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Working Paper

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Nota di Lavoro, No. 3.2001

Provided in Cooperation with:

Fondazione Eni Enrico Mattei (FEEM)

Suggested Citation: Pench, Alberto (2001) : Green tax reforms in a computable general equilibrium model for Italy, Nota di Lavoro, No. 3.2001, Fondazione Eni Enrico Mattei (FEEM), Milano

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Fondazione Eni Enrico Mattei

Green Tax Reforms in a Computable General Equilibrium Model for Italy

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NOTA DI LAVORO 3.2001

JANUARY 2001

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1. Introduction.

The paper studies the effects of green tax reforms in Italy using a computable general equilibrium model of the Italian economy. The model is calibrated from a microconsistent data set mainly derived from the Input-Output table for year 1990.

The aim of the paper is to assess whether it is possible to implement a tax reform that would reduce total emissions of some pollutants and benefit some or all consumers. The research is still at its beginning and the model may be interpreted as a base version: deviations from its strictly walrasian structure may be added in the future.

The plan of the paper is as follows: section 2 describes the structure of the model and its main features; section 3 presents the simulations performed and analyzes the results; section 4 is devoted to sensitivity analysis; a final section summarizes the results, comments on some policy implications and examines further developments of the model.

2. The Model.

The model, denominated IT30, is a standard walrasian static computable general equilibrium model disaggregated on both production and consumption. There are 30 production sectors each producing a single output using intermediate inputs of all other goods, primary factors and imported goods; on the consumption side consumers are divided into 6 classes according to family income. There are three primary factors: capital and two types of labour. Capital is fixed in supply; self employed workers are separated from employees but a variable supply is modelled only for a labour aggregate.

In the present version of the model all markets are perfectly competitive and the standard behavioral assumptions are employed: profit maximization for production sectors and utility maximization for (representative) consumers.

The database used for the calibration¹ of the model is derived from the Input-Output table of Italian economy for year 1990, largely integrated with other statistics particularly on the side of final demand; details on this subject may be found in Cavalletti and Accardo (2000)².

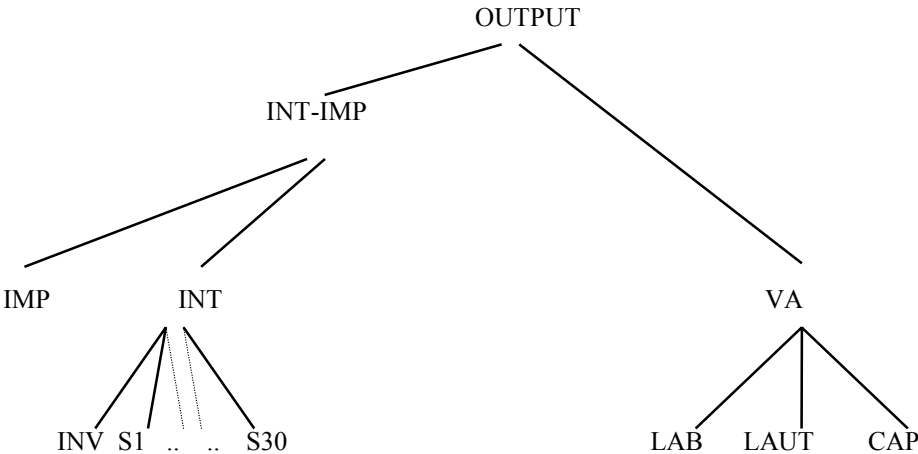
¹ On calibration the reader is referred to Mansur and Whalley (1984).

The 30th production sector aggregates the final branches of the I-O table and represents the supply of public services; there is a further fictitious production sector corresponding to investments and variations of inventories in the I-O table: this sector produces the “investment good” using inputs of all other goods and no primary factors and its output is demanded by production sectors as depreciation, by consumers as savings and is also employed to model public and trade deficit in the benchmark year.

Besides the 6 (private) consumers there are two additional fictitious consumers: the first, which may be called “public household”, models the activity of the public sector demanding the output of the final (30th) sector, collecting the revenue from all taxes and making transfers to private consumers: this modelling choice amounts to a supply, free of charge, of public goods entering in an additively separable manner into individual (private) utility functions. The second fictitious consumer is called ROW (Rest Of the World) and plays the role of modelling international transactions: it demands exports according to a downward sloping demand curve and supplies imports according to upward sloping supply curve³.

Both on the production side and on the consumption side of the model the functions employed are of the same constant elasticity of substitution type. The production function of each sector is a nested structure⁴ as shown in figure 1. At the bottom stage there are two nests: the former produces “value added” (VA in the figure) through the use of the three pri-

Figure 1: the structure of production.

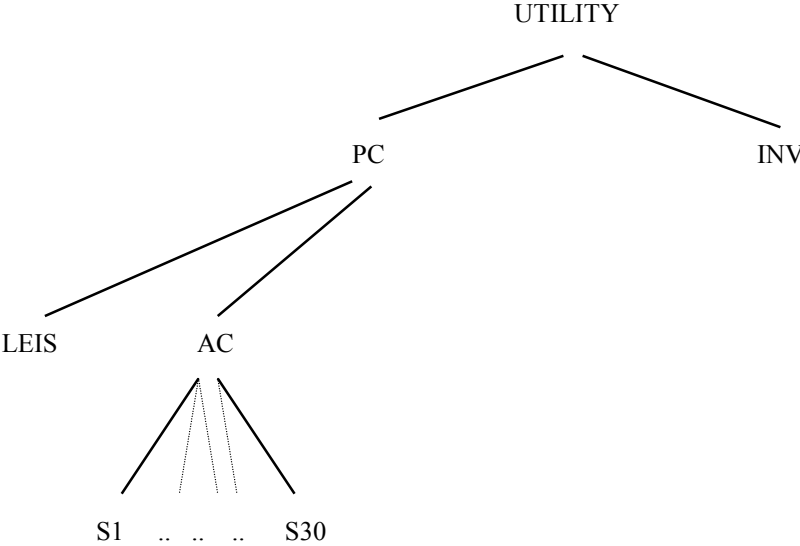


² Or may be requested to the author of this paper.
³ That is Italy is not considered a small open economy.
⁴ On nested functions the classical reference is Keller (1976).

mary factors according to a Cobb-Douglas function⁵; the latter aggregates intermediate inputs of all other goods and of the investment good by means of a zero elasticity of substitution function; this aggregate enters a higher stage with an imported good of the same type as that produced by the production sector: the elasticity of substitution employed at this stage is equal to 0.1, which means that a limited substitutability exists between imported and domestic goods, according to the Armington (1969) assumption, even if imported good joins all other inputs to give a single homogeneous sectoral output. At the top stage value added and the aggregate of domestic intermediate inputs and imported goods are combined with a zero elasticity of substitution to obtain the output.

The utility function of each private consumer is a three stages nested structure as shown in figure 2. At the highest stage the consumer makes the choice between present and future consumption, the latter represented by a demand of the investment good as savings: the function employed for this stage is a Cobb-Douglas. At the following stage, within present consumption (PC in the figure), the demand for leisure is modelled; the elasticity of substitution for this nest differs from household to household and is computed so as to repli-

Figure 2: the utility function.



⁵ With elasticity of substitution equal to 1.

cate an own price elasticity of labour supply equal to 0.2 for each consumer class⁶. The resulting labour supply is formulated for an aggregate of the two types of labour and is then divided between them in fixed proportions derived from benchmark figures. At the bottom stage the demand for each good is formulated through a function with an elasticity of substitution equal to 0.5.

Each consumer has a disposable income made of labour income (of both types) and capital income paid by production sectors and of capital income and transfers received from the public household: the former represents interests on public debt while the latter are pensions and subsidies.

Consumers pay the following taxes: a value added tax on each good, taxes on capital income, a personal income tax and some minor taxes. On the production side the following taxes are levied: social security contributions on both types of labour, a tax on capital input, taxes on sectoral output net of subsidies, value added tax and tariffs on imports.

The algorithm employed is MPSGE⁷, which is particularly well suited for general equilibrium models since it eases the tedious work of functions calibration: the current version of MPSGE, interfaced with GAMS⁸, employs GAMS syntax for the definition of all relevant parameters and makes it possible any manipulation on them which is necessary for their use in the model.

3. The Simulations.

The simulations performed concern green tax reforms with the aim of reducing the emissions of some pollutants by increasing the tax burden on the energy sector⁹ which is responsible for a large fraction of total emissions of some of the pollutants considered. A warning is in order at this point: in the current version of the model there is a single energy sector aggregating all branches of the I-O table concerned with the production and distribution of energy¹⁰. This feature has two important consequences: first of all taxes, which are largely differentiated among these branches, are levied on total output of the (aggregate) energy sector; more

⁶ The methodology for this computation can be found in Fehr, Rosenberg and Wiegard (1995).

⁷ For details see Rutherford (1994).

⁸ GAMS too, is a powerful computing algorithm: see Brooke, Kendrick and Meeraus (1992).

⁹ Sector 2 in the model.

precisely on total output of this sector is also levied the unit tax on mineral oils with a resulting rate, in the benchmark equilibrium, of only 25.6%. The second consequence is that the proposed reforms are not capable of discriminating among different energy products on the basis of their environmental impact.

Four tax reforms have been analyzed:

1. a 90% increase in the revenue of the above mentioned unit tax¹¹ on energy sector compensated by a reduction in personal income tax rates¹²; it will be referred to as alternative PTPIT;
2. the same reform as in 1) compensated by a reduction in social security contributions on employees (alternative PTSSC);
3. introduction of a 30% tax on final demand of energy products with the same compensation as in 1) (alternative CTPIT);
4. introduction of the same tax as in 3) with the same compensation as in 2) (alternative CTSSC).

The compensation is always made so as to keep public expenditure constant in real terms. The main results are presented in table 1. The column labels correspond to the four proposed reforms while the row labels are the most interesting variables: WELF% (from C1 to C6) is the

Table 1: the effects of the reforms.

	PTPIT	PTSSC	CTPIT	CTSSC
WELF%.C1	-1.161401	-0.353422	-0.908511	-0.662657
WELF%.C2	-0.762294	0.180630	-0.738339	-0.451222
WELF%.C3	-0.537939	0.314857	-0.642464	-0.382662
WELF%.C4	-0.408945	0.379745	-0.614515	-0.374183
WELF%.C5	-0.275402	0.517995	-0.580896	-0.339479
WELF%.C6	0.200535	0.058865	-0.347572	-0.389044
P2%	22.113489	21.611655	1.921629	1.827179
TAX	0.504124	0.504124	0.300000	0.300000
SCALA	0.803998	0.098961	0.941456	0.030818
Y2%	-3.690486	-2.960333	-4.628739	-4.405817

¹⁰ For example extraction of coal and petroleum and natural gas, refining, production and distribution of electricity.

¹¹ Which is levied on all transactions of energy products.

¹² At present personal income tax is imputed proportionally so that marginal rate coincides with average rate.

percentage change in the welfare of each class of consumers; $P2\%$ is the percentage change in the market price of the taxed good, which is expressed as gross of production taxes but net of consumption taxes¹³, with respect to the price of capital¹⁴; TAX is the rate of the relevant tax; SCALE is an index of the required compensation and represents a scaling factor on personal income tax rates or the reduction in social security contributions; finally $Y2\%$ is the percentage change in the activity level (or scale of operation) of the taxed sector.

The most striking feature is that alternatives PTPIT, CTPIT and CTSSC generate a welfare loss for each class of consumers, except the richest (class 6) in alternative PTPIT, while alternative PTSSC favors all consumers except the poorest. A common feature of all reforms is their regressivity and a sharp difference in welfare result of household 1 with respect to households 2 to 5; this is probably due to the share of expenditure on energy products on total gross income which is much higher for the poorest with respect to other households¹⁵. Under alternative PTSSC the welfare loss for the poorest is the smallest so that this reform will be selected by a maximin criterion.

It is interesting to point out that, where a common scaling factor applies to personal income tax rates, the richest are the only who benefit under alternative PTPIT and those who suffer the least welfare loss under alternative CTPIT; this may be explained by the fact that the richest have the highest personal income tax rate so that the scaling factor has a larger effect on net factor prices.

The welfare loss for the poorest under reform PTSSC may be due to the composition of household income which shows, somehow unexpectedly, the highest ratio between capital income and aggregate labour income¹⁶; this explanation seems to be confirmed by the relatively low welfare gain of the richest which have the second highest ratio of capital income on aggregate labour income. Similarly, under alternative CTSSC, if we order households decreasingly according to the welfare loss (in absolute value) the richest are third and the poorest are first.

All proposed reforms consist of increasing the tax burden on a single good while reducing taxes with larger bases; from a theoretical point of view we should expect a welfare loss in the

¹³ This explains the discrepancy between PTPIT and PTSSC, on the one hand, and CTPIT and CTSSC, on the other hand.

¹⁴ Only relative prices matter in general equilibrium.

¹⁵ In the benchmark equilibrium it is equal to 6.2% for the poorest, between 4.8% and 4.2% for households 2 to 5 and 3.2% for the richest.

aggregate by virtue of standard results in the theory of tax reforms and optimal taxation: Hatta (1986) argues that an optimal tax structure is not so far from uniformity so that such a reform would surely be welfare decreasing¹⁷. Examining in more detail alternative PTSSC, however, we realize that the compensation on social security contributions on employees¹⁸ reduces a presumably highly distorting tax with differentiated rates ranging from a minimum of 20.5% to a maximum of 75%: it may be the case that the reduction in distortions brought about by the compensation scheme more than offsets the increase in distortions due to the increase in taxation on the energy sector.

The welfare effects discussed so far are, in a sense, partial because they don't take into account the beneficial effect generated by a plausible reduction in total emissions achieved by the proposed reforms. A first, truly crude, index of emissions reduction might be the variation in the activity level of the taxed sector. In order to have more precise measures of the impact on emissions reference has been made to a recent database available on the web site of the Italian National Bureau of Statistics¹⁹: in detail it has been constructed a matrix showing the share of each sector on total emissions. For the pollutants considered in the database the results are shown in table 2 where the columns, again, refer to the proposed reforms and the rows indicate the percentage change in total emissions of different pollutants.

Table 2: the effects on emissions.

	PTPIT	PTSSC	CTPIT	CTSSC
SOX	-2.301901	-1.615335	-2.771971	-2.562385
NOX	-1.095739	-0.427384	-1.176672	-0.972918
CH4	-0.508664	0.303532	-0.753151	-0.506685
CO2	-1.486447	-0.812321	-1.680615	-1.475058
N2O	-0.487667	0.398341	-0.671468	-0.402518
NH3	-0.003346	0.972505	-0.182997	0.112646

As it may be seen the picture is largely differentiated among the alternatives and among pollutants. Taking, particularly, the best reform on welfare grounds, alternative PTSSC, it is worth stressing the relatively poor performance in terms of reduction in SO_x, NO_x and CO₂

¹⁶ This feature may be due to the typologies of incomes included into capital income in the I-O table.

¹⁷ For a survey on commodity tax reforms the reader is referred to Bulckaen (1992).

¹⁸ Implying a cut of almost ten percentage points as shown by SCALE in table 1.

¹⁹ Conti integrati economici e ambientali.

emissions and the increase in CH₄, N₂O and NH₃ emissions; such increases are largely due to a 1% increase in the activity level of sector 1 (agriculture).

What emerges from table 2 is that for a thorough assessment of each proposed tax reform it would be necessary to estimate the welfare loss due to emissions.

In any case the results so far examined may be considered, nonetheless, a useful guide for a policy maker in order to assess the relative desirability of this kind of reforms.

It may be interesting to integrate the above considerations with the effects of the alternatives on labour supply by households. Within the model labour supply derives from optimizing choices of rational individuals in a context of perfectly competitive markets and full employment of resources. Nonetheless it may be tempting to interpret a contraction in labour supply in terms of increase in unemployment if we wish to model involuntary unemployment as the effect of a downward rigidity of real wage. The percentage change in labour supply by households is shown in table 3.

Table 3: the changes in labour supply.

	PTPIT	PTSSC	CTPIT	CTSSC
LABSUP%C1	-0.310709	0.480213	-0.015990	0.222051
LABSUP%C2	-0.453520	0.598445	-0.178202	0.140662
LABSUP%C3	-0.380326	0.627345	-0.174962	0.131027
LABSUP%C4	-0.302858	0.673456	-0.147576	0.149398
LABSUP%C5	-0.220061	0.689741	-0.127269	0.150067
LABSUP%C6	0.042718	0.582601	0.015697	0.178586

In the present version of the model it is illuminating to interpret the change in labour supply with reference to the relative price of the labour aggregate with respect to the goods aggregate, that is, the two aggregates in the second nest of individual utility functions²⁰. The findings are that for alternatives PTPIT, PTSSC and CTPIT and for each household except the poorest in PTSSC and the richest in CTPIT, the change in labour supply fits the change in the relative price of the above aggregates. More precisely as the relative price of aggregate consumption with respect to (aggregate) leisure rises the labour supply decreases²¹ and viceversa; the two exceptions may be explained by an income effect due to the composition of total disposable income among different sources: under reform PTSSC the increase in labour supply of the

²⁰ This relative price is not reported in the table.
²¹ The own price elasticity of labour supply is positive.

poorest, with a rising relative price of aggregate consumption, may be due to a negative income effect on other income sources; this explanation is confirmed by sensitivity analysis showing a larger increase with a smaller own price elasticity of labour supply and viceversa with a larger elasticity.

Under reform CTSSC, on the contrary, the change in labour supply for each household is just the opposite of the prediction based on the relative price of aggregate consumption with respect to leisure; whereas this price rises labour supply rises as well. Again a negative income effect on other income sources may be at work in this case where only one factor price is affected by the compensation; to confirm this intuition sensitivity analysis shows a further increase with a smaller own price elasticity of labour supply and a decrease in labour supply for consumers 1 to 3 with a greater elasticity of labour supply: in these last cases the effect generated by the relative price of aggregate consumption²² dominates the effect due to other income sources.

4. Sensitivity Analysis.

Sensitivity analysis represents an important part in commenting the results of any computable general equilibrium model which is calibrated on data for a single year rather than being estimated from time series. This analysis should apply to those parameters whose value has been chosen from existing literature, on order to assess the robustness of the results.

Given the functions employed in the model, sensitivity analysis has been performed on the following elasticities:

- the elasticity of substitution in production between imported good and composite intermediate good, equal to 0.1 in the base case, has been perturbed to 0.0 and 0.3;
- the elasticity of substitution in production between primary factors, equal to 1.0 in the base case, has been perturbed to 0.2, 0.5 and 1.5;
- the elasticity of substitution in consumption between different goods, equal to 0.5 in the base case, has been perturbed to 0.2 and 0.7;

²² Which is very close to the base case.

- finally the own price elasticity of labour supply, equal to 0.2 in the base case, has been perturbed to 0.0 and 0.4.

The comment on sensitivity analysis is concentrated on the effects of a change in the above parameters on the consumers' welfare, in order to point out whether and under which values of those parameters the sign of the welfare change is reversed with respect to the base case simulations.

As a general finding it must be noted that, for the alternatives PTPIT, CTPIT and CTSSC, the sign of the welfare change is confirmed for each household so that the base case results may be considered quite robust.

For the alternative PTSSC one finds two inversions in the sign of the welfare change for the richest, which turns into a welfare loss; these occur for a value of the elasticity of substitution in consumption between different goods equal to 0.7 and for a zero own price elasticity of labour supply. In the latter case the richest show a larger increase in labour supply with respect to other households: this may be due to a relatively larger negative income effect, which may also explain the welfare loss. In the former case there is, probably, not a single explanation and a role may be also played by the magnitude of the compensation which is smaller with respect to the base case because of a larger contraction in the activity level of the taxed sector. In both cases, however, the inversion from a welfare gain into a welfare loss is due to a change of less than 0.09 percentage points. The greatest discrepancies²³ are registered, in the case of PTSSC, for a value of the elasticity of substitution in production between primary factors equal to 0.2 and, for all the other alternatives, for a value of the elasticity of substitution in consumption between different goods equal to 0.2.

Generally speaking it is useful to note that the magnitude of the welfare change is monotone with respect to the value of tested parameters and that the value of the elasticity of substitution in consumption between different goods has a significant impact on the contraction in the activity level of the taxed sector: as an example the base case reduction of 4.6%²⁴ in alternative PTPIT falls to 1.9% with an elasticity of substitution equal to 0.2 while rises to 6.4% with a value of 0.7; similar ranges are registered also under the other reforms. Such changes are obviously reflected in emissions reduction with respect to those shown in table 2.

²³ Ranging from 0.16 to 0.26 percentage points but not enough strong to reverse the sign of welfare changes.

²⁴ See row Y2% in table 1.

A sort of sensitivity analysis has been also performed on the magnitude of the proposed reforms: the increase in the revenue of the unit tax, which is 90% in the base case, has been perturbed to 30%, 60%, 120% and 150%; the tax rate on final demand, equal to 30% in the base case, has been perturbed to 10%, 20%, 40% and 50%. Concentrating on welfare changes it is worth noting a linear relationship between the results and the change in revenue or in tax rate, a characteristic somehow unexpected. Much less linear, on the contrary, the relationship with the change in the activity level of the taxed sector: its contraction is less and less proportional as revenue or tax rate rises; these findings suggest not to implement reforms with large increases in tax burden.

5. Summary and Further Extensions.

The present paper has examined the effects of alternative green tax reforms: all of them imply an increase in the tax burden on the energy sector compensated by a reduction in other taxes so as to keep public expenditure constant in real terms. The results have been mainly analyzed under two profiles which were thought to be the most relevant for the policy maker: the welfare change of consumers and the change in total emissions of some pollutants. The aim of the paper has been to give some preliminary insights into possible tax reforms in order to point out the most desirable one.

Under the former profile the most desirable reform consists of an increase in the revenue of the unit tax on all transactions of energy products compensated by a reduction in social security contributions on employees; such a reform benefits all classes of consumers except the poorest: if this regressivity feature were thought to be undesirable it would be possible to mitigate it by altering the compensation mechanism²⁵.

Under the latter profile, on the contrary, the above reform implies the smallest reduction in total emissions of SO_x, NO_x and CO₂ and the largest increase in total emissions of CH₄, N₂O and NH₃. The reform achieving the largest reduction in each pollutant consists of the introduction of a tax on final demand of energy products compensated by a reduction in personal income tax rates, but a welfare loss emerges for all households.

Two comments are in order: first of all the model is static and, given the value of some parameters²⁶, it may be thought to give a picture of the effects in the medium run. Secondly emissions are computed only with reference to the output of polluting sectors and not as a function of different uses as intermediate input or final demand; in addition as a consequence of the fact that there is a single energy sector, the results may hidden a largely diversified impact on the environment.

Sensitivity analysis has shown a fundamental robustness of the results with respect to changes in a number of parameters.

In addition to the simulations discussed in the paper other reforms have been implemented and they will be surely pursued further in the future. Among them an endogenous computation of tax rates (or increase in revenue) so as to achieve a predetermined target of emissions' reduction or a shifting of the tax burden from the unit tax on all transactions to a tax final demand in order to achieve, again, a predetermined target on emissions.

As for further extensions of the model the most promising are, on the one hand, the introduction of imperfections in the labour market so as to model involuntary unemployment and, on the other hand, a disaggregation of the energy sector so as to model more realistically palusible reforms. Furthermore in the present version the personal income tax is imputed proportionally to each class of consumers; an immediate extension is to introduce some allowances so as to discriminate between marginal and average rates.

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²⁵ This possibility has not yet been investigated but it is surely implementable through a tax and transfer compensation.

²⁶ Particularly the elasticities of substitution in production.

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