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journal homepage: [www.elsevier.com/locate/ejor](http://www.elsevier.com/locate/ejor)Personal income tax reforms: A genetic algorithm approach<sup>☆</sup>Matteo Morini<sup>a,b,1</sup>, Simone Pellegrino<sup>b,\*</sup><sup>a</sup> ENS Lyon, Institut Rhône-Alpin des Systèmes Complexes (IXXI), Site Jacques Monod 46, allée d'Italie, 69007 Lyon, France<sup>b</sup> Department of Economics and Statistics, University of Torino, Corso Unione Sovietica 218 bis, 10134 Torino, Italy

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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 maximisation 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.

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## 1. Introduction

Personal income tax (hereafter, PIT) is characterised around the world by several parameters that define its structure: marginal tax rates, upper limits of 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, as well as influences economic efficiency, first of all work incentives and tax compliance.

The existing economic literature represents a fundamental tool for the PIT design and for the need of balancing equity and efficiency, as well as social preferences for redistribution. This literature first focused on axioms that are required in order to equally apportion the burden of taxation among citizens (Mill, 1848; Samuelson, 1947). However, starting with the seminal paper by Mirrlees (1971), the theoretical literature has mainly focused on the equity–efficiency trade-off in optimum taxation. This is a difficult task, since many empirical simulation studies have, in fact, shown that in the short-run it is almost impossible to find a tax reform, which does not decrease efficiency or equity and, at the same time, is still financially and politically feasible. Moreover, if applied to a real-world tax system, most of the results of the

economic literature would imply considerable modifications of the present tax structure and would certainly affect the tax revenue, which is one of the most important concerns that policymakers have to face. In other words, governments are certainly interested in setting up a tax system by implementing the literature's results, at least in the long-run. In the short-run, they are undoubtedly subject to budget constraints and to the political feasibility of a reform.

Despite these arguments, the PIT structure is subject to continuous evolution around the world. Peter, Buttrick and Duncan (2010) study and categorize the trends in the PIT structure over the period of 1981 to 2005 in 189 countries. They show that many governments substantially and/or frequently change the PIT structure; according to their analysis, about 45 per cent of governments changed at least one parameter of the PIT every year. They also emphasize that *'The high frequency of changes may also be due to the gradual enactment of tax reforms that get implemented over several years, fiscal policy responses to the business cycle, or continuous experimentation and search for the best tax structure.'*

This paper focus on these key issues by considering a recently proposed real-world tax cut; it evaluates a feasible tax reform by optimizing the government's target and, in the meantime, by exactly complying with the government's budget constraint. The solution for this problem can be obtained by employing a genetic algorithm (hereafter, GA): a search heuristic inspired by natural selection, well-suited to the identification of the most promising solution to the problem under consideration. To our knowledge, no previous attempts at employing GAs for PIT structure optimisation exist. The unique applications to tax systems deal with other and simpler aspects (Brooks, 2000; Chen & Lee, 1997).

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The tax cut, which we study, has recently been implemented by the Italian government. 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 maximisation), the Italian government recently reduced the PIT revenue by 9.324 billion euros<sup>1</sup> (about 6 per cent of the PIT tax revenue) 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).<sup>2</sup>

Considering this reform, 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 leaving no taxpayers worse-off with respect to the present tax structure? The GA is an appropriate tool, and Italy is a perfect case study, since the Italian PIT is very complicated and its structure incorporates more than thirty parameters. Our results show that a more general, better, and more equity-oriented reform is possible; moreover, this methodology can be applied to any other specific target.

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

Even if by employing the 'best' tax structure (almost) 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 we also do not consider taxpayers' responses to the new parameters of the tax structure; it is a 'short run' solution that can help policy makers when they think of PIT reform. In order to consider taxpayers' responses further research can be done regarding a long-run perspective: for example by modelling the equity-efficiency trade-off in a genetic algorithm framework or by employing agent-based models. This is the baseline of our further research.

The structure of the paper is as follows. Section 2 briefly reviews the existing economic literature on the design of the tax system and further explains the motivation of this paper. Section 3 describes in greater detail the 2010 structure of the Italian personal income tax, the baseline for our analysis. Section 4 presents how tax progressivity and the redistributive effect exerted by the tax can be measured. Section 5 shows the data and peculiarities of the static micro-simulation model employed for simulations. Section 6 first describes how genetic algorithms work and it then presents the implementation used in this work. Section 7 shows the results, whilst Section 8 offers a conclusion.

<sup>1</sup> According to the official statistics made available by the Department of Finance of the Ministry of Finance (2016), the tax cut amounts to 9.1 billion euros and affects 11.3 million taxpayers.

<sup>2</sup> There is a political explanation behind this choice. The government announced that it would reduce PIT liability by 80 euros per month for all taxpayers belonging to the middle class. Of course, such an announcement proved to be too expensive; moreover, it would have been very difficult to be reached 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 of 80 euros for all these taxpayers. In order to at least partially meet its commitment, the government decided to only apply the 80 euros pledge to a group of taxpayers, given the revenue constraint. In order to not modify the PIT structure and ensure exactly 80 euros, it chose the cash transfer instrument.

## 2. Literature review and purpose of the paper

Given its progressive nature, the PIT is a globally fundamental tool through which the redistributive effect of the whole tax system of a country is achieved, even if a large variability, in terms of both tax revenue and redistributive effect, is observed around the world (Verbist & Figari, 2014; Wagstaff et al., 1999). The two key reasons for this variability deal with the role played by social preferences for redistribution (Lefranc, Pistoiesi, & Trannoy, 2008) and the equity-efficiency trade-off of taxation (Feldstein, 1976; Saez, 2001; Sandmo, 1981; Stern, 1976; Tuomala, 2016).

Starting from Mill's (1848) approach, economic theory has first elaborated precise axioms to equally apportion the burden of taxation among citizens. The principle of equal sacrifice can thus give normative and positive contents to the ability-to-pay principle and justify the tax progressivity. The resulting degree of progressivity depends on the amount of tax revenue to be raised, as well as the social welfare function characterizing preferences of the society. Within this framework, Young (1990) proposed a theoretical strategy in order to test the possibility of stating that a country's lawmaker adopts a precise criterion of distributive justice and a particular social welfare function when he determines vertical equity and modifications in the PIT structure (e.g., Pellegrino, 2008 for an application to the Italian case). Young's (1990) framework does not consider efficiency and incentive effects, so his methodology favours high marginal tax rates on higher incomes. Berliant and Gouveia (1993) introduce incentive effects within Young's (1990) methodology, finding conditions for progressive taxation similar to the standard ones elaborated by Samuelson (1947).

On the other hand, Mirrlees (1971) introduces the theory of optimal direct taxation, which also deals with the equity-efficiency trade-off. As the real-world PIT systems are very complex, empirical applications of the optimal income tax theory are based on stylised tax, which involve only a few tax parameters. Within this framework, the most effective estimation difficulties deal with the economic behaviour modelling since the labour supply responses (Aaberge & Colombino, 2013; Bargain, Orsini, & Peichl, 2014; Blundell & Shephard, 2012) and the tax base responses to tax changes have to be introduced and parameterised (Saez, 2001; Saez, Slemrod, & Giertz, 2012).

On the contrary, governments have to face PIT structures composed by several parameters and, most importantly, the PIT structure observed in a country (in a given year) is indeed the result of several and partial adjustments that have occurred over the previous years. Focusing on those aspects, this paper differs from the existing literature for several reasons. First of all, it has a different the point of view from which the PIT reform is evaluated. Usually, the existing empirical literature evaluates the effects of a tax reform *after* the government introduces it. On the contrary, in this paper, we consider the government's point of view *before* such a reform is introduced.

Let us consider a generic government. Every year, this government plans finance law, which sets the annual adjustments on the level of the overall value of public spending and tax revenue to be obtained by the current legislation, in order to achieve some specific goals (such as the level of the government deficit) set in the long-term budget. One possible adjustment is the level of the PIT revenue. Starting from the actual PIT structure, the government may then want to cut 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; or, it may want to increase tax revenue by letting the richest taxpayers face the whole tax increase, or it may want to modify the PIT structure in order to reduce the inefficiencies of the tax. These are, of course, only some explanatory perspectives. Whatever the target, which parameters of the tax should be changed in order to

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