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ASSESSING THE DOUBLE DIVIDEND HYPOTHESIS IN GENERAL EQUILIBRIUM FRAMEWORK - IS THERE A CHANCE AFTER ALL?

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Abstract: The paper presents small scale CGE models designed to analyze the double dividend problem i.e. the simultaneous improvement of efficiency and environment through a revenue neutral tax reform. We show that in a one factor model with leisure weakly separable from consumption, a double dividend in welfare sense may arise only if the Laffer curve is downward sloping. However, backward bending labor supply is sufficient for both employment and environment to improve. Introducing an additional primary input considerably widens the scope for a double dividend by allowing for the possibility of environmental tax to shift the tax burden on the relatively undertaxed factor. In an open economy the optimal division of tax burden depends on the relative mobility of the primary factors. We show that with pollution related to final consumption, a double dividend is likely to arise only if capital is relatively immobile. However, with pollution related to an imported production input, capital mobility increases the likehood of a double dividend.

Keywords: double dividend, environmental taxes, CGE modeling.

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Tiivistelmä: Keskustelualoitteessa esitetään yksinkertaisia, numeerisesti ratkaistavia yleisen tasapainon malleja, jotka soveltuvat ns. tuplapottihypoteesin analysointiin. Tuplapottihypoteesin mukaan verojärjestelmän painopistettä muuttamalla voitaisiin saavuttaa samanaikaisesti tehokkuushyötyjä ja ympäristön laadun paraneminen julkisten menojen tasoa alentamatta. Simuloinnit osoittavat, että yhden panoksen mallissa, jossa vapaa-aika on kulutuksen suhteen heikosti separoituva, tuplapotti voidaan saavuttaa vain Lafferin käyrän alaspäin kääntyvällä osalla. Työllisyyden ja ympäristön laadun paranemiseen riittää, että työn tarjontakäyrä on taaksepäin kallistuva. Kahden panoksen mallissa tuplapotin mahdollisuus kasvaa, koska ympäristöperusteinen verouudistus voi siirtää verotaakkaa "liian lievästi" verotetulle panokselle. Avotalouden mallissa verotaakan optimaalinen jakautuminen riippuu panosten suhteellisesta liikkuvuudesta. Simuloinneissa osoitetaan, että ympäristövaikutusten liittyessä lopputuotteisiin tuplapotti voidaan saavuttaa vain, jos pääoma on suhteellisen liikkumatonta. Ympäristövaikutusten liittyessä tuontipanokseen pääoman liikkuvuus sitävastoin kasvattaa tuplapotin mahdollisuutta.

Asiasanat: tuplapottihypoteesi, ympäristöverot, numeeriset yleisen tasapainon mallit.

Contents

1. Introduction

The recent discussion on fiscal systems has stressed the role of environmental taxes as preferable instruments to raise revenues in the presence of other distortionary taxes. In particular, environmental taxes have been considered desirable substitutes for labor taxes. Such a shift in the tax mix is hoped to simultaneously reduce pollution and increase non-environmental welfare (or employment) and thus create a "double dividend" (e.g. European Economy, 1994). The story is particularly appealing to policy makers, since it would justify an increase in environmental taxes even in the cases where the environmental benefits cannot be guaranteed.

The debate has given rise to a number of studies elaborating the theoretical underpinnings of the double dividend (for a survey see Goulder, 1994). Most of the effort has concentrated on the derivation of first and second best optimal tax rules and on the comparative statics of the optimal tax equilibrium facing a shock in the environmental preferences (e.g. Bovenberg and van der Ploeg, 1994a). The general message of this work is scepticism about the double dividend: In the presence of pre-existing distortionary taxes, the optimal pollution tax typically lies below the Pigovian tax (Bovenberg & Mooij,1994). Greener preferences typically result in capital flight and employment declines (Bovenberg & van der Ploeg, 1994b). Though valuable as such, we find that this approach to some extent miss the point of the issue: how likely it is to achieve a double dividend through reforming the prevailing tax systems?

The question clearly falls into the category of problems tackled in tax reform literature (see e.g. Feldstein, 1976). Allowing for the limitations of real world tax design this literature examines the effects on welfare of changes in the tax rates such that global tax optimum is not necessary achieved. For some reason, the tax reform approach has to large extent been neglected or left unnoticed in the recent papers on the double dividend hypothesis (DDH hereafter). In this paper we analyse the DDH from the tax reform point of view.

In the light of the tax reform results, the likelihood of a double dividend to rise in real economies remains an empirical question. A possible way to address the issue is to build an applied model suitable for simulating the effects of change in the tax mix in favour of environmental taxes. In such a model, the possibility of a double dividend depends among others on the structure of current tax system, the incidence of the environmental tax and specification of the foreign trade.

This paper presents a series of small scale CGE-models suitable for analysing the DDH. Section 2 reviews key results of the tax reform literature and suggests some projections for the DDH . Section 3 presents the simplest possible specification with labor as the single input and two categories of consumption goods produced, the other one bearing an inverse environmental externality. Section 4 extends the model with another primary input and shows that possibility of the double dividend is then widened. An open economy version with product differentiation is specified to assess the role of factor mobility. In section 5 the open economy model is modified to allow for pollution arising from the use of an imported input. The stylized social accounting matrices used in the models are presented in the Appendix.

2. DDH and the Theory of Tax Reform

The double dividend problem clearly falls into the category of problems tackled in tax reform literature (see e.g. Feldstein, 1976). Allowing for the limitations of real world tax policies this literature examines the effects on welfare of changes in the tax rates such that global tax optimum is not necessary achieved. For some reason, the tax reform approach has to large extent been neglected or left unnoticed in the recent papers on the DDH (e.g. the articles by Bovenberg and his associates). Much of the work around the DDH has concentrated on the derivation of first and second best optimal tax rules and on the comparative statics of the optimal tax equilibrium faced with a shock in the environmental preferences (e.g. Bovenberg and van der Ploeg, 1994). These approaches, though interesting as such, to some extent miss the point of the DDH problem that is strongly policy orientated and originates from the need for realignments in the existing tax systems.

In what follows we apply the tax reform approach to the DDH problem. We first characterise the DDH problem by decomposing the welfare effects involved. Then we review some of the key results from the tax reform theory and derive implications for the current problem.

2.1 Key Features of the DDH

The special feature of the double dividend problem is that we are not only interested in the overall welfare but require that in addition to the environmental benefits also non-environmental efficiency gains arise. In other words, improvement of welfare after a change in the tax structure will not qualify for a double dividend if it is solely due to improved environment and comes at the cost of reduced efficiency in non-environmental terms. This is the case even if the environmental benefits more than offset the efficiency losses.

To tackle the DDH it is helpful to assume preferences being at least weakly separable between environmental quality and "private goods", the latter referring to leisure and consumption goods. This assumption, not that implausible at the aggregate level, allows us to evaluate the changes in the two components of the perceived utility separately. We note that in terms of welfare effects a revenue neutral change in the tax mix may result in one of six possible outcomes listed in table 1.

Table 1: Possible welfare outcomes of a revenue neutral change in the tax mix.

	A	B	C	D	E	F
overall welfare	-	-	-	+	+	+
environmental	-	-	+	-	+	+
non-environmental	-	+	-	+	-	+

From the possible outcomes only case F qualifies for a double dividend. The sceptical views presented in the previous work on the DDH suggest cases C and E being the likely outcomes of a "green tax reform": selective environmental taxes tend to fall on a narrow base and thus come at the cost of growing inefficiency of the tax system. In case C these inefficiencies dominate and overall welfare decreases. Cases A,B and D are left outside the analysis of the DDH since it is usually assumed that the an increase in the environmental taxes has non-negative effect on the environmental quality. This, however, does not mean that they would not be plausible outcomes in real world tax reforms. In particular, case D would be the outcome if the increased efficiency of the tax system would stimulate private demand (e.g. through increased labor supply) to the extent that a positive income effect would dominate the demand for the polluting good and its consumption would increase despite of the increased price. Consequently, environmental quality would decline and only the "second dividend" would arise.

2.2 Some Results from Theory of Tax Reform

A possible reason for the lack of reference to the theory of the tax reform is that in this difficult field of study, only few general results can be found. However, those few are worth reviewing in this context. The key finding of the tax reform theory is that partial reforms of the tax system towards the optimal system do not necessarily improve welfare. In other words, even if we are able to derive the optimal tax structure, we cannot say much about the desirability of a change in the prevailing tax rates falling short of the full optimum. This reflects the fact that starting from an arbitrary equilibrium, the path to the optimal tax equilibrium is not generally characterised by monotone increases in welfare. (Note that the uncertainty works also to the opposite direction: a shift in the tax structure away from the optimum may in fact increase welfare.)

Following Atkinson and Stiglitz (1980) and Auerbach (1985) we note that the relevant cases of tax reforms can be classified in two dimensions depending on the starting point and the available tax instruments. The starting point may be either the second best optimal tax equilibrium or some arbitrary tax equilibrium. As for the tax instruments, we may assume the availability of lump sum taxes or more realistically, confine ourselves to distortionary taxes only.

Atkinson and Stern (1974) have shown that starting from the second best optimum, welfare will improve if distortionary taxes are partially replaced by lump sum taxes so that the remaining distortionary taxes are set at the optimal levels for collecting the revenue exceeding that of the lump sum taxes. Otherwise, partial substitution of lump sum for distortionary taxes is not guaranteed to improve welfare. If we exclude the availability of lump sum taxes improving welfare through a change in the tax structure becomes impossible by definition.

Leaving behind the second best optimal tax equilibrium we are left with even less rules to judge the welfare effects of a change in the tax mix. Whether or not lump sum taxes are available, the most we can do is to derive the sufficient conditions for welfare improvement as is done by Dixit (1975) and Dixit and Munk (1977). However, failure to satisfy these rather specific conditions does not exclude the possibility of an improvement.

2.3 Tax Reform and the Second Best Optimum

To apply the above results in the DDH framework, consider the following model. We assume preferences separable between environmental quality and private goods so that the level of the former does not affect the choice between the latter. Individuals can then be thought to maximize utility

$$U = u(z, h(x)) \tag{2.1}$$

where z denotes environmental quality, x is a vector of consumption goods including leisure and h is a homothetic subutility function. The private budget constraint is

$$px^{*} = T \tag{2.2}$$

where x* is a vector of net purchases of consumption goods, p is the vector of consumer prices and T is a lump sum transfer from the government. We assume there is a negative environmental externality related to the consumption of one of the goods such that

$$z = z(x_k^{*}) \quad , dz/dx_k^{*} < 0 \tag{2.3}$$

As usually we assume, that a representative consumer neglects the effect of her/his consumption of x_k , the polluting good, on the environment.

Now the second best optimal tax problem of the government is to collect a given revenue (here equal to T) with distortionary taxes so as to maximize the welfare of the representative consumer. Following Sandmo's (1975) original exposition Auerbach (1985) derives the optimal tax structure in such a setting. As long as producer prices are constant or the technology exhibits constant returns to scale the optimal tax structure is characterized by

$$-\lambda x_i + u_z(dz/dp_i) + \mu[x_i + \Sigma_j t_j(dx_j/dp_i)] = 0 \tag{2.4}$$

which can be solved for the tax rates t_j (in terms of the elasticities) by choosing one of the goods untaxed without loss of generality.

First consider the case where environmental concern is not allowed for. The government problem reduces to maximize subutility h from which u is a monotone transform. The optimal tax rates in such a situation is found by setting $u_z = 0$ in (2.4) which then reduces to the solution of the classic optimal tax problem of Ramsay. Then consider the case where $u_z > 0$, but we want to maximize the non-environmental component of private welfare. Clearly, due to the separability assumption government can choose h as its maximand. Since we assume the ignorance of the environmental consequences of consumption decisions by the individuals, the private response remains unaltered. Consequently, the tax rates to maximize non-environmental efficiency are the same as in the case where environmental effects are not considered at all. This principle can be stated in the form of the following proposition:

Proposition 1: With preferences separable between environmental quality and other private demand aggregates, a necessary condition for achieving a double dividend through a revenue neutral change in the distortionary taxes is that the initial equilibrium is suboptimal when environmental concern is not allowed for.

What can we conclude on the basis of the above proposition? Facing a potential case for a double dividend we should solve the Ramsay problem with no reference to the environment and determine whether the existing tax system is optimal in that respect. If this were the case, we could throw the hope for a double dividend. With exception to this rather unlikely case, in all other cases we could not exclude the possibility of a double dividend without further evidence against it. Consequently, in most cases a more detaile analysis is required.

2.4 Tax Reform with Arbitrary Initial Equilibrium

To take a closer look at the case with an arbitrary initial tax equilibrium and no access to lump sum taxes, we first solve the consumer problem defined by (2.1) - (2.2). This gives rise to an indirect utility function

$$U = v(p, z, T) \qquad (2.5)$$

which gives the maximum attainable utility of the consumer as a function of consumer prices, environmental quality and government transfer.

Total differentation of (2.5) yields

$$dU = \Sigma_i (dv/dp_i)dp_i + (dv/dz)dz + (dv/dT)dT \qquad (2.6)$$

where the terms in brackets denote partial derivatives of the indirect utility. Assuming fixed producer prices and invoking the envelope theorem we get an expression for the change in utility after a revenue neutral change (dT=0) in the tax rates t_i.

$$dU = -\lambda\, \Sigma_i\, q_i x_i dt_i + u_z z_k \Sigma_i (dx_k/dt_i)dt_i \qquad (2.7)$$

where λ refers to the marginal utility of income, q is producer price, u_z is the marginal utility of environmental quality and z_k is the marginal damage to environment caused by consumption of the polluting good x_k. The government budget constraint can be written as

$$\Sigma\, t_i q_i x_i = T \qquad (2.8)$$

which by total differentation and after some manipulation gives the balanced budget condition dT=0 as

$$\Sigma_i\, [q_i x_i + \Sigma_j\, t_j q_j (dx_j/dt_i)]dti = 0 \qquad (2.9)$$

Now consider a tax reform increasing the tax on the polluting good x_k and decreasing the tax on labor supply, say x_l , such that the total tax revenue remains unaltered. We can think of (2.7) as decomposing the welfare effects of such a reform into two components: the first term on the right hand side represent the change in the non-environmental welfare and the second term the environmental benefits. The effect on the overall welfare is a weighted sum of the two terms with marginal utilities of income and environment as the corresponding weights. Taking derivative of (2.7) with respect to t_k yields

$$dV/dt_k = -\lambda(q_k x_k + q_l x_l(dt_l/dt_k)) + u_z z_k[(dx_k/dt_k) + (dx_k/dt_l)(dt_l/dt_k)] \qquad (2.10)$$

where dt_l/dt_k refers to the change in t_l induced by the balanced budget requirement and can found from (2.9) by setting the changes in other taxes to zero. This gives

$$dt_l/dt_k = -(q_k x_k/q_l x_l)\frac{\Omega_k}{\Omega_l} \qquad (2.11)$$

where

$$\Omega_i = 1 + \frac{\sum_j t_j q_j (dx_j/dt_i)}{q_i x_i} \qquad (2.12)$$

Substituting (2.11) for dt_l/dt_k in (2.10) we find that the condition for the non-environmental term to be positive is that

$$\Omega_k \geq \Omega_l \qquad (2.13)$$

where we have used the fact that both sides of (2.13) have to be positive.[1] From (2.8) we note that

$$\Omega_i = (dT/dt_i)/q_i x_i \qquad (2.14)$$

Thus the terms in (2.13) can be expressed as a power the tax base of the ith tax and the change in overall revenue caused by a change in the ith tax. This is the variable to consider if one wants to find out whether a revenue neutral shift in the (nominal) tax burden increases non-environmental welfare. Assuming uniform inintital distortion, i.e. $t_i = t$ for all i, it can be shown that the value of the r.h.s. of (2.14) is inversely related to the compensated cross-price elasticity between the ith good and the untaxed good, ε_{i0}. Then (2.13) can be written

$$\varepsilon_{k0} < \varepsilon_{l0} \qquad (2.15)$$

Which is the result originally derived by Corlett and Hague and generalized to cover multiple goods by Dixit (1975). This result, though appealing in its simplicity, is of little help in analysing real tax reforms. It is rather unlikely that all the tax rates would be proportional in the pre-reform equilibrium. In the more general case of arbitrary initial distortions (2.13) still holds but does not allow an expression anything as neat as (2.15). Instead we get

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1 To see this note that omega(i)$q_i x_i = dT/dt_i$. By assuming omega(i) positive we exclude the possibility that increasing one tax alone would reduce tax revenue. This amounts to being on the upward sloping part of the "Laffer curve".

$\Sigma_j \tau_j \varepsilon_{kj} > \Sigma_j \tau_j \varepsilon_{lj}$ (2.16)

where $\tau_j = t_j/(1+t_j)$ and ε_{ij} denote the compensated cross-price elasticities. Note that the number of terms in both sides of (2.16) is equal to the number of taxed goods. As in our exercise only two tax rates are changed, condition (2.16) is both sufficient and necessary for improved welfare in non-environmental terms.

Proposition 2: With fixed producer prices and no environmental concern a revenue neutral change in the tax mix will improve welfare if and only if the sum of compensated cross-price elasticities weighted by the corresponding tax rates is higher for the good whose tax is increased.

This result is a generalization of the Corlett and Hague & Dixit result and applies to infinitesimal changes in the tax rates.

Now turning to the environmental effects, the condition for the second term in (2.10) to be positive is

$-dx_k/dt_k \geq (dx_k/dt_l)(dt_l/dt_k)$ (2.17)

Condition (2.17) reflects the fact that as long as higher taxation of labor supply reduces demand for the polluting good, the labor tax is in fact also an environmental tax and reducing it causes (gross) environmental harm. What (2.17) is saying is that the reduction in pollution caused by increased tax on the polluting good must be larger than the increase in pollution due to a lower labor tax. It should be noted that the first derivative on the l.h.s. of (2.17) is partial in the sense that the indirect effect through t_l is not allowed for. Condition (2.17) may be in terms of elasticities as follows:

$\varepsilon_{kk} \leq \frac{p_k x_k \Omega_k}{p_l x_l \Omega_l} \varepsilon_{kl}$ (2.18)

where ε_{ij} denote uncompensated cross-price elasticity. We note that (2.13) does not guarantee fulfilment of (2.18) and thus increased efficiency does not necessarily implicate environmental benefits. As already noted above, it is common the DDH literature to abstract from the possibility that environmental quality would actually decline after the reform. The implication of such an assumption is given by (2.18). It may be relevant in a theoretical setting to confine oneself in cases where (2.18) holds. However, in assessing the possibility of a double dividend to rise in real economies one surely has to allow for the possibility of failure to achieve the "first dividend" as well as the second.

The analysis presented in this section, though quite heavy in notation, is subject to a number of simplifying assumptions. First, we assume the separability of preferences between environmental and non-environmental goods. This assumption is necessary if we want to judge the two "dividends" referred to in the double dividend problem. But releasing it may affect the results in terms of overall welfare. Separability implies that the level of environmental quality does not affect the choice between private goods, which simplifies the results presented. Second, and more importantly, we have assumed fixed producer prices and thus ignore the general equilibrium effects working through the supply side of the economy. Allowing for these generalizations would make the analytical approach unwieldy. This is why we suggest an alternative approach which will be applied in the rest of thje paper. In the next section we develop computable general equilibrium model (CGE model hereafter) suitable for analysing the problem in a more flexible framework. The strenght of this type of models is that they are theoretically consistent but also easily applicaple to empirical work.

3. Single Input Model with Polluting Output

3.1 Structure of the Model

We now develop a framework suitable for deriving some simulation results of the DDH problem discussed in the previous section. In purpose to relax the assumption of fixed producer prices and to analyse some specific cases we parametrise the model presented in section 2 as follows. To keep the exercise tractable, we assume the commodity space consisting of leisure and two consumption goods, one of which creates an environmental externality. If utility is presented by nested constant elasticity of substitution function, (2.1) takes the form

$$u = [\alpha Z^{\rho} + (1-\alpha)h^{\rho}]^{1/\rho}$$

$$h = [\beta V^{\varsigma} + (1-\beta)x^{\varsigma}]^{1/\varsigma}$$

$$x = [\gamma C^{\vartheta} + (1-\gamma)D^{\vartheta}]^{1/\vartheta} \qquad (3.1)$$

where Z is the environmental quality, V is leisure, C is the "clean" consumption good and D the polluting good.

We assume that tax revenue is fully used to finance public expenditure and thus no transfers to consumers arise. Thus (2.2) takes the form

$$C + (1+t_d)q_d D = (1-t_l)q_l L \qquad (3.2)$$

Correspondingly, the government budget becomes

$$p_g G = t_d q_d D + t_l q_l L \qquad (3.3)$$

where G is the exogenously given level of public expenditure and p_g is the supply price of public output. The effect of polluting good on environment is assumed to take the form

$$Z = Z_0 - \eta D \qquad (3.4)$$

where Z_0 is the initial level of environmental quality and η is the marginal damage to environment.

To start with, we specify the production side simply as follows

$$X_i = \omega_i L_i^{\phi_i} \qquad (3.5)$$

where X_i is the output of consumption good for i=C,D and public good for i=G and L_i the corresponding labor input so that $\Sigma L_i = L$. Assuming constant returns implies $\phi_i = 1$ for all i. We normalise units so that also ω_i equals unity to all goods.

Assuming utility maximization by consumers and profit maximization by producers under perfect competition gives rise to the conventional demand and supply schedules. Then (3.1)-(3.5) augmented with the derived demand and supply equations form a general equilibrium model that can be parametrized and solved numerically.[1]

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[1] The model is implemented and solved using GAMS/MPSGE programming package that allows speci-

3.2 Simulation Results with Separable Consumption

Next, we want to consider the effects of a non-infinitesimal increase in the tax on the polluting good compensated through a reduction in labor tax leaving real government expenditure (G) intact. For that purpose we construct a stylistic benchmark equilibrium satisfying the above equations and then solve numerically for the counterfactual equilibrium. To start with, we assume that initial equilibrium has positive tax rate only on labor supply.

It can be shown, that with the specified structure of preferences equation (2.4) suggests a uniform tax on consumption goods when environmental concern is not allowed for (see e.g. Auerbach, 1985). Given the formulation of the model a uniform tax on consumption goods is just equivalent to a tax on labor supply, so the initial equilibrium represent the second best tax optimum. This prediction is indeed confirmed in simulations with elasticity of substitution between leisure and consumption set at unity. The simulations show a drop in non-environmental welfare after the revenue neutral introduction of a tax on the polluting good. Although the overall welfare increases after such a reform, the efficiency of the tax system in non-environmental terms deteriorates and no double dividend rises. The real wage drops, but employment stays unaltered due to inelastic supply. These effects are reflected in the first column of Table 3.1. The first four columns of the table show simulations results with different elasticity parameter values between leisure and consumption with all other substitution elasticities set to unity. Thus, the first column corresponds to a "Cobb-Douglas" economy that we find a useful point of reference.

The above findings, however, turn out to be sensitive to the value of the elasticity of substitution between consumption and leisure, $\sigma = 1/(1-\varsigma)$. With $\sigma < 1$ employment expands reflecting the dominance of the income effect over the substitution effect in labor supply. The labor supply curve bends backward and a drop in the real wage caused by the tax reform leads to increased supply of labor. The overall welfare increases due to reduced consumption of the polluting good, but non-environmental efficiency declines. This outcome is reflected in the results of second column of Table 3.1, where the elasticity parameter is reduced to 0.5.

With $\sigma > 1$ labor supply curve slopes upward and the real wage drop leads to reduction in employment. In welfare terms, results are similar to those above as can be seen from the third column of Table 3.1 with elasticity parameter set to 1.5. As σ is increased even further to exceed a critical value, the simulations show an increase in the real wage and labor supply. In this case not only environmental quality but also non-environmental efficiency improve. We clearly gain a double dividend. This can be seen from the fourth column of Table 3.1 where the elasticity parameter is increased to 5.

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fying the model without explicit derivation of the first order conditions (see Rutherford ,1993).

The results warrant a few comments. First, looking at the case with elasticity values lower than one, we note that though efficiency declines, employment expands. Thus we record a "double dividend" in environmental and employment sense.

Second, explanation to the at first sight contradictory result for elasticity values above some critical value[2] is given by the "Laffer curve" (see e.g. Cullis and Jones,1992). With the given initial tax rate on labor, the benchmark equilibrium lies on the downward sloping part of the Laffer curve. Then an increase in t_d facilitates a large drop in t_l without reduction in the total revenue. Such a reform indeed represent an improvement relative to the initial tax system. However, it does not contradict the optimality result quoted above, since efficiency could be further improved by setting t_d to zero and increasing t_l slightly to preserve the revenue.

The above results are in line with those presented by Bovenberg and de Mooij (1994). However, they restrict their analysis to the case where σ lies between unity and the critical value. The authors find that employment decline and no double dividend can be achieved in such a setting. Our exercise extends the scope of their analysis allowing for a wider range of parameter values. We conclude the following: With preferences weakly separable between consumption and leisure, revenue neutral introduction of a selective tax on the polluting good improves employment if labor supply is backward bending or the Laffer curve slopes downward. Efficiency may improve and a double dividend rise if and only if the Laffer curve slopes downward.

3.3 Simulation Results with Non-separable Consumption

Above we have assumed preferences such that the demand for consumption goods is weakly separable from the demand for leisure. We next specify a model where this no longer holds by assuming the following utility schedule

$$u = [\alpha Z^{\rho} + (1-\alpha)h^{\rho}]^{1/\rho}$$

$$h = [\delta C^{\varsigma} + (1-\delta)x^{\varsigma}]^{1/\varsigma}$$

$$x = [\varepsilon V^{\vartheta} + (1-\varepsilon)D^{\vartheta}]^{1/\vartheta} \qquad (3.6)$$

where leisure V and the polluting consumption appear in the same subnest. As an example of such a structure could be car-driving and spare time forming a composite leisure expenditure group. As for the elasticities, ς now measures the elasticity of substitution between leisure composite and the rest of consumption, whereas ϑ reflects the corresponding elasticity within leisure group.

Allowing for such a structure of preferences changes the effects of revenue neural tax mix change quite dramatically. As the theory of optimal taxation would now suggest a uniform tax on leisure and the polluting good, it is clear that the initial equilibrium with tax on labor supply no longer represent the second best optimum.

[2] Using the Laffer relation the critical value can be shown to equal $1+(1/s_v)(1-t_l)/t_l$, where s_v is the share of leisure in total expenditure and t_l is the tax rate on labor defined on gross basis. With the current specification the critical value amounts to 4.3.

Simulating the introduction of selective tax on polluting consumption compensated with equal revenue reduction in labor tax we find that with quite plausible elasticity values a double dividend may arise. For example, with the elasticity of substitution between the leisure composite and the rest of consumption equal to 1.5 and the elasticity within leisure group equal to unity, labor supply expands, demand for polluting good drops and non-environmental efficiency improve. Results from such a simulation are presented in the final column (1.5 ns) of Table 3.1 . With the reverse order of elasticity values, however, labor supply declines and so does efficiency. This reflects the fact that as elasticity of substitution between leisure composite and consumption becomes higher relative to elasticity between leisure and polluting good, increase in the price of the polluting good tend to induce increased demand for non-polluting consumption rather than leisure. By these findings we conclude, that the possibility of a double dividend is considerably increased as we relax the assumption of separability between leisure and consumption.

Table 3.1 : Effects of a revenue neutral environmental tax reform on selected variables in an economy with polluting domestic output. All entries except the tax rates are per cent changes from the base level.

	leisure/consumption elasticity of substitution				
	1	**0.5**	**1.5**	**5**	**1.5 (ns)**
tax rates					
polluting good	0.050	0.050	0.050	0.050	0.05
labor	0.488	0.487	0.488	0.485	0.485
output					
non-polluting	0.84	0.85	0.83	1.17	1.50
polluting	-4.20	-4.19	-4.21	-3.88	-4.26
employment					
labor	0.00	0.005	-0.006	0.22	0.35
environment index	4.2	4.2	4.2	3.9	4.3
efficiency index	-0.007	-0.006	-0.008	0.03	0.06

4. The Numerical Model with Two Primary Factors

4.1 Closed Economy with Capital Input

The numerical model specified in the previous section represented the simplest possible setting for analysing the DDH. The tractability and transparency of such a specification comes at the cost of a number of imposed restrictions. In particular, the single factor assumption together with constant returns to scale in effect fixes the relative producer prices and thus excludes a potentially significant channel of general equilibrium effects. To allow for more flexibility in producer prices we now specify a model with another primary input, capital. With this formulation we also capture the most common structure of empirically implemented CGE-models and may analyze e.g. questions related to the international mobility of factors. At the same time, we have less straightforward results of optimal tax theory to be used as a benchmark of the analysis.

Assuming first that all capital is held by the domestic households we redefine the equations of the model presented in section 3 as follows: Household budget constraint (3.2) now becomes

$$C + (1 + t_d)q_d D = (1 - t_l)q_l L + (1 - t_k)q_k K \qquad (4.1)$$

Where K is the capital stock, q_k and t_k are the producer price and tax rate on capital. The government budget (3.3) is replaced by

$$p_g G = t_d q_d D + t_l q_l L + t_k q_k K \qquad (4.2)$$

The production activities (3.5) are now described by

$$X_i = \eta_i(\theta_i K_i^{\pi_i} + (1 - \theta_i)L_i^{\pi_i})^{1/\pi_i} \qquad (4.3)$$

where $\sigma_{KLi} = 1/(1 - \pi_i)$ is the elasticity of substitution between capital and labor inputs, θ_i is the share of capital in total value added and η_i is the scaling parameter in activity i, i=C,D . This formulation allows us to capture a variety of constant elasticity of substitution technologies with Cobb-Douglas ($\pi_i \to 0$), Leontief ($\pi_i \to -\infty$) and linear technologies ($\pi_i = 1$) as special cases. In addition, we need to add the market clearing condition for capital, $\Sigma_i K_i = K$. Otherwise the structure of the model is similar to the on defined by (3.1) - (3.5), i.e. we assume weak separability between leisure and consumption in utility. Also, we maintain the assumption that public expenditure is spent on labor inputs only.

The key difference to the single input model is that with the current formulation we can distinguish the two consumption categories not only in terms of environmental effects but also in terms of factor intensities in production. In the simulations, we assume a benchmark equilibrium where production of the polluting good is relatively capital intensive and production of non-polluting good relatively labor intensive. The initial tax is assumed to consist of a general income tax with a uniform rate on labor and capital earnings. We then simulate, as before, the effects a revenue neutral tax reform where an increase in the selective commodity tax on the polluting good is compensated through a decrease in the tax on labor input. In the current formulation, this means that taxation of capital is not touched by the reform.

With a range of reasonable elasticity values we find that a revenue neutral switch in the tax rates improves both, environmental quality and non-environmental efficiency. In other words we encounter a double dividend. In addition, consumer real wage increases and employment expands. Results for the benchmark case with all substitution elasticities equal to one ("Cobb-Douglas economy") are presented in the first column of table 4.1.

Intuitively, since capital input is of fixed supply, it is a desirable tax base and relatively "undertaxed" in the initial equilibrium. Substituting tax on the polluting good for tax on labor shifts part of the tax burden to capital which is intensively used in its production. This is a mechanism we could not capture in the single input model of the previous section. In that formulation, tax on the polluting good in effect increased the tax burden of labor thus offsetting the effect of easing of the labor tax.

In the current formulation, if we would have chosen the production of the polluting good to be labor intensive, the favourable effect of the reform on the tax burden of labor would be much weaker and the probability of a double dividend smaller. However, assuming the production of polluting goods being labor intensive relative to production non-polluting goods does not seem to be that unrealistic approximation of real world production patterns.

The results of the two input model clearly stem from the fact that labor is relatively heavy taxed in the initial tax system. This is guaranteed by the fixed total stock of capital, an assumption widely used in CGE-models. Though unrealistic and not very suitable for describing the supply conditions specially in open economies, this formulation highlights the fact that in models with multiple inputs the scope for a double dividend is enlarged and depends on the relative mobility of those inputs. Assuming a small open economy formulation with infinitely elastic supply of capital would reverse the above results. A realistic model would probably lie somewhere between these two extremes, thus leaving the outcome to depend on the relative supply elasticity of primary inputs.

4.2 Open Economy Model

As noted above, the relative elasticity of factor supplies can be thought to be connected to the openness of the economy to international transactions, in particular capital imports. To see how the possibility of international trade affects our results we next specify an open economy version of the model. For that purpose we need to augment the model with a few equations. We assume the economy trades final demand aggregate and capital and is small in the sense that it cannot affect its international terms of trade. Concerning the final demand aggregate, we assume product differentiation such that domestically produced and imported goods are imperfect substitutes. Also, in the supply side, domestic sales and exports are imperfect substitutes. This fairly standard formulation in CGE models suggested by de Melo &

Robinson, 1989 allows us to capture some realistic features of small open economies with non-traded goods and domestic price changes deviating from world inflation.

The final demand aggregate is produced domestically according to

$$X = (\alpha_c X_c^{\rho_x} + (1-\alpha_c) X_d^{\rho_x})^{1/\rho_x} \qquad (4.4)$$

where X_i for i=C,D refers to sectoral output determined by (4.3). Thus the final demand aggregate is a constant elasticity of substitution composite of the sectoral outputs. Total output is further divided between domestic sales and exports by

$$X = (\beta_x X_h^{\delta_x} + (1-\beta_x) X_e^{\delta_x})^{1/\delta_x} \qquad (4.5)$$

where X_h is the output supplied to domestic market and X_e is exports. With $\delta_x > 1$ (4.5) defines a constant elasticity of transformation production possibility frontier for the economy in terms of exports and non-tradables.

The consumers demand a composite of domestic and imported final demand good

$$X_a = (\alpha_a X_h^{\rho_a} + (1-\alpha_a) X_m^{\rho_a})^{1/\rho_a} \qquad (4.6)$$

where X_h now refers to the domestically produced final demand aggregate sold at domestic market, X_m is the imports and X_a is the composite demanded by the consumer. For capital we have

$$K_a = (\alpha_k K^{\rho_k} + (1-\alpha_k) K_f^{\rho_k})^{1/\rho_k} \qquad (4.7)$$

where K is domestic capital, K_f is its imperfect foreign substitute and K_a is the capital composite used in production. For simplicity, we assume that capital exports can be neglected.[1]

Household budget constraint for open economy can be written in the form

$$p_h X_h + p_m X_m = (1-t_l) q_l L + (1-t_k) q_k K \qquad (4.8)$$

which replaces (4.1). Here p_h and p_m refer to consumer prices of domestically produced and imported final demand aggregate, respectively. As capital tax applies to foreign capital as well as domestic, government budget constraint becomes

$$p_g G = t_d q_d D + t_l q_l L + t_k (q_k K + q_f K_f) \qquad (4.9)$$

where K_f is capital imports and q_f is the producer price of foreign capital. The domestic prices of final demand imports and exports and capital imports are determined by world market prices π_i and the exchange rate e as follows [2]:

$$p_m = e\pi_m$$

1 The key results presented below would not change if we would explicitly add capital exports to the model.

2 Choosing the price of domestic supply as numeraire e can be interpreted as the real exchange rate governing the allocation of resources between tradable and non-tradable sectors (de Melo & Robinson,1989). Note that with our notation, depreciation of e corresponds to appreciation of domestic currency.

$p_e = e\pi_e$

$q_f = e\pi_f$ (4.10)

Finally, to close the model we specify the trade balance,

$\pi_e X_e - \pi_m X_m - \pi_f K_f = 0$ (4.11)

which can be thought as a market clearing condition for foreign exchange. In addition, the market clearing conditions for commodity and capital markets has to be slightly modified. Demand must equal supply for the non-traded good, i.e.

$X_h^D = X_h^S$ (4.12)

where indices D and S refer to demand and supply. Capital demands by production activities must sum up to total supply of the capital composite

$\Sigma_i K_i = K_a$ (4.13)

Simulating the effects of the proposed tax reform confirms the prediction that results depend on the elasticity of capital supply. Choosing as benchmark case the "Cobb-Douglas economy" with all substitution elasticities equal to one, the proposed tax reform leads to increased employment and improved environmental quality, but this comes at the cost of reduced non-environmental efficiency due to a drop in capital supply. Thus, no double dividend in efficiency sense arises. The simulation results are shown in the second column of table 4.1 (open economy "C-D"). However, as we reduce the elasticity of substitution between domestic and foreign capital and/or increase the elasticity of substitution between leisure and consumption, a double dividend will result. The simulation results with elasticity parameter between domestic and foreign capital reduced from 1 to 0.25 are presented in the third column of Table 4.1 (open economy, reduced mobility). Relative to the Cobb-Douglas case, employment of capital now drops less and consequent gross effciency losses remain smaller.

Table 4.1 : Effects of a revenue neutral environmental tax reform on selected variables in an economy with polluting domestic output. All entries except the tax rates are per cent changes from the base level.

	closed economy	open economy	
		"C-D"	reduced mobility
tax rates			
polluting good	0.05	0.05	0.05
labor	0.19	0.20	0.20
capital	0.25	0.25	0.25
output			
non-polluting	3.0	2.1	2.6
polluting	-2.1	-3.2	-2.5
employment			
labor	1.3	0.8	1.0
capital	0.0	-1.2	-0.5
environment index	2.1	3.2	2.5
efficiency index	0.1	-0.1	0.03
imports			
final demand	-	1.6	1.4
capital	-	-2.5	-0.9
exports	-	-1.1	-0.1

5. Three Factor Model with Pollution in Production

5.1 Structure of the Model

In the simulations presented this far we have assumed for simplicity that the environmental externality is related to an output. Thinking about real economies, environmental damage is more easily attributed to the use of e.g. energy inputs than consumption of final demand commodities. In this section we take a step towards empirical implementation by assuming that the environmental damage is related to a resource input. We maintain the open economy framework introduced in section 4.2 above. We assume that the polluting input is imported. Since the output is no longer divided into polluting and non-polluting parts, only single output is produced[1]

As we introduce the third primary input, the production can be described by a nested constant elasticity of substitution structure as follows

$$X = (\alpha_x L^{\rho_x} + (1-\alpha_x)N^{\rho_x})^{1/\rho_x}$$

$$N = (\alpha_n R^{\rho_n} + (1-\alpha_n)K_a^{\rho_n})^{1/\rho_n}$$

$$K_a = (\alpha_k K^{\rho_k} + (1-\alpha_k)K_f^{\rho_k})^{1/\rho_k} \qquad (5.1)$$

where R is the imported resource and others are as before. In other words, we assume that the imported resource can be substituted by capital input e.g. through energy saving investment. Polluting resource forms together with capital an aggregate non-labor input N which is an upper level substitute for labor. As before, capital used in production is a composite of foreign and domestic capital. The environmental quality now depends on the level of R used, so (3.4) is replaced by

$$Z = Z_0 - \delta R \qquad (5.2)$$

As the polluting resource is imported we must augment the balanced trade condition (4.10) as follows:

$$\pi_e X_e - \pi_m X_m - \pi_f K_f - \pi_r R = 0 \qquad (5.3)$$

where π_i is the world market price of exports, imports, capital and resource, respectively. The domestic price of imported resource is given by

$$q_r = e\pi_r \qquad (5.4)$$

where q_r is the domestic price net of tax and π_r is the world market price. Government budget is now given by

$$p_g G = t_r q_r R + t_l q_l L + t_k q_k K \qquad (5.5)$$

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[1] Of course, we could have simultaneous environmental effects arising from both production and consumption . To focus on the supply side effects, we abstract from the latter in this section.

5.2 Simulation Results

With this specification the tax reform consists of an increase in the tax on the imported polluting resource and a compensating drop in the labor tax. Starting from a "Cobb-Douglas economy" with unitary substitution elasticities, such a reform increases employment and environmental quality without efficiency cost. The effects of introduction of a five per cent tax on imported resource allowing roughly a two percentage point cut in labor tax are presented in the first column of table 5.1. In new equilibrium, consumer real wage would increase slightly relative to the pre-reform level and employment would adjust to a higher level. The use of the imported resource would decline and environmental quality improve. The non-environmental efficiency would improve slightly. Contrary to the case where pollution was related to output, increasing the substitutability between domestic and foreign capital would now increase the efficiency gains from the tax reform. This can be seen from the second column of Table 5.1 presenting the results of a simulation with elasticity of substitution increased from 1 to 4. Thus the model suggests that the proposed environmental tax reform becomes more desirable as capital becomes more mobile internationally.

To understand this somewhat counterintuitive result we must take a closer look at the key mechanisms driving the model results. To isolate the effects of the two tax changes involved in the reform, we ran a simulation where an increase in the resource tax was compensated through a lump sum rebate to consumers. With such a policy, employment of labor would decline and employment of capital would stay unchanged (or drop only slightly). Intuitively, in the production block of the model the imported resource is substitutable for both capital and labor inputs. Thus, increased tax on the use of the resource causes a substitution effect in favour of the both. However, increased resource tax also tends to increase the price of the output. This leads to reduced demand for output and lowered consumer real wage and thus discourage labor supply. As the latter effect dominates, employment of labor falls. Domestic supply of capital being inelastic and foreign supply not responding to changes in the output price, capital employment is less sensitive to real return changes. The only depressing effect on capital comes from the reduced demand for domestic output. As the tax tends to reduce demand for tradables in the economy, a drop in the real exchange rate (appreciation of the domestic currency) is needed to preserve the external balance.

Next we simulated the effects of a drop in the labor tax compensated by a lump sum transfer of income from the households[2]. Such a policy would increase employment of labor clearly and lead to a modest increase in the employment of capital. Obviously, in this case the factor substitution and supply response would both work in favour of increased labor employment. Factor substitution would mitigate the

[2] In both of the single tax simulations we let the labor tax to adjust to keep the government real expenditure fixed. To facilitate comparison, we chose the individual tax rates to correspond the rates resulting from the final tax reform simulation (0.05 for t_r and 0.23 for t_l).

positive effects of increased domestic output on capital and resource usage. Due to an increase in the resource inputs, environmental quality would deteriorate.[3] Since we assume no technological differences in the production of tradables and non-tradables, reduction in the labor tax has no effect on the real exchange rate.

The effects of the revenenue preserving tax switch from labor to resource taxation can to large extent be inferred from the two simulations involving changes in one of the taxes only. As for the labor, the strong positive effect caused by the drop in labor tax dominates and its employment increases. For the imported resource, the negative effect caused by the increased environmental tax dominates and its use decreases. Given that no equally harmfull substitutes arise this leads to a corresponding improvement in environmental quality. For capital, the modest positive effect due to reduced labor tax dominates the almost negligible negative effect of incresead resource tax.

Simulations with alternative parameter values show that the sign and magnitude of labor and capital responses depend on the elasticity of substitution between labor and non-labor aggregate relative to that between capital and the imported resource. As the substitution elasticity parameter between capital and imported resource increases relative to that between labor and non-labor input, labor employment increases less or even declines. This is because in that case, substitution away from the imported resource tends to promote demand for capital in the first place and to a lesser extent demand for labor. The labor market response is then more strongly governed by the reduced real wage discouraging labor supply.

With all plausible elasticity parameters for labor and non-labor inputs, the suggested reform tends to increase employment of capital in the economy. Then, the more flexible is total capital supply, the higher are the gains in efficiency. With low international capital mobility, the incresead demand is reflected mostly in the incresead rent of domestic capital and to a minor extent in increasead capital usage. In the previous section with the environmental tax levied on the output the effect of capital mobility on efficiency gains was of the opposite sign.

These results are contrary to Bovenberg and Goulder (1995) who examine the effects of similar tax reform in a small open economy. They argue that increased tax on a polluting resource compensated by lower labor taxes reduces private welfare. Their result, however, is derived from a model where domestic and foreign goods are perfect substitutes and intraindustry trade is impossible. In such a framework supply of the the traded goods is infinitely elastic and shifting tax burden from labor towards the other inputs is inferior. Our framework instead allows for the less than perfect substitutability between domestic and foreign varieties of capital and traded commodities. This formulation gives real exchange rate a role in the adjustment process. Depreciation of the real exchange rate due to the tax reform mitigates the drop in the tax base of the environmental tax and reinforce the increase in the capital

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[3] It is worth noting that the non-environmental efficiency improved more in the labor tax simulation with lump sum rebate than in the actual tax reform simulation.

use by encouraging capital imports. These both effects serve to reduce the gross efficiency costs of the tax reform relative to the "Heckscher-Ohlin" case with perfect substitution and no role for real exchange rate.

Finally, it should be noted that we simulated cases with relatively low tax rates on the imported resource. Increasing the resource tax further would finally turn the results opposite in terms of efficiency. In real economies tax rates on imported resources are likely to be somewhat higher, but so are the effective tax rates on labor inputs. Nevertheless, the results are sensitive to the existing tax rates and relative shares of inputs in the economy. Thus, for any decisive results empirical implementation of the model framework is warranted.

Table 5.1 : Effects of a revenue neutral environmental tax reform on selected variables in an open economy with polluting imported resource. All entries except the tax rates are per cent changes from the base level.

	"C-D"	**increased mobility**
tax rates		
polluting good	0.05	0.05
labor	0.23	0.23
capital	0.25	0.25
output	-0.3	-0.2
employment		
labor	0.2	0.2
capital	0.1	0.2
environmental index	8.9	8.8
efficiency index	0.02	0.04
imports		
final demand	1.0	1.0
capital	0.4	0.8
resource	-4.4	-4.3
exports	-1.0	-0.9

6. Conclusions

The paper examines the possibility to gain a double dividend through a revenue neutral tax reform under various assumptions of underlying economic structure. We started with the simplest possible closed economy model to show that necessary conditions for a double dividend are quite restrictive, though not unplausible. In addition we noted that relaxing the widely used assumption of weak separability between consumption and leisure in private utility widens the scope for a double dividend.

Simulations with a two input model showed that environmental taxes can serve to correct the inefficiencies in the existing tax systems and thus bring about efficiency gains in addition to improved environmental quality. In particular, we examined the case where a polluting good is produced by relatively capital intensive technology. In that case environmentally motivated tax reform will result to a double dividend if capital is relatively immobile.

Finally, we specified a model of a small open economy with pollution related to an imported input such as fossil fuels. Contrary to some earlier results (Bovenberg and Goulder, 1995) we found that even in this case achieving a double dividend through an environmental tax reform is quite likely. The result stems from the specification of foreign trade activities to allow for product differentation and existence of non-tradable goods.

To sum up, the calculations presented in this paper give a little more optimistic view of the double dividend that has been the case in much of the previous material published on the subject. In most of the stylistic calculations presented in this paper, the rise of a double dividend depends solely of the supply and demand elasticities of the key variables and the structure of the existing tax system. Thus the possibility of a double dividend cannot be excluded a priori, but remains an empirical question.

The type of models presented in this paper offer a consistent framework for further empirical research on the subject that clearly seems warranted. As persistent involuntary unemployment has been one of the main causes for the double dividend issue to arise, it would be tempting to develop the framework further to allow for non-clearing labor markets. Then the results would become dependent on the prevailing wage formation mechanish and might be considerably changed from those above.

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Appendix: Stylized social accounting matrices (SAM) used in the simulations. Columns represent commodities. Rows stand for activities and agents. Inputs are denoted by negative entries. For details of the SAM approach see e.g. Pyatt (1988).

1. Single input model.

	CS	DS	LS	WS	GS	CON	GOV
L	-50	-10	90		-30		
C	50			-50			
D		10		-10			
LE			-60	-90		150	
E						(-10)	
TAX			-30				30
W				150		-150	
G					30		-30

2. Two input model. Closed economy.

	CS	DS	LS	KS	WS	GS	CON	GOV
L	-50	-10	100			-40		
K	-40	-60		100				
C	90				-90			
D		70			-70			
LE			-80		-60		140	
KE				-80			80	
E							(-10)	
TAX			-20	-20				40
W					220		-220	
G						40		-40

3. Two input model. Open economy.

	CS	DS	XS	LS	KS	TRA	WS	GS	CON	GOV
L	-50	-10		100				-40		
K	-40	-60			100					
C	90		-90							
D		70	-70							
X			160			-40	-120			
LE				-80			-60		140	
KE					-40				40	
KF					-40	40				
E									(-10)	
TAX				-20	-20					40
W							180		-180	
G								40		-40

4. Three input model.

	XS	LS	KS	TRA	WS	GS	CON	GOV
L	-60	100				-40		
K	-100		100					
X	180			-40	-140			
LE		-80			-60		140	
KE			-60				60	
KF			-20	20				
R	-20			20				
E							(-10)	
TAX		-20	-20					40
W					200		-200	
G						40		-40

Commodities: L labor LE leisure KE domestic capital KF foreign capital K capital composite R imported resource C non-polluting output D polluting output X final demand composite W welfare aggregate of consumption and leisure E environmental services G public output TAX taxes.

Activities: LS labor supply KS capital supply CS supply of non-polluting good DS supply of polluting good XS supply of final demand composite WS supply of welfare aggregate GS supply of public output TRA trade activity.

Agents: CON consumers GOV government.