Environmental progressive tax reform through a dynamic general equilibrium analysis

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The challenge of climate change needs to be tackled with environmental policy instruments carefully designed in order to achieve environmental benefits and to avoid negative economic effects. As a rule, an environmental tax reform designed to reduce greenhouse gas (GHG) emissions, under specific conditions, can generate additional benefits when tax revenue is recycled in the economy in order to finance the reduction of pre-existing taxes. These further benefits, known as blue second (or third) dividend, integrate the first green dividend that represents the environmental target. In particular, a green tax on commodities output, that is applied with a progressive structure according polluting capacity of each production process, can generate a double/triple dividend when tax revenue is recycled by means of a reduction of income tax or value added taxes. Such tax reform should be tested through a dynamic general equilibrium analysis in order to quantify its environmental and welfare effects over time period. International environmental agreements in fact, set clear temporal objectives for each country about the reduction of GHG. Thus environmental policies that aim to restore the correct level of emission without neglecting GDP growth should be tested over time. In this respect, the paper develops a dynamic general equilibrium model based on the SAM framework that allows to quantify in the long time both the economic and the environmental effects that the environmental tax reform can generate.

Keywords: Environmental taxation, SAM, Dynamic CGE model.
JEL classification: H23, D58, D57.

1 Introduction

In recent years environmental sustainability, especially the reduction of greenhouse gas emissions (GHG), have been representing one of the economic policy objective for European countries. Among the variety of economic measures, more than a few Central Governments adopted emission taxes and emission permits trading that are widely known as market-based policy instruments dealing with externalities of pollution (Baumol and Oates 1988). Alongside these National experiences, the scientific debate mainly concentrates on the cost-benefit analysis of the instrument adopted to pursuit the environmental policy and stimulate the environmental protection (Parry 2004).

The environmental taxation, in particular, is considered a powerful instrument for pollution control but more important, it provides public revenue that can be opportunely recycled in order to enhance not only the environmental quality but also the non-environmental welfare (Pearce 1991). Empirical studies for several countries, such as Schneider (1997), Bovenberg and De Mooij (1998), Manresa and Sancho (2005), Takeda (2007), Glomm et al. (2008), Bor and Huang (2010), demonstrate that a non-environmental benefits (blue second or third dividends) can be added

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to the first green dividend that represents the environmental target [1]. Actually the possibility to get a double and a triple dividend through an environmental policy depends on the structure of the existing fiscal system, the technology adopted and above all on the structure of tax reform[2].

The aim to assess the direct and indirect effects of environmental policy in order to verify the existence of the double dividend hypothesis, leads to concentrate on static and dynamic general equilibrium models (CGE) as suitable analysis instruments (Radulescu and Stimmelmayr 2010). These models in fact allow to measure the impacts of an exogenous shock on macroeconomic variables in the income circular flow. This paper, in particular, develops a bi-regional multisectoral dynamic CGE model in order to analyze the dynamic impact over the time of environmental fiscal policies. The advantages associated using the dynamic CGE model refer to three main aspects. First, static CGE is based upon a single set of equilibrium conditions and leaves aside relationships over time. As an example, producers and consumers, which maximize their utility choosing the optimal allocation of consumes and savings become myopic in the between period decisions (savings and investment). Hence the second aspect, the equilibrium prices that solves the static equilibrium do not hold over time and refers to a quite uncertain time horizon. Finally, even if the assumptions on elasticity of supply and demand can be interpreted as relatively long run adjustments, static models do not account for more than a few factors such as capital accumulation, population growth and technological change (Lau et al. 2002).

In this respect, the paper attempts to evaluate the existence of a regional double dividend for the Italian economy when the Central Government adopts an environmental fiscal reform. In particular an effort is made to introduce a progressive *eco-tax* according to the CO_2 emission coefficient of each commodity. Thus the corresponding tax revenue is completely recycled in order to reduce both the income tax and the regional tax on activities' value added. Since good prices may be affected by tax shift, the reduction of income tax aims to mitigate the negative effect on real disposable income of Households while the reduction of the regional tax on activities' value added is applied to face tax shift.

Furthermore, the aim to identify the convenient green tax reform for the Italian economy requires the integration of the SAM with the environmental data set concerning CO_2 emissions by each commodity. In this respect, the European Commission suggests the use of the National Accounting Matrix including Environmental Accounts (NAMEA) as basic tool for the integration between environmental and economic flows[3].

The next section points out the main features of the dynamic model implemented to carry out the analysis and the following section gives a descriptions of the database. The third section introduces the environmental policy targets for the Italian case and suggests a suitable environmental tax reform consistent with the reduction of CO_2 emissions. The last section provides a description of the simulations and the results emerging from the application for the Italian instance, in term of CO_2 emissions by activities, total output, price trend, gross investment and final consumption over time[4].

[1]These results integrate the previous theoretical studies which neglects the existence of the second dividend. Among them it is worth to mention Goulder (1995), Bovenberg and Goulder (1996), Bovenberg and Goulder (1997) and Böhringer et al. (1997) which showed the absence of the second dividend in presence of a carbon regulation even if the environmental variables improve.

[2]According to Bovenberg and Goulder (2002) the conditions under which the double dividend arises, can be summarised in: i) pre-existing distortion taxes on primary factors; ii) factors supplied are inelastic; iii) relative international immobility of capital; iv) elasticity of substitution between energy (the environmental input) and labour greater than elasticity of substitution between energy and capital; v) real wages rise little when unemployment falls, so that the reduction in taxes on labour are not offset by wage rises.

[3]The NAMEA integrates the major economic aggregates - total output, value added and final demand - with the GHG emissions data in physical terms according to the input output disaggregation (CE 1994). This approach avoids the difficulties connected to a correct valuation of environmental costs.

[4]All variables are disaggregated.

2 Dynamic CGE model relationships

Our model is a multisectoral dynamic CGE model where the evolution path is a sequence of single period static equilibriums linked each other by the capital accumulation conditions (Lau et al. 2002). It is a recursive dynamic model that can be illustrated in two phases: the first refers to the description of the single period equilibrium, the second introduces the dynamic component.

The model considers an open economy with m commodities, c components of value added, h Institutional Sectors including Households, Government and Rest of the World. In every time period the demand is equal to supply for all commodities and for all primary factors market (*market clearing* conditions) and extra profits are not allowed (*no profit* conditions) (Pretaroli and Severini 2009).

It can be described as an integrated representation of the bi-regional income circular flow where the entire process of generation, primary and secondary distribution of income is represented by a system of behavioural equations and income constrains for agents (they are all maximises and price takers). The model is a coordinated set of matrices of flows that take place according to the relationship among the principal economic functions such as production, consumption, redistribution and accumulation.

The total output ($\mathbf{X}$) resulting from combining domestic and imported output ($\mathbf{M}$)[5] is equal to the intermediate demand ($\mathbf{B}$), the personal consumption expenditures ($\mathbf{C}$), the Government current expenditures ($\mathbf{G}$), the gross capital formation ($\mathbf{I}$) and the exports ($\mathbf{E}$). Likewise the primary factors' endowments correspond to the primary factors' demands in the production process ($\mathbf{Y}$) and their markets are perfectly competitive.

The domestic production is formalized by a nested constant return to scale technology. Assuming the Leontief production function, the domestic output is the combination of intermediate goods ($\mathbf{B}$), depending on total output and prices, and the value added that is affected by total production and primary factor compensations ($\mathbf{Y}$). The value added is therefore generated by combining capital and labour that are perfectly mobile across activities.

Following the logic of the Ramsey model, the Institutional Sectors (Households, Government and Rest of the World) maximise the present value of their intertemporal utility function which depends on final consumption ($\mathbf{C}$ and $\mathbf{G}$) and gross saving ($\mathbf{S}$) subject to the lifetime budget constraint.Budget constrain for Households is verified when the total disposal income ($\mathbf{R}$) is equal to the total personal consumption expenditures ($\mathbf{C}$) and savings ($\mathbf{S}$). The primary factor compensations ($\mathbf{R}$) plus net transfers from Institutional Sectors ($\mathbf{Tr}$) determine consumers total endowments in every time period. As for the Government, the total government current expenditure and transfers to other Institutional Sectors, ($\mathbf{G}, \mathbf{Tr}$) balance the total tax revenue collected ($\mathbf{T}$). Taxes can be divided into direct income tax and a set of indirect taxes (tax on products, value-added tax and payroll taxes).

The single period equilibrium regarding the condition on gross capital formation requests that total gross investments ($\mathbf{I}$) becomes equal to gross savings by Institutional Sectors ($\mathbf{S}$).

The dynamic component in the model is given by the intertemporal capital accumulation condition. According to the market clearing condition for the capital, any changes in investment must affect the capital annual growth given a constant rate of capital depreciation (δ). Than in a dynamic model the optimization problem for all the consumers becomes (Böhringer et al. 1997):

$$max \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho} \right)^t u[\mathbf{C}_t(y_{d_t}, p_t)] \tag{1}$$

[5]Following the Armington's hypothesis (1969), imported and domestically produced commodities are not perfect substitutes. This solves the problem that the same kind of good is found to be both exported and imported.

s.t.

$$\mathbf{C}_t = \mathbf{X}_t(\mathbf{Y}_t, \mathbf{M}_t, \mathbf{T}_t) - \mathbf{I}_t - \mathbf{E}_t \tag{2}$$

$$\mathbf{K}_{t+1} = (1-\delta)\mathbf{K}_t + \mathbf{I}_t \tag{3}$$

Every Institutional Sector maximizes intertemporal utility which depends on consumption, under the constraint represented by two main conditions: i) the total output produced by each commodity $\mathbf{X}_t$ is divided into personal consumption expenditures ($\mathbf{C}_t$) and government current expenditures ($\mathbf{G}_t$), gross domestic investment $\mathbf{I}_t$ and exports $\mathbf{E}_t$ (*market clearing conditions*); ii) the capital stock in period $t+1$ is equal to the capital stock in period t ($\mathbf{K}_t$), less depreciation (δK_t) plus investment in period t ($\mathbf{I}_t$). The rate of capital depreciation is fixed in every period and exogenously specify as the steady state interest rate r and the steady state growth rate g[6].

In order to solve the model for a finite number of periods, we approximate the infinite horizon equilibriums with endogenous capital accumulation condition according to Lau et al. (2002). Thus to obtain the terminal period equilibrium we set the terminal investment growth rate equal to the growth rate of aggregate output.

Table 1. Fundamental relationship in CGE model

	Comm.	*Fact.*	*Ins. Sec.*	*Gov.*	*CF*	*RoW*
Commodities (1,..,n)	$\mathbf{B}(x,p)$		$\mathbf{C}(y_d,p)$	$\mathbf{G}(y_d,p)$	$\mathbf{I}(r)$	$\mathbf{E}(e,p)$
Primary Factors (1,..,c)	$\mathbf{Y}(x,p_f)$					
Institutional Sectors (1,..,s)		$\mathbf{R}(y)$		$\mathbf{Tr}(y,t)$		
Government (1,..,g)	$\mathbf{T}(x)$	$\mathbf{R}(y)$	$\mathbf{T}(y)$			
Capital Formation (1)			$\mathbf{S}(y_d)$	$\mathbf{S}(y_d)$		
Rest of World (1)	$\mathbf{M}(x,e)$			$\mathbf{Tr}(y)$		$(+/-)a$

3 The environmental tax reform and CO_2 emissions in the SAM framework

The analysis is carried out on the bi-regional Italian SAM for the year 2003(Pretaroli and Socci 2008), which represents the production system features and the income circular flow in terms of intra-regional and inter-regional flows (Socci 2004). A scheme of the bi-regional flows is showed in figure1.

A set of rows and columns of the SAM are headed to 16 commodities[7] and 5 Institutional Sectors[8] in each Italian region that are represented by the North-Centre region and the South region (Pretaroli and Severini 2008). A disaggregation of Institutional Sectors flows is provided in order to test the impacts of the fiscal policy reforms. We distinguish different typologies of revenues and expenditures. In particular we consider the social contribution, the regional value added income tax, a set of indirect taxes on commodities and the household income tax. The tax rates are calibrated on the SAM data and are constant at their benchmark levels in all scenarios.

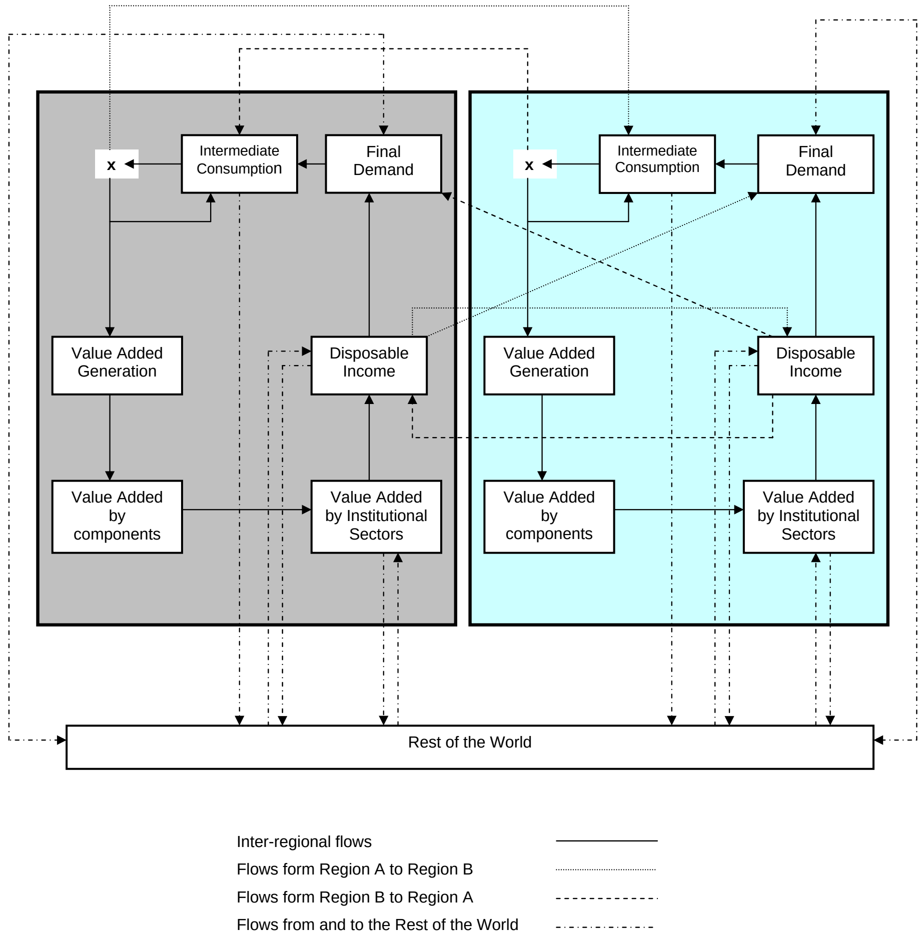
Since the paper aims to assess economic and environmental impacts of a fiscal reform at the regional level, the SAM must be integrated with environmental indicators provided by the National Accounting Matrix including Environmental Accounts (NAMEA) developed by the ISTAT for the period 1990-2008 (ISTAT 2010). We concentrate in particular on CO_2 emissions by

[6]In our model we assume $r = 4\%$ (nominal interest rate) and $g = 0.6\%$ (real growth rate). According to the rule for investment on a steady state $I_t = (d+g)K_t$ we calibrate the value of the depreciation rate δ on the SAM data.

[7]1.Products of agriculture, 2.Energy products, 3.Metal and non metal ore, 4.Non metallic mineral products, 5.Chemical products, 6.Mechanics, 7.Transport equipment, 8.Food products and beverages, 9.Textile, 10.Other manufacturing products, 11.Construction work, 12.Trade, 13.Transport, 14.Financial services and Insurance, 15.Private services, 16.Government services.

[8]I. Households, II. Firms, III. Regional Government, IV. Central Government, V. Rest of the World.

Figure 1. The bi-regional income circular flow



commodity and we emended these physical flows in order to match the commodities classification in the SAM. This phase allows to construct a data scheme in which the economic flows related to the 16 commodities in each region (North-Centre and South) are associated to a specific level of CO_2 emissions. The different polluting power associated to each commodity depends on the technology employed in the production process and is measured by the CO_2 emission coefficient[9].

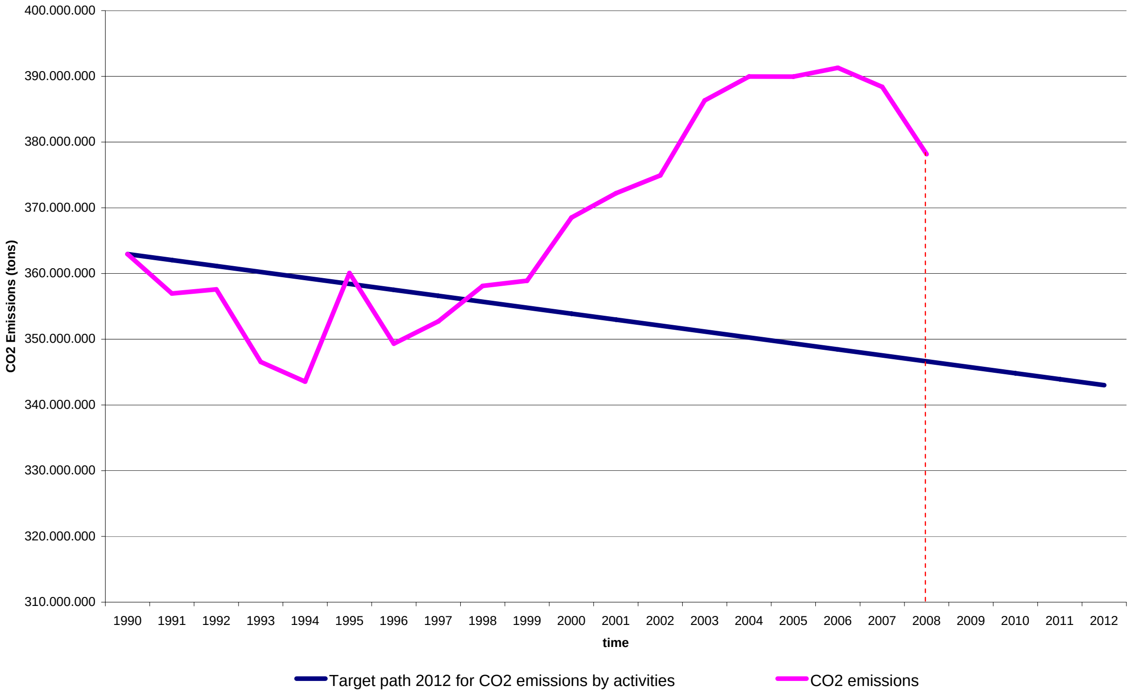
The Kyoto protocol fixed the objective on GHG for the Italian economy in the reduction of 5.5% of CO_2 emissions for the period of 2008-2012[10]. Starting from the year 1990, when the total CO_2 emissions were 360 million of t, the Italian system should have reduced them of around 0.897 million tons in each followed year in order to achieve the Kyoto target represented by 340 million tons in the year 2012 (ISTAT 2010)[11]. Actually in 2008, Italian CO_2 emissions were 31,5 million tons more than the annual target. The difference can be easily interpreted as the Italian debit of CO_2 emissions, while 346,6 million tons represent the admitted level of CO_2 emissions. We assume that it corresponds to total polluting license that should be divided among commodities according to their coefficient of CO_2 emission (Ciaschini et al. 2010a,b).

Thus the linear reduction path (figure 2) allows to find the distance from the Kyoto target on CO_2 emissions for 2008 in 3.8 basic points.

The simulations implemented concern the introduction of an environmental tax on commodity output differentiated according to CO_2 emissions. For this purpose we introduce a "no-tax area"

[9]The emission coefficient by commodity is the ratio between the of CO_2 emission tons by commodity and the total output.
[10]Since the Kyoto protocol established the reduction of 6.5% of Italian GHG, that are represented by CO_2 for the 85%, the Kyoto target for Italian CO_2 is around 5.5%.
[11]We consider only emission of CO_2 by commodities.

Figure 2. Emissions of CO2 by Italian commodities (distance from the exemption level)



represented by the level of CO_2 emissions in order to reach Kyoto Protocol target. The goods charged by the taxation burden are those with the CO_2 emissions level higher than the top level of 10.8 million tons, as shown in figure 3.

The exemption area is calculated as the ratio between the total level of CO_2 allowed for Italy for the year 2008[12] and the number of commodities in the *benchmark*[13]. In this way less polluting commodities are not taxed and those which over-pass the permitted level (10.8 million tons for each commodity) have an incentive to reduce their emissions to avoid the taxation.

The tax is designed with a progressive structure: there are 5 classes of taxation and all commodities pay a fixed price per ton of CO_2 emission. The higher is the class, the higher is the burden of the tax by the commodity. The structure of this *eco-tax* can be described as follow:

- Class 0. from 0 to 10.871.958 t: no-tax area,
- Class 1. from 10.871.958 t to 15.000.000 t: 9 euro per CO_2 t,
- Class 2. from 15.000.001 t to 30.000.000 t: 16 euro per CO_2 t,
- Class 3. from 30.000.001 t to 50.000.000 t: 22 euro per CO_2 t,
- Class 4. over 50.000.001 t: 32 euro per CO_2 t.

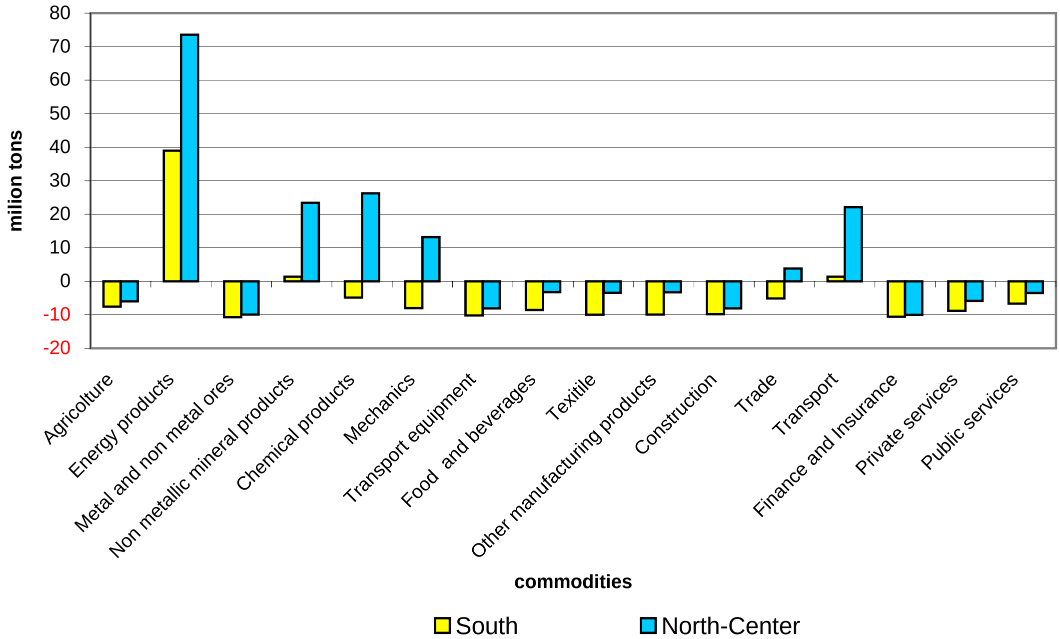
In North-Centre region, the commodities which pay the eco-tax on output are: 'Energy products', 'Non metallic mineral products', 'Chemical products', 'Mechanics', 'Trade' and 'Transport'. In South region, 'Energy products', 'Non metallic mineral products' and 'Transport'.

4 Simulations and results

The policy aims to promote the reduction in polluting goods consumption in order to cut CO_2 emissions and reach the first dividend (environmental dividend). Moreover, since the economic system is integrated and all variables are connected, it is crucial to evaluate the policy effects on

[12]According to the path of CO_2 reduction the emissions foreseen for Italy for 2008 are 346,6 million of tons
[13]The commodities number is 32 (16 for North-Center area and 16 for South area).

Figure 3. Emissions of CO_2 by Italian commodities (distance from the exemption level)



the whole income circular flow in order to assess the existence of a second dividend for the Italian economy. For this purpose the tax revenue is completely recycled following two hypothesis:

- in the first scenario s_1 the tax revenue is recycled to cut the regional tax on commodities value added;
- in the second scenario s_2 the tax revenue is recycled to reduce Households income tax.

The reasons that led us to model these two scenarios refers to the opportunity of reducing the distorting effect of eco-tax and pre-existing taxes. The introduction of the eco-tax mainly affects the most polluting goods by increasing their costs of production. This effect should encourage productive sectors to reduce the supply but may lead to higher final prices. For this purpose, by reducing the income tax we attempt to compensate Households for the loss purchasing power linked to the tax-shift on the final good prices. Similarly the reduction of regional value added activities tax should reduce the pressure of taxes on final prices formation.

The simulation compares the baseline equilibrium (or benchmark equilibrium) without any environmental taxation, and the aftershock equilibrium resulting from the environmental policy reform. The distances between the baseline trend path and the path generated after the simulations allow to determine the impacts of the policy introduced on the main environmental and welfare variables in the long run.

The results of the simulations are presented starting from the effects on output, prices, CO_2 emission, and final demand.

In both two scenarios the eco-tax is imposed on total output. In particular the burden is on the commodities whose CO_2 emissions exceed the allowed level (no-taxed level). Among the other, the Energy commodity is the most pollutant in both two regions, thus pays a higher eco-tax (class 4). As a result of the environmental fiscal reform, the total output of Energy good decrease and the price increases with respect to the benchmark path (figure4 and figure5).

The effect on price and output is greater in the North-Centre region, where the Energy commodity production process generate a higher level of CO_2 emission and in particular when the tax revenue is recycled through a reduction on Households income tax (s_2). In the first scenario in fact, the cut in the regional tax on commodities value added (s_1) mitigate the translation of the tax burden on final prices and reduce the effect on the production. Similarly, the total output of all the other goods affected by the eco-tax decrease and the prices increase with respect to

Figure 4. Effects on Energy price - % change from 2008 to 2020

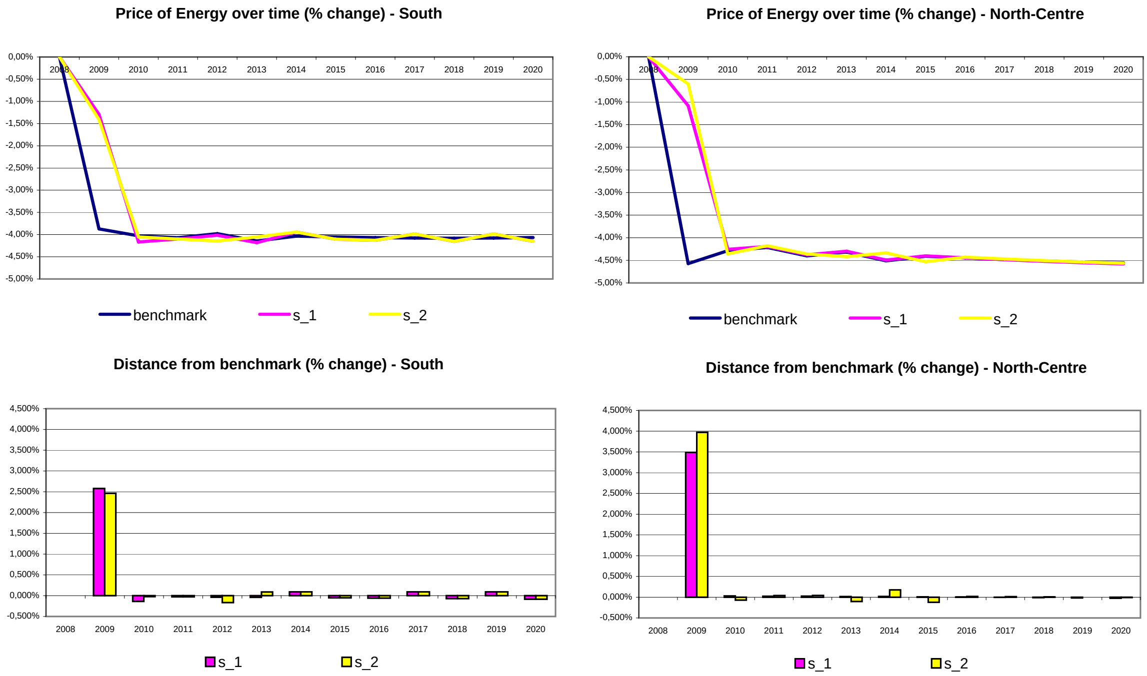
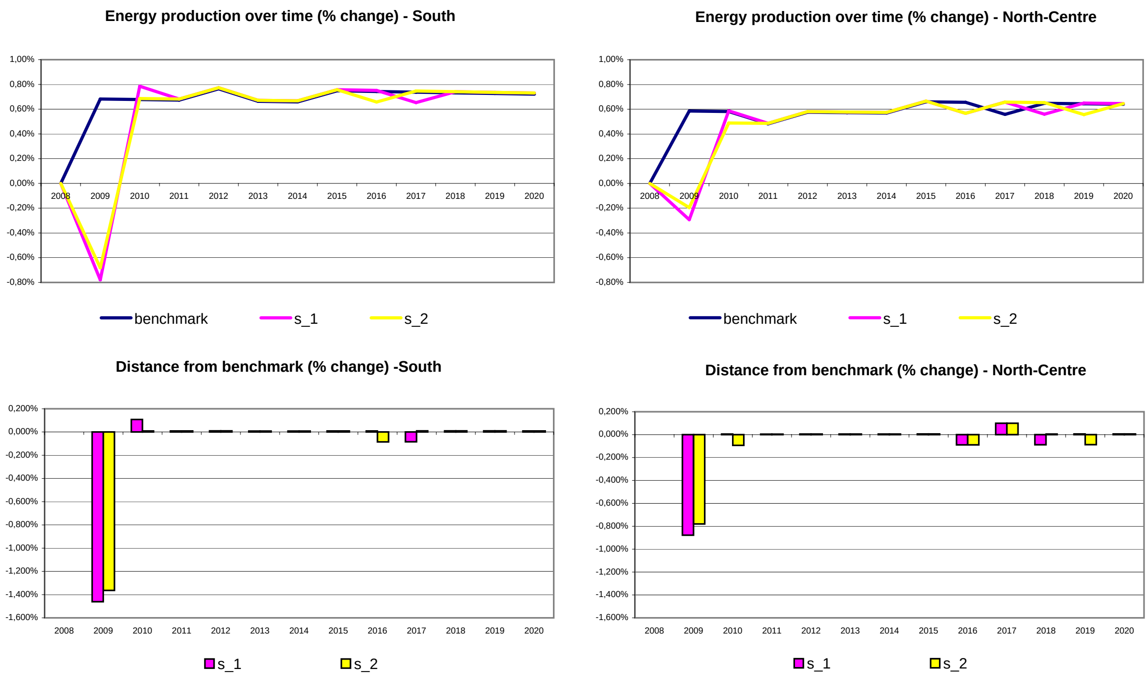


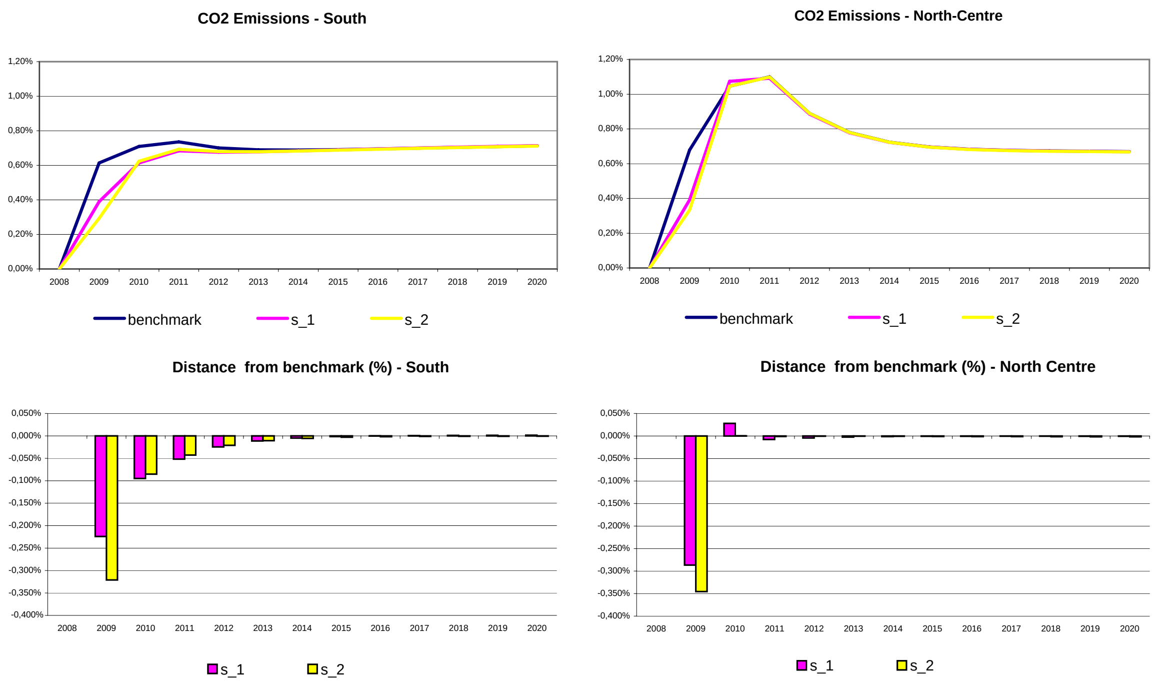
Figure 5. Effects on Energy output - % change from 2008 to 2020



the benchmark. Nevertheless the impact of the environmental reform on commodity output and final prices is relevant only in the short run. In the long run the changes become similar to the benchmark trend.

The impact of the eco-tax on total output affects the level of CO_2 emissions. In both two scenarios the fiscal reform reaches the environmental target by reducing the regional level of emissions as shown in figure 6. The decrease in CO_2 emissions is greater in the North-Centre area but, as already observed for the commodity total output, the distance from the benchmark

Figure 6. Effects on total CO_2 emissions - % change from 2008 to 2020



path almost disappear over the time period.

In all scenarios therefore, policy instruments adopted and the channels of transmission of the effects can reach the Environmental Dividend although for a short time and with regional differences. The results allow us to identify the prevalence of the second tax revenue recycling scheme, which provide the reduction of Households income tax, in order to reach a better environmental performance in both two regions[14].

Given the positive results in terms of first green dividend, our analysis now requires the check of further benefits associated to the recycling scheme of the eco-tax revenue. In order to identify a welfare second dividend, we consider the evolution over the time of the final demand. To be more specific we distinguish the impact of the fiscal reform both on investment and final consumption. Since the intertemporal utility depends on period utility and period utility depends on personal consumption expenditures and Government current expenditures, observing the change in final consumption we derive information on consumers utility.

In the South region we observe a reduction in consumption for the first year in both two scenarios (see figure7). For the subsequent years the trend follow the benchmark path. Differently in the North-Center region, the consumption in the short run increase with respect to the benchmark in the first scenario when the environmental tax is recycled by reducing the regional tax on commodities value added (s_1). As already observed for the South region, this rise in final demand is exhausted in the long run[15].

As for the other component of the final demand, in South region it is possible to observe a reduction of Investment with respect to the benchmark path in the short run regardless the recycling assumption. Differently in the North-Centre region, the policy does not affect the investments that almost replicate over the time, the same benchmark trend in both two scenario as shown in figure8.

The combination of the effect on consumption and gross investment can be summarised by the final demand performance. In general the introduction of the eco-tax in the economic system generates positive effects on final demand only in the North-Centre region in the first scenario.

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[14]The disaggregate results for some activities are shown in appendix A (See figures A1, A2 and A3)).
[15]See figure A4 for major detail on intertemporal Households consumption expenditure and Government current expenditure.

Figure 7. Effects on Final Consumption - % change from 2008 to 2020

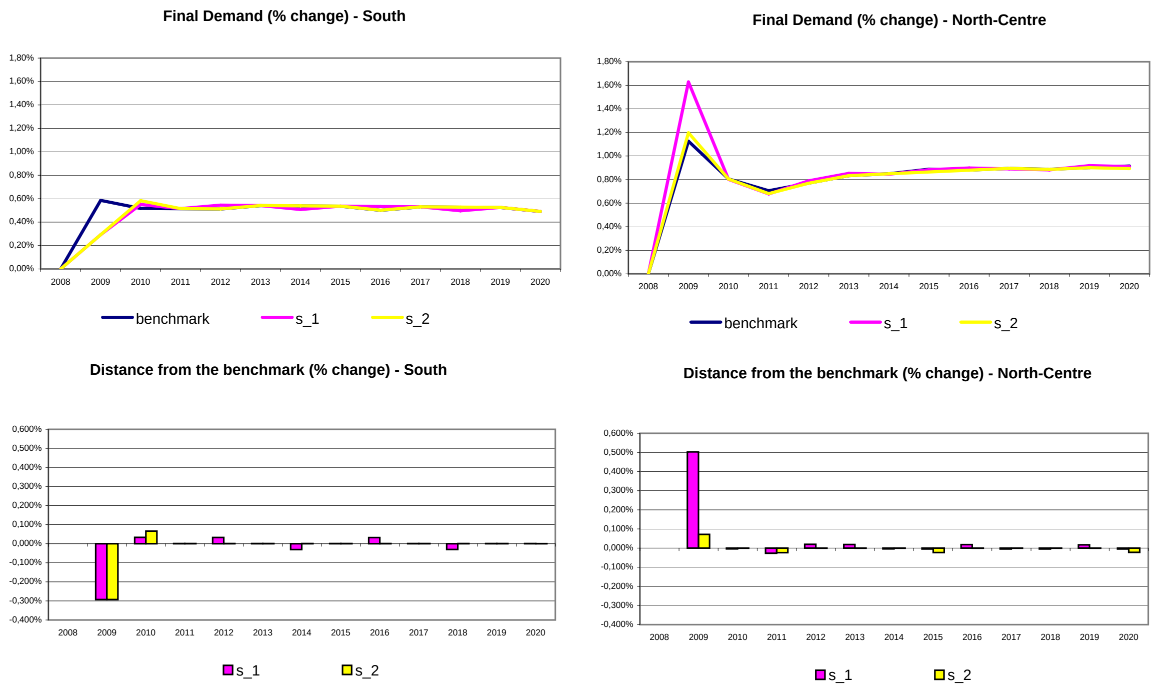
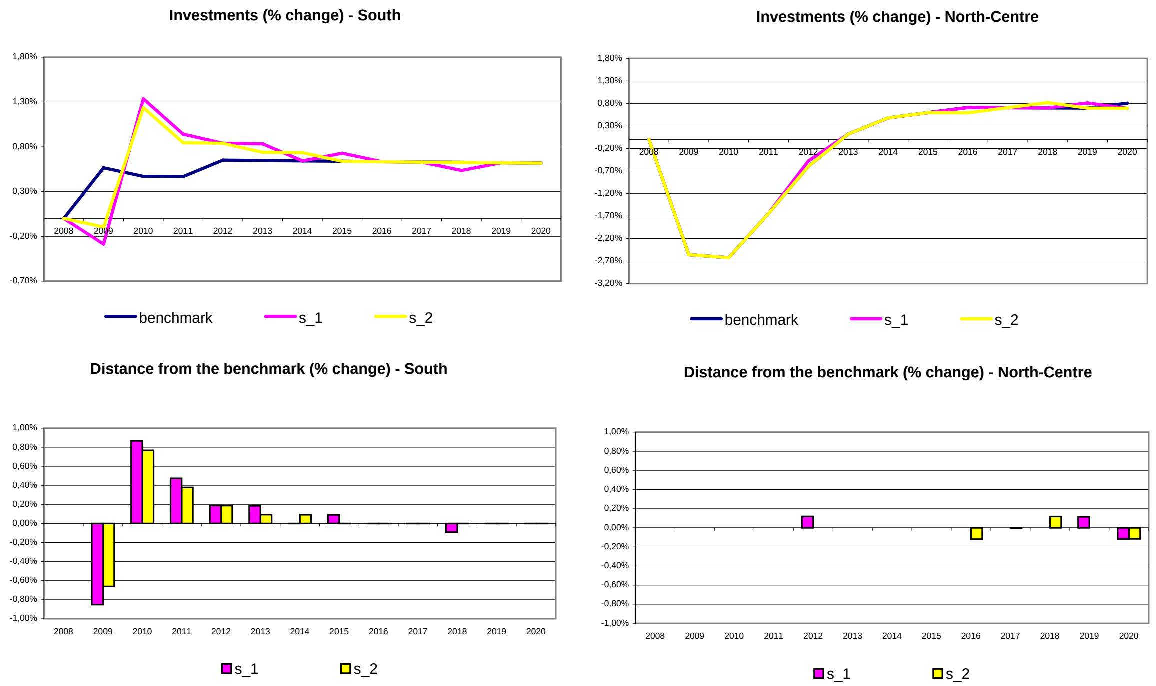
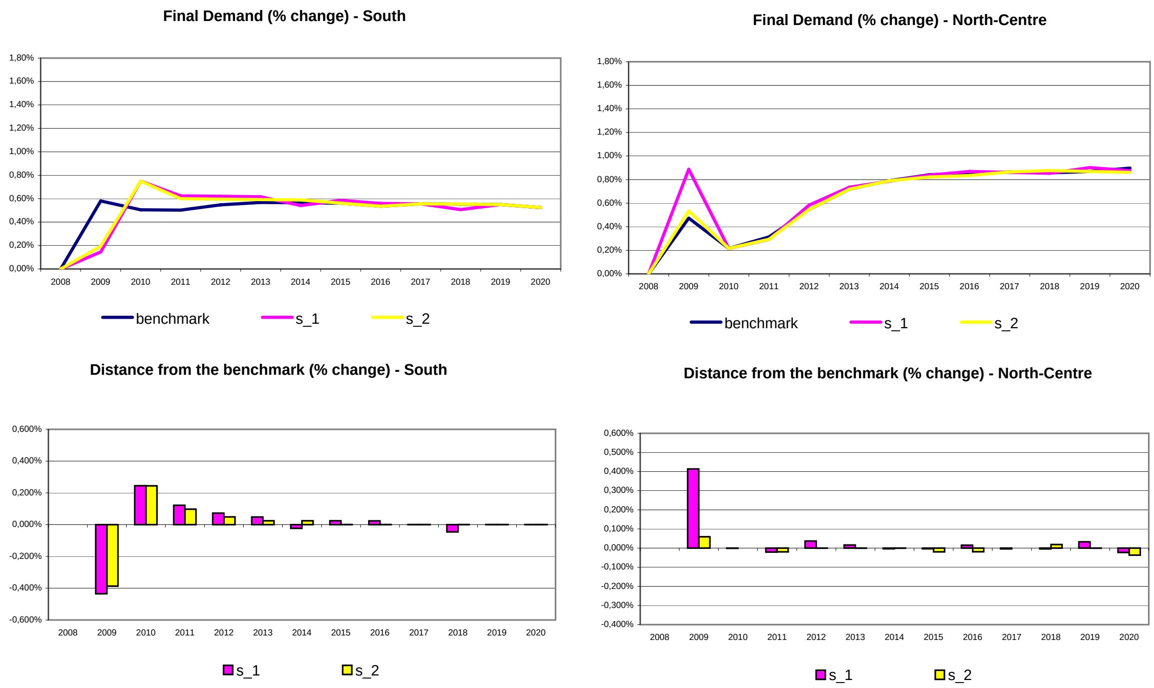


Figure 8. Effects on Gross Investment - % change from 2008 to 2020



This result means that recycling tax revenue directly to the households through a reduction of income taxes is a less efficient measure than cutting taxes on value added activity.

Figure 9. Effects on Final demand - % change from 2008 to 2020



5 Conclusions

The aim to test the desirability of an environmental policy can be achieved by multisectoral instruments such as SAM framework integrated with environmental data on emissions of CO_2. This typology of data base allows to implement a dynamic CGE model to assess over time the environmental feasibility and economic breakdown of an environmental fiscal policy reform.

The environmental tax introduced for the Italian economy aims to affect the pollution power of each activity following the objective "those who pollute more, should pay more".

The first step of this analysis (defined 'ex-ante') is related to the definition of the tax structure. In particular, disaggregated data on CO_2 emissions permits the classification of commodities according to their polluting capacity and they allow to identify the production processes that exceed the permitted level of emissions. In order to restore the correct level of CO_2, we introduced a green tax designed with a progressive structure on these commodities output. Than two scenarios of tax revenue redistribution have been developed: the first refers to the reduction of income tax, the second one concerns the reduction of regional value added activities tax. Both scenarios suggest a possible alternative to reduce distortions related to the pre-existing taxes.

The second step (defined 'ex-post') concerns the assessment of the environmental and the social-economic benefits (the *green* and the *blue* dividends). The results show the importance of using a detailed database in the general equilibrium analysis to detect the different impacts of an environmental fiscal reform within the economic system. Indeed we verified the *first environmental* dividend in the economy as a whole regardless of the different type of revenue distribution, but we find out that the main reduction in CO_2 performs only in the short run. In the long run the level of emissions is lower with respect to the benchmark path, but in the long run the percentage change follow the baseline trend.

As for the *second* dividend evidence, we considered the evolution over the time of the final demand in order to obtain information on intertemporal utility change which strictly depends on the consumption over time. The results show that the final demand in the North-Centre region increases in particular when the tax revenue is recycled through a reduction of regional value added taxes. This result is consistent with several studies on double dividend (e.g. Takeda (2007)), according to which the combination of environmental taxation and the reduction in capital taxes improves welfare. Thus if we concentrate on the benefits connected with environmental policy, the introduction of a green tax with a progressive structure and the distribution of the tax revenue by reducing income taxes and regional value added taxes allows to reach the *green* dividend and in disaggregate terms also the second *blue* dividend.

Appendix A: Disaggregate

Figure A1. Disaggregated effects CO_2 emissions for "Non Metallic Mineral" and "Chemical"

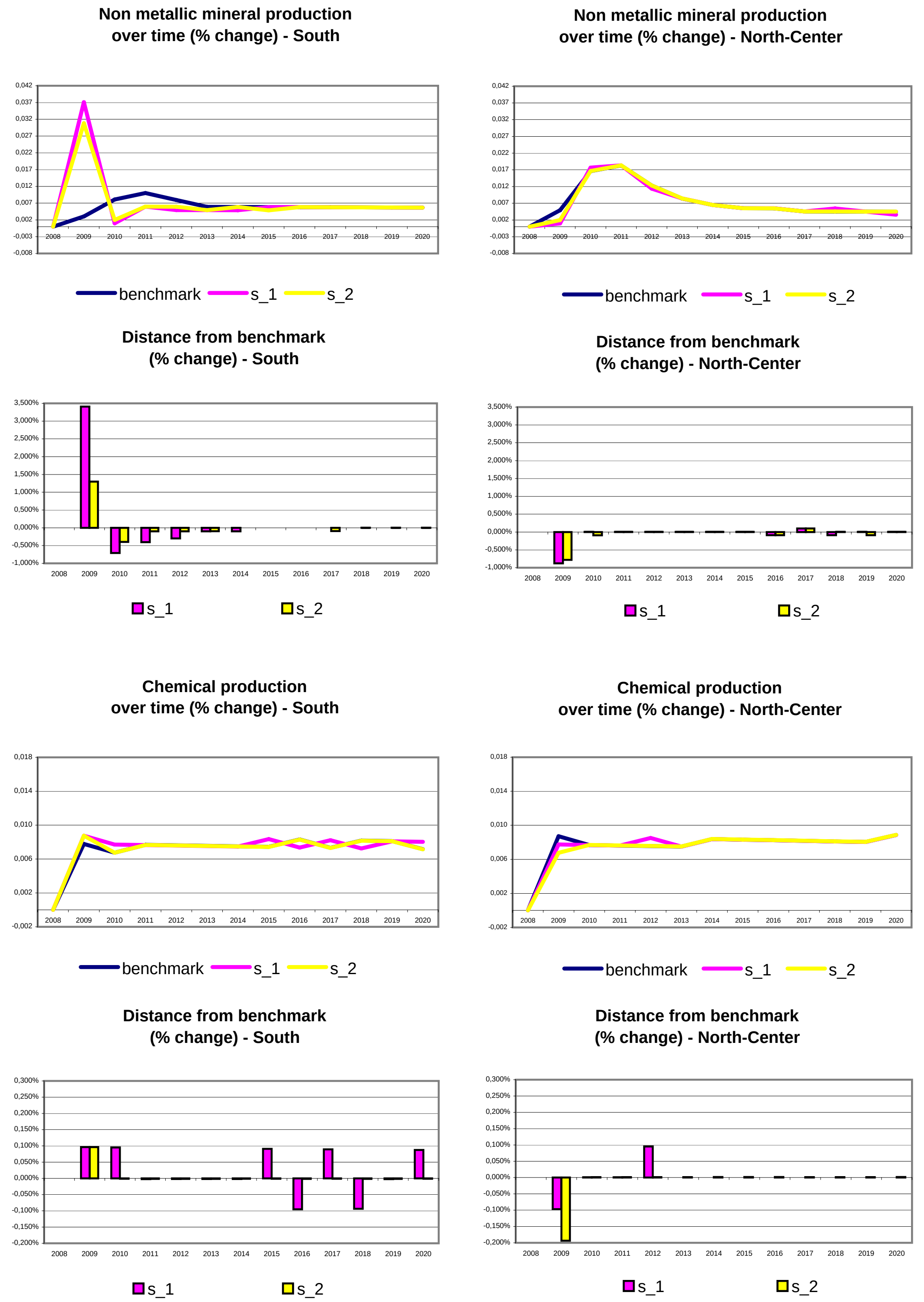


Figure A2. Disaggregated effects CO_2 emissions for "Mechanic" and "Transport"

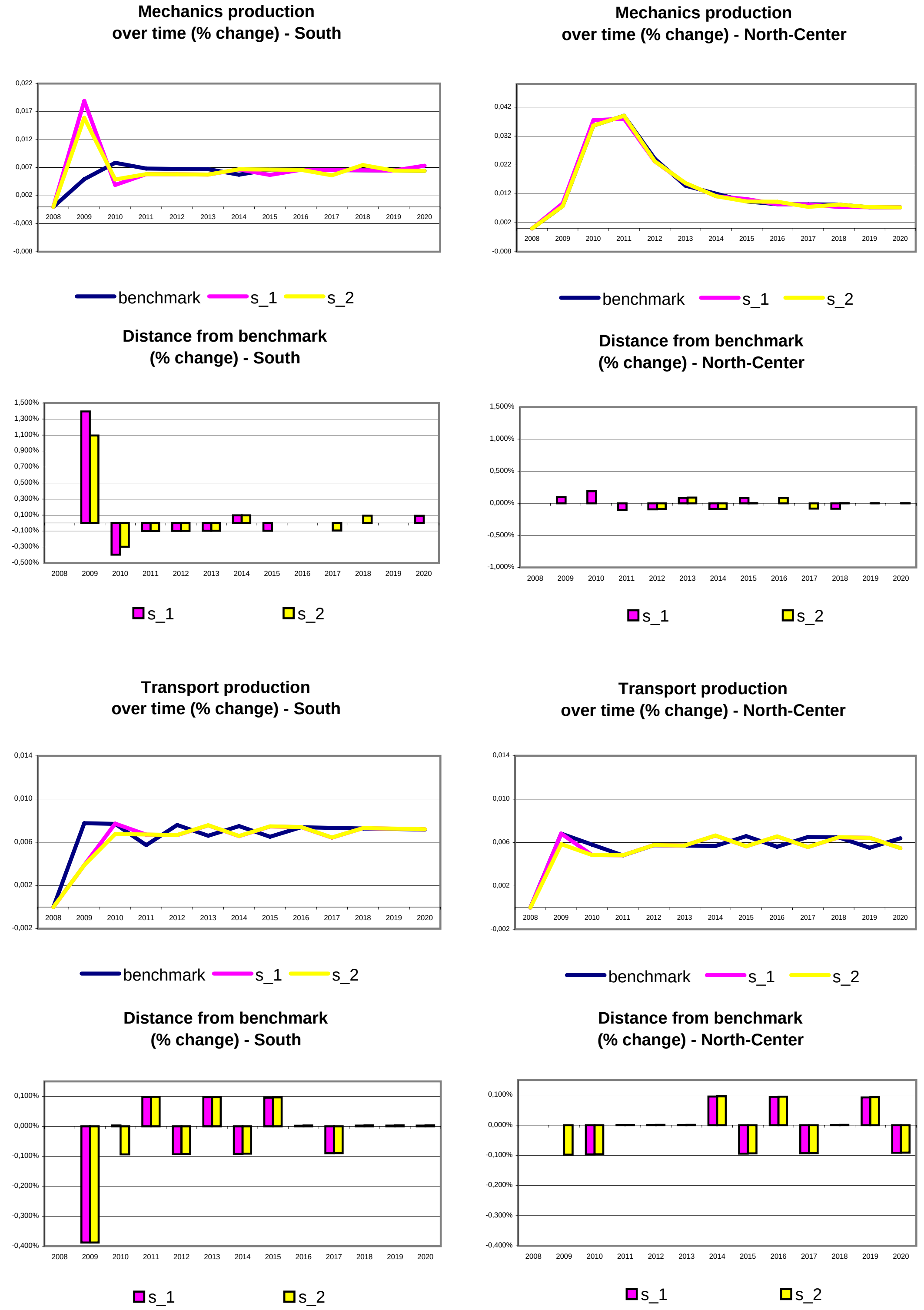


Figure A3. Disaggregated effects CO_2 emissions for "Trade"

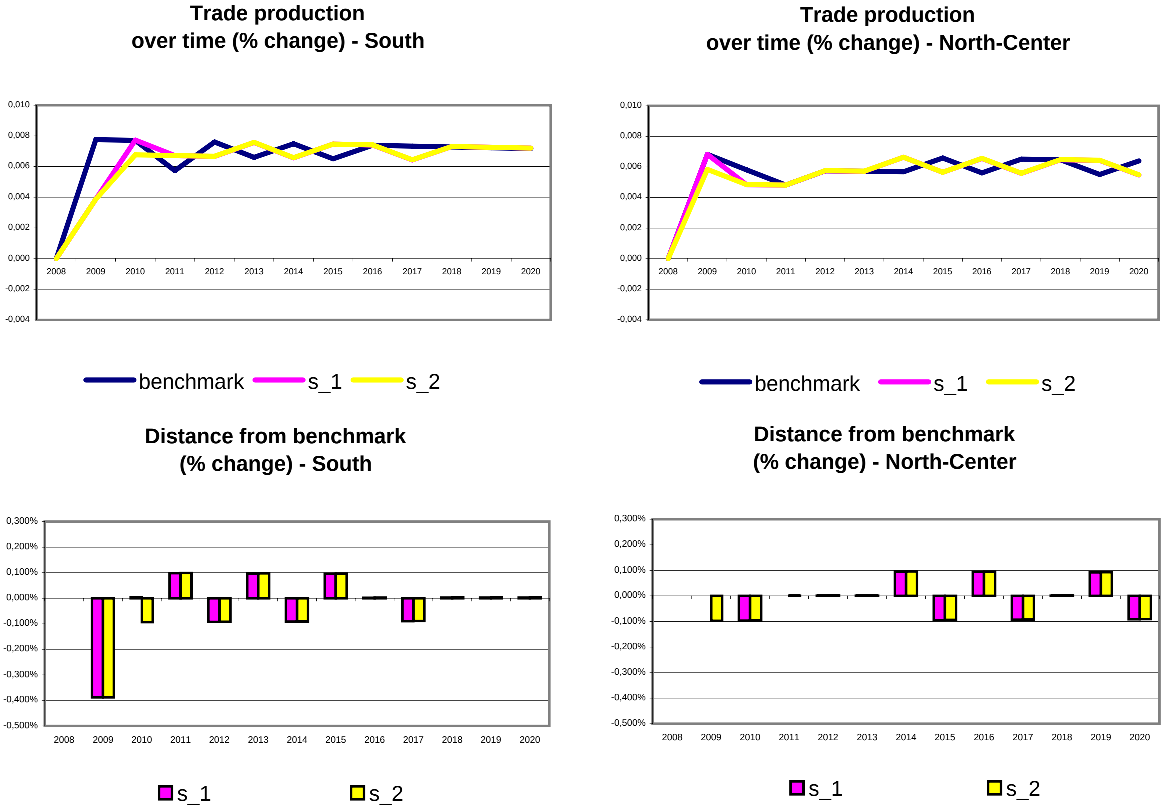
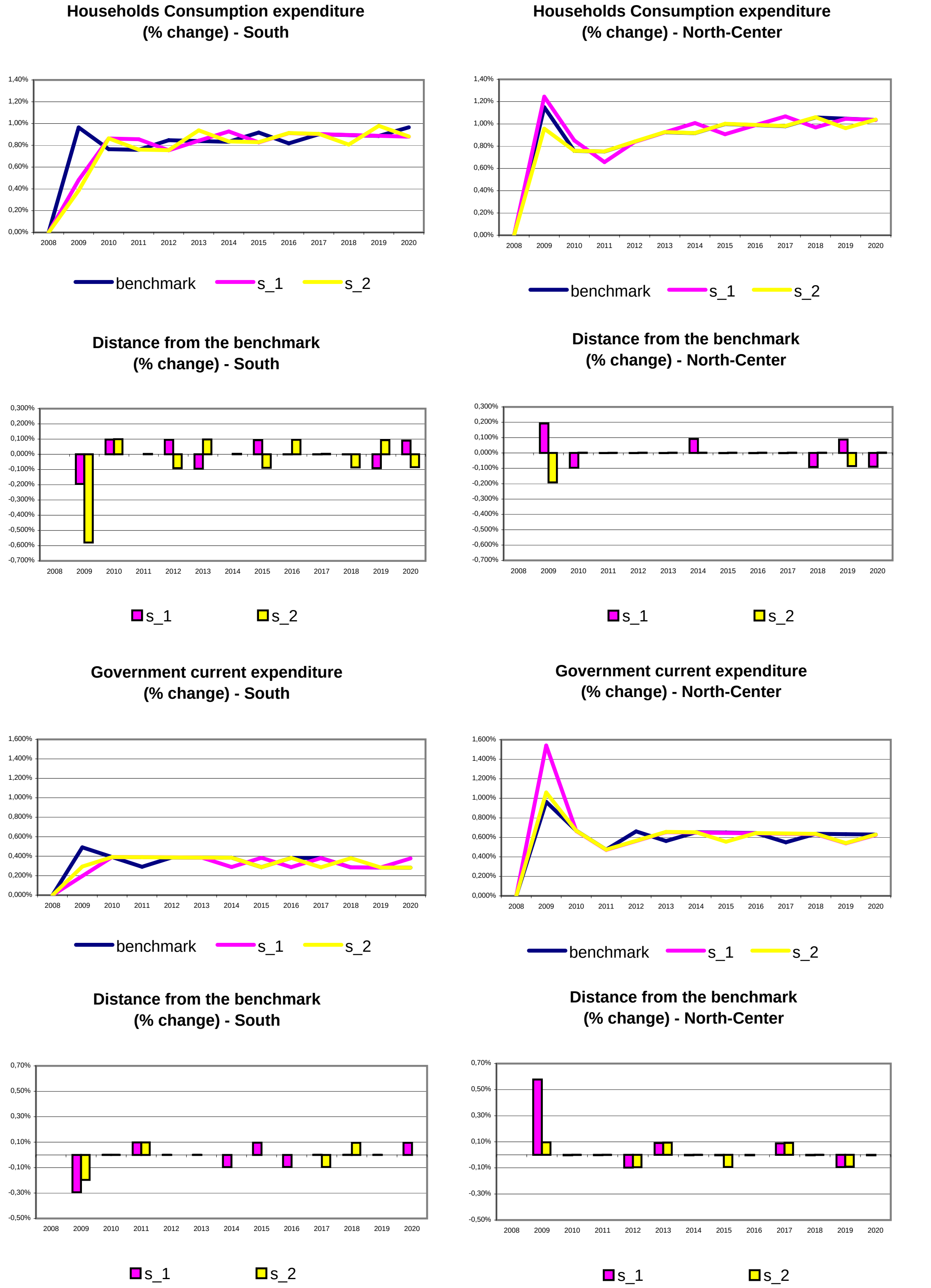


Figure A4. Effects on Households consumption expenditure and Government current expenditure



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