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**PERSONAL INCOME TAX REFORMS: A GENETIC  
ALGORITHM APPROACH**

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# **Personal Income Tax Reforms: a Genetic Algorithm Approach**

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## **Abstract**

Given a settled reduction in the present level of tax revenue, and by exploring a very large combinatorial space of tax structures, in this paper we employ a genetic algorithm in order to determine the ‘best’ structure of a real world personal income tax that allows for the maximization of the redistributive effect of the tax, while preventing all taxpayers being worse off than with the present tax structure. We take Italy as a case study.

**JEL Codes:** C63, C81, H23, H24

**Keywords:** Personal Income Taxation, Genetic Algorithms, Micro-simulation Models, Reynolds-Smolensky Index, Tax Reforms

## 1. Introduction<sup>1</sup>

Personal income tax (hereafter, PIT) around the world is characterized by several parameters that define its structure: marginal tax rates, upper limits of the thresholds, allowances and deductions, as well as tax credits. Applied to the distribution of income observed in a specific country, the PIT structure of that country determines a given tax revenue and a given redistributive effect.

Starting from this position, a Government may want to cut down PIT revenue in order to increase the purchasing power of taxpayers; conversely, it may want to increase the redistributive effect of the tax leaving the tax revenue unchanged; finally, it may want to increase tax revenue by letting the richest taxpayers face all the tax increase.

In order to achieve one of these specific targets, how should the whole PIT structure change? For several reasons, it is not the case that policy makers consider this question when thinking of a PIT reform. The PIT structure observed in a country is indeed the result of several and partial adjustments that have occurred over the past years and, given a revenue constraint, whether those tax reforms were aimed at achieving the best way to obtain the specific target is debatable.

With respect to these arguments, Italy is perfect case study: the Italian PIT is very complicated and its structure incorporates more than thirty parameters. Moreover, in order to increase the purchasing power of ‘poor’ PIT taxpayers, as well as taxpayers belonging to the ‘middle class’ (a proxy of the redistributive effect maximization), the Italian Government recently reduced the PIT revenue by about 9.31 billion euros<sup>2</sup> by introducing a cash transfer of 80 euros per month, only for employees with a PIT gross income in the range of 8-26 thousand euros (about 10.9 million taxpayers).

Then two questions arise. Is this tax cut allocation the best one the Government could have considered? Or, given this settled amount of the tax cut, which is the best way to reform the whole PIT structure in order to achieve the highest redistributive effect, whilst having no taxpayers being worse off, with respect to the present tax structure?

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<sup>1</sup> This is a revised version of the working paper “Personal Income Tax Reforms: a Genetic Algorithm Approach” by Matteo Morini and Simone Pellegrino. Some of the results have been updated to reflect better results provided by the algorithm. An earlier version (September 2014) of this working paper can be found at <https://ideas.repec.org/p/tur/wpapnw/026.html>. The paper was presented at the XXVI Annual Conference of the Italian Association of Public Economics, Pavia, September 2014. We would like to thank Tito Boeri, Paola Profeta, Federico Revelli and Ivica Urban for their useful comments that helped us improve the paper.

<sup>2</sup> According to the official statistics made available by the Government, the tax cut amounts to 9.5 billion euros. Here we consider the tax cut resulting from the micro-simulation model employed in this work.

The solution of this problem can face an equity-efficiency trade-off: in order for the redistributive effect to be the highest, the efficiency of the tax, (i.e. the level of the effective marginal tax rates), can worsen. As an example, in this paper we mainly focus on the equity side of the problem. This does not imply that we forget about the efficiency side; we suggest a few constraints to the allowable parameters of tax structure, in order not to arrive at both trivial and inefficient solutions.

To answer the above questions, we rely on a static micro-simulation model written in STATA (technical details are available in Pellegrino *et al.* (2011)) that employs, as input data, those provided by the Bank of Italy in its Survey on Household Income and Wealth, published in 2012 with regard to the 2010 fiscal year. The results of this micro-simulation model are very close to the official statistics made available by the Italian Ministry of Economy and Finance for the 2010 fiscal year; as a consequence, this instrument is suitable for the type of empirical analysis we propose.

The static micro-simulation model had to be re-implemented in a more versatile way, in order for the kind of analysis we are interested in to be feasible. We rewrote the modules of the micro-simulation model evaluating the Italian PIT in Python, a very mainstream language that conveniently allows for the use of parallel computing techniques, distributed across multiple nodes. Python also offers an excellent compromise between agility in programming – providing the developers with several libraries optimized for numerical calculations – and computational performance.

We then employed a genetic algorithm; that is, a search heuristic inspired by natural selection, well suited to the identification of the most promising solution to the problem under consideration. We were interested in coming up with a reasonable tax structure that inhibits both trivial and inefficient solutions. The genetic algorithm then had to be provided with a few specific constraints that had to be obeyed, in terms of some parameters of the tax structure. If this were not the case, problematic solutions would appear. For example, having to find the highest redistributive effect with no constraints at all, the genetic algorithm would certainly impose excessively high marginal tax rates on higher income earners and a zero marginal tax rate on too many of the poorest taxpayers; as a result, a polarization of tax rates and bandwidths of thresholds would appear and the tax revenue would consequently be too high. Or the genetic algorithm would disproportionately favour high levels of some peculiar tax credits, simply

because they are enjoyed by a small group of taxpayers, resulting in a negligible impact on the tax revenue, but in awkward preferential treatment for some income groups.

In order to avoid these unpleasant outcomes, we imposed two constraints.

First, we impose a condition that no taxpayers should be worse off as a result of the tax reform; that is, all taxpayers must pay a lower (or, at most, equal) amount of taxes than the present one. Therefore, since the Italian personal income tax does not allow for negative income taxation, and as we are looking for a tax reform with no losing taxpayers, we let the 'no tax' area be greater, or at least equal, to the present one. We also require the highest marginal tax rate, as well as the lower limit of the top threshold, to be lower, or at most equal, to the present values.

Second, we keep the rank applied by the present tax structure to certain kinds of tax credits unchanged: for example, the present tax credit applied to employees is greater than the one applied to pensioners, and the one applied to pensioners is greater than that which is applied to self-employed taxpayers; similarly, the tax credit for tenants is greater with regard to younger ones.

In doing so, we do not allow the genetic algorithm to run free with too 'imaginative' solutions.

Then, we have to define our target: we are interested in obtaining the highest possible redistributive effect of the tax. To measure it, we refer to the Reynolds-Smolensky index, given by the difference between the Gini coefficient for the pre-tax income distribution and the corresponding concentration coefficient for the post-tax distribution. Instead of the equivalent household gross and net income distributions, we refer to the taxpayers' ones. The main reasons are twofold: the cash transfer introduced by the Italian Government favours taxpayers; this is the first exercise that employs a genetic algorithm for a tax system optimization, so that by observing the composition of the tax cut by income classes, we can ensure that our result is among the 'best'. By referring to the equivalent household income distribution, this check could be much harder to assess.

We then let the genetic algorithm set up a 'population' of 200 different tax structures, each of them composed of 33 different parameters defining the present structure of the Italian personal income tax, and we let it evolve for 10 thousands of generations until the desired result was achieved.

Even if by employing the ‘best’ tax structure no taxpayer is worse off, its actual applicability could face political resistance, since all parameters of the tax change and, consequently, taxpayers could hardly believe that no one is worse off. We do not discuss these political economy inconveniences. Finally, it has to be noted that here we also do not consider taxpayers’ responses to the new parameters of the tax structures: it is a ‘short run’ solution that can help policy makers when they think of a PIT reform. In order to consider taxpayers’ responses, agent-based models could be employed. This is the baseline of our further research.

The structure of the paper is as follows. Section 2 describes in greater detail the 2010 structure of the Italian personal income tax, the baseline for our analysis. Section 3 briefly presents how tax progressivity, and the redistributive effect exerted by the tax, can be measured. Section 4 shows the data and peculiarities of the static micro-simulation model employed for simulations. Section 5 first describes how genetic algorithms work and then presents the implementation used in this work. Section 6 shows the results, whilst section 7 offers a conclusion.

## 2. The Personal Income Tax in the 2010 Fiscal Year: Technical Details

Let  $x_i$  be the personal gross income of taxpayer  $i$  ( $i = 1, 2, \dots, n$ ). The 2010 Italian tax law considers two different kinds of deductions:  $d_i^1$  is deduction for the main residence cadastral income;  $d_i^2$  is the sum of deductions for social security contributions and alimonies as well as donations. The taxable income  $y_i$  is evaluated as:

$$y_i = \begin{cases} x_i - d_i^1 - d_i^2 & \text{if } d_i^1 + d_i^2 < x_i \\ 0 & \text{if } d_i^1 + d_i^2 \geq x_i \end{cases} \quad (1)$$

From 2007 onwards the rate schedule  $S(y_i)$  contemplates 5 thresholds as reported in Table 1.

**TABLE 1 AROUND HERE**

The upper limits  $UL_j = LL_{j+1}$  ( $j=1,2,3,4$ ) of thresholds are 15, 28, 55, 75 thousand euros, being the first lower limit  $LL_1 = 0$ ; tax rates  $t_j$  range between 23 and 43 percent.

By applying the rate schedule to the tax base the gross tax liability  $GT_i$  is obtained.

In order to determine the net tax liability  $T_i$ , tax law admits three distinct kinds of effective tax credits. They are: tax credits for earned income  $c_i^1(x_i^{MR})$ , tax credits for dependent individuals within the household  $c_i^2(x_i^{MR})$ , and tax credits for items of expenditure  $c_i^3$ , where  $x_i^{MR} = x_i - d_i^1$ .

The net tax liability  $T_i$  is then evaluated as:

$$T_i = \begin{cases} GT_i - c_i^1(x_i^{MR}) - c_i^2(x_i^{MR}) - c_i^3 & \text{if } GT_i > c_i^1(x_i^{MR}) + c_i^2(x_i^{MR}) + c_i^3 \\ 0 & \text{if } GT_i \leq c_i^1(x_i^{MR}) + c_i^2(x_i^{MR}) + c_i^3 \end{cases} \quad (2)$$

In what follows we do not consider regional and municipal surtaxes and then we evaluate taxpayer  $i$ 's net income as  $z_i = x_i - T_i$ .

Focusing on tax credits for employees and pensioners as well as self-employed,

$$c_i^1(x_i^{MR}) = \begin{cases} t_1 m_r & \text{if } x_i^{MR} \leq m_r \\ (t_1 m_r - a_r) + a_r \left( \frac{LL_2 - x_i^{MR}}{LL_2 - m_r} \right) & \text{if } m_r < x_i^{MR} \leq LL_2 \\ (t_1 m_r - a_r) \left( \frac{LL_4 - x_i^{MR}}{LL_4 - LL_2} \right) + b & \text{if } LL_2 < x_i^{MR} \leq LL_4 \\ 0 & \text{if } x_i^{MR} > LL_4 \end{cases} \quad (3)$$

where  $t_1$  is the lowest marginal tax rate (23 percent);  $m_r$  with  $r = (1,2,3,4)$  (the level of  $x_i^{MR}$  below which taxpayer has a nil net tax liability) is equal to 8,000 euros for employees ( $m_1$ ), 7,500 for pensioners younger than 75 ( $m_2$ ), 7,750 for pensioners older than 75 ( $m_3$ ), 4,800 for the self-employed ( $m_4$ ), and zero for non-working taxpayers;  $a_r$  is equal to 502 euros for employees ( $a_1$ ), 470 for pensioners younger than 75 ( $a_2$ ), 486 for pensioners older than 75 ( $a_3$ ), zero for self-employed ( $a_4$ );  $b$ , that ranges from 10 to 40 euros in the bandwidth 23-28 thousand euros, is applied only to employees (as discussed later, we always set  $b = 0$  in simulations). Non-working taxpayers have no

tax credit for earned incomes. Finally, this tax credit decreases from zero to  $m_4$ , and from  $m_4$  to  $LL_4$  only for self-employed taxpayers.

Four different tax credits for type of relationship are allowed: tax credit for dependent children  $c_i^{2H}(x_i^{MR})$ , further tax credit for households with more than three children  $c_i^{2HF}$ , tax credit for dependent spouse  $c_i^{2S}(x_i^{MR})$ , and tax credit for other household components  $c_i^{2O}(x_i^{MR})$ . The overall value for  $c_i^2(x_i^{MR})$  is then  $c_i^2(x_i^{MR}) = c_i^{2H}(x_i^{MR}) + c_i^{2HF} + c_i^{2S}(x_i^{MR}) + c_i^{2O}(x_i^{MR})$ . In particular,

$$c_i^{2H}(x_i^{MR}) = \begin{cases} c_i^{2Hp} \frac{q + (f-1)e - x_i^{MR}}{q + (f-1)e} & \text{if } 0 < x_i^{MR} \leq q + (f-1)e \\ 0 & \text{if } x_i^{MR} > q + (f-1)e \end{cases} \quad (4)$$

where  $f = \sum_{l=1}^4 f_l$  is the overall number of dependent children;  $f_1$  is the number of dependent children older than 3 years if the dependent children within the household are 3 or less;  $f_2$  is the number of dependent children younger than 3 years if the dependent children within the household are 3 or less;  $f_3$  is the number of dependent children older than 3 years if the dependent children within the household are more than 3;  $f_4$  is the number of dependent children younger than 3 years if the dependent children within the household are more than 3;  $e$  is equal to 15,000 euros;  $q$  is equal to 95,000;  $c_i^{2Hp} = \sum_{l=1}^4 f_l c_i^{2Hpl}$ ; the present values for the potential tax credits are:  $c_i^{2Hp1} = 800$ ,  $c_i^{2Hp2} = 900$ ,  $c_i^{2Hp3} = 1,000$ ,  $c_i^{2Hp4} = 1,100$  euros.

Moreover, whenever  $c_i^{2H}(x_i^{MR}) > 0$  and the dependent children within the households are more than 3 the tax law admits a further tax credit  $c_i^{2HF}$  equal to 1,200 euros for all beneficiaries. The tax credits for dependent children have to be split between spouses whenever both of them have a positive gross income. Finally,



$$c_i^{2S}(x_i^{MR}) = \begin{cases} c_i^{2Sp} - u \frac{x_i^{MR}}{LL_2} & \text{if } x_i^{MR} \leq LL_2 \\ c_i^{2Sp} - u & \text{if } LL_2 < x_i^{MR} \leq w \\ (c_i^{2Sp} - u) \frac{k - x_i^{MR}}{k - w} & \text{if } w < x_i^{MR} \leq k \\ 0 & \text{if } x_i^{MR} > k \end{cases} \quad (5)$$

and

$$c_i^{2O}(x_i^{MR}) = \begin{cases} c_i^{2Op} \frac{k - x_i^{MR}}{k} & \text{if } x_i^{MR} \leq k \\ 0 & \text{if } x_i^{MR} > k \end{cases} \quad (6)$$

where  $u$  is equal to 110 euros,  $w$  is equal to 40 thousand euros,  $k$  is equal to 80 thousand euros,  $c_i^{2Sp}$  is equal to 800 euros and  $c_i^{2Op}$  is equal to 750 euros. The present tax code considers higher values than  $c_i^{2Sp} - u$  in the income range 29,000-35,200 euros. Instead of 690 euros, in this income range values ranging from 700 to 720 euros are applied. We do not consider these differences in simulations, always letting  $c_i^{2Sp} - u$  be equal to a same value.

Tax credits for items of expenditures  $c_i^3$  can be classified in two groups according to the percentage of the expense the tax law admits as a tax credit. There are expenses that allow a tax credit of 19 percent and 36 percent, respectively.<sup>3</sup> The 19 percent tax credits (we label this variable *expenditure*<sub>1</sub>) are very large, 19 different cases, such as expenses for health care, mortgage interests, etc.; 36 percent tax credits (*expenditure*<sub>2</sub>) are allowed for home restructuring-related expenses. All together, tax law admits 30 different tax credits for items of expenditure. Finally, tax law admits a tax credit for tenants; it is 300 euros if  $x_i \leq 15,494$  (we label this variable *tenants*<sub>1</sub>); 150 if  $15,494 < x_i \leq 30,987$  (*tenants*<sub>2</sub>); 992 euros if  $x_i \leq 15,494$  and if the taxpayers are younger than 30 (*tenants*<sub>3</sub>).

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<sup>3</sup> The tax code considers also a 55 percent tax credit for interventions for energy saving and a 20 percent tax credit for purchasing of a washing machine. Because of the low number of taxpayers interested in these two kinds of tax credits, we did not considered them in the micro-simulation model.

### 3. Distribution of Income and Personal Income Tax Progressivity

Let  $x_1, x_2, \dots, x_n$  be the pre-tax income levels associated to  $n$  income units. The corresponding post-tax income levels and tax levels are  $z_1, z_2, \dots, z_n$  and  $T_1, T_2, \dots, T_n$ , respectively. We denote the pre-tax and the post-tax income distribution as well as the tax distribution by  $X, Z$  and  $T$ , respectively.

As is well known, inequality among pre- and post-tax income levels as well as tax levels can be evaluated by the Gini coefficient. Let  $G_X, G_Z$  and  $G_T$  be the corresponding Gini coefficient for pre-tax income, post-tax incomes and taxes, respectively. Then,

$$G_\varepsilon = \frac{2\text{cov}[\varepsilon, F(\varepsilon)]}{\mu_\varepsilon} \quad (7)$$

where  $\varepsilon = X, Z, T$ ,  $\mu_\varepsilon$  is the average value for pre-tax and post-tax incomes and taxes,  $\text{cov}$  represents the covariance and  $F(\varepsilon)$  is the cumulative distribution function.

After the tax, it is not guaranteed that post-tax ordering be equal to the pre-tax income one. Indeed, it is most likely that these two orderings differ because of the re-ranking due to the tax. Therefore, the inequality of  $Z$  and  $T$  can be evaluated once these distributions are ordered according to the corresponding pre-tax incomes, ranked in a non-decreasing order. For what concerns post-tax incomes and taxes, the corresponding concentration coefficient can then be evaluated as follows:

$$C_\varepsilon = \frac{2\text{cov}[\varepsilon, F(X)]}{\mu_\varepsilon} \quad (8)$$

Progressive taxation produces two different effects on the distribution of pre-tax incomes: post-tax income inequality is lower than that measured on pre-tax income distribution, whilst tax inequality is greater. The first effect is known as the redistributive effect of the tax and the second one as departure from proportionality of the progressive taxation (Lambert, 2001). The overall redistributive effect of the tax  $RE$  can be evaluated as

$$RE = G_X - G_Z = (G_X - C_Z) - (G_Z - C_Z) = RS - R^{APK} \quad (9)$$

where  $RS = G_X - C_Z$  is the Reynolds-Smolensky index, whilst  $R^{APK} = G_Z - C_Z$  is the Atkinson-Plotnick-Kakwani index. The more the tax is progressive, the greater  $RE$  and  $RS$ ; the more the tax causes re-ranking, the greater the negative contribution of re-

ranking to the overall redistributive effect. Note that if the tax does not cause re-ranking ( $R^{APK} = 0$ ), then  $RE = RS$ .

The departure from proportionality of the progressive taxation can instead be evaluated by the Kakwani index  $K = C_T - G_x$ . The Kakwani and the Reynolds-Smolensky indexes are linked by the overall average tax rate  $\theta$ , namely

$$\theta = \frac{\sum_{i=1}^n T_i}{\sum_{i=1}^n x_i} \quad (10)$$

As a consequence,  $RS = \frac{\theta}{1-\theta} K$ . This formula tells us that the Reynolds-Smolensky

index has two determinants: the overall average tax rate and the Kakwani index.

In what follows we focus only on the Reynolds-Smolensky index and then we are interested in finding the ‘best’ tax structure able to determine a given tax revenue (smaller than the present one) and to yield to the greatest  $RS$  while getting no loser taxpayers.

Since we impose a reduction of the tax revenue, note that the value of  $\theta$  will be smaller than the present one. Note also that the simulated  $K$  will be greater than the present one in order for  $RS$  to be the highest.

#### 4. The Data and the Static Micro-simulation Model

The micro-simulation model used in this work estimated the most important taxes and contributions which characterise the Italian fiscal system. Here we employ the micro-simulation model module concerning the PIT. It considers as input data those provided by the Bank of Italy in its 2012 Survey on Household Income and Wealth (hereafter, BI-SHIW). The survey contains information on household income and wealth in the year 2010, covering 7,951 households and 19,836 individuals (Bank of Italy, 2012). The sample is representative of the Italian population, composed of about 24 million households and 60 million individuals.

The BI-SHIW provides information only on each individual's disposable income, which considers items of income that are taxed within the PIT or that can be exempt from the tax, as well as can be taxed under a separate regime. Therefore, the micro-simulation model first distinguishes all incomes included in the PIT taxable income definition, incomes exempt from any taxes and incomes taxed under a separate regime. Then the PIT gross income distribution is evaluated, starting from the PIT net income distribution. The transition from the post- to the pre-tax personal income of each individual has been computed by applying the algorithm proposed by Immervoll and O'Donoghue (2001).

Using original sample weights, the grossing-up procedure simply proportions the sum of individuals' sample weights to the dimension of the population as estimated by the National Statistical Office (ISTAT). Then the grossed-up number of PIT taxpayers has been obtained by considering individuals with a positive gross income within the sample (13,791 taxpayers, corresponding to about 40 million in the population).

Considering the income units, results concerning the PIT gross income distribution are very close to the Ministry of Finance's (2011) official statistics, both considering the gross income distribution by income classes and the composition of PIT income units by work status, as well as by their mean gross income. In addition, the overall tax revenue resulting from the micro-simulation model (148.75 billion euros) is very close to that showed in the official statistics. Considering all individual taxpayers, Figure 1 compares the frequency density function obtained with the micro-simulation model and the one obtained using the Ministry of Finance's official data by income classes. Similar pictures emerge considering the frequency density function for pensioners and employees, as well as the self-employed.

### **FIGURE 1 AROUND HERE**

The column 'Present value' of Table 2 shows the inequality indices for individual taxpayers in the 2010 fiscal year, which is our reference situation for the Reynolds-Smolensky index maximization. The Gini coefficient for the gross income distribution is 0.44338, whilst that for the net income distribution is 0.39138. The overall redistributive effect *RE* is 0.05200. The concentration coefficient for the net income

distribution is 0.39076, whilst that on the net tax liability distribution is 0.67215; therefore, the Reynolds-Smolensky  $RS$  index is equal to 0.05262 and the Kakwani index  $K$  is 0.22877. The overall average tax rate is 0.18699, whilst the Atkinson-Plotnick-Kakwani  $R^{APK}$  index is equal to 0.00062.

## TABLE 2 AROUND HERE

Table 2 (column ‘With cash transfer’) also shows the overall redistributive impact of PIT joined with the cash transfer  $\Phi_i$ .  $\Phi_i$  favours only employees with a PIT gross income in the range of 8-26 thousand euros (about 10.9 million taxpayers), as follows:

$$\Phi_i = \begin{cases} 960 & \text{if } m_1 < x_i \leq 24,000 \ \& \ GT_i - c_i^1(x_i^{MR}) > 0 \\ 960 \frac{26,000 - x_i}{2,000} & \text{if } 24,000 < x_i \leq 26,000 \ \& \ GT_i - c_i^1(x_i^{MR}) > 0 \\ 0 & \text{if } x_i > 26,000 \ \& \ GT_i - c_i^1(x_i^{MR}) > 0 \end{cases}$$

It does not modify the PIT structure at all. Beneficiaries obtain  $\Phi_i$ , and continue to pay the same amount of PIT net tax liability  $T_i$ . The net effect  $z_i^* = y_i - T_i + \Phi_i$  is an increase in these taxpayers’ disposable income by 960 euros per year, in the income range 8-24 thousands euros and a decreasing amount up to 26 thousand euros.<sup>4</sup> Note also that if  $T_i < \Phi_i$  beneficiaries obtain a subsidy. Taxpayers other than employees, on the contrary, do not gain from this cash transfer. The cost of this measure is 9.31 billion euros.

Even if only one taxpayer out of four obtains the cash transfer, the redistributive effect of the PIT joined with the transfer considerably improves: the Reynolds-Smolensky  $RS$  index increases by 8.5 per cent; on the contrary, the overall redistributive effect  $RE$  increases only by 7.9 per cent, since the Atkinson-Plotnik-Kakwani  $R^{APK}$  index worsens by about 53 per cent. On the efficiency side, the effective marginal tax rate resulting in the income range of 24-26 thousand euros increases by up to 80 per cent;

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<sup>4</sup> There is a political explanation behind this choice. The Government announced that it would reduce PIT tax liability by 80 euros per month for all taxpayers. Of course, such an announcement proved to be too expensive; moreover, it would have been very difficult to reach through a PIT structure reform, since it is hard to reform such a complex tax structure and, in the meantime, ensure an equal tax reduction for all taxpayers. In order to at least partially meet its commitment, the Government decided to apply the 80 euros pledge only to a group of taxpayers, given the revenue constraint of 9.31 billion euros. In order not to modify the PIT structure, it chose the cash transfer instrument.

for all other income levels, on the contrary, the effective marginal tax rates do not change with respect to the present tax structure.

By employing a genetic algorithm, in the next sections, we show that a more equity-oriented and more efficient reform is possible. From the methodological point of view, the specific measure employed by the Italian Government is not particularly interesting; it refers only to employees and then, a few parameters of the tax could be simultaneously changed in a genetic algorithm framework, i.e. parameters defining the structure of the tax credit for employees. We discuss an overall reform, which considers all the parameters of the tax are able to be trimmed. Since we split the tax cut between all taxpayers, both the average reduction of the net tax liability for all taxpayers and the value of  $R^{APK}$  are smaller than that guaranteed to employees by the Government's cash transfer.

## **5. Genetic Algorithm**

### **5.1. General Overview**

Genetic algorithms (henceforth, GAs) are a heuristic search which belong to the field of evolutionary algorithms, a subfield of artificial intelligence. Since their inception (Holland, 1975), GAs found a wealth of applications in the most varied research disciplines, beyond computational science, mathematics, physics, bioinformatics, etc. Applications in economics also exist, broadly including game theory, finance related works, schedule optimization and whenever some sort of learning mechanism is needed; historically, the first attempt at employing GAs in economics is due to Miller's (1986) research on adaptive behaviour.

To our knowledge, no previous attempts at employing GAs for tax system optimization exist, to date.

The huge solutions search space, which is the aftermath of the combinatorial effect of very many parameters, posing a serious challenge to traditional optimization techniques; brute force methods are out of the question, just like iterative methods (cfr. Newton's); GAs appear as an obviously appropriate choice.

Candidate solutions, which in the GA are internally represented as ‘individuals’ (each of them is characterized by her own ‘genome’, a vector of ‘chromosomes’)<sup>5</sup>, are generated as an initial ‘population’ at random. Evolutionary operators iteratively select, cross-breed and mutate the best (most ‘fit’, according to an objective function called ‘fitness function’) ‘individuals’, in order to produce an offspring of ‘individuals’ – the subsequent ‘generation’ – that will enter a new reproduction step. The ‘individuals’ average fitness increases after every generation, until a satisfactory solution is found. The stopping criterion normally employed is related to the ‘population’ homogeneity: as the search process becomes closer to an optimum, the ‘individuals’ become more and more similar among them.

The GA implementation employed in this work is based on Python’s open-source Pyevolve library (Perone, 2009); the ‘population’ selection mechanism across generations is the standard roulette wheel (fitness proportional) with elitism selection (the very best individuals in each generation are kept unaltered and carried over across successive generations), while the evolutionary crossover operator is a standard one-point. A low mutation rate value and a high crossover rate have also been utilized, in order to let the search process converge reasonably quickly on solutions, whilst maintaining the ability to escape local maxima. The “population size vs. number of generations” trade-off has been tackled and solved, favouring a small population vs. numerous evolutionary steps.

Detailing the trimming of the GAs technical parameters is out of the scope of this work; suffice it to say, as agreed upon by a vast literature, it is an ad-hoc process, to be performed mostly by trial and error, on every specific search domain.

## **5.2. The Structure of the Genetic Algorithm We Employ**

As the starting point, we let the GA set up a ‘population’ of 200 different tax structures (‘individuals’ from the GA point of view) and then we let it evolve them for 10,000 ‘generations’. Consequently, the GA has to evaluate as much as 2 million candidate solutions, applying all these different tax structures to the same pre-tax income

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<sup>5</sup> In the early GA implementations (BCGA, binary-coded genetic algorithms), the solutions space had to be coded in binary numbers; RCGA, real-coded genetic algorithms, allow working with variables in continuous domains; cfr. Herrera et al. (1998).

distribution, composed of 13,791 taxpayers. We set the crossover rate as equal to 0.75, as well as the mutation rate as equal to 0.05 and the elitism selection equal to 7.

For each tax structure and each taxpayer, the GA computes all the relevant tax variables in the transition from the pre- to the post-tax income. For each tax structure, it then computes the overall tax revenue, the share of loser taxpayers by considering each taxpayer's actual net tax liability, the average loss for the loser taxpayers, as well as the Reynolds-Smolensky *RS* index (the four parts of the objective fitness function to maximize, see below); it then saves all these resulting values, in addition to all the parameters of the tax, on a dump file. We employ a computer powerful enough to evaluate 2 million runs in about 4 days; the duration of our average run is then 0.18 seconds.

The GA has to maximize a fitness function. We employed

$$fitness = e^{\frac{\alpha RS - \beta \Delta - \delta \Pi - \lambda \Omega}{10}} \quad (11)$$

where  $\Delta$  is the percentage deviation of the computed tax revenue of each run from the target one (139.44 billion euros, 9.31 billion euros less than the present tax revenue), whilst  $\Pi$  is the share of taxpayers losing with the simulated tax structure,  $\Omega$  is the average loss (in euros) for the loser taxpayers,  $\alpha$ ,  $\beta$ ,  $\delta$  and  $\lambda$  are all positive parameters. We fix  $\alpha = 575$ ,  $\beta = 53$ ,  $\delta = 20$  and  $\lambda = 150^{-1}$ . We made several attempts, with different parameters and different functional forms; this fitness function has proved to be the most effective.

The exponential form of the fitness function helps the GA to always converge to the 'best' solution, since generation after generation, more-than-linearly high scores are assigned to the most promising candidate solutions.

The first term of the exponent shows the part of the fitness function depending on *RS*. We highly favour *RS* with respect to  $\Delta$ ,  $\Pi$ , and  $\Omega$ , since we are interested in obtaining the highest Reynolds-Smolensky index. The second and third, as well as the fourth terms of the exponent of the fitness function, show the 'penalties' we impose on the fitness value when  $\Delta$ ,  $\Pi$  and  $\Omega$  became too large. As a result, the smaller  $\Delta$ ,  $\Pi$  and  $\Omega$ , the more the fitness value increases. The parameter  $\lambda$  is crucial for the convergence of the GA: there are combinatorial spaces where *RS* increases even if  $\Pi$  increases; a low value for  $\lambda$  allows the GA to attribute low scores to those candidate solutions.



When the GA has evolved for a reasonable number of generations, we obtain  $\Delta \approx 0$ ,  $\Pi \approx 0$ , the smallest  $\Omega$ , and the highest  $RS$ . The parameters of the ‘best’ structure of the tax can then be observed.

Figure 2 shows the maximum value of the fitness function applied in this work for each generation. As can be noted, the maximum value tends to increase generation after generation; top 1 per thousand highest values are reached starting from generation 2,500. The highest fitness value is 25.47, and it is reached in generation 8,914.

### **FIGURE 2 AROUND HERE**

Each candidate tax structure is characterized by 33 different parameters (see Table 3), each of them related to a specific parameter of the Italian PIT structure described in Section 2. In order to evaluate each of the 33 parameters, the GA couples 36 ‘chromosomes’ that are values ranging from zero to 1.

We now turn to describing how we let the GA trim each ‘chromosome’.

First of all, we let the GA choose five marginal tax rates as in the actual tax code. Given the constraints we impose, we know that the top marginal tax rate cannot be too much higher than the present one (since we impose a ‘no loser’ taxpayers’ constraint); moreover, we do not want it to be higher than the present value. Conversely, we do not know the minimum allowable value of the bottom marginal tax rate; we set the lowest marginal tax rate at not lower than 10 per cent (being the present value equal to 23 per cent).

In particular, the GA randomly sets a group of six chromosomes serving for the definition of the five marginal tax rates. It then adds them up in order to obtain a

normalization value as follows:  $norm_t = \frac{0.43 - 0.10}{\sum_{\varphi=1}^6 chromosome_{\varphi}}$ .

The GA finally chooses the five tax rates  $t_{\lambda}$  with  $\lambda = (1, 2, 3, 4, 5)$  as follows:

$$t_{\lambda} = 0.10 + \sum_{\varphi=1}^{\lambda} chromosome_{\varphi} * norm_t.$$

We then set a second group of 5 chromosomes (7-11) defining the four upper limits  $UL_j = LL_{j+1}$  of the thresholds, being  $LL_1 = 0$  by definition and  $UL_j < UL_{j+1}$ . We applied an empirical strategy similar to that employed for the definition of the marginal tax rates and we impose  $UL_1 \geq 15,001$  (see on for the choice of this value) and we let the highest value of  $UL_4$  be 75 thousand euros (as in the present tax structure). As a consequence,

$$norm_{UL} = \frac{75,000 - 15,001}{\sum_{\varphi=7}^{11} chromosome_{\varphi}}$$

and, for  $j = 1, 2, 3, 4$ ,

$$UL_j = 15,001 + \sum_{\varphi=1}^j chromosome_{\varphi} * norm_{UL}.$$

Afterwards, we define 25 chromosomes related to the tax credits' structure. Starting at the tax credit for employees (Equation (3)), we let the GA choose the no tax area  $m_1$  applied to employees, that is the limit of pre-tax income below which these taxpayers face a zero net tax liability, between 8 thousand euros (the present value) and  $\psi * UL_1$ :

$m_1 = 8,000 + chromosome_{12} * (\psi * UL_1 - 8,000)$ . We set  $\psi = \frac{8}{15}$ , equal to the present value. As a consequence,  $UL_1$  has to be set greater than or, at most equal, to 15 thousand euros being  $\frac{8}{15} * 15,000 = 8,000 = m_1$ .

Note that the choice of the parameter  $\psi$  influences the equity-efficiency trade-off. The higher the value chosen by the GA, the more likely the slope of the effective marginal tax credit in the income level  $m_r - LL_2$  is high; therefore, the higher the effective marginal tax rate for this income bandwidth.<sup>6</sup> The constraint we impose on the share of loser taxpayers lets the GA chose the highest admissible value for  $m_1$  and at the same time keep under control the level of the effective marginal tax rates (see on).

The GA then choose  $m_2, m_3, m_4$  as follows:

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<sup>6</sup> If we let the GA to run free with respect to this parameter, for example by letting the GA choose it up to 1, a lower than 1 value would be chosen (given the constraints we impose), a higher redistributive effect would be obtained, as well as a confiscatory effective tax rate for incomes just above the 'no tax' area. The reason is clear: *ceteris paribus*, having to maximize the Reynolds-Smolensky index given a revenue constraint, the larger the share of taxpayers with a nil net tax liability, the higher the Reynolds-Smolensky index (and the higher the tax rates and narrower the upper limit of each threshold in order to obtain the target tax revenue). As a consequence, the larger the 'no tax' area, the narrower the income bandwidth between the 'no tax' area and the upper limit of the bottom threshold, and then the more sharply the subsequent reduction of the effective tax credit.

$$\begin{aligned}
m_2 &= (0.9375 * m_1) - (\text{chromosome}_{13} * 0.2 * 0.9375 * m_1) \\
m_3 &= m_2 + \text{chromosome}_{14} * (0.96875 * m_1 - m_2) \\
m_4 &= 0.6 * m_1 - \text{chromosome}_{15} * 0.6 * m_1
\end{aligned}$$

where 0.2 is arbitrarily chosen, whilst  $0.9375 = \frac{m_2}{m_1}$ ,  $0.96875 = \frac{m_3}{m_1}$ , and  $0.6 = \frac{m_4}{m_1}$  are

the corresponding values according to the present tax structure. In so doing, we let the GA choose  $m_r$  with  $r = (1, 2, 3, 4)$  in a large combinatorial space preserving the present rank of  $m_r$ .

Having the GA chosen  $t_1$  and  $m_r$ , note that the potential tax credits  $t_1 m_r$  are automatically defined. We then let the GA choose also the parameters  $a_r$  with  $r = (1, 2, 3)$  in the range  $(0 - t_1 m_r)$  by defining chromosomes 16, 17, and 18 (as described in Section 2, parameter  $a_4$  is equal to zero and we keep it unchanged). In so doing, a very large combination of tax credits for earned incomes is allowable.

Finally, we always set the parameter  $b$  equal to zero. At present, it is applied only to employees and its values range from 10 to 40 euros for levels of  $x_i^{MR}$  belonging to the threshold 23-28 thousand euros. We prefer this parameter to be fixed at zero since, if it were positive, it would not let the tax credit under discussion be a continuous function for all levels of  $x_i^{MR}$ .

Finally, note that we do not let the effective tax credits for earned income be piecewise decreasing with respect to limits, others than those observed in the rate schedule. If  $c_i^1(x_i^{MR})$  were piecewise decreasing with respect to other thresholds, the number and the level of effective marginal tax rates would not be under control, leading to unpleasant and inefficient outcomes.

We continue by defining specific chromosomes, in order to set the combinatory space for the three tax credits for dependent individuals within the household:  $c_i^{2H}(x_i^{MR})$ ,  $c_i^{2S}(x_i^{MR})$  and  $c_i^{2O}(x_i^{MR})$ .

Starting with the tax credits for dependent children  $c_i^{2H}(x_i^{MR})$ , we let the GA choose the potential level of the tax credits  $c_i^{2Hpl}$  in the range 600-3,000 euros (being the present values ranging between 800 and 1,100 euros). Similar to the choice of the tax rates and the

upper limits of the thresholds, we then define 5 different chromosomes (from 19 to 23) to set the 4 kinds of tax credits for dependent children. In so doing, we set specific constraints, in order to let the potential tax credit be higher for households with more than 3 children and lower for those with fewer than 3 children, as well as higher for children aged 3 or less and lower for a child aged more than 3. Then we introduce chromosomes 24 and 25 for the choice of parameters  $q$  and  $e$ . We let the GA choose  $q$  between 50 and 130 thousand euros (being the present value equal to 95 thousand), and the parameter  $e$  between zero and 40 thousand euros (being the present value equal to 15 thousand). Note that these are very large ranges, so that the GA can choose an extremely large set of combinations. Finally, the GA chooses chromosome 26 in order to set  $c_i^{2HF}$  between zero and 1,500 euros (being the actual value 1,200 euros).

Turning to the effective tax credit for the spouse  $c_i^{2S}(x_i^{MR})$ , we generate chromosome 27 in order for  $c_i^{2Sp}$  to range between 500 and 2 thousand euros (being the present value equal to 800 euros), and a further chromosome 28 in order for the parameter  $u$  to range between zero and  $c_i^{2Sp}$ . Chromosomes 27 and 28 let the effective tax credit for the spouse be a non-increasing function with respect to  $x_i^{MR}$  and let the GA choose among a very large combination of structures for this tax credit.

Looking at Equation (5), this effective tax credit  $c_i^{2S}(x_i^{MR})$  is piecewise linearly decreasing with respect to three thresholds: from zero to  $LL_2$ , from  $LL_2$  to  $LL_3 < w < LL_4$ , and from  $w$  to  $k > LL_5$ . In order to define  $w$  and  $k$ , we introduced chromosomes 29 and 30 as follows:

$$w = LL_2 + chromosome_{29} * (LL_4 - LL_2)$$

$$k = w + chromosome_{30} * (80,000 - w)$$

Finally, concerning the tax credit for other dependent individuals within the household, we introduce chromosome 31 in order for  $c_i^{2Op}$  to range between  $0.75 * c_i^{2Hp1}$  and  $0.95 * c_i^{2Hp1}$ , and we impose  $c_i^{2O}(x_i^{MR})$  to be linearly decreasing between zero and  $k$ , and to be zero if  $x_i^{MR} > k$ .

Afterwards, we let the GA choose chromosomes 32, 33 and 34 in order to set tax credits for tenants:

$$tenants_1 = chromosome_{32} * 1,000$$

$$tenants_2 = chromosome_{33} * tenants_1$$

$$tenants_3 = tenants_1 + chromosome_{34} * (tenants_1 * 2)$$

According to the present tax code, these tax credits are applied to two income thresholds: 15,494 and 30,987 euros; we consider this aspect by letting them change according to  $UL_1$  and  $UL_2$ .

Finally, the GA chooses chromosomes 35 and 36 in order to set the percentage of the expenses the tax law admits as further tax credits for items of expenditure. We let it chose  $expenditure_1$  between 0 and 40 per cent (at present equal to 19), and  $expenditure_2$  between 20 and 70 per cent (at present equal to 36).

## 6. Results

Table 3 shows all the parameters of the ‘best’ tax structure able to maximize the Reynolds-Smolensky  $RS$  index, given that the tax revenue is 9.31 billion euros lower than the present one and no taxpayers have to be worse off due to the tax reform.

As can be noted, the bottom marginal tax rate  $t_1$  significantly decreases from 23 to 19.42 per cent; this reduction lowers the gross tax liability, not only for the poorest taxpayers but also for all the other taxpayers.  $t_4$  decreases from 41 to 39.95 per cent, whilst  $t_5$  remains unchanged as expected. The other two marginal tax rates increase:  $t_2$  from 27 to 27.96 per cent, and  $t_3$  from 38 to 39.95 per cent. Note that  $t_3 = t_4$ : according to the GA, the highest redistributive effect can be obtained with 4 instead of 5 thresholds. In terms of the bandwidth of the thresholds, the first one broadens from 0-15,000 to 0-22,871 euros, whilst the second narrows from 15,000-28,000 to 22,871-26,454 euros. Then the original third and fourth thresholds unite and the after-reform third threshold goes from 26,454 to 57,158 euros. Finally, the top marginal tax rate is applied to incomes above 57,158 euros instead of 75 thousand euros.

**TABLE 3 AROUND HERE**

The ‘no tax’ area enlarges for all the four kinds of taxpayer:  $m_1$  increases from 8,000 to 11,028 euros,  $m_2$  from 7,500 to 10,339,  $m_3$  from 7,750 to 10,684, whilst  $m_4$  rises from 4,800 to 5,116. Note that  $\frac{m_1}{UL_1} = 0.48220$  is not set to its maximum value.

The parameters defining the shape of the effective tax credits for earned income considerably increase:  $a_1$  from 502 to 2,142 euros,  $a_2$  from 470 to 2,008, and  $a_3$  from 486 to 2,075 euros. Note that in all cases the GA sets  $a_r = t_1 m_r$ . This means that the shape of the tax credits for earned incomes changes with respect to those originally observed.

Since we impose the tax credit  $c_i^1(x_i^{MR})$  piecewise decreasing with respect to  $LL_2$  and  $LL_4$ , note also that after the tax reform, it is positive up to  $LL_2$ . As an example, Figure 3 compares the effective tax credits for employees before and after the tax reform. After the reform, the slope of the effective tax credit is higher (in absolute value) in the income range  $(m_1 - LL_2)$ . This shape also affects the level of the effective marginal tax rates (EMTR) in this income bandwidth, which increase with respect to the ones observed before the tax reform (Figure 4). Therefore, an equity-efficiency trade-off emerges: in order for the Reynolds-Smolensky index to be the highest, we have to agree to higher effective marginal tax rates.

**FIGURE 3 AROUND HERE**

**FIGURE 4 AROUND HERE**

The shape of the tax credit for a spouse  $c_i^{2S}(x_i^{MR})$  is very similar to the present one (Figure 5). The potential tax credit is a little bit higher than before, and the effective one is higher in the income range 0- $w$ ; it becomes zero above 80 thousand euros.

In terms of the tax credits for dependent children, the two tax credits for children if the dependent children within the household are 3 or less are very similar to those observed before the tax reform:  $c_i^{2Hp1}$  decreases from 800 to 788 euros, whilst  $c_i^{2Hp2}$  increases from

900 to 907. The other two tax credits are significantly higher:  $c_i^{2Hp3}$  increases from 1,000 to 1,687, whilst  $c_i^{2Hp4}$  from 1,100 to 2,265 euros.

### FIGURE 5 AROUND HERE

Note also that since  $c_i^{2Hp3}$  and  $c_i^{2Hp4}$  are so much higher than before,  $c_i^{2HF}$  can be set equal to zero. The income limits above which this tax credit becomes zero, also change:  $q$  is equal to 86,803, whilst  $e$  is equal to 25,515. A similar picture emerges when considering the tax credit for other dependent individuals within a household: the potential tax credit is a little lower than the present value (748 euros), and is positive for income below 80 thousand euros.

Focusing on the remaining parameters of the tax, the tax credit for tenants with gross income below  $UL_1$  is approximately the same (301 euros against 300); the tax credit for tenants with income in the range  $(UL_1 - UL_2)$  is set to 209 euros instead of 150, whilst the tax credit for younger tenants is lower (589 euros instead of 992).

Finally, the percentages of expenses the tax law admits as a tax credit also remain relatively unchanged: 18.54 per cent instead of 19 per cent and 41.17 per cent instead of 36 per cent.

Very few taxpayers are worse off as a result of this tax reform (1.1 per cent and, on average, they lose 43 euros per year), whilst 24.5 per cent are unaffected (we consider as unaffected the taxpayers for whom the absolute value of the computed net tax liability differs from the present one by, at most, one euro). The remaining 74.4 per cent of taxpayers gain from the reform. Looking at the composition of the tax cut in terms of income classes (Table 4), 85.6 per cent of the tax cut favours taxpayers in the income range 8-28 thousands euro, whilst 2.5 per cent favours taxpayers with lower incomes. This is due to the fact that the Italian personal income tax system does not admit negative income taxation; therefore, taxpayers with a nil net tax liability (almost all taxpayers with income lower than 8 thousand euros) are not affected by the tax reform. If the Italian PIT allowed negative income taxation, the tax reform would show a different distribution in terms of the tax cut among income classes: in particular, there would be lower gains for the top income earners and higher gains for the bottom ones.

#### TABLE 4 AROUND HERE

Only 9 per cent of the tax cut favours taxpayers with incomes in the range 28-55 thousand euros, whilst the remaining 3.1 per cent favours richer taxpayers. It can be observed that the  $RS$  could be higher, were the (low) gains of the richer taxpayers transferred to the poorest ones. Given the structure of ‘chromosomes’ described in subsection 5.2, this is not possible, or at most, not likely, since the GA has to balance the effects on  $RS$ ,  $\Delta$ ,  $\Pi$  and  $\Omega$  due to 33 parameters.

Finally, Table 5 compares the inequality indexes for taxpayers according to the present tax structure, and those obtained by applying the new structure of the tax to the same pre-tax income distribution. As can be noted,  $RS$  is 8.3 per cent higher than the present value: since the overall average tax rate decreases from 18.70 per cent to 17.53 per cent, the Kakwani index increases by 17.2 per cent. Note also that this tax reform positively affects  $R^{APK}$ .

#### TABLE 5 AROUND HERE

### 7. Concluding Remarks

In this paper, we propose a new methodology to implement a personal income tax reform. In particular, given a settled tax cut decided upon by the Government, (note that a similar strategy can be applied if the tax revenue increases), we show how a genetic algorithm can be employed, in order to find out the values of all parameters defining the structure of the personal income tax able to satisfy a specific target. Our methodology can be applied to any other specific target; as an example, in this work our target is the maximization of the redistributive effect of the tax, while preventing all taxpayers being worse off with respect to the present tax structure. We apply this methodology to the Italian personal income taxation system for two reasons: the tax structure is quite complicated, and recently the Government decided to reduce tax revenue by about 9.31 billion euro starting from 2015. The aim of this tax cut is to increase the purchasing

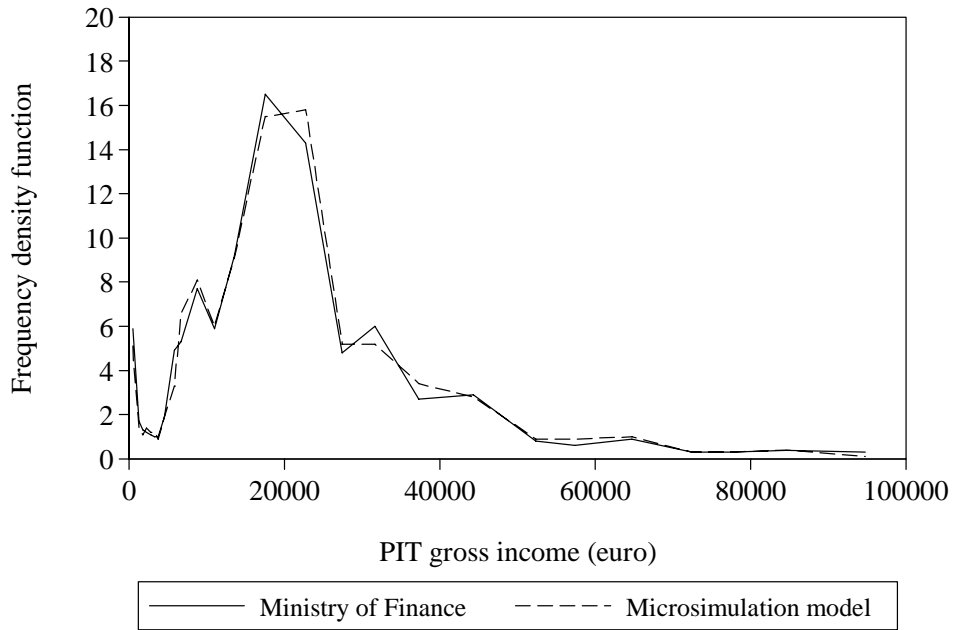


power of 'poor' taxpayers and taxpayers belonging to the 'middle class', and the instrument is the introduction of a cash transfer (not related to the structure of the personal income tax) only for employees with gross incomes in the range 8-26 thousand euros (in order for the yearly gain to be about one thousand euros), whilst all other kinds of taxpayer are not affected by this money transfer. Here we show that a better and more equity-oriented reform is possible. This methodology allows a short run reform, and can help policy makers when they think of a tax reform.

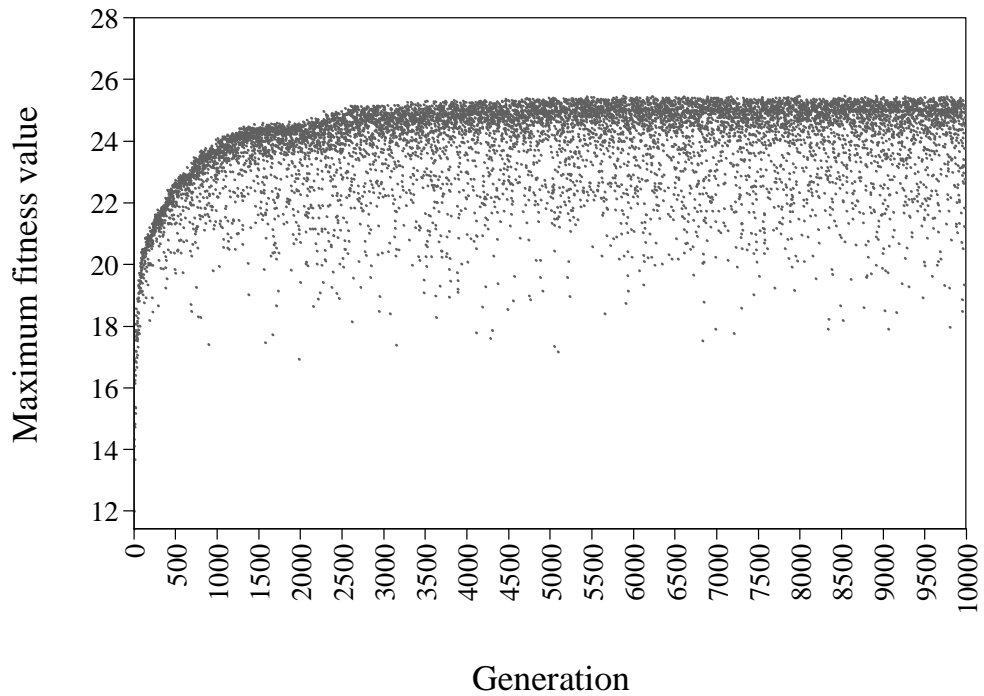
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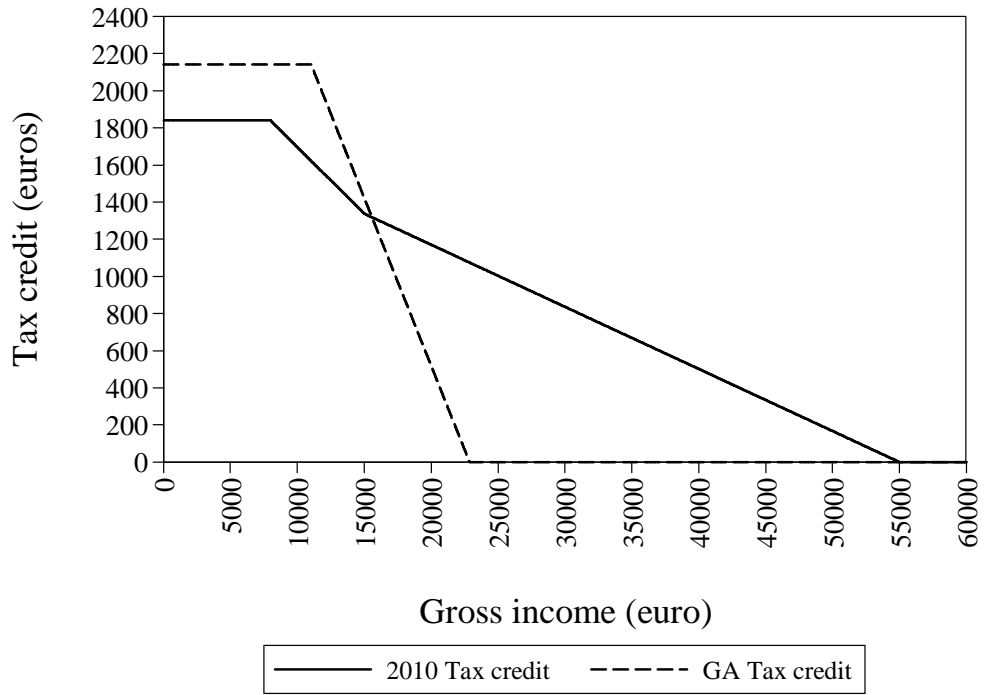
**Figure 1: Frequency density function for all individual taxpayers**



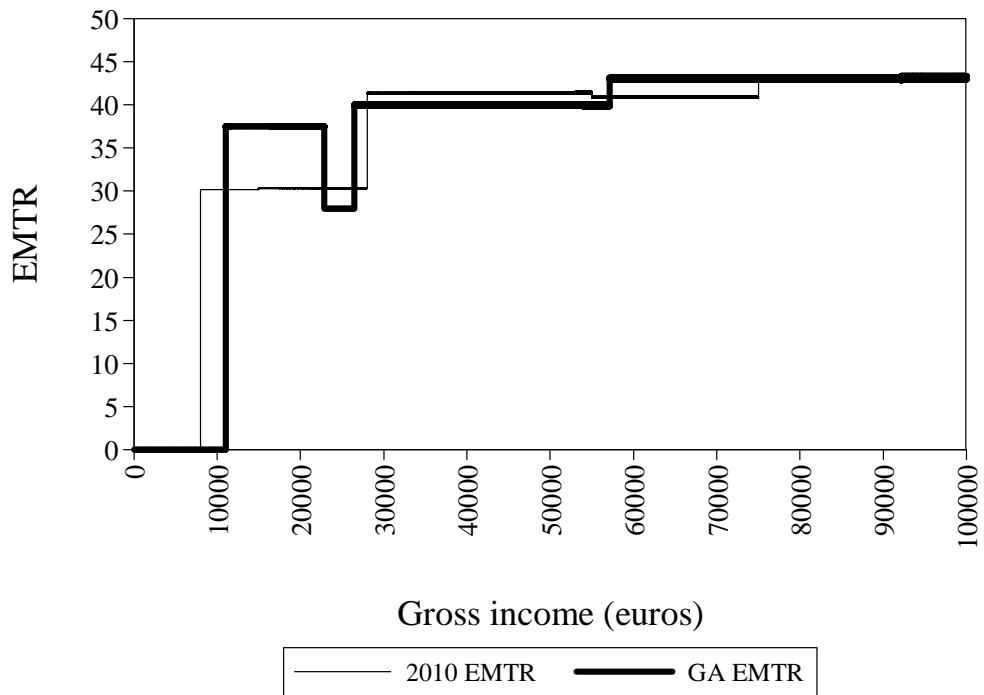
**Figure 2: Maximum values of the fitness function**



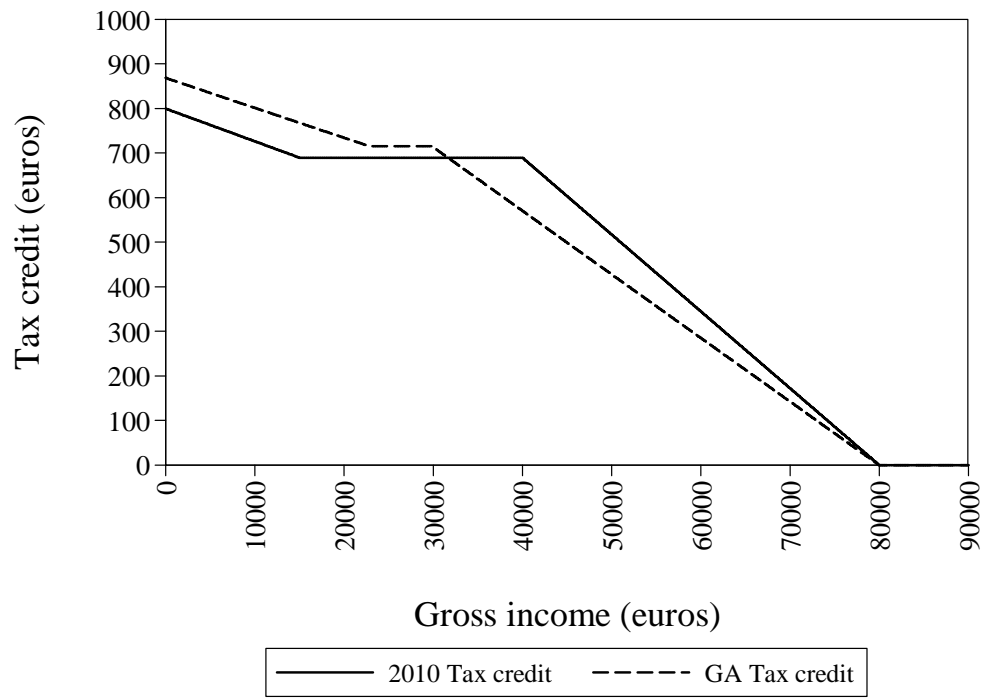
**Figure 3: The effective tax credit for an employee**



**Figure 4: The effective marginal tax rates for a celibate employee without children**



**Figure 5: The effective tax credit for a spouse**



**Table 1: Rate schedule**

<b>Taxable income (euros)</b>			
<b>Threshold (j)</b>	<b>Lower limit (LL)</b>	<b>Upper limit (UL)</b>	<b>Tax rate (%) (t)</b>
1	0	15,000	23
2	15,000	28,000	27
3	28,000	55,000	38
4	55,000	75,000	41
5	75,000	-	43

Source: Italian Tax Code.

**Table 2: Inequality indexes for taxpayers**

<b>Index</b>	<b>Present value</b>	<b>With cash transfer</b>	<b>Absolute difference</b>	<b>Percentage difference</b>
Gini coefficient for the gross income	0.44338	0.44338	0.00000	0.0
Gini coefficient for the net income	0.39138	0.38727	-0.00412	-1.1
Concentration coefficient for the net income	0.39076	0.38632	-0.00445	-1.1
Gini coefficient for the net tax liability	0.68150	0.73255	0.05104	7.5
Concentration coefficient for the net tax liability	0.67215	0.71187	0.03972	5.9
Redistributive effect	0.05200	0.05611	0.00412	7.9
Reynolds-Smolensky index	0.05262	0.05707	0.00445	8.5
Kakwani index	0.22877	0.26849	0.03972	17.4
Atkinson-Plotnik-Kakwani index	0.00062	0.00095	0.00033	53.3
Average tax rate (%)	18.70	17.53	-1.17	-6.3

Source: Own elaborations based on BI-SHIW.

**Table 3: Present and computed parameters of the tax**

<b>Parameters</b>	<b>Present value</b>	<b>Best value</b>
$t_1$	0.23	0.19421
$t_2$	0.27	0.27955
$t_3$	0.38	0.39952
$t_4$	0.41	0.39952
$t_5$	0.43	0.43000
$UL_1$	15,000	22,871.01
$UL_2$	28,000	26,453.94
$UL_3$	55,000	44,296.30
$UL_4$	75,000	57,157.63
$m_1$	8,000	11,028.41
$m_2$	7,500	10,339.13
$m_3$	7,750	10,683.77
$m_4$	4,800	5,115.92
$a_1$	502	2,141.85
$a_2$	470	2,007.98
$a_3$	486	2,074.91
$c_i^{2Sp}$	800	868.82
$u$	110	153.46
$w$	40,000	29,870.12
$k$	80,000	80,000.00
$c_i^{2Op}$	750	748.18
$c_i^{2Hp1}$	800	787.56
$c_i^{2Hp2}$	900	907.11
$c_i^{2Hp3}$	1,000	1,687.32
$c_i^{2Hp4}$	1,100	2,265.06
$q$	95,000	86,802.79
$e$	15,000	25,514.69
$c_i^{2HF}$	1,200	0.00
$tenants_1$	300	301.47
$tenants_2$	150	208.55
$tenants_3$	992	588.65
$expenditures_1$	0.19	0.18538
$expenditures_2$	0.36	0.41171

Source: Own elaborations based on BI-SHIW.

**Table 4: The composition of the tax cut by income classes**

<b>Income class (thousand euros)</b>	<b>Composition of the tax cut (%)</b>	<b>Winner (%)</b>	<b>Indifferent (%)</b>	<b>Loser (%)</b>	<b>Total (%)</b>	<b>Average win (euros)</b>	<b>Average loss (euros)</b>
0-8	2.5	6.1	19.3	0.0	25.3	91	0
8-15	40.5	17.3	4.7	0.0	21.9	542	0
15-28	45.1	34.4	0.4	0.5	35.3	294	52
28-55	9.0	13.0	0.1	0.5	13.5	158	39
55-75	2.8	2.2	0.0	0.0	2.2	290	41
above 75	0.3	1.5	0.0	0.1	1.7	42	14
<b>Total</b>	<b>100.0</b>	<b>74.4</b>	<b>24.5</b>	<b>1.1</b>	<b>100.0</b>	<b>307</b>	<b>43</b>

*Source:* Own elaborations based on BI-SHIW.



**Table 5: Inequality indexes for taxpayers**

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Concentration coefficient for the net income	0.39076	0.38639	-0.00437	-1.1
Gini coefficient for the net tax liability	0.68150	0.72020	0.03870	5.7
Concentration coefficient for the net tax liability	0.67215	0.71150	0.03935	5.9
Redistributive effect	0.05200	0.05642	0.00442	8.5
Reynolds-Smolensky index	0.05262	0.05699	0.00437	8.3
Kakwani index	0.22877	0.26812	0.03935	17.2
Atkinson-Plotnik-Kakwani index	0.00062	0.00057	-0.00005	-8.3
Average tax rate (%)	18.70	17.53	-1.17	-6.3

Source: Own elaborations based on BI-SHIW.

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