. There is a 'triple' dividend in case a green, red, and pink dividend occur simultaneously, i.e. if not only the environment benefits but also public consumption and employment increase. One of the main objectives of the paper is to explore the optimal trade-off between the four components of overall welfare (i.e. green, red, blue, and pink welfare). In particular, we explore under which conditions a double dividend may occur in the sense that an increase in environmental concern is compatible with a boost to employment or public consumption or both (i.e. a triple dividend).

Section 2 analyses the behaviour of firms and households and the causes of involuntary unemployment. Section 3 characterises the optimal public policy, paying particular attention to the modified Samuelson rule, the optimal tax structure and the marginal cost of funds. Section 4 derives the general comparative statics of more environmental concern. Section 5 explores the special case of a 100 per cent profit tax, while section 6 discusses the general case. Section 7 concludes with a summary of results.

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1 We call income from the fixed factor 'profits', but it can also be interpreted as income from land.
2 Factor demand, labour supply and involuntary unemployment

Firms face a concave production function \( F(L,R) \) with decreasing returns to scale, where \( L \) represents labour demand and \( R \) denotes the use of polluting resources in production. They maximise profits taking as given the producer wage, \( w_p \), and producer resource cost, \( q_p \). This yields the following factor demand functions:

\[
L = l(w_p, q_p), \quad R = r(w_p, q_p)
\]  

(14)

where \( l_w = \partial l/\partial w_p = F_{RR}/\Delta < 0 \), \( r_q = \partial r/\partial q_p = F_{L}L/\Delta < 0 \) and \( l_q = \partial l/\partial q_p = \tau_w = \partial r/\partial w_p = -F_{LR}/\Delta \) with \( \Delta = F_{LL}F_{RR} - F_{LR}^2 > 0 \). Hence, for a given producer wage, a higher cost of resources raises the demand for labour \((l_q > 0)\) if the substitution effect dominates the output effect. In that case, resources and labour are non-cooperant factors of production \((F_{LR} < 0)\). Pre-tax profits, \( \Pi \), follow from \( \Pi = F(L,R) - w_pL - q_pR = \tau(w_p, q_p) \) with \( \tau_w = -L \) and \( \tau_q = -R \). Profits are distributed to households. Private consumption, \( C \), is thus given by \( C = wL + (1 - \tau)\Pi \) where \( w \) stands for the consumer wage and \( \tau \) denotes the profit tax rate.

Resources can be bought on the world market for a given price \( q \). The producer cost of resources thus amounts to \( q_p = q(1 + t_R) \), where \( t_R \) denotes the tax on resources. Imports of resources must equal exports of final goods, so that \( q_R = Y - C - G \) where \( G \) denotes the level of public consumption and \( Y = F(L,R) \) stands for the level of output. The government finances public consumption through revenues from the labour tax, the resource tax and the profit tax, hence \( G = t_cwL + t_RqR + \tau\Pi \) where \( t_c \) denotes the wage tax (so that \( w_p = w(1 + t_c) \)). Involuntary unemployment \((U)\) is caused by a rigid and too high exogenous consumer wage \((w)\). Hence, labour demand determines employment while labour supply \((L^*\) \) is rationed. Whereas the consumer wage is exogenous, the producer wage and thus labour demand are affected by the

\[ \text{The Appendix shows that resources and labour are typically cooperant. However, they may be non-cooperant if these two factors are separable from the fixed factor, the production share of the fixed factor is large (i.e. labour and resources exhibit strongly decreasing returns to scale), and the substitution elasticity between labour and resources is large relative to that between the fixed factor and the labour-resource composite.} \]

\[ \text{Alternatively, one can interpret our economy as a closed economy in which the producer prices of dirty inputs (resources) are fixed by a fixed rate of transformation between dirty inputs and other (consumption) goods.} \]

\[ \text{This may be justified by efficiency wages. For example, if production is given by} \ Y = f(A(w)L), \text{where} \ A(w) = (w - \omega)^\theta, 0 < \theta < 1, \text{stands for the efficiency for labour and} \ \omega > 0 \text{denotes the fixed 'outside' wage, producers set} \ wA'(w) = \omega/(1 - \theta) > \omega \text{and output is given by} \ Y = f(A(\omega/(1 - \theta)L) = F(L). \text{Big incentives to recruit, retain, motivate or discipline workers (i.e. a high value of} \ \theta \text{thus cause high wages and low levels of employment.} \]
wedge between producer and consumer wages. Environmental damages are an increasing function of the use of resources. Utility losses on account of environmental damages can thus be expressed as $D(R)$, $D' > 0$, $D'' \geq 0$. Utility of public consumption can be written as $Z(G)$, $Z' > 0$, $Z'' \leq 0$. The concave and homogeneous sub-utility function $M(C/N, 1-L/N)$ denotes utility of private consumption and leisure enjoyed by an individual household, where $N$ denotes the number of households. With this specification of preferences, social welfare amounts to:

$$ W = M(C, N-L) + N Z(G) - N D(R). \tag{1} $$

Notional labour supply ($L'$) corresponds to the hours households would like to work at the going wage. From the optimality condition for the marginal rate of substitution between leisure and consumption $M_{NL}/M_C = w$ and the notional budget constraint $C = wL' + (1-r)\Pi$, we obtain (notional) labour supply as a function of the consumer wage and after-tax profits, $L' = l(w, (1-r)\Pi)$. Figure 1 shows that leisure $N-L$ consists of voluntary unemployment ($V = N-L$) plus involuntary unemployment ($U = L'-L$).

3 Optimal public policy

The government selects $G$, $t_L$ and $t_R$ to maximise social welfare, $W$:

$$ W = M[w(l(w(1+t_L), q(1+t_R)) + (1-r)\pi(w(1+t_L), q(1+t_R)), N-l(w(1+t_L), q(1+t_R))] + N Z(G) - N D[r(w(1+t_L), q(1+t_R))] \tag{2} $$

subject to a given consumer wage ($w$) and world price for resources ($q$) and taking account of the government budget constraint

$$ t_L w[l(w(1+t_L), q(1+t_R)) + t_R q r[w(1+t_L), q(1+t_R)] + \tau \pi(w(1+t_L), q(1+t_R))] = G. \tag{3} $$

We call $\mu$ the shadow price of public revenue (in terms of utility). Accordingly, $\eta = \mu/M_C$ denotes the marginal cost of public funds (or the MCPF).

Public consumption follows from the modified Samuelson rule, i.e. the sum of the marginal rates of substitution between private and public consumption should equal the product of the corresponding marginal rate of transformation (unity) and the MCPF:

$$ NZ'(G)/M_C = \eta. \tag{4} $$
Hence, a higher MCPF induces substitution away from public towards private consumption.

The virtual tax on labour (s) and the virtual pollution subsidy (p) measure the distortions due to, respectively, a rigid consumer wage and pollution externalities. They are defined as:

\[ s = (w - w')/w' \eta \quad \text{and} \quad p = ND'(R)/qM_{c\eta} = D'(R)/qZ'(G), \]

where the reservation wage \((w' = M_{NL}/M_r)\) amounts to the marginal rate of substitution between private consumption and leisure at the rationed level of labour supply (cf. Neary and Roberts, 1980). The virtual tax on labour is due to rationing of labour supply and is proportional to the gap between the exogenous consumer wage and the virtual wage (see Figure 1). The pollution subsidy may be interpreted as a virtual subsidy on economic activity, because producers do not bear the social costs of environmental damages due to their emissions. This subsidy is proportional to the sum of the marginal environmental damages of pollution. The first-order conditions for the optimal tax rate on labour and on resources are, respectively:

\[ \frac{1 + s}{L} = \left[ 1 - \tau \right] \left( 1 - \frac{1}{\eta} \right) - \varepsilon_{Lq} \left( \frac{1}{1 + \tau} \right) \left( \frac{1}{\eta} \right) \]

\[ \frac{t_r - p}{1 + t_r} = \left[ 1 - \tau \right] \left( 1 - \frac{1}{\eta} \right) - \varepsilon_{Rw} \left( \frac{1}{1 + \tau} \right) \left( \frac{1}{\eta} \right) \]

where the elasticities of factor demand are defined as \(\varepsilon_{Lq} = -q_{Lq}/L > 0, \varepsilon_{Rw} = -q_{Rw}/R > 0\), \(\varepsilon_{Lq} = -q_{Rw}/L\), and \(\varepsilon_{Rw} = -q_{Lq}/R\). The cross elasticities \(\varepsilon_{Lq}\) and \(\varepsilon_{Rw}\) are positive (negative) if the output (substitution) effect dominates, that is if resources and labour are cooperant (non-cooperant) factors of production. If the government can freely adjust the profit tax rate, possibly above 100 per cent, the government has in fact access to a lump-sum tax. Accordingly, the MCPF is unity and raising public revenue does not yield any welfare losses. In that case, the first-best outcome can be sustained in a decentralised market economy. We, however, focus on a second-best situation in which the profit tax rate is exogenous.\(^5\)

If the resource tax cannot be adjusted, the labour tax must be set so as to strike a balance between three objectives (see expression (6)). First, it must be large if public revenue is

\(^5\) Monitoring problems associated with imperfect information may preclude a 100 per cent profit tax (see, e.g., Atkinson and Stiglitz, 1980, pp. 467-468).
scarce, i.e. if the MCPF ($\eta$) is high and the profit tax rate ($\tau$) is low. For a given MCPF, the revenue-raising component of the labour tax declines with the wage elasticity of labour demand. If the profit tax rate amounts to 100 per cent, the revenue-raising component of the labour tax vanishes. Intuitively, the labour tax does not raise any net revenue; with a fixed consumer wage, this tax is borne by profits and thus, with a 100 per cent profit tax, by the government.

Second, rationing of labour supply requires a labour subsidy to offset the labour-market distortion on account of the virtual tax. Just as an explicit labour tax, rationing causes a wedge between the producer wage ($w_r$) and the virtual wage ($w^\tau$). A labour subsidy serves to reduce the gap between the social value of marginal employment (i.e. $w_p$) and its marginal cost (i.e. $w^\tau$). This subsidy declines with the MCPF (see (5)). If public revenue is scarce, less resources are available for labour subsidies. Indeed, offsetting the virtual labour tax due to rationing by an explicit labour subsidy reallocates resources from the public to the private sector. The cost of this reallocation rises with the MCPF.

Third, the labour tax affects the use of resources and thus plays a role as an indirect instrument to internalise the environmental externality. In particular, if the resource tax is set too low to offset the virtual pollution subsidy ($t_R < p$), labour should be taxed (subsidised) if resources and labour are cooperant (non-cooperant) factors of production. In that case, a labour tax (subsidy) primarily reduces economic activity (induces substitution away from resources to labour), so that the demand for resources and thus environmental damages fall. The labour tax (subsidy) is used more intensively for this environmental purpose if labour demand is less elastic with respect to the product wage (small $\epsilon_{lw}$).

If the labour tax cannot be adjusted, the resource tax has to compromise between internalising the environmental externality, raising revenue, and alleviating the rationing of labour supply (see expression (7)). In order to fight unemployment (caused by $t_L > s$), resources are subsidised (taxed) if resources and labour are cooperant (non-cooperant) factors of production, because this raises economic activity (causes substitution away from resources to labour) and thus boosts employment.

If the government can employ the labour tax and the resource tax simultaneously, equations (6) and (7) can be solved to yield expressions for the MCPF and the optimal structure of taxes on labour and resources:
$$\eta = \left[ \frac{1 - \tau}{1 - \tau + \frac{p - t}{1 + t}} \right] = \left[ \frac{1 - \tau}{1 - \tau - \frac{t + s}{1 + t}} \right]$$

(8)

$$\left( \frac{t + s}{1 + t} \right) = \left( \frac{e_{R_q} - e_{L_q}}{e_{L_w} - e_{R_w}} \right) \left( \frac{t - p}{1 + t} \right)$$

(9)

with $e_L = \frac{(e_{L_w} - e_{R_q} - e_{L_q} + e_{R_w})}{e_{R_q} - e_{L_q}}$ and $e_R = \frac{(e_{L_w} - e_{R_q} + e_{L_q} - e_{R_w})}{e_{L_w} - e_{R_w}}$, where $e_{L_w} - e_{R_q} + e_{L_q} - e_{R_w} = \frac{w_p q}{\Delta L R} > 0$. The MCPF rises with the gap between the social benefits and social costs of additional employment as measured by the sum of the explicit labour tax ($t_L$) and the virtual tax on labour ($s$), especially if labour demand is fairly elastic (i.e. if $e_L$ in (8) is large). The MCPF falls with the non-distortionary component of the resource tax aimed at offsetting the pollution subsidy implicit in the environmental externalities (i.e. $p - t_R$). In an economy without unemployment and environmental externalities, a small tax does not yield any first-order welfare effects. Hence, the MCPF of the first unit of public revenues is unity. However, in the presence of labour-market distortions and environmental externalities, small taxes generally yield first-order implications for welfare. The reason is that raising revenues may either exacerbate or alleviate these market imperfections. In particular, the decline in employment associated with a higher tax level worsens labour-market distortions but, by cutting pollution, alleviates environmental damages. The MCPF of the first unit of public revenues exceeds unity if $s L - p R > 0$. In that case, the non-distortionary components of the tax system, which are designed to offset non-tax distortions, yield negative revenue. Raising the first dollar of revenue yields a first-order welfare loss by worsening the distortions due to rationing.

Expression (9) shows the optimal structure of the distortionary components of the input taxes. These distortionary components measure the wedges between the social benefits and costs of the two inputs. These wedges are affected by not only explicit tax rates but also by virtual tax and subsidy rates. The optimal magnitude of the sum of explicit and virtual tax rates depends on how sensitive factor demands are with respect to these wedges. To illustrate, if cross-

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The Appendix computes the various elasticities under three alternative separability assumptions. It shows that $e_L$ and $e_R$ are generally positive. However, $e_L$ may be negative if labour is a much better substitute for the fixed factor than resources. In that case, the optimal labour tax is negative. Similarly, $e_R$ may be negative if, compared to labour, resources are a much better substitute for the fixed factor. In that case, the optimal distortionary component of the dirt tax ($t_R - p$) is negative. By subsidising factors that are good substitutes for the fixed factor, the government in effect taxes profits. We assume that $e_L$ and $e_R$ are not negative. This ensures that the distortionary components of both the labour and the resource tax are non-negative. Concavity of the production function ensures that $e_{L_w} - e_{R_q} + e_{L_q} - e_{R_w}$ is positive.
price effects are insignificant, the distortionary component of the labour tax exceeds that of the resource tax if labour demand is fairly inelastic with respect to the producer wage while resource demand is fairly elastic with respect to the producer price of resources. In this way, the government can best tax the fixed factor. Indeed, the government implicitly taxes the fixed factor by levying the heaviest taxes on factors that are complements or poor substitutes for the fixed factor. The parts of the optimal labour and resource tax rates that correct for the labour-market and environmental distortions are inversely related to the MCPF, because they are measured in terms of public revenue (see (5)). Hence, scarcer public funds, as indicated by a higher MCPF, imply that, ceteris paribus, the optimal tax system focuses more on raising revenue and less on correcting the labour market distortion or internalising the environmental externality (cf. Bovenberg and van der Ploeg, 1992).

4 Derivation of the comparative statics results

In order to investigate shocks in preferences for environmental quality, we loglinearise the conditions describing private behaviour, market equilibrium and optimal government policy. For this purpose, we denote relative changes by a tilde (e.g. \( \tilde{C} = \frac{dC}{C} \)). For the tax rates we define \( \tilde{t}_i = \frac{dt_i}{1 + t_i} \), \( i = L, R \), and \( \tilde{\tau} = \frac{d\tau}{1 - \tau} \). We assume that \( Z(\cdot) \) and \( D(\cdot) \) are linear, say \( Z(G) = \gamma_G G \) and \( D(R) = \gamma_R R \). Loglinearisation of (4) yields:

\[
\tilde{\eta} = \gamma_G + [\tilde{C} + (L/(N-L)) \tilde{L}(1-\alpha)/\sigma]
\]

where \( \sigma \) stands for the substitution elasticity between consumption and leisure in private utility \( M(.) \) and \( \alpha = M_C/C = M/[C + w'(N-L)] \) denotes the share of consumption of private commodities in private utility. Substitution of private consumption for leisure reduces marginal utility from private consumption \( (M_C) \) and thus raises the MCPF society is willing to bear \( (\eta = \mu/M_C) \). Alternatively, a higher MCPF raises the relative cost of public consumption, thereby crowding in private consumption.

The relative changes in the reservation wage, the virtual tax on labour and the virtual pollution subsidy are (from (5)):

\[
\tilde{\omega} = [\tilde{C} + (L/(N-L)) \tilde{L}] / \sigma = \tilde{\eta} / (1-\alpha),
\]

Alternatively, one can interpret this 'green' shock as the arrival of new information about more serious environmental effects of resource use.
A higher MCPF decreases the virtual tax on labour for two reasons. First, a higher MCPF boosts the virtual wage \( w' = M_{c+1}/M_c \) by reducing marginal utility of private consumption. The resulting reduction in the labour market distortion depresses the virtual labour tax. Moreover, a higher MCPF implies that public resources becomes more expensive. Hence, the gap between consumer and reservation wages becomes smaller if measured in terms of public revenue. This is the second reason why the virtual labour tax, which is measured in terms of public revenue, falls with the MCPF.

The relative change in notional labour supply is given by

\[
\tilde{L}^s = \frac{(\sigma \omega + \omega_x)\psi - \omega_x(\bar{I} - \tau)}{1 - \omega_x + \frac{\tilde{L}^s}{N - \tilde{L}^s}}
\]

(10)

where \( \omega_x = \frac{(1 - r)\Pi}{w'L' + (1 - r)\Pi} \) stands for the share of after-tax profits in household income. Since the consumer wage is fixed, only income effects affect notional labour supply. In general, labour supply declines if after-tax profits rise, i.e. if the labour tax rate falls. However, if all profits are taxed away, labour supply is fixed.

5 Consequences of more environmental concern under a 100 per cent profit tax

If profits are fully taxed away, (6) and (7) reduce to \( \tau_L = s \) and \( \tau_R = p \). In this case, production efficiency holds; the distortionary components of the tax rates are zero. Hence, labour should be subsidised rather than taxed in order to offset the virtual tax on labour (s). Furthermore, the resource tax should equal the virtual pollution subsidy (p), thereby internalising pollution externalities. The relative changes in the labour subsidy and the resource tax are given by:

\[
\left( \frac{1-s}{s} \right) \tilde{r}_L = \tilde{s}, \quad \left( \frac{1-p}{p} \right) \tilde{r}_R = \tilde{p}.
\]

(11)

The modified Samuelson rule (4'') and equations (5') and (11) yield the demand curve for private consumption goods:
\[
\dot{C} = \left[ e_{lw} \left( \frac{s}{1-s} \right) \left( \frac{L}{N-L} \right) + \left( \frac{\sigma}{1-\alpha + \left( \frac{w^*}{\omega_{NS}} \right)} \right) \right] s + e_{la} \left( \frac{p}{1+p} \right) \left( \frac{L}{N-L} \right) \dot{\gamma}_E
\]

where use has been made of the employment equation

\[
L = \dot{C} = e_{lw} \left( \frac{s}{1-s} \right) s - e_{la} \left( \frac{p}{1+p} \right) \dot{\gamma}_E.
\]

Since all profits are taxed away \((C = wL)\), equation (13) also corresponds to the supply curve of private consumption goods. Hence, we find the optimal change in the labour subsidy:

\[
s = \left( \frac{\left( \frac{p}{1+p} \right) \left( \frac{N}{N-L} \right)}{e_{lw} \left( \frac{s}{1-s} \right) \left( \frac{N}{N-L} \right) + \left( \frac{\sigma}{1-\alpha + \left( \frac{w^*}{\omega_{NS}} \right)} \right)} \right) e_{la} \dot{\gamma}_E.
\]

The corresponding change in employment and private consumption is thus:

\[
\dot{C} = \dot{L} = -\left( \frac{\sigma \left( \frac{p}{1+p} \right)}{e_{lw} \left( \frac{s}{1-s} \right) \left( \frac{N}{N-L} \right) + \left( \frac{\sigma}{1-\alpha + \left( \frac{w^*}{\omega_{NS}} \right)} \right) + \sigma} \right) e_{la} \dot{\gamma}_E.
\]

The change in public consumption can be written as:

\[
\omega_\alpha \dot{G} = -\left( \frac{s}{1-s} \right) \omega_L \dot{L} + \left( \frac{p}{1+p} \right) \omega_R \dot{R}
\]

where \(\omega_L = \omega_P L / Y\), \(\omega_R = \omega_R R / Y\) and \(\omega_G = G / Y\) denote the output shares of, respectively, labour costs, resource costs and public consumption. Only changes in the labour and resource tax bases affect public revenue; changes in the labour and resource tax rates do not impact public revenue due to the induced fall in (taxed) profits. Intuitively, the labour and resource taxes are shifted towards profits as the consumption wage and the world price of resources are exogenously given. Expression (16) reveals that a reduction in the use of natural resources and an increase in employment lowers revenue from the resource tax and boosts expenditures on labour subsidies so that less resources are left for public consumption. Hence, a triple dividend (better environmental quality, more employment, and more public consumption) can not occur.

If resources and labour are cooperator factors (i.e. \(F_{LR} > 0\) and thus \(e_{la} > 0\)), employment declines (see (15)). However, public consumption may rise (see (16)). Intuitively, a higher
resource tax depresses employment (due to the dominance of the output effect). This reduces spending on labour subsidies, thereby creating room to raise public consumption. The expansion of public consumption is particularly likely if resource use falls only marginally, so that the base of the resource tax is not eroded much. Intuitively, the red component of welfare is not crowded out because the green component of welfare rises only marginally while the pink component of welfare falls substantially. A sufficient condition for labour and resources to be cooperant, and hence for employment to decline, is that the fixed factor and labour are separable from resources in production, i.e. \( Y = F(Q(K,L),R) \) where \( Q \) denotes value added (see Appendix). Alternatively, the fixed factor and natural resources should be separable from labour for labour and resources to be cooperant.

If resources and labour are non-cooperant factors (i.e. \( F_{LR} < 0 \)), environmental quality improves and employment expands. In that case, the substitution effect dominates the income effect. Hence, the higher resource tax raises the demand for labour. Higher employment raises spending on labour subsidies while lower demand for resources reduces revenues from the resource and profit taxes. Hence, society pays for the pink and green dividends in the form of a fall in public consumption. With a 100 per cent profit tax, private income consists only of labour income. Accordingly, the private component of social welfare, \( M \), moves in the same direction as employment and private consumption (\( M = \eta_{as}L - \eta_{as}C \)). Hence, also private welfare expands in case of employment double dividend. Resources and labour may be non-cooperant if resources and labour are separable from the fixed factor (see Appendix). Moreover, the fixed factor should account for a large production share (i.e. \( \omega_L + \omega_R \) small), so that production exhibits strongly decreasing returns to scale in labour and resources, substitution between resources and labour is easy, while substitution between the fixed factor and the labour-resource composite is difficult (see expression (A7) in the Appendix). In summary, if resources and labour are cooperant factors, a 'social' double dividend (i.e. green and red dividends) may arise. If these factors are non-cooperant, in contrast, an 'employment' double dividend (i.e. green and pink dividends) emerges. In the latter case, a shift towards greener preferences reduces public consumption but raises private consumption and welfare.

Proposition 1: If all profits are taxed away, a shift towards greener preferences raises the pollution tax and reduces the use of resources. If labour and resources are cooperant factors, the optimal labour subsidy rises while employment, output, private consumption and the private component of social welfare fall. The MCPF declines while public consumption may rise. However, if resources and labour are non-cooperant factors, the labour subsidy and public
consumption decrease while employment, private consumption, private welfare and the MCPF increase.

6 Consequences of more environmental concern under a general profit tax

We now turn to the comparative statics results for the general case under the assumption that \( e_L \) and \( e_R \) remain constant.\(^8\) If we follow the same procedure as before, we obtain (4'), (5') and, instead of (12),

\[
\frac{\partial C}{\partial n} = \left( \frac{L}{N-L} \right) \left( e_L \tilde{t}_L \tilde{e}_L + e_R \tilde{t}_R \tilde{e}_R \right) + \rho \tilde{t}_L, \quad \rho = \frac{\sigma \eta e}{(1-\alpha)(1+t_L) + e(1-\alpha)\eta s + w^{-1} / w} > 0 \tag{17}
\]

where \( e = e_L / (1-\gamma) \). The second term at the right-hand side of (17) (i.e. \( \rho \tilde{t}_L \)) captures the positive effect of a higher labour tax on the MCPF, thereby moving the composition of aggregate demand towards private and away from public consumption. This effect is particularly large if a high elasticity of substitution between consumption and leisure (\( \alpha \)) makes private consumption rather sensitive to the the MCPF - see (4'). However, the impact on the MCPF is weakened by the associated downward pressure on the virtual tax on labour - see the second term in the numerator of the expression for \( \rho \). The first term at the right-hand side of (17) reveals that a higher labour tax depresses labour demand and thus raises leisure and, therefore, the demand for private consumption.

The optimal structure of factor taxation (9) yields, upon substitution of the expression for \( s \) in (5') with \( \tilde{e}_R = (1-\alpha)\rho \tilde{t}_L / \sigma \) and \( \tilde{p} = \gamma e \), the relative change in the resource tax:

\[
\tilde{t}_R = p \tilde{y}_R \chi \tilde{t}_L, \quad \chi = \frac{e_L (1+t_L)}{e_R \left[ 1 + t_L + e \left[ \eta s + \frac{w^{-1} / w}{w(1-\alpha)} \right] \right]} > 0. \tag{18}
\]

The resource tax rises with more environmental concern. The labour tax also raises the optimal resource tax. Intuitively, the government finds it optimal to spread the tax burden over labour and resources. The positive effect of the labour tax on the resource tax is weakened by the negative effect of the labour tax on the virtual tax on labour (s) on account of the associated upward pressure on the MCPF.

Substitution of (18) into (17) yields the demand curve for private consumption:

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\(^8\) The Appendix presents three special cases for which \( e_L \) and \( e_R \) are constant. In the cases that \( e_L \) and \( e_R \) are not constant, our results on comparative statics hold only approximately.
The demand curve slopes upwards (see Figure 2), i.e. that \( x_\ell \) is not too large in absolute value and negative. A higher wage tax raises private consumption by raising the MCPF, thereby making public consumption more expensive. However, it reduces employment, thereby raising leisure demand and thus private consumption.

Loglinearisation of the household budget, \( C = wL + (1-r)\Pi \), yields:

\[
\omega \cdot C = \left[ \omega_L/(1+t_L) \right] L - (1-r) \left( \omega_L \tilde{t}_L + \omega_R \tilde{t}_R \right)
\]  

Upon substitution of labour demand and (18) into (20), we arrive at the supply curve for private consumption:

\[
\omega \cdot C = \left\{ \left[ (1-r) \omega_R + \omega \left[ (1-t_L) \right] \right] \phi \left[ \left( (1-r) (\omega_L + \omega_\ell \chi) + \left[ (1-t_L) \right] (\epsilon_{Lw} + \epsilon_{Lq}) \right] \right] \right\} \tilde{t}_L.
\]  

The supply curve slopes upwards (see Figure 2). A higher labour tax raises the total tax burden, which is fully born by the fixed factor. Hence, profit income declines. The higher labour tax also depresses labour income by reducing labour demand. Both effects reduce private consumption. A greater concern with environmental damages shifts the supply curve downwards. Intuitively, the government can charge a higher price for the environment, which is publicly owned. This creates more room for more public spending at the expense of private consumption.

We can solve for \( \tilde{C} \) and \( \tilde{t}_L \) from (19) and (21). Equation (18) then gives \( \tilde{t}_R \), so that \( \tilde{L} \), \( \tilde{D} \), \( \tilde{N} \), and \( \tilde{M} \) can be computed. The results of these computations are presented in Table 1. Note that with a 100 per cent profit tax rate \( (r=1) \), we have \( \omega_L = (1+t_L) \omega_C \) and \( e^{-\infty} \) upon which Table 1 reduces to the results derived in section 5. We now discuss the general comparative statics results presented in Table 1.

6.1 The resource tax, the labour tax, and the cost of public funds

Table 1 shows, not surprisingly, that a shift towards greener preferences always raises the optimal resource tax. A sufficient condition for more environmental concern to reduce the
labour tax rate is that resources and labour are cooperant factors of production. If not all profits are taxed away, a higher resource tax reduces private consumption by raising the total tax burden, thereby depressing profit income. In addition, the higher resource tax depresses labour demand (if $\epsilon_{lq} > 0$) and thus labour income. The fall in private consumption and the rise in leisure raises marginal utility from private consumption. The government thus finds it optimal to reduce the labour tax rate in order to prevent private consumption from declining too much. If the wage elasticity of labour demand ($\epsilon_{lw}$) is small, the labour tax is relatively ineffective in raising consumption by boosting the demand for labour. Hence, the labour tax has to fall substantially. If the profit tax rate is small, the higher tax burden on resources is mostly borne by private consumption. Accordingly, the labour tax has to fall significantly to protect private consumption. The fall in the labour tax is thus particularly large if the wage elasticity of labour demand and the profit tax rate are small. Under these circumstances the fall in the MCPF is also substantial.

If the elasticity of labour demand with respect to the resource price ($\epsilon_{lq}$) is large, the rise in the resource tax exerts substantial adverse effects on labour demand and private income. Consequently, the labour tax rate must fall substantially to stem the fall in private consumption. If consumption and leisure are poor substitutes (i.e. $\sigma$ and thus $\rho$ are small), the resource tax rises by only a small amount. In that case, more leisure due to lower employment and less private consumption on account of a higher tax burden raises marginal utility from private consumption. This expands the demand for private consumption, thereby curtailing the rise in the overall tax burden on account of a lower MCPF.

6.1 Employment

Even if resources and labour are on the borderline of being cooperant and non-cooperant factors of production (i.e. $\epsilon_{lq}=0$), more environmental concern expands employment, as long as not all profit income is taxed away ($\tau < 1$). Figure 2 shows that the tax rate on labour falls, which boosts employment. Despite the cut in labour costs, profit income falls on account of the higher resource costs. This depresses private consumption even though labour income rises. More generally (i.e. $\epsilon_{lq}$ not zero), the 'employment' double dividend becomes more likely, the lower the profit tax rate, the larger the production share of the fixed factor,

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9 Section 5 discussed the case in which factors are non-cooperant and the profit tax rate is 100%. Table 1 shows that the (negative) labour tax increases in this case. Indeed, section 5 showed that, if resources and labour are non-cooperant factors of production and the profit tax rate is 100%, the labour tax rate rises, i.e. the labour subsidy falls, and the MCPF rises (cf. Proposition 1).

10 The sign of $\epsilon_{lw} - \epsilon_{kw}$ corresponds to that of $\epsilon_k$, which is non-negative.
and the larger the substitution possibilities between labour and resources are. These three factors make it easier to shift the costs of the green dividend associated with a higher environmental tax to the fixed factor rather than to labour (in the form of less employment). The important role of fixed factors suggests that an 'employment' double dividend is more likely in the short than in the long run, because in the short run more factors are fixed.

Consider a situation in which labour and resources are separable from the fixed factor. In that case, a pink dividend requires a lot of substitution possibilities between labour and resources (i.e. $\epsilon_{Lw}$ and $\sigma_{LR}$ large, see Appendix) and only little substitution between the fixed factor and the labour-resource composite (i.e. $\sigma_{H}$ and thus $\epsilon_{Lq}$ small, see Appendix). Hence, labour should be a much better substitute for resources than the fixed factor. This implies that labour substitutes for resources, thereby making production more labour intensive. At the same time, production does not fall substantially as the fixed factor is a poor substitute for resources. Indeed, as a poor substitute for resources, the fixed factor bears much of the burden of the additional resource tax. If substitution between labour and resources is excluded, more environmental concern always reduces employment (as $\epsilon_{Lw}$ and $\sigma_{LR}$ are small, see Appendix).

If resources and the fixed factor are separable from labour in production, resources and labour are always cooperant factors (see Appendix). Nevertheless, an 'employment' double dividend is possible if substitution between the fixed factor and resources is difficult while substitution between labour and the other two factors is relatively easy ($\sigma_{HR}$ small relative to $\sigma_{L}$, so that $\epsilon_{Lw}$ is large while $\epsilon_{Lq}$ is small, see Appendix). Clearly, for a pink dividend to occur, the fixed factor needs to bear a large part of the burden of the higher resource tax. This requires the fixed factor to play an important role in production ($\omega_{H}$ large), to be a poor substitute for resources, and to face a low profit tax.

If resources and labour are cooperant, consumption and leisure should be poor substitutes (i.e. $\sigma$ and thus $\rho$ small) for the pink dividend to occur. In that case, a fall in the MCPF, associated with a larger non-distortionary component of the resource tax, produces only a small rise in the overall tax burden as marginal utility of private consumption rises rapidly with falling consumption and employment. The relative small rise in the tax burden prevents a decline in employment.

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11 The Appendix shows that a higher production share of the fixed factor reduces the term $\epsilon_{Lq}$ in the numerator of the entry for employment in Table 1. Large substitution possibilities between labour and resources raise the term $\epsilon_{Lw}$ and reduce the term $\epsilon_{Lq}$ thereby increasing the numerator of the entry for employment in Table 1.
Proposition 2: Even if resources and labour are cooperator factors, more environmental concern may boost employment. In particular, employment rises if the profit tax rate is low, the production share of the fixed factor is large, labour is a better substitute for resources than the fixed factor, and consumption and leisure are poor substitutes in utility.

6.3 Profits, notional labour supply and involuntary unemployment

The absolute value for the entry \((1-r)\bar{\Pi}\) in Table 1 measures the overall tax burden. The total tax burden rises (as we assume that \(e_{LW} \leq e_{RW}\) is non-negative). It rises substantially if the profit tax rate is small, the share of resources in production \(\omega_R\) is large, labour is a better substitute for resources than the fixed factor (i.e. \(e_{LW} - e_{RW}\) large), and substitution between leisure and consumption is easy \((\sigma\) and thus \(\rho\) large).

Expression (10) shows that a fall in profit income raises notional labour supply. Hence, the notional labour supply curve in Figure 1 shifts out, thereby raising involuntary unemployment, \(U\), and reducing voluntary unemployment, \(V\). The conditions for involuntary unemployment to fall are thus more stringent than the conditions for employment to rise.

6.4 Private consumption and private welfare

Private consumption typically declines due to a rise in the total tax burden, which depresses profit income. The fall in private consumption is particularly large if employment expands. The reason is twofold. First, a boost to employment requires that the fixed factor bears the burden of the higher resource tax, thereby depressing profit income. Second, a higher level of employment reduces leisure. A lower level of leisure reduces the marginal utility of private consumption, thereby decreasing the optimal level of private consumption (see the modified Samuelson rule (4')). The first effect is important if the profit tax rate is low while the latter effect is particularly strong if leisure and private consumption are poor substitutes.

Private consumption may rise if the profit tax rate is large and resources and labour are non-cooperator factors of production. With a high profit tax, a large share of the fixed factor is owned by the government. Hence, the burden of higher tax rates is borne by the government while private consumption benefits from higher labour income due to the expansion of employment (see also section 5). The private component of welfare (i.e. \(M\)) typically 'pays' for the cleaner environment. However, if resources and labour are non-cooperator factors \((e_{LW} < 0)\), private welfare may rise if the profit tax rate is large (see section 5). In that case, there is a private as well as a green dividend.
6.5 Environmental quality

Resource use is cut back, so that environmental quality improves. There are three effects on the demand for resources: (i) fall in demand on account of a higher overall tax burden (measured by \( \rho R_k \)); (ii) substitution between resources and the fixed factor (measured by \( \varepsilon_{L_k} \varepsilon_{R_q} \varepsilon_{R_w} \)); and (iii) substitution between labour and resources on account of the change in the relative input prices (measured by \( \varepsilon_{R_q} \varepsilon_{R_w} \)). The first effect represents the decline in employment and output (and hence emissions) due to substitution between leisure and private consumption in utility. A large value for the substitution elasticity between leisure and consumption (which corresponds to a large value for \( \rho \)) boosts the improvement in environmental quality. The reason is that reducing emissions by decreasing output, and hence employment and consumption, is relatively cheap if leisure is a good substitute for consumption. The second effect stands for the substitution between resources and the fixed factor. This effect also depresses the level of output. Finally, the third term represents the substitution between labour and resources due to the lower labour tax and the higher resource tax. In contrast to the other two effects, this latter effect accomplishes a better quality of the environment through a cleaner composition rather than a lower level of output.

6.6 Public consumption

Public consumption is likely to rise if resource demand does not decline much or if the initial tax rate on resources is small. Intuitively, the increase in green welfare should be either cheap (i.e. if the initial tax rate is small) or small (if resource use declines only marginally). Indeed, if resource use does not fall much, pollution taxation is a poor instrument for improving environmental quality but a splendid device for generating public funds. The substitution elasticity between leisure and private consumption of commodities is another determinant of the effect on public consumption. In particular, public consumption is likely to rise if a large value for this elasticity (and hence for \( \rho \)) makes the level of private consumption rather sensitive to the MCPF. In that case, the decline in the MCPF on account of a larger non-distortionary component of the resource tax produces a substantial rise in tax rates. This yields a large rise in public revenues as long as the Laffer curve slopes upwards on account of small tax rates or small elasticities.\(^\text{12}\)

If the initial resource tax and profit tax rates are small, easy substitution between labour

\(^{12}\) For the Laffer curve to slope upward, the profit tax rate must be smaller than 100%. The importance of the initial tax rates indicates that public consumption is unlikely to expand if public consumption is large initially.
and resources in production is likely to raise public consumption. One reason is that the associated substitution of labour for resources tends to decrease leisure. This reduces the optimal level of private consumption, thereby leaving more room for the public sector. If the tax rate on labour is positive, another channel through which easy substitution between labour and resources boosts public consumption is the expansion of the base of the labour tax. However, substitution between labour and resources may reduce public consumption if the initial tax rate on resources is high. In that case, the erosion of the base of the resource tax due to the lower demand for resources has substantial adverse consequences for public revenues. Through this channel of the erosion of the resource-tax base, substitution between resources and the fixed factor tends to reduce public consumption.

**Proposition 3:** If the own price elasticity of resource demand is small, labour is a better substitute for resources than the fixed factor, substitution in utility between consumption and leisure is strong, and the initial tax rates on resources and profits are small, more environmental concern is likely to raise public consumption.

6.7 Green, pink, red and blue

To analyse whether double or even triple dividends are possible, we analyse the marginal changes in the various components of social welfare. Converting marginal welfare changes into dollars (by dividing through the marginal utility of private consumption) and expressing them as fractions of national income, we obtain:

\[
\frac{dW}{M_cY} = \frac{dM}{M_cY} + \frac{Z'dG}{M_cY} + \frac{-D'dR}{M_cY} = \left[ \eta \left( \frac{s}{1+t_L} \right) \omega_L L \right] + \left[ (1-t) \hat{R} \right]
\]

\[
+ \left[ \eta \left( \frac{t_L}{1+t_L} \right) \omega_L \hat{L} + \eta \left( \frac{t_R}{1+t_R} \right) \omega_R \hat{R} - \eta (1-t) \hat{M} \right] + \left[ -\eta \left( \frac{\omega_R}{1+t_R} \right) \hat{R} \right],
\]

where the terms in the square brackets on the right-hand side contain the pink, blue, red and green dividends, respectively. The red dividend may, alternatively, be viewed as the tax burden as measured by collected tax revenue. A decline in profit income boosts the red dividend, but deteriorates the blue component of welfare. A rise in employment raises the labour tax base and, if the tax rate on labour is positive, contributes to the red dividend. With involuntary unemployment (as measured by the virtual tax on labour due to rationing, s), a rise in employment contributes also to the pink dividend. Upon substitution of (8), (22) becomes:

\[
\frac{dW}{M_cY} = (1-t)(\eta-1) \left[ (\omega_L/\epsilon_L)\hat{L} + (\omega_R/\epsilon_R)\hat{R} - \hat{M} \right].
\]
Given \( \epsilon_R > 0 \), the resource tax exceeds the virtual pollution subsidy \((t_R > p)\) so that the distortionary component of the resource tax is positive. Since the social benefit of additional tax revenue more than offsets the social costs due to additional environmental damage, a higher level of resource use enhances welfare at the margin. Hence, cutting back pollution depresses social welfare. Similarly, given \( \epsilon_L > 0 \), the distortionary tax on labour, which amounts to the sum of explicit and virtual taxes, exceeds zero. Hence, raising employment contributes to welfare at the margin.

The left-hand side of (23) is zero, because we start from an optimal tax and expenditure system. Hence, given \( \epsilon_L, \epsilon_R > 0 \), a green dividend (i.e. \( \hat{R} < 0 \)) can occur only if either employment or profits (or both) fall. Setting the left-hand side of (22) equal to zero, we obtain an expression for the red dividend:

\[
\frac{Z/dG}{M_{cY}} = -\eta \left( \frac{s}{1 + t_L} \right) \omega_L \hat{L} + \eta \left( \frac{p}{1 + t_R} \right) \omega_R \hat{R} - (1 - \tau) \hat{F}. \tag{24}
\]

Compared to expression (16) for the case with a 100 per cent profit tax, expression (24) includes an additional term representing the change in after-tax income from the fixed factor (i.e. the last term at the right-hand side of (24)). This additional term makes a triple dividend possible in which the green, red and pink components of welfare all rise. In that case, the fixed factor (i.e. blue welfare) bears all costs of the additional social priorities (i.e. additional employment, higher public consumption, and improved environmental quality). For a triple dividend to occur, initial environmental concern must be small (i.e. \( p \) small), so that a better quality of the environment is cheap. As far as the production structure is concerned, labour must be a good substitute for resources. This ensures that the demand for labour rises, thereby providing a pink dividend. The expansion of employment contributes to a red dividend also by reducing leisure, thereby decreasing the demand for private consumption and leaving more room for the public sector.

In contrast to labour, the fixed factor should be a poor substitute for resources for a triple dividend to occur. This in order to prevent that a large drop in the demand for resources would erode the base of the resource tax. Another condition for a triple dividend to occur is that the production share of the fixed factor is large and the profit tax small so that after-tax income accruing to the fixed factor is large. Only in that case is the fixed factor able to absorb the costs associated with the additional social priorities.

If we start from an undistorted equilibrium with no involuntary unemployment \((s=0)\), no initial concern for the environment \((p=0)\), and a profit tax of less than 100 per cent \((\tau < 1)\), public consumption typically increases. The increase in the size of the public sector corresponds
to a decline in after-tax profits on account of a rise in the tax burden associated with a fall in the MCPF. Starting from a situation of widespread involuntary unemployment but only small environmental concern (i.e. large $s$ and low $p$), the government is likely to reap a triple dividend if employment rises. The reason is that the costs of additional employment are borne by the fixed factor (in the form of a higher tax rate) rather than by the government budget. If initial environmental concern is high, however, a shift towards even greener preferences is likely to reduce public consumption. Intuitively, the costs of a higher provision of the public good of the environment is borne by the other public good, i.e. public consumption.

**Proposition 4:** For a triple (green, red and pink) dividend to occur, initial environmental concern must be small. At the same time, the fixed factor must account for a large production share while the profit tax should be low. Moreover, substitution between resources and the fixed factor should be difficult. Substitution between resources and labour, in contrast, should be easy.

4 Concluding remarks

This paper has investigated various second-best claims about the impact of more ambitious environmental policies on involuntary unemployment and the costs of financing public goods. If profits are taxed away and labour and resources are cooperant factors, the labour subsidy rises while employment, output, private consumption and the private component of social welfare fall. However, if resources and labour are non-cooperant, the labour subsidy falls while employment, private consumption and private welfare rise and public consumption declines. If not all profits are taxed away, employment may rise even if resources and labour are cooperant factors of production. For employment to rise, labour must be a better substitute for resources than the fixed factor of production, the profit tax rate must be low, and the production share of the fixed factor should be large. Hence, employment rises only if it is possible to shift a large proportion of the burden of a cleaner environment to the fixed factor. However, the fall in profit income raises notional labour supply. Hence, involuntary unemployment may rise even if employment expands.

More environmental concern is associated with more public consumption if tax rates on resources and profits are low while other inputs are poor substitutes for resources in production, and consumption and leisure are good substitutes in utility. With easy substitution in utility, the fall in the cost of public funds raises tax rates substantially by inducing a large reallocation away from private consumption. With low initial tax rates and poor substitution in production, the
erosion of the base of the resource and profit taxes does not yield large adverse effects on public revenues. Consequently, revenues rise, thereby creating room for more public consumption. However, if initial tax rates are high, i.e. the public sector is large, a shift towards greener preferences is likely to depress public consumption, especially if the fixed factor is a better substitute for resources than labour. In that case, higher tax rates erode the tax base and employment is likely to fall. Income from the fixed factor typically declines, thereby depressing private consumption and private welfare. Private consumption and the private component of utility rise only if the profit tax rate is high and labour and resources are non-cooperant factors of production, e.g. if resources and labour are good substitutes for each other but not for the fixed factor.

If the initial equilibrium is characterised by much concern for the environment, additional environmental policy is expensive. Hence, a green dividend crowds out not only blue welfare but also red welfare (i.e. other public goods). If, in contrast, the initial situation features little environmental concern, a shift towards greener preferences may yield both a green and a red dividend. In that case, a triple dividend of more employment, less pollution and more public consumption at the expense of profits may emerge if labour is a better substitute for resources than the fixed factor. This may be exactly what various green left-of-centre politicians on both sides of the Atlantic have in mind. Such a triple dividend, however, requires that fixed factors play an important role in production. This is unlikely to be the case in the long run and in open economies – especially as economic integration proceeds.

References
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Appendix: Factor demand elasticities

This appendix analyses the implications of three separability conditions on the production function for the factor demand elasticities. The fixed factor, say H, has price \( p_H \). We calculate the factor demand elasticities at a given level of the fixed factor (rather than at a given level of output). Production displays constant returns to scale with respect to \( L \), \( H \) and \( R \), so that the zero-profit condition becomes:

\[
\omega_H \, \tilde{p}_H + \omega_L \, \tilde{w}_L + \omega_R \, \tilde{q}_R = 0, \quad \omega_H + \omega_L + \omega_R = 1. \tag{A1}
\]

We assume in each case a sub-production function \( Q() \) with price index \( p_Q \), which also exhibits constant returns to scale. First, consider the separable production function \( Y = F(Q(H,L),R) \). Profit maximisation yields \( Q_L/Q_H = \tilde{w}_L/\tilde{p}_H \), so (with \( H = 0 \)):

\[
\tilde{L} = L - \tilde{H} = \sigma_{LH} (\tilde{p}_H - \tilde{w}_L) \tag{A2}
\]

where \( \sigma_{LH} = \frac{\text{dlog}(L/H)}{\text{dlog}(Q_H/Q_L)} \) denotes Allen's substitution elasticity for \( H \) and \( L \) in \( Q(.) \). Using (A1) to eliminate \( \tilde{p}_H \) in (A2), we find labour demand with the following elasticities:

\[
\varepsilon_{Lq} = \sigma_{LH}(1-\omega_L)/\omega_H \geq 0 \quad \text{and} \quad \varepsilon_{Lq} = \sigma_{LQ} \omega_H/\omega_H \geq 0. \tag{A3}
\]

Homogeneity of \( Q(.) \) implies (making use of (A1)):

\[
(1-\omega_L) \, Q = \omega_L \, L \quad \text{and} \quad (1-\omega_L) \, \tilde{p}_Q = \omega_H \, \tilde{p}_H + \omega_L \, \tilde{w}_L - \omega_R \, \tilde{q}_R. \tag{A4}
\]

Profit maximisation, i.e. \( F_R/F_Q = q_R/p_Q \), yields:

\[
\tilde{R} = R - \tilde{Q} = \sigma_R (\tilde{p}_Q - \tilde{q}_R) = - \sigma_R \, \tilde{q}_R/(1-\omega_R) \tag{A5}
\]

where \( \sigma_R \) stands for Allen's substitution elasticity for \( Q \) and \( R \) in \( F(.) \). Substitution of (A3) and (A4) into (A5) yields the elasticities for the demand for natural resources:

\[
\varepsilon_{Rq} = \frac{\sigma_R + \sigma_{RH}(\omega_L/\omega_H)}{1 - \omega_R} \geq 0 \quad \text{and} \quad \varepsilon_{Rq} = \sigma_{RH}(\omega_L/\omega_H) \geq 0. \tag{A6}
\]

Hence, if labour and the fixed factor are separable from resources, labour and resources are cooperant factors of production. For this case we have \( \varepsilon_{Lq}, \varepsilon_{Rq} = \sigma_{LH} \geq 0 \), \( \varepsilon_{Lq}, \varepsilon_{Lq} = (\sigma_{LQ} \omega_H \sigma_{LH})/(1-\omega_L) \), \( \varepsilon_R = \sigma_R/\omega_H \geq 0 \), and \( \varepsilon_L = \sigma_{LH}(1-\omega_L)/[\omega_H (\sigma_R \omega_H \sigma_{LH})] \).

Second, if resources and the fixed factor are separable from labour, i.e. \( Y = F(Q(R,H),L) \), labour and resources are cooperant factors as well. The expressions for the factor demand elasticities are \( \varepsilon_{Lq} = (\sigma_L + \sigma_{RH}(\omega_L/\omega_H))/(1-\omega_L) \), \( \varepsilon_{Lq} = \sigma_{RH}(\omega_L/\omega_H) \geq 0 \), \( \varepsilon_{Rq} = \sigma_{RH}(1-\omega_L)/\omega_H \) and \( \varepsilon_{Rq} = \sigma_{RH} \omega_H/\omega_H \geq 0 \). Hence, for this case we have \( \varepsilon_L = \sigma_L/\omega_H \geq 0 \), \( \varepsilon_{Lq}, \varepsilon_{Lq} = \sigma_{RH} \geq 0 \), \( \varepsilon_{Rq} = (\sigma_L \omega_L \sigma_{RH})/(1-\omega_L) \) and
$$\epsilon_r = \sigma_{RH}(1-\omega_r)/[\omega_r(\sigma_L \omega_L \sigma_{RH})]$$, where \(\sigma_L\) stands for Allen's substitution elasticity for Q and L in F(.).

Finally, consider the case in which labour and resources are separable from the fixed factor, i.e. \(Y = F(Q(L,R), H)\). A similar procedure yields the labour demand elasticities

$$\epsilon_L = \left[ \frac{\sigma_H}{\omega_H} \right] \left[ \frac{1}{\omega_L + \omega_R} \right] > 0, \quad \epsilon_{L4} = \left[ \frac{\sigma_H}{\omega_H} - \frac{\sigma_{LR}}{\omega_L + \omega_R} \right]$$

and the resource demand elasticities

$$\epsilon_R = \left[ \frac{\sigma_H}{\omega_H} + \frac{\sigma_{LR}}{\omega_L} \right] \left[ \frac{1}{\omega_L + \omega_R} \right] > 0, \quad \epsilon_{R4} = \left[ \frac{\sigma_L}{\omega_L} \right] \epsilon_{L4}$$

where \(\sigma_{RH}\) stands for Allen's substitution elasticity for Q and H in F(.), and \(\sigma_{LR}\) for the elasticity of substitution associated with L and R in Q(.). The condition for L and R to be non-cooperant factors of production is that \(\sigma_{RH}\) is large while \(\sigma_{LR}\) and the share of the fixed factor in production (\(\omega_R\)) are small. Conversely, the condition for labour and resources to be non-cooperant factors is that \(\sigma_{LR}\) and the share of the fixed factor in production are large while \(\sigma_{RH}\) is small. In general, we have \(\epsilon_L \cdot \epsilon_{L4} - \epsilon_R = \epsilon_{R4} \leq 0\). Since \(\epsilon_L = \epsilon_L = \sigma_L / \omega_L\), the taxes on factors of production must satisfy \((t_L - p)/(1 + t_L) = (t_R - s)/(1 + t_R)\) (see (8) and (9)).

The special case of a Cobb-Douglas production function, i.e. \(Q(L,R) = L^\eta R^\xi\), gives \(\epsilon_L = (1-\omega_L)/\omega_L, \epsilon_{L4} = (1-\omega_L)/\omega_L, \epsilon_R = (1-\omega_L)/\omega_L, \epsilon_{R4} = (1-\omega_L)/\omega_L\) so that \(\epsilon_L \cdot \epsilon_R = \epsilon_{L4} \cdot \epsilon_{R4} = 1\).

Summarising, we find three cases in which \(\epsilon_L\) and \(\epsilon_R\) in (8) are constant:

(i) No substitution between labour and the fixed factor and these factors are separable from resources. Hence, \(\sigma_{RH} = 0\) and thus \(\epsilon_L = \epsilon_{L4} = 0\) so that \(\epsilon_L = 0, \tau_L = p\) and \(\eta = 1\) in (8) and (9). Since substitution between the fixed factor and labour is impossible, the government cannot do anything about the labour market distortion. Hence, the labour tax \(t_L\) simply adjusts to raise the required amount of public revenue. In fact, as employment is fixed, the labour tax can be shifted towards profits. Hence, the labour tax can raise public revenue without any excess burden. Consequently, the MCPF is unity.

(ii) No substitution between resources and the fixed factor and these factors are separable from labour in production. Hence, \(\sigma_{RH} = 0\) and thus \(\epsilon_R = \epsilon_{R4} = 0\) so that \(\epsilon_R = 0, \tau_R = s\) and \(\eta = 1\) in (8) and (9). There is thus a labour subsidy while the MCPF is unity. In this case, the resource tax rather than the labour tax adjusts to raise the required amount of public revenue. The resource tax can thus not be adjusted to fight pollution. There is no welfare cost associated with using the resource tax to raise revenue, since the use of resources is inelastic and the burden of taxation is entirely borne by profits.

(iii) Production is separable in labour and resources on the one hand and the fixed factor on the other hand and, furthermore, the elasticity of substitution between the fixed factor and the labour-resource composite is unity (i.e. \(\sigma_{RH} = 1\)). This implies that \(\epsilon_L = \epsilon_R = 1/\omega_H\) with \(\omega_H\) constant.
Figure 1: Rationing in the labour market

Note: The virtual tax on labour due to rationing of labour supply, $s = (w - w')/w\eta$, causes involuntary unemployment, $U$.

Figure 2: Private consumption and the optimal tax rate

Note: If the demand for labour does not depend on the cost of resources (i.e. $\epsilon_{t\eta} = 0$) and not all profits are taxed away, an increase in environmental concern shifts $E$ to $E'$, thereby reducing the tax rate on labour, expanding employment and depressing private consumption.
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<tr>
<th>Resource tax ($t_R$)</th>
<th>$\rho + (1-\tau)(\omega_L/\omega_C) + \kappa e_{Lw} &gt; 0$</th>
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<tr>
<td>Labour tax ($t_L$)</td>
<td>$[\kappa e_LQ + (1-\tau)\omega_R/\omega_C]$</td>
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<tr>
<td>MCPF ($\eta$)</td>
<td>$[\kappa e_LQ + (1-\tau)\omega_R/\omega_C] \rho(1-\alpha)/\sigma$</td>
</tr>
<tr>
<td>Employment ($\bar{L}$)</td>
<td>$-\rho e_{LQ} + (e_{Lw} - e_{Rw})(1-\tau)\omega_R/\omega_C$</td>
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<tr>
<td>Profits ($C(1-\tau)\Pi$)</td>
<td>$- (1-\tau) [\rho + \kappa (e_{Lw} - e_{Rw})] \omega_R \leq 0$</td>
</tr>
<tr>
<td>Private consumption ($\omega_C \bar{C}$)</td>
<td>$-\rho[\omega_L/(1 + t_L)] e_{LQ} + (1-\tau)\omega_R (e_{Lw} - e_{Rw})(1-\tau)\omega_R [L/(N-L)]$</td>
</tr>
<tr>
<td>Private utility ($\omega_C \bar{M}/\alpha$)</td>
<td>$-\rho[\omega_L/(1 + t_L)] e_{LQ} \eta + (1-\tau)\omega_R [(L/(N-L)) + (1-\tau)\omega_L/(1 + t_L)]$</td>
</tr>
<tr>
<td>Public consumption ($\omega_C \bar{G}$)</td>
<td>$\rho[\omega_R(1-\tau) - (t_R/L)] e_{LQ} - (1-\tau)\omega_R [(L/(N-L)) + (1-\tau)\omega_L]$</td>
</tr>
<tr>
<td>Pollution ($\bar{D} = \bar{R}$)</td>
<td>$-\rho e_{RQ} - \kappa (e_{Lw} e_{RQ} e_{LQ} e_{Rw}) - (e_{Rw}/(1-\tau)(\omega_L/(1 + t_L)\omega_C)$</td>
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**Note:** Logarithmic deviations in endogenous variables are entries shown times $p\bar{y}_E/\Delta^*$.  

**Key:**  
$\Delta^* = \rho + (1-\tau)[(\omega_L + \omega_R\chi)/\omega_C] + \kappa (e_{Lw} + \chi e_{Lw}) > 0$  
$\kappa = [L/(N-L)] + [\omega_L/(1 + t_L)\omega_C] > 0$  
$\rho = \sigma e/[((1-\alpha) + (1 + t_L + e\eta) + e(w'/w)] > 0$  
$\chi = [(e_{Lw} - e_{Rw})/(e_{Rw} - e_{Lw})] (1 + t_R)/(1-\alpha) [(1-\alpha)(1 + t_L + e\eta) + e(w'/w)] \geq 0$  
$\epsilon = [(e_{Lw} e_{RQ} e_{LQ} e_{Rw})/(e_{Rw} e_{LQ})]/(1-\tau) \geq 0$  
if we assume $e_{Lw} \geq e_{Rw}$ and $e_{Rw} \geq e_{LQ}$.
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