CARBON TAX AND ITS MITIGATION EFFECT THROUGH TECHNOLOGY SUBSTITUTION: AN EVALUATION FOR ITALY

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Abstract

The Parliament recently approved a bill (n. 448 of 23.12.98) and introduced a carbon tax in Italy like in other European countries as a first instrument to reach the Kyoto target, which consists in a reduction of business as usual emissions of about 100 MtCO2 in 2010. The paper compares revenues and mitigation effects of the tax with an equivalent flat rate tax of 17$/t$CO_2$, uniform over all sectors and fuels, and a business as usual development without additional taxes. In this evaluation the technology substitution effects are analysed through a bottom-up technical economic model (Markal-Italy). It is found that the actual carbon tax is as efficient in reducing CO_2 emission as a flat rate tax: it will achieve in 2010 a reduction of 12 MtCO_2/y with a total collection of about 6 B$/y, compared to a reduction of 14 MtCO_2/y and a collection of about 7 B$/y in the flat rate case.

1. The Framework

Energy related CO_2 emissions in Italy amounted to 401.6 Mt in 1990 [Ministero dell'Ambiente, 1998]. The total anthropogenic emissions of the six greenhouse gasses have been 555 MtCO_2 equivalent in 1990 (1). As an effect of the Kyoto Protocol to the United Nation Framework Convention for Climate Change (UNFCCC) and of the EU burden sharing Italy has the target to reduce these yearly emissions of 6.5% in the period 2008-2012. The goal is very ambitious: the 1990 per capita emission in Italy, which does not use the nuclear option, is at the same level as France and Japan, which use it, 40% less than in Germany and in the average of OECD countries, 60% less than in USA.

The Italian government has set a GHG emission reduction path: with reference to a business as usual scenario, 20/25 MtCO_2eq/y have to be reduced in the year 2002, 45/55 MtCO2eq/y in 2006 and 95/112 MtCO_2eq/y in the period 2008-2012 [CIPE, 1998]. Average CO_2 emissions in the period 2008-2012 should be 3%–5%

This study compares the sectoral mitigation effects of the actual taxation scheme with an ideal one, in which an additional duty of 30 ITL/kgCO_2, proportional to the carbon content of the fuel is introduced in three years. The effect of such an additional carbon tax on fuel prices is quite different from the actual tax (see table 2). The revenues from this flat energy taxation would increase by 12,300 GITL, about 20% of the total present collection (4).

2. Scenario Assumptions and Methodology

Generally speaking an energy–carbon tax directly (5) reduces CO_2 emissions through two mechanisms: it promotes the substitution of business as usual technologies with more efficient and environmentally favourable ones; and it reduces the amount of energy services demanded by consumers. Although it is possible to evaluate the effects of the two mechanisms together, including the indirect effects (6), it has been deemed useful to highlight separately the driving forces behind the effects, especially the first one (7).

Keeping the demand for energy services insensitive to the price increase, the fuel and technology substitution effects of both carbon tax schemes have been evaluated by means of a bottom up model of the Italian energy system, built making use of the Markal software (8). Basically, it generates intertemporal least cost technical –economic models, subject to all kind of environmental constraints. The national reference energy system, whose development has to be optimised, is represented by means of options: technologies (the knots of the system) and energy carriers (the flows). Refineries, plants, cars, devices, appliances, etc., which use or produce energy goods and services and contribute to pollution, are characterised by means technical, cost and emission data; electricity, heat, diesel oil, methane etc. are represented by prices and quantities.

The Markal – Italy model (9) represents the integrated national energy – environment system from 1990 to 2030. Recently it has been used to prepare the energy scenarios presented at the National Energy Environment Conference [Tosato et al., 1998], the mitigation scenarios of the Second National Communication to the UN Framework Convention for Climate Change [Ministero above the price of fuel oil and natural gas in industry and energy sectors. The effect should gradually reduce and vanish in 2020, when it is foreseen an increase of hydrocarbon prices and coal should become again competitive.

Model calculations show that emission reduction mainly takes place in the industry and energy sectors. Furthermore, 2/3 of the reduction are due to a more efficient use of energy in the supply and in the consumption sectors combined with a less carbon intensive fuel mix; less than 1/3 is directly induced by price increase and the corresponding energy services demand reduction.

In the *transport sector*, where the absolute increase of fuel prices is less significant in percentage (+8% as weighted average) emissions are reduced by about 1.5 $MtCO_2$/y (-1.2%), mainly due to price induced demand reductions (12). The price increase due to the carbon tax is not enough to push the use of new transportation technologies, to promote low consumption vehicles and low carbon fuels. If additional measures are set, a limited fleet of low consumption vehicles may be diffused and emissions may further reduce by about 4 $MtCO_2$ in 2005 (7 in 2010).

In the *civil sector* the impact of the tax is limited (13) and emissions are reduced by about 1.4 $MtCO_2$/y in 2005 (-1.8%), mainly induced by the use of more energy efficient technologies. In the following years those effects should increase, but they remain small in absolute terms.

In the *industry, agriculture and refineries sectors*, the emissions might reduce by about 3 $MtCO_2$/y (-3%), nearly all due to fuel substitution effect and the corresponding end uses efficiency increase. In the following years those effects should stay stable in absolute value. This result comes from an increase of energy prices of about 15%, weighted average (14), that is half of the one occurring with the flat rate additional carbon tax.

In *thermoelectric generation* the greater potential is available: emission are estimated to lower by about 6 $MtCO_2$ in 2005; in 2010 the reduction becomes higher and maintains that level thereafter (15). The average input energy prices increase by about 12%. The cost of kwh produced by coal and heavy oil become nearly equivalent. The reduction is due to substitution effects, induced mainly by following years. The main effect of this taxation is on coal consumption in the industry and energy sectors (see tables 3), because the price of coal price exceeds the price of fuel oil and natural gas (see table 2).

In the *transport sector* the effects are similar to the case of the actual tax: emission reduction of 1.2 MtCO2 in 2005, mainly due to the reduction of the demand induced by price increase of about 5% (weighted average). Also the diffusion of low consumption cars and of less carbon intensive fuels, associated with additional measures, may have an effect similar to the actual tax case: emission reduction of about 3 MtCO2 in 2005 and 6 in 2010 (see figure 2).

In the *civil sector*, the impact of the flat tax is negligible, with emissions reduction of about 1 $MtCO_2$ in 2005, mainly due to substitution effect (more efficient technologies). In the following years those effects should increase, but they remain small in absolute numbers. This result comes from a limited increase in final prices, about 7% as a weighted average.

In the *industry, agriculture and refineries sectors* emissions should reduce by about 2 $MtCO_2$ in 2005, constant thereafter, mainly due to fuel substitution effect. This result comes from a relevant increase in the final energy prices, about 30% as a weighted average. The energy demand elasticity is limited in this sector. The reduction of energy consumption occurs mainly in the refineries – with loss of competitiveness and possible reduction of export capability – and in blast furnaces steel making factories - due to a 45% increase of coal price.

In *thermoelectric generation*, emission reduction may reach 4 $MtCO_2$ in 2005, mainly due to fuel substitution effect, 2/3 for changes in the technological mix and 1/3 for price induced demand reductions. The weighted average of input fuels prices would increase by about 35%.

Endnotes

(1) the inventory refers to IPCC-OECD 1996 methodology.
(2) an exchange rate of 1710 ITL per US$ has been used; the total amount is calculated on 1998

(6) for instance, making use of the capabilities of the equilibrium version of Markal (Macro, Micro, Elastic) [Manne, Wene, 1992; Van Regemorten, 1995, Loulou, 1994].

(7) The effects of the tax on the demand for energy services, via the increase of the retail prices, have been approximated in this exercise by means of sectoral elasticity to the own prices: 0.2 in the transportation sector, 0.1 in the residential, 0.01 in industry and agriculture, 0.05 in thermoelectric production.

(8) the basic documentation of the Markal model generator, developed by the International Energy Agency thorough the Energy Technology Systems Analysis Project [Goldstein et al, 1983, 1996], and its most recent development – including the stochastic version and the inter-regional general equilibrium international trade version - are posted at the web site of the operating agent: http://www.ecn.nl/unit_bs/etsap, or in the linked sites.

(9) The present version of the Markal-Italy model has been originally built in the early nineties to evaluate potential and costs of reducing CO_2 NO_x and SO_x emissions and comply with international protocols [Pinchera et al., 1992]. Since then it has been continuously updated. Some elements characterising the main technologies included in the model are summarised in another presentation to this conference [Simbolotti et al., 1999].

(10) Those taxes have been introduced using a special set of instructions that allows to specify the tax by fuel and by sector of use. This is particularly useful in our national environment because the excise duty system is complex, it do not simply refers to final sector of use but it also foresee different duties for different uses of the some fuel in the some factory. For example the same fuel can be used, with different excise duties, to generate electricity on a power plant, in a combined heat and power plant or just generate process heat. This module also allow to specify subsidies for any technologies up to specified maximum total amount. This is very useful, for example, for electricity produced with renewables that receives different subsidies for each specific primary font, solar, wind, biomass, small hydro, often linked to a defined maximum amount of money. The output of the model specify amount of taxes/subsidies paid for each sector and fuels, separating them from the other operating costs.

(11) similar values have been estimated independently by means of econometric models [Prometeia, 1999; Osculati et al., 1998]

(12) according to the new tax, the companies that transport goods by road may claim back the extra duties paid to the state to purchase diesel fuel.

(13) the final energy prices increase by about 3% (weighted average); only the fuel oil for domestic services, previously nearly tax free, suffers a relevant price increase and its use is significantly reduced compared to the flat additional tax scenario.

(14) The actual carbon tax penalises coal and high sulfur heavy fuel oil; to avoid loss of competitiveness of domestic industries on international markets, coal used in blast furnaces and, partially, fuels used in refineries are exempted from taxation.

(15) The scenario results for the year 2010 are in line with the conclusion of the energy – environment conference held in Rome (25-28.11.99) [CNEA, 1998] and maintain a minimum use of both fuel oil and coal in electricity generation. This approach is suggested by the important principle of primary sources diversification stated by IEA for developed countries, but limits the scope for possible emission reduction in the thermoelectric sector.

Law 23 December 1998, n. 448: *Measure of public finance towards stabilisation and development*, GU n. 302 of 29 December 1998, chapter 2 (Indirect Excises), art. 8 (Carbon Dioxide Emissions Tax and Compensation Measures) and Annex 1 (List of Products submitted to Excises and Taxation Levels at 1.1.2005).

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Table 1: Fuel prices in 2005, as modified by the actual carbon – energy tax

Sector / Fuels	Unit	Effect on total price: Value (Lire/unit)	%	Value Lire /kep	c-tax+VAT Taxation (Glire)
Trasport			**8.7%** (a)		**6852**
petrol, 98	lt	46	2.5%	60	447
petrol, 95	lt	154	8.7%	198	2272
diesel fuel	lt	190	13.9%	223	4404
LPG	lt	-133	-15.7%	-209	-307
NGL	mc	120	18.8%	145	37
Civil			**3.0%** (a)		**1627**
diesel fuel	lt	190	14.0%	223	704
natural gas	mc	20	2.0%	25	413
n. gas: cooking, w. water	mc	7	0.9%	8	45
very fluid f. oil, low s.	lt	199	15.3%	221	11
fluid fuel oil, low s.	lt	309	51.1%	343	338
LPG	lt	30	4.5%	44	105
fuel oil, low s.	lt	360	127.0%	400	0
coke / coal	kg	50	24.0%	72	10
wood	kg	0	0.0%	0	0
Agricolture / fishing					
diesel fuel	lt	36	6.0%	43	97
natural gas	mc	7	1.2%	8	1
Industry					
diesel fuel	lt	190	14.0%	223	141
diesel fuel	lt	57	7.9%	67	13
fuel oil, high s.	kg	175	66.4%	179	35
fuel oil, low s.	kg	83	34.9%	84	286
natural gas	mc	24	7.3%	29	433
coal	kg	0	0.0%	0	0
pet coke	kg	71	74.1%	86	142
Refinery			**11.8%** (b)		**30**
refinery gas	mc	0	0.0%	0	0
fuel oil, low s.	kg	12	7.1%	12	30
Power plants			**9.2%** (a)		**838**
fuel oil, aver.	kg	14	5.1%	14	285

Table 2: Fuel parameters, base prices and additional duty of 30 lire/kg CO2.

Sector / Fuels	Unit	CO2 kg / unit	average 98 price (Lire/ unit) industrial	average 98 price (Lire/ unit) total	Effect on total price: variation Lire/unit	Effect on total price: %	Effect on total price: variation Lire/kep	total revenue Glire/a
Transport						**5,4%**		**3279**
petrol, 98	lt	2,24	460	1886	79	4,2%	103	736
petrol, 95	lt	2,24	450	1767	81	4,5%	103	904
diesel fuel	lt	2,64	395	1371	94	6,5%	111	1419
LPG	lt	1,68	366	851	57	6,2%	95	196
NGL	mc	1,94	530	636	69	10,7%	84	24
Civil						**7,5%**		**1993**
diesel fuel	lt	2,64	380	1353	94	6,7%	111	262
fuel oil, low s.	lt	2,92	155	287	113	25,3%	115	0
natural gas	mc	1,94	570	978	68	7,4%	82	1598
LPG	lt	1,80	340	662	56	7,5%	93	133
coke / coal	kg	3,17	174	209	100	38,5%	140	25
wood	kg	0,00	150	150	0	0,0%	0	0
Agricolture / fishing								**258**
diesel fuel	lt	2,64	390	602	78	11,9%	92	231
petrol	lt	2,23	480	1200	66	5,5%	86	18
natural gas	mc	1,94	500	566	58	10,2%	70	9
Industry								**2767**
fuel oil, low s.	kg	3,18	170	290	94	23,3%	96	392
fuel oil, high s.	kg	3,18	150	320	94	20,8%	96	0
diesel fuel	lt	2,64	380	1240	78	12,4%	92	154
natural gas	mc	1,94	254	301	58	19,2%	70	1365
coal	kg	2,93	104	125	86	68,5%	120	856
Refinery			(stima)			**30,2%**		**481**
refinery gas	mc	2,10	100	100	66	43,6%	78	210
fuel oil, low s.	kg	3,02	150	164	89	41,8%	96	270

Table 3: Total primary energy supply development for Italy:
a - base case, without changes in the 1998 energy excise level, Mtoe, Mt;

	1990	1995	2000	2005	2010	2015	2020
OIL / LIQUIDS	**92,4**	**92,9**	**89,6**	**89,8**	**90,7**	**92,4**	**92,4**
COAL / SOLIDS	**15,8**	**14,6**	**14,8**	**15,0**	**14,4**	**12,7**	**9,8**
of which: wood, biomass	1,7	2,1	2,4	2,2	2,3	2,3	2,4
NATURAL GAS	**38,5**	**45,2**	**55,7**	**62,6**	**70,4**	**77,1**	**85,4**
IMPORTED ELECTR.	**7,9**	**7,9**	**8,8**	**8,0**	**7,5**	**5,9**	**5,9**
IDRAU.+ GEO+ RENEW.	**8,7**	**9,5**	**9,2**	**9,2**	**9,9**	**10,0**	**10,9**
TOTAL EQ. PRIMARY EN.	**163,3**	**170,2**	**178,0**	**184,6**	**192,9**	**198,1**	**204,4**
Mt CO2, IPCC-OECD Method.	**401**	**409**	**427**	**442**	**459**	**472**	**479**

b – scenario with the actual carbon - energy tax;

	1990	1995	2000	2005	2010	2015	2020
OIL / LIQUIDS	**92,4**	**93,0**	**89,5**	**88,8**	**90,3**	**91,1**	**93,3**
COAL / SOLIDS	**15,8**	**14,6**	**14,9**	**13,9**	**12,4**	**13,0**	**10,3**
of which: wood, biomass	1,7	2,1	2,4	2,2	2,4	2,4	2,5
NATURAL GAS	**38,5**	**45,2**	**55,4**	**64,3**	**71,9**	**76,0**	**83,0**
IMPORTED ELECTR.	**7,9**	**7,9**	**8,8**	**8,0**	**7,5**	**7,2**	**6,1**
IDRAU.+ GEO+ RENEW.	**8,7**	**9,5**	**9,2**	**9,1**	**9,9**	**9,9**	**10,9**
TOTAL EQ. PRIMARY EN.	**163,3**	**170,3**	**177,7**	**184,1**	**192,0**	**197,2**	**203,5**
Mt CO2, IPCC-OECD Method.	**401**	**409**	**425**	**437**	**452**	**468**	**479**

c – scenario resulting from an addition duty of 30 lire/kg CO2

Figure 1: Italian primary energy supply development in different scenarios.

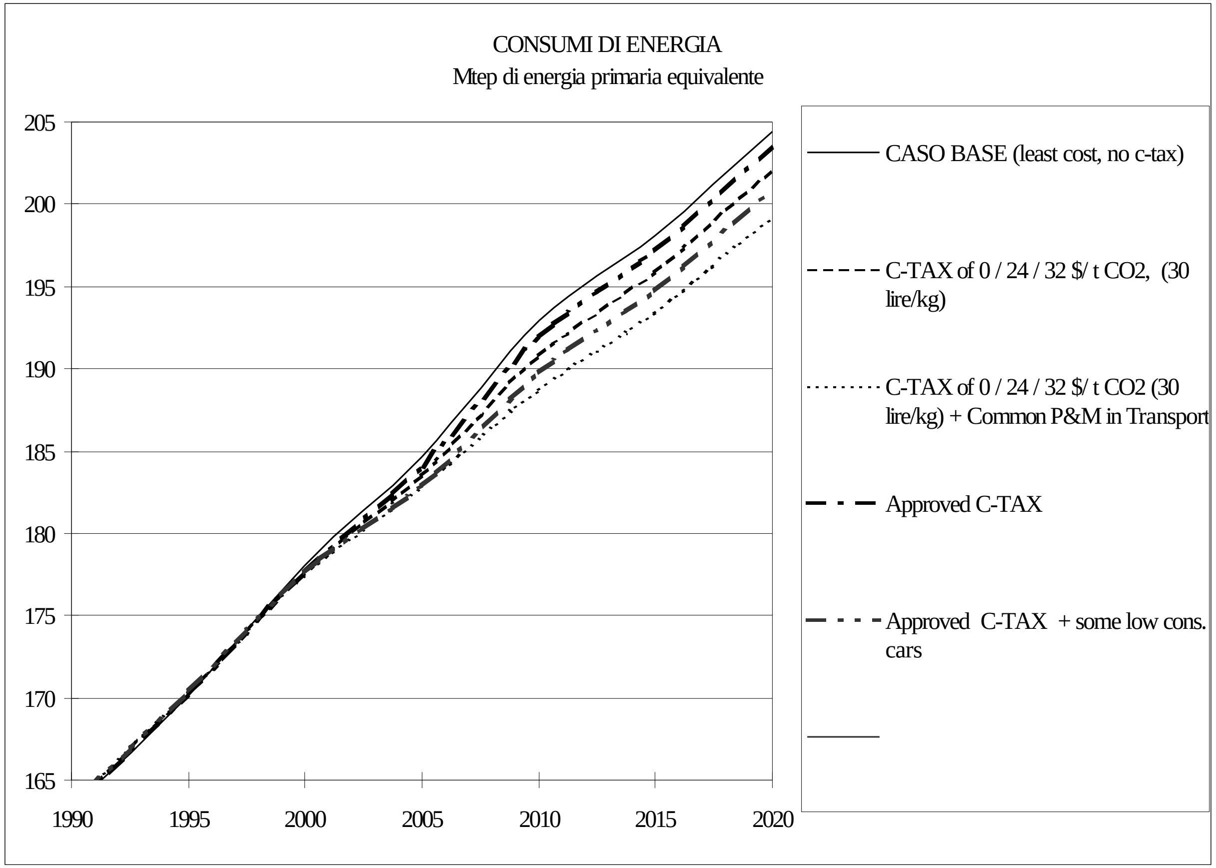

Figure 2: Italian carbon dioxide emissions development in different scenarios.