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**Wirtschaftswissenschaftliche Fakultät
der Eberhard-Karls-Universität Tübingen**

**Computational General Equilibrium
Analysis and Economic Reasoning***

CHRISTIAN GLIESMANN
ANNA RUOCCO



Tübinger Diskussionsbeiträge

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**Computational General Equilibrium
Analysis and Economic Reasoning***

**CHRISTIAN GLIESMANN
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1. INTRODUCTION

Computable General Equilibrium (CGE) analysis has become a well-established and valuable methodological tool in economics. It allows us to gain considerable insight into complex theoretical models and to derive policy conclusions in all fields of economics. CGE-models, however, are not undisputed. One serious objection is that they are a kind of black box for the general reader. For a number of reasons, he will hardly be able to replicate the numerical results produced in CGE-papers. And in most cases it is hard for an outsider to judge how robust the policy conclusions are. FULLERTON and LYON (1986) have illustrated that this could become a real problem. Only slightly changing some parameter values might change the ranking of the tax reform proposals. All in all, the general reader of CGE-contributions often has no other choice than believing or not believing the numerical results. Quite obviously, this is not a solid basis for good economics. There is, however, a way out of this dilemma: Authors of CGE-papers should supplement their numbers by convincing economic explanations. They should make clear how robust their conclusions are with respect to parameter values as well as functional forms and they should be able to convince sceptical readers by persuasive economic reasoning.

In a recent issue of the Swiss Journal of Economics and Statistics, FELDER and SCHLEINIGER (FS) presented a CGE-analysis of domestic environmental policy in a small open economy. The authors were interested in answering the question whether or not a „double dividend“ occurs when increasing the taxation of polluting commodities and inputs. Their results seem to be quite robust: „We conclude that in all tax reform simulations with taxes on the consumption of the dirty good, a double dividend occurs... By comparison, in all scenarios where the energy input is taxed directly, the double dividend claim fails“ (p.557).

At least to us, however, the economic explanations given by FS were not fully convincing and we could not see the economic rationale behind the tax experiments performed. We agree that one can gain some insight into the double dividend controversy even by using highly stylised models. But the FS paper leaves some questions open and allows for a much richer economic analysis than the authors provide. In addition, there are some inaccuracies in that paper, which make it difficult to understand the results. On the other hand, the FS paper is not without merits. In our view its main contribution lies in extending a simple model developed by JENSEN (1994) to incorporate foreign labour supply and non-traded domestic capital. We will not, however, elaborate on these variants but try to gain additional economic insights into their basic model. Hence our paper may be seen as complementary to the FS paper. In the next section we briefly sketch the double dividend hypothesis and describe the FS model and the data set. Section 3 asks what kind of tax reform in general and „green“ tax reform in particular could be recommended for a country which is characterised by the FS model structure and data. Section 4 gives some concluding remarks.

2. THE DOUBLE DIVIDEND HYPOTHESIS AND THE FS MODEL

In its strong form the double dividend hypothesis claims that substituting an eco-tax for a distortionary tax involves a zero or negative gross cost¹. This means that the overall excess burden of the tax system is reduced if a revenue neutral eco-tax reform is performed. The benefit of the decreased excess burden then is the second dividend, while the first dividend is the welfare gain due to the improved environment.

¹ See GOULDER (1995), p. 159.

So, if this hypothesis would hold, an eco-tax reform would always lead to an increase in welfare apart from environmental benefits². This means that for a small open economy a green tax reform would be profitable even if it does not contribute to a reduction of global environmental damage. The possibility of a welfare improvement arises from the recycling of the eco-tax revenues, which will be used for a cut of other distortionary taxes, for example the tax on labour income. Whenever the marginal excess burden induced by newly introduced or increased eco-taxes is smaller than that of pre-existing distorting taxes, a revenue-neutral eco-tax reform will be welfare improving.

Even if the double dividend hypothesis is intuitively appealing, it does not automatically hold. Especially, GOULDER (1995) as well as BOVENBERG and DE MOOIJ (1994) casted some doubt upon this hypothesis. While the BOVENBERG and DE MOOIJ argument is theoretically correct, it depends on some strong assumptions. Unfortunately these assumptions are forgotten all too easily and the double dividend hypothesis is rejected too hastily. FS are a typical example for a somewhat naive handling of the BOVENBERG and DE MOOIJ results. According to FS, BOVENBERG and DE MOOIJ „show that the levy of a tax on the dirty commodity combined with an equal yield cut of the existing tax on labour involves no double dividend, provided that the uncompensated wage elasticity of labour supply is positive“ (p.548). This is simply wrong. A positive labour supply elasticity is neither sufficient nor necessary for a rejection of the double dividend. What really matters is the optimality or non-optimality of the tax structure in the benchmark equilibrium. In the BOVENBERG and DE MOOIJ framework, a wage income tax is second best - any environmental considerations apart - due to the assumption of a homothetic and weakly separable utility function and the absence of any fixed income. Then, of course, it is impossible to reap a double dividend, i.e. improving the overall efficiency of the tax system by a „green“ tax reform. Hence a necessary condition for a double dividend to occur is that the tax system in the benchmark equilibrium is not second best.

In contrast to the BOVENBERG and DE MOOIJ paper, the FS model opens up the opportunity to reap a double dividend because the authors start from a highly distorted tax system. FS consider a small open economy in which two goods are produced: a dirty good, D , which is not traded, and an internationally traded clean good Y . Whereas quantities C and G of the clean good are sold to domestic consumers and to domestic government respectively, the difference between domestic production and domestic absorption is exported. In exchange for its exports the domestic economy imports energy and capital at fixed world market prices. Both, the clean and the dirty commodity are produced by nested production functions combining energy and capital at the bottom level and a composite energy-capital input and labour at the upper level. The representative household consumes the clean and the dirty commodity, and receives income from labour supply and from transfers received from the government. It is assumed that the utility function is a nested combination of CES functions, aggregating the clean and the dirty good at the lower level and leisure (or labour) and the aggregate consumption good at the top level. The government buys a fixed quantity of the clean good, \bar{G} , which is supplied free of charge to the representative household³ and pays transfers. These expenditures are financed by consumption taxes on the clean and the dirty commodity and by taxes on the use of labour and energy in production. All markets clear where it is assumed that foreign supply of capital and energy is perfectly elastic. FS consider two variants of this base model. While we restrict our comment on their base model, all of our remarks could be applied to these two variants as well.

² If it fails, information about environmental damage is necessary to evaluate the reform. If the welfare increase due to the improved environment is greater than its gross cost in terms of an increase in the overall excess burden, an eco-tax reform will still be profitable.

³ Because the publicly provided good \bar{G} is assumed to be fixed in supply it can be omitted in the utility function.

The theoretical model is supplemented by a data base and some exogenously specified (base case) substitution elasticities, which are reproduced in Tables 1 and 2. We have slightly changed the benchmark equilibrium values, because quite obviously the social accounting matrix as given by FS (Table 1 p.552) is not consistent. Whether or not the data base represents the Netherlands - as FS claim - or the Danish economy - as JENSEN claims- is of minor importance.

TABLE 1

Values of main parameters in the benchmark equilibrium - base case -	
σ_{EK} ⁴ energy (E) and capital (K)	1.3
σ_T (K-E) and labour (L)	0.8
σ_{CD} clean (C) and dirty good (D)	0.3
σ_U aggregate consumption and leisure	1.9

TABLE 2

Benchmark equilibrium			
CLEAN SECTOR		DIRTY SECTOR	
Production side		Production side	
Y	371.07917	D	14.00545
E_Y	5.0023	E_D	3.1580
K_Y	44.02027	K_D	6.8043
L_Y	163.0751	L_D	1.77637
t_E^0	0.1707	t_E^0	0.1707
t_L^0	0.9665	t_L^0	0.9665
Consumption side		Consumption side	
\bar{C}	229.08916	DD	14.00545
\bar{G}	83		
\bar{TR}	116		
t_C^0	0.1528	t_D^0	0.2142

The index ⁰ stands for the benchmark value and the following notation is used:

- t_L^0 = tax rate on the use of labour in production
- t_D^0 = consumption tax rate on the dirty commodity
- t_E^0 = tax rate on the energy input
- t_C^0 = consumption tax rate on the clean commodity
- Y = level of production of the clean commodity
- E_Y = quantity of energy input used in the clean sector
- K_Y = quantity of capital used in the clean sector
- L_Y = quantity of labour used in the clean sector
- D = level of production of the dirty commodity
- E_D = quantity of energy input used in the dirty sector
- K_D = quantity of capital used in the dirty sector
- L_D = quantity of labour used in the dirty sector
- C = final consumption of the clean commodity

⁴ σ denotes the elasticity of substitution

\bar{G} = public expenditure
 \bar{TR} = transfer payments to the household
 DD = final consumption of the dirty commodity

3. GREEN TAX REFORMS IN THE FS-FRAMEWORK

For the tax expert, a cursory glance at the tax rates as given in Table 2 should suffice to realise that the initial tax system is highly inefficient. For example, from the DIAMOND and MIRRLEES (1971) paper it is well known that there is no room for any input taxation in a second best framework. Furthermore, due to the weak separability and the homotheticity of the utility function, tax rates on consumption should be uniform. There are, therefore, considerable inefficiencies in the initial tax system, giving rise to the possibility of a double dividend.

FS perform two different kinds of equal yield tax experiments. First, they increase the tax rate on the dirty commodity and adjust the tax rate on the use of labour, while the tax rates on energy and the clean good are kept fixed. Second, the tax rate on energy is increased, the tax rate on the use of labour is adjusted and the consumption tax rates are fixed.

More specifically, FS pretend to perform an „equal-yield tax reform that impose a 50 ... and a 100 ... percent tax rate, respectively, on the household's consumption of dirty good or on the firm's energy input, and reduces the labour tax rate accordingly“ (p.552-553). But this is not what they actually do. When trying to replicate the numerical results as given in Table 2 in FS, it turned out that they consider a 50 or 100 per cent increase in the gross (i.e. tax inclusive) prices of the dirty commodity on the one hand, the energy input on the other. Increasing the gross prices of the dirty commodity and the energy input by 50 or 100 per cent, respectively, is equivalent to imposing a tax rate on the dirty commodity of 82 and 142 per cent and a tax rate on energy input of 75.6 or 134.1 per cent. This is equivalent to increasing the tax rate on the dirty commodity by 283.4 or 566.8 per cent and on the energy input by 342.8 or 685.7 per cent. These, of course, are quite different tax reform packages than FS pretend to analyse. For the general reader, who will not try to replicate the numerical results, it is impossible to detect the difference.

Let us now turn to the simulation results obtained by FS. Our main objections are the following. First, there is no obvious reason why we should consider the very special case of a price increase of the dirty commodity or the energy input by exactly 50 or 100 per cent. In fact, tax rate increases of 283 and 685 per cent do not seem to be particularly realistic. Second, the FS policy considerations depend on the (more or less arbitrary) choice of substitution elasticities in production and consumption. For different parameter choices, the policy conclusions reverse: An increase in the tax rate on the dirty commodity decreases welfare and an increase in the tax rate on the energy input increases it. Third, as mentioned above, the tax system in the benchmark equilibrium is highly inefficient and leaves considerable room for welfare improvement. From a welfare point of view, the tax reforms considered by FS are clearly dominated by some other tax reform packages, which do not harm the environment by more than the initial tax system.

To illustrate these points, consider first the equal yield tax experiments on the dirty commodity, as performed by FS⁵. Increasing the tax rate from about 21 per cent in the benchmark equilibrium to 82 or even 142 per cent in the two counterfactual equilibria with compensating adjustments in the labour tax rate in both cases results in welfare increases as measured by the Hicksian equivalent variation (EV)⁶.

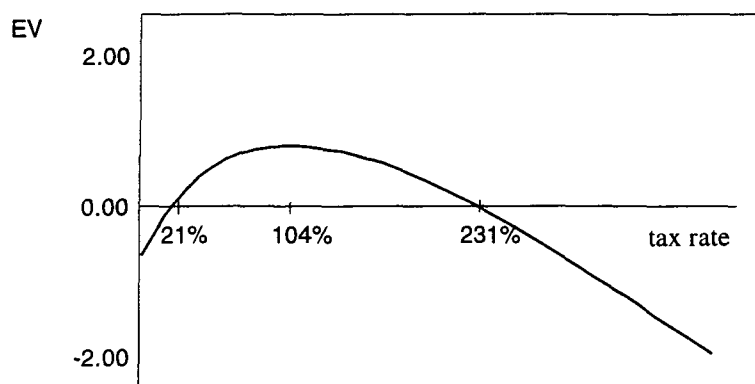
⁵ Table A1 in the appendix contains all the numerical results of the relevant simulations.

⁶ Contrary to what they claim, FS do not calculate the EV in the last line of their Table 2 (p.553) but the percentage change in utility - which is not the same as EV.

At first sight this seems surprising. As a rule of thumb, excess burdens increase quadratically with tax rates and it is not at all obvious why increasing the tax rate on the dirty commodity by 283 or even 566 per cent should result in welfare gains. The only reason could be that the demand for the dirty commodity is highly inelastic, whereas the demand for leisure is elastic. Even then one wonders what the special attractiveness is of a price increase of 50 or 100 per cent, respectively. If the demand for the dirty good is inelastic, why not choose the optimal, i.e. welfare maximising tax rate?

In Figure 1 we show the welfare effects of gradually increasing the tax rate on the dirty good from its benchmark equilibrium value of 21 per cent and adjusting the tax rate on labour input in order to generate the same total tax revenue as before. The figure illustrates that any increase in the dirty consumption tax rate up to a value of about 231 per cent will be welfare increasing. Of course the most natural tax reform would be to choose the optimum tax rate on the dirty commodity of 104 per cent.

Figure 1 Welfare effects of increasing the tax rate on the dirty commodity



This rather high welfare maximising tax rate is due to the inelastic demand for the dirty commodity, which itself depends on the rather low value of the elasticity of substitution between the clean and the dirty commodity. An increased substitution elasticity σ_{cd} implies a more elastic demand for the dirty commodity. If our above reasoning is correct it should lead to a lower optimal tax rate on the dirty good.

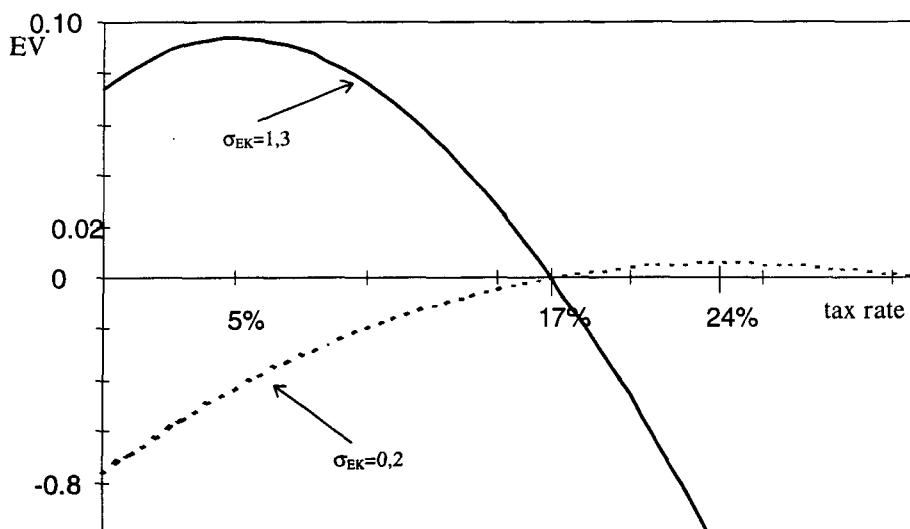
As an extreme example we have chosen a substitution elasticity of $\sigma_{cd}=1.81741$ and recalibrated the endogenous parameters to replicate the same benchmark equilibrium as before. The reason for choosing this special elasticity value is that in this case the optimum tax rate on the dirty commodity exactly coincides with its benchmark value. This means that the tax structure in the benchmark equilibrium is second best with respect to the available tax instruments, the tax rates on dirty commodity and on labour input. As a consequence, any revenue-neutral change in the dirty good's tax rate must be welfare decreasing. As the second part of Table A1 illustrates, the particular price increases considered by FS would result in considerable welfare losses.

As a preliminary lesson we conclude that, contrary to the FS statement, an increase in the taxation of the dirty commodity does not necessarily imply that a double dividend could be reaped. The results heavily depend on the extraneously specified substitution elasticities and the implied price elasticities of demand. Experience and economic reasoning should tell the model builder and the tax analyst which is the welfare increasing direction of the tax reform.

Quite similar reasoning applies to the second set of tax simulations performed by FS, where they consider an increase in the taxation of the energy input combined with a revenue-neutral decrease in labour taxation. In this case the authors conclude that welfare will decrease

and, hence, no double dividend occurs. This is illustrated in the first part of Table A2 in the appendix. Even if this result seems to accord more with economic intuition, it is not really self-evident. For a small open economy one would expect that it cannot gain by taxing internationally mobile factors of production. More generally, in a second best framework any input taxation should be avoided. On the other hand, whenever second best taxation is excluded for whatever reasons, introducing additional distortions through input taxes could compensate for unavoidable distortions of the existing tax system and, hence, might be welfare increasing⁷. In the FS model, second best taxation is excluded because consumption tax rates are kept fixed in the second set of tax experiments. A tax on energy input could contribute to economic welfare if it would move the economy towards the second best optimum. If it does, the level of input taxation depends on substitution possibilities and the price elasticity of factors demand. In this context, the substitution elasticity σ_{EK} is of crucial importance. The base case value of $\sigma_{EK}=1.3$ corresponds to an elastic factor demand, which in turn requires a rather modest taxation of the use of energy in production. According to Table A2 in the appendix the welfare maximising tax rate on the energy input for the base case parameter set is about 5 per cent. In this case, any increase in the energy tax rate from its benchmark equilibrium value of about 17 per cent will decrease welfare. But this result, too, is not robust. Reducing the factor price elasticity of demand for the energy input by lowering the substitution elasticity to $\sigma_{EK}=0.2$, the optimal tax rate on energy rises to about 24 per cent. Table A2 contains the corresponding equilibrium values and Figure 2 plots the welfare gains against the energy tax rate for different substitution elasticities.

Figure 2 Welfare effects of increasing the tax rate on the energy input



Under the new substitution elasticity an increase in the energy tax rate from its benchmark equilibrium value would be welfare improving up to a tax rate of 30.9 per cent. Once again, this contrasts to the FS claim that the double dividend hypothesis fails when energy taxes are increased.

As a final exercise we want to extend the FS simulations by assuming that all taxes can be reformed. If only lump-sum taxes are excluded but all the other tax instruments can be chosen optimally, input taxes should be avoided and consumption tax rates should be uniform. This is a standard result from the optimal taxation literature if the utility function of the representative

⁷ This type of argument can be found in NEWBERRY (1986).

consumer is weakly separable and homothetic. Table A3 in the appendix illustrates that a welfare gain could be realised which is almost 15 times higher than that produced by FS in their first set of tax experiments. As a possible disadvantage of the optimal tax reform one could consider the fact that both the use of energy in production as well as consumption of the dirty commodity, will be higher as in the benchmark equilibrium. Even if the FS model does not include any environmental damage function one could argue that tax reforms should at least not contribute to a further deterioration of the environment. Let us call such a tax reform „environmentally sustainable“. The optimal sustainable tax reform is illustrated in the final column of Table A3. To depress the use of energy and consumption of the dirty commodity to its benchmark values, an energy tax and a differentiated tax rate on consumption should be introduced, taxing the dirty commodity more heavily than the clean good. The following points seem to be worth mentioning. First, the sustainable tax rate on energy is higher than its benchmark value. Second, a differentiated consumption tax is more efficient than a tax on labour. Third, the welfare gain of an environmentally sustainable tax reform is still much higher than the gains under the FS green tax reforms. Fourth, compared with the second best tax system the sustainable one is associated with only a small welfare loss. It can be interpreted as the price for preserving the environment if environmental benefits are unknown.

4. CONCLUDING REMARKS

Recently, CGE models have come into vogue to evaluate the double dividend claim of a green tax reform. We, too, feel that computational economics can indeed contribute much to our understanding of tax reforms in general and the double dividend hypothesis in particular. On the other hand, often enough, the general reader is left alone with a number of tables and figures. Replication of the numerical results is almost impossible and in some cases it is even hard to understand the line of argument.

The basic message of our paper is that computational studies should spend much more time and effort on convincing economic arguments and explanations. Usually, even the qualitative conclusions depend on exogenous parameter values. The CGE modeller should make clear how robust results are and how they depend on different choices of uncertain parameters. And he should be able to explain and grasp computational results in an intuitive manner.

Our impression was that the interesting article by FELDER and SCHLEINIGER, at least in this respect, was not fully satisfactory. The intention of our paper is to complement theirs by providing additional results and additional economic reasoning.

Appendix

TABLE A1: Green tax reform package I: Taxing dirty commodities instead of labour

Benchmark equilibrium		Base case parameter values			Changed parameter value $\sigma_{cd} = 1.8741$		
		gross price increase of 50%	gross price increase of 100%	optimal taxation	gross price increase of 50%	gross price increase of 100%	optimal taxation
$t_L^0 = 0.9665$; $t_C^0 = 0.1528$ $t_D^0 = 0.2142$, $t_E^0 = 0.1707$;		$t_L = 0.8674$; $t_C = t_C^0$ $t_D = 0.8214$; $t_E = t_E^0$	$t_L = 0.7929$; $t_C = t_C^0$ $t_D = 1.4285$; $t_E = t_E^0$	$t_L = 0.8382$; $t_C = t_C^0$ $t_D = 1.0425$; $t_E = t_E^0$	$t_L = 0.9239$; $t_C = t_C^0$ $t_D = 0.8214$; $t_E = t_E^0$	$t_L = 0.9220$; $t_C = t_C^0$ $t_D = 1.4285$; $t_E = t_E^0$	$t_L = 0.9696$; $t_C = t_C^0$ $t_D = 0.1707$; $t_E = t_E^0$
Y	371.07917	373.85346	375.76148	374.61849	373.73280	374.04493	371.07924
E _Y	5.0023	5.0397	5.06542	5.05002	5.03808	5.04228	5.0023
K _Y	44.02027	44.34938	44.57573	44.44014	44.33507	44.3721	44.02028
L _Y	163.0751	164.2943	165.13281	164.6305	164.24127	164.37845	163.07513
D	14.00545	12.58638	11.66062	12.20979	6.76387	3.98254	14.0053
E _D	3.1580	2.83802	2.62928	2.75311	1.52514	0.898	3.15796
K _D	6.8043	6.11948	5.66938	5.93639	3.28859	1.9363	6.80936
L _D	1.77637	1.59639	1.47897	1.54862	0.85789	0.50512	1.77635
C	229.08916	232.50687	234.82168	233.43885	236.54593	238.79626	229.08933
\bar{G}	83	83	83	83	83	83	83
\overline{TR}	116	116	116	116	116	116	116
EV	-	0.74594	0.69165	0.78581	-2.21751	-5.12248	-

TABLE A2 Green tax reform package II: Taxing energy input instead of labour

Benchmark equilibrium		Base case parameter values			Changed parameter value: $\sigma_{EK} = 0.2$
		gross price increase of 50%	gross price increase of 100%	optimal taxation	optimal tax rate
$t_L^0 = 0.9665; t_D^0 = 0.2142$ $t_E^0 = 0.1707; t_C^0 = 0.1528$		$t_L = 0.9514; t_C = t_C^0$ $t_E = 0.7561; t_D = t_D^0$	$t_L = 0.9522; t_C = t_C^0$ $t_E = 1.3414; t_D = t_D^0$	$t_L = 0.9751; t_C = t_C^0$ $t_E^* = 0.0498; t_D = t_D^0$	$t_L = 0.96144; t_C = t_C^0$ $t_E^* = 0.2386; t_D = t_D^0$
Y	371.07917	368.50475	366.41922	371.65435	370.80391
E_Y	5.0023	2.99936	2.08199	5.73536	4.92258
K_Y	44.02027	44.71254	45.11276	43.80321	43.80979
L_Y	163.0751	162.859	162.53343	163.06504	163.09097
D	14.00545	13.52462	13.16052	14.12143	13.94885
E_D	3.1580	2.09104	1.5462	3.51719	3.10935
K_D	6.8043	7.63799	8.20923	6.58200	6.78055
L_D	1.77637	1.871	1.92884	1.74783	1.79183
C	229.08916	228.06383	226.46905	229.0166	229.18163
\bar{G}	83	83	83	83	83
\overline{TR}	116	116	116	116	116
EV	-	-1.66984	-3.73111	0.09388	0.00595

TABLE A3: Optimal tax reforms (base case parameter values)

Benchmark equilibrium		Second best tax reform	Optimal sustainable tax reform
$t_L^0 = 0.9665$; $t_D^0 = 0.2143$ $t_E^0 = 0.1707$; $t_C^0 = 0.1528$		$t_L^* = 0$; $t_C^* = 0.7615$ $t_E^* = 0$; $t_D^* = 0.7615$	$t_L^* = 0$; $t_C^* = 0.72113$ $t_E^* = 0.2072$; $t_D^* = 1.32969$
Y	371.07917	393.22654	392.24704
E _Y	5.0023	6.44521	5.08999
K _Y	44.02027	46.20884	46.61494
L _Y	163.0751	172.40368	172.45447
D	14.00545	15.49516	14.00545
E _D	3.1580	4.03341	3.07031
K _D	6.8043	7.08561	6.88981
L _D	1.77637	1.89676	1.78849
C	229.08916	246.45347	247.58199
\bar{G}	83	83	83
\bar{TR}	116	116	116
EV	-	10.96569	10.38874

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