



# Optimality of Relaxing Revenue-neutral Restrictions in Green Tax Reforms\*

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## Abstract

Green Tax Reforms [GTR] have been initially devised as a policy proposal to tackle simultaneously several political goals. Recent fiscal stress episodes have defied this view. In this paper, we assess a key issue of interest for policymakers: departing from a fiscal system that does not include any environmental tax, would the tax menu resulting from the implementation of revenue-neutral GTR be the closest available to the optimal one? Our work illustrates in a simple, parametrized model that the answer is negative. These findings deviate from general wisdom and provide theoretical support for the third generation of GTR.

*Keywords:* Green tax reforms, revenue neutrality, optimal taxation.

*JEL Classification:* H23, Q48.

## 1. Introduction

Global trends regarding fiscal and environmental issues are increasingly among the top priorities on the policy agenda in many developed countries. On the one hand, fiscal stress episodes in some European countries subsequent to the economic and financial crisis have hit in most OECD countries in such a way that “consolidating the public finances is an important challenge for many countries” (OECD, 2012). On the other hand, the shift in global economic power, with a significant rebalancing towards Asian countries, drives some of the main Global Megatrends (EEA, 2011). Particularly, those concerning the impact on natural resources, such as an intensified global competition for resources (energy, non-energy minerals, biomass, etc.)

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and an increasingly environmental pollution.<sup>1</sup> Some policy initiatives have been proposed to tackle both concerns simultaneously, as it is the case of the nationally based Green Tax Reforms [GTR] implemented in Europe for the last two decades.<sup>2</sup> More recently, the European Commission [EC] has once again –the previous GTR proposal was in 1992– launched a GTR proposal linking fiscal and environmental issues (European Commission, 2011).

Strictly speaking, GTR consist of setting environmental taxes and then recycling the revenue by reducing distorting taxes in order to improve the efficiency of the tax system, thus keeping the government budget unchanged.<sup>3</sup> However, alternative recycling procedures can be devised. In fact, there exists a new wave on GTR schemes with extra revenues recycled for fiscal consolidation (see, for instance, Gago *et al.*, 2014 and 2016 surveys). This has been certainly an appealing idea in the recent troubled times for developed economies facing a scenario of economic crisis and growing public deficits, when new policy strategies have been needed to recover economic growth and stabilise public budgets (OECD, 2010). The interest in considering environmental taxes to accommodate global trends (i.e., environmental and fiscal issues) relates to the idea that they might play an important role in easing political constraints regarding the reform of public budgets (calling for spending cuts and tax increases).<sup>4</sup> In that context, environmental and energy-related taxes might become “the lubricating oil” that makes a fiscal or public budget reform possible.

Nonetheless, any researcher considering the orthodox view with regard to GTR –implemented in an *ideal world*– will be reluctant towards any departure from revenue-neutral GTR (i.e., budget-neutrality adjustment policies), considering such a departure as something undesirable for the general goal of efficiency improvements of the tax system.<sup>5</sup> Realpolitik, however, may regard the departure from revenue-neutral conditions as an unavoidable cost for policymaking. Because real policymaking faces additional constraints and not only aims to maximize efficiency, as it is subject, for instance, to fiscal stress episodes or distributional issues (e.g. perceived impacts on competitiveness and on low-income population groups). Indeed, the emphasis on the efficiency benefits of revenue-neutral GTR posed by the proponents of the orthodox view –a (restricted) taxation proposal– greatly contrasts with the efficiency improvements potentially achieved by a benevolent government optimally redesigning a tax system, a divergence that is worthy of exploring.

In this paper, we study the role played by revenue-neutral restrictions on GTR in achieving a more efficient tax system. Specifically, we analyse the possibility of giving up revenue-neutral restrictions to improve the efficiency of the whole tax scheme by comparing three fiscal systems designed under different tax scenarios: the *Full public intervention*, the first-best optimal tax scheme; the *Non-environmental public intervention*, a tax system without recognizing the environmental externality (thus, without incorporating the environmental tax); and, the *Constrained GTR public intervention*, a policy that departs from the “non-environmental public intervention” scenario and incorporates the environmental tax within a revenue-neutral framework.

The key issue of interest for academics and policymakers addressed in this paper is the following: would the resulting tax menu from the *Constrained GTR public intervention* sce-

nario be the closest available to the optimal one? This paper illustrates in a simple, parametrized model that the answer is negative. The reason is that the “revenue-neutral” condition on the green tax reform imposes on policymakers an additional constraint which reduces degrees of freedom for policy design and thus imposes some social costs. In addition, our theoretical model also illustrates the inability of a neutral-revenue GTR in achieving a double dividend when the negative externality (e. g. pollution) greatly affects households’ welfare.

Our findings deviate from general wisdom supporting the convenience of GTR (e. g., Goulder, 2013), and provides theoretical support to the *third generation of GTR* (Gago *et al.*, 2014, 2016), which proposes giving up revenue-neutral constraints and designing GTR schemes with extra revenues recycled to fiscal consolidation, following some recent legal European experiences (such as Sweden, the UK, Ireland and Spain).

In the following section, we present the economic context and a review of the academic literature regarding the new generation of GTR. Section 3 presents our methodology, and section 4 develops the main theoretical analysis. We summarise the main conclusions and policy implications in section 5.

## 2. A new generation of GTR

There exists an extensive literature on GTR and the double dividend hypothesis.<sup>6</sup> The double dividend hypothesis provides the main theoretical support for implementing GTR by postulating that green reforms deliver two dividends: an improved environment plus fiscal efficiency gains when extra revenues are “recycled”<sup>7</sup> by reducing some other distorting taxes. The academic literature<sup>8</sup> has aimed to integrate the contributions on the double dividend within the realm of optimal taxation<sup>9</sup> by analysing (i) the optimal environmental taxation in the presence of other taxes; and, (ii) under what conditions a positive “double dividend” is indeed an outcome. For this strand of the literature, the interest has mostly hinged on the deviations of the optimal environmental taxation from the Pigouvian norm. Siegmeier *et al.* (2015) have recently provided a survey on usually neglected interactions of carbon pricing with other fiscal policy instruments.

Concerning policy implementation, this literature also recognises that policymakers usually depart from a non-optimal tax system, and that any fiscal reform aiming to improve social welfare is bounded by socioeconomic constraints. The purpose of the double dividend literature has been to provide an operative and implementable tax reform that involves environmental improvements and efficiency gains of the fiscal system (see for instance Bovenberg 1999).<sup>10</sup> However, the pathway of research findings translating into implementable policy measures is not without difficulties (e. g., the necessary actions to consolidate public deficits or to attract special interest groups to lobby in support of regulations). Thus, when scientific arguments and political forces meet, some departures from the original revenue-neutral GTR scientific arguments may arise.

The EC’s GTR proposal launched in April 2011 (European Commission, 2011 a) evidences what happens at the boundary of policy and science (i. e., real policymaking con-

straints as opposed to theoretical model restrictions). The EC's proposal pursues several objectives, namely, (i) to contribute to growth and employment by shifting taxation from labour to consumption; and, (ii) to promote energy efficiency and consumption of more environmentally friendly products. An additional aim of the GTR proposal is to complement the existing EU Emissions Trading System [EUETS] by applying a carbon tax to sectors that are out of its scope (transport, households, agriculture, and small industries) plus an energy tax, then counterbalancing some EUETS weakness.

The EC's GTR proposal leaves open the use of additional tax revenues: the EC recommends reducing labour taxes, but countries are allowed to use those revenues for fiscal consolidation. Accordingly, the European Environment Agency published a Staff Position Note addressing the role for environmental fiscal reform in Portugal, which claims for a "dynamic approach to revenue-neutrality" under the current circumstances and calls for fiscal consolidation (Andersen *et al.*, 2013). Similar arguments can be found in OECD (2010): "the prospective need for fiscal consolidation increases the presumption that environmental objectives like reducing greenhouse gas emissions should be addressed through measures that raise revenues".

Some examples of this relaxation on the revenue-neutral condition at the time of GTR implementation may also be found in recent legislation released by several European countries, as well as several EC's proposals already mentioned. References to this legislation may be found in Gago *et al.* (2014, 2016). For instance, in 2002 Sweden introduced a green fiscal change program with a collection forecast of 3,200 million euros for fiscal consolidation. In 2006, the UK raised several taxes related to landfill disposal of waste and climate change that were integrated into the budget process. At the end of 2009, Ireland introduced a carbon tax on energy products (but without levying electricity) where revenues were devoted to fiscal consolidation. The Spanish law *Fiscal Measures for Environmental Sustainability (Ley 15/2012 de medidas fiscales para la sostenibilidad energética)* provided another recent example of this trend in 2012. This law introduces energy and environmental-related tax reforms without revenue recycling considerations: new taxes on hydropower production and nuclear waste generation, increased rates on consumption of hydrocarbons for cogeneration and electricity production (coal, natural gas, light fuel oils), and a new tax levied on the production of electricity (uniform for all producers including renewable sources). The Spanish government forecasted an increase of as much as 2.729 million euros of additional fiscal revenues devoted to fiscal consolidation.

Fiscal stress episodes in the Eurozone are only examples of new constraints faced by policymakers to design a comprehensive fiscal system that additionally includes environmental taxes. Gago *et al.* (2014, 2016) review GTR designs on the grounds of the latest political experiences. These authors identify this departure from revenue-neutral conditions as the "third generation of GTR". Accordingly, this new generation of non-revenue-neutral GTR is prone to use additional tax revenues for fiscal consolidation. In some cases, as Gago *et al.* (2016) illustrate, a share of the extra revenues are earmarked to provide funding to environmental programs (e.g. energy efficiency, renewables, and R+D+i).

Despite all these political experiences on the "third generation of GTR", most academic works are "largely focusing on revenue-neutral carbon tax swaps to fund marginal rate

cuts in distortionary taxes” (Rausch, 2013). In a dynamic general-equilibrium model with overlapping generations calibrated for the United States, Rausch (2013) examines whether a carbon pricing policy may be socially desirable if it is combined with a fiscal policy aimed at reducing public debt instead of revenue-neutral carbon tax swaps. Such a policy “implies a relaxation of future public budgets as debt repayment results in lower future interest obligations”, which introduces an intergenerational view on the tax recycling and GTR debate. His calibrated economy provides numerical support to devote revenues from climate instruments to finance existing public spending. Although Rauch’s result lacks from a formal treatment on the robustness of its findings, and therefore cannot be reached any general conclusion, it is worth exploring whether implementing a non-revenue-neutral GTR brings about higher economic and welfare outcomes than implementing a revenue-neutral GTR.

Thus, the convenience of relaxing revenue-neutral constraints on GTR lacks from sound theoretical support, and it should be circumscribed on the boundary of the optimal taxation and the double dividend literature. The purpose of this piece of research is to analyse the possibility of improving the efficiency of the whole tax scheme by giving up revenue-neutral restrictions on GTR.

### 3. The benchmark model

Our setting is similar to the static model developed by Parry *et al.* (1999) –so there are neither savings nor capital accumulation–, but we simplify their framework to find closed-form analytical equilibrium solutions. Different from Parry *et al.* (1999), our setting additionally considers an externality from public expenditure following the works by Bovenberg and Mooij (1994) and Fullerton and Metcalf (2001). The economy is populated by three types of agents: households, firms, and a government.

*Households.*—There exist  $H$  identical households, who are owners of the firms, and each endowed with 1 unit of time (e.g., a year) that are allocated between working time  $n^h$  and leisure time  $l^h$ . Labour compensation  $w^h$  is the only source of income for any household  $h$ . Households enhance welfare by enjoying leisure time  $l^h$  and consuming a combination of goods purchased by the household: a “clean” (non-polluting) good,  $x^h$ , and a “dirty” (polluting) good  $y^h$  produced from industries that use an intermediate good  $E$  (e.g., fossil fuels). In addition, households find their welfare affected by two externalities: pollution, a negative externality resulted from combustion of fossil fuels  $E$ ; and, the provision of goods funded by the State, a (real) public expenditure  $G$  that generates a positive externality (e.g., health, education or any other goods provided by the government), as governmental decisions on  $G$  levels will impact on individual’s welfare levels.

Each household’s preferences are represented by a twice-continuously differentiable utility function. We follow Bovenberg *et al.* (1994) by assuming that the externalities are separable in utility from leisure and consumption, and that the combination of consumption goods is homothetic and separable from leisure. Our parametrized function is similar to that by Parry *et al.* (1999),

$$U^h(V(Q(x^h, y^h), l^h), E, G) = \alpha \ln\{[x^h]^\beta [y^h]^{1-\beta}\} + (1 - \alpha)l^h + \psi(E, G), \quad (1)$$

with  $\alpha \leq 1/2$  and  $\beta \in (0, 1)$  being positive welfare parameters, and  $\psi(\cdot, \cdot)$  being a decreasing function in the first argument—representing the disutility from pollution—, and an increasing function in the second one—representing the utility from public expenditure. For simplicity, we will assume the following parametric specification:<sup>11</sup>  $\psi(E, G) = \gamma \ln\{G - \phi E\}$ , with  $\gamma$  and  $\phi$  being two positive parameters of preferences that denotes how each variable affects the household's welfare.

*Firms.*—In the economy, there are three industries that produce three commodities: an intermediate good,  $E$ ; and, two final goods, a “clean” (non-polluting) good  $X$  and a “dirty” (polluting) good  $Y$ . At each industry, there is a continuum of identical firms of unit measure, so that the market structure is competitive in all industries. All firms at each industry share the same technology, with labour  $N$  a required input for any production; however, the dirty technology requires additionally the intermediate good  $E$  as an input. We consider the following parametrizations for the technologies. The intermediate good is produced with a linear technology,  $E = E(N_E) = \frac{B}{C} N_E$ ; the clean good is also produced with a linear technology,  $X = X(N_X) = D N_X$ ; and, the dirty good is produced combining the intermediate good and labour in constant ratios, so that the Leontief technology becomes  $Y = Y(N_Y, E) = A \min\left\{N_Y, \frac{1}{B} E\right\}$ . The technological parameters  $A, B, C$  and  $D$  are all positive. We denote the price of good  $E$  by  $P_E$ , the price of good  $X$  by  $P_X$ , and the price of good  $Y$  by  $P_Y$ . We normalize the price of the clean good  $X$  to one, i.e.  $P_X = 1$ .

*The government.*—The presence of pollution and (real) public expenditure might require some government intervention to improve the efficiency of the economy. Specifically, consider there exists a benevolent government that maximizes households' welfare by choosing a menu of taxes  $\{t_E, t_c, t_w\}$ , where  $t_E$  is an ad-valorem tax rate on the value of the intermediate good that generates pollution,  $t_c$  is a tax on consumption spending, and  $t_w$  is a tax on income. For convenience, we denote  $1 - \tau = \frac{1 - t_w}{1 + t_c} < 1$ , representing the income purchasing power net of distorting taxes (e.g. on labour and consumption) with  $\tau$  indicating the *tax burden of distorting taxes* (hereafter, for the sake of simplicity, we will call it “distorting tax burden”).<sup>12</sup> Observe that if no distorting taxes exist, then  $\tau = 0$ ; in addition, note that the higher the tax rates, the lower the income purchasing power net of distorting taxes and the higher their distorting tax burden  $\tau$ . To save notation, we will denote generically the tax menu as the pair distorting tax burden of distorting taxes and the environmental tax,  $\{\tau, t_E\}$ . Observe that while environmental taxes require that pollutant agents internalize their negative external costs, the tax revenues finance the public expenditure. We will assume that the government purchases goods to the private sector,<sup>13</sup> and for simplicity, we suppose that only purchases the non-polluting good, i.e.  $G = G_X$ .

#### 4. Public intervention: three scenarios

In this section, we will explore the optimality of the tax system in our economy under three scenarios:

1. *Full public intervention* (Section 4.1), the first best optimal tax scheme designed by a benevolent government that recognizes the environmental externality and set up an optimal public intervention incorporating an environmental tax;
2. *Non-environmental public intervention* (Section 4.2), a tax system designed by a benevolent government that, for whatever reason, does not recognize the environmental externality –thus, without incorporating the environmental tax–, yet designed optimally; and,
3. *Constrained GTR public intervention* (Section 4.3): a governmental policy that departs from the non-environmental public intervention scenario –a fiscal system that does not include any environmental tax, yet designed optimally– by incorporating an environmental tax while observing a revenue-neutral constraint. That is, the government is self-constrained to keep constant the revenues attained at the “non-environmental public intervention” scenario.

The analysis of these scenarios will allow us (in Section 4.4) to answer the key issue of interest for policymakers addressed in this paper; namely, whether departing from a fiscal system that does not include any environmental tax, a revenue-neutral GTR may provide the best available outcome for policymakers.

#### 4.1. The full public intervention scenario: The first-best tax menu

We begin by presenting the first-best optimal taxation. Firstly, we find the competitive equilibrium with public intervention for any given menu of taxes on consumption, income, and environment,  $\{t_c, t_w, t_E\}$ . Then, we compute the first-best tax menu.

##### 4.1.1. The decentralized equilibrium allocation with full public intervention

Given a menu of taxes, the competitive equilibrium with public intervention comprises a vector of prices that coordinate optimal agents’ decisions on production and consumption, so that all markets clear. The representative household’s problem, the representative firm’s problem at each industry and the competitive equilibrium are described in detail and solved in Appendix 1.

Each household  $h$  maximizes her welfare (1) subject to the budget constraint

$$(1 + t_c) \left[ x^h + \frac{P_y}{P_x} y^h \right] = (1 - t_w) \left[ \frac{w}{P_x} (1 - l^h) + \pi^h \right], \quad (2)$$

and taking as given the relative prices  $P_y/P_x$ , the real wage  $w/P_x$ , the household income from the firm’s profits  $\pi^h$  and the level of pollution ( $E$ ) and real public expenditure ( $G$ ).

Concerning the firms, the functional forms assumed greatly simplifies the supply side of the commodity markets and the labour demand. Thus, the equilibrium real wages and the



equilibrium commodity price ratio are set, respectively, by the infinitely elastic labour demand  $w^* = D$ , the infinitely elastic supply of the intermediate good  $P_E^* = CD/B$ , and the infinitely elastic commodity supply

$$P_y^* = \frac{D}{A} [1 + C(1 + t_E)]. \quad (3)$$

Finally, the government budget constraint is balanced as long as the tax revenue finances public expenditure, i.e.,

$$P_x G_x = t_E P_E E + t_c \sum_{h=1}^H [P_x x^h + P_y y^h] + t_w \sum_{h=1}^H [w(1 - l^h)], \quad (4)$$

which can be analogously represented, after substitution of (2), in terms of relative prices

$$G_x = P_E t_E E + \left( \frac{1}{1-\tau} - 1 \right) \sum_{h=1}^H [x^h + P_y y^h]. \quad (5)$$

From the optimal agent decisions, a competitive equilibrium with public intervention and taken as given a menu of taxes  $\{\tau, t_E\}$  is described by the demand and supply functions, the market clearing conditions and the government budget constraint. This allows us to find the equilibrium allocations (see Appendix 1):

$$l^{h*}(\tau, t_E) = 1 - \frac{\alpha}{1-\alpha}, \quad (6)$$

$$(x^{h*}(\tau, t_E), y^{h*}(\tau, t_E)) = \left( \frac{\alpha\beta}{1-\alpha} D(1-\tau), \frac{\alpha(1-\beta)}{1-\alpha} \frac{A}{1+C(1+t_E)} (1-\tau) \right), \quad (7)$$

for each household  $h$ ; while in the equilibrium aggregate variables are

$$\begin{aligned} & \left( N_x^*(\tau, t_E), N_y^*(\tau, t_E), N_E^*(\tau, t_E) \right) = \\ & \left( \frac{\alpha H}{1-\alpha} (1-\tau) \left[ \frac{C t_E (1-\beta)}{1+C(1+t_E)} + \frac{1}{(1-\tau)} - (1-\beta) \right], \frac{\alpha(1-\beta)}{1-\alpha} H \frac{(1-\tau)}{1+C(1+t_E)} \right), \end{aligned} \quad (8)$$

$$N^*(\tau, t_E) = H \frac{\alpha}{1-\alpha}, \quad (9)$$

$$E^*(\tau, t) = \frac{\alpha(1-\beta)}{1-\alpha} H B \frac{(1-\tau)}{1+C(1+t_E)}, \quad (10)$$

$$G_x = \frac{\alpha}{1-\alpha} H D (1-\tau) \left[ \frac{C t_E (1-\beta)}{1+C(1+t_E)} + \frac{1}{(1-\tau)} - 1 \right], \quad (11)$$

$$X^*(\tau, t_E) = D N_x^*(\tau, t_E), \quad (12)$$

and,

$$Y^*(\tau, t_E) = A N_y^*(\tau, t_E). \quad (13)$$



#### 4.1.2. The optimal tax menu with full public intervention

Next, we consider the *full (optimal) public intervention scenario* –the first best situation– with the benevolent government aimed to set the optimal tax menu  $\{\tau^*, t_E^*\}$  that considers an environmental tax. The equilibrium allocations for any tax menu  $\{\tau, t_E\}$  (described in Section 4.1.1), allow us to define the individual *utility function* for each household  $h$  as a function of the tax menu:

$$\begin{aligned} U^h(\tau, t_E) &= U^h(c^h(\tau, t_E), l^h(\tau, t_E), E(\tau, t_E), G(\tau, t_E)) = \\ &= K_0 + \alpha \text{Ln}\{K_1(1 - \tau)[1 + C(1 + t_E)]^{-(1-\beta)}\} + \\ &\quad \gamma \text{Ln}\left\{D - D\beta(1 - \tau) - K_2 \frac{1 - \tau}{1 + C(1 + t_E)}\right\}, \end{aligned} \quad (14)$$

with  $K_0 = (1 - \alpha) \left[1 - \frac{\alpha}{1 - \alpha}\right]$ ,  $K_1 = \frac{\alpha}{1 - \alpha} [D\beta]^\beta [(1 - \beta)]^{(1-\beta)}$  and  $K_2 = (1 - \beta) [\phi B + D(1 + C)]$ .

The *aggregate social welfare function* becomes  $U(\tau, t_E) = \sum_{h=1}^H \lambda_h U^h(\tau, t_E)$ , where  $\lambda_h$  is the household weights. Since all households are identical, we take the value  $\lambda_h = 1$  for all  $h$ . A benevolent government will choose the optimal tax menu  $\{\tau^*, t_E^*\}$  that maximizes the *aggregate social welfare function*; that is,

$$\max_{\tau, t_E} U(\tau, t_E) = \max_{\tau, t_E} \sum_{h=1}^H U^h(\tau, t_E). \quad (15)$$

First order conditions –i.e.  $\partial U^h(\tau^*, t_E^*)/\partial \tau = 0$  and  $\partial U^h(\tau^*, t_E^*)/\partial t_E = 0$  (see Appendix 2)– determine the optimal tax menu:

$$\begin{aligned} t_E^* &= \frac{\phi B}{CD} \\ \tau^* &= 1 - \frac{\alpha}{\alpha + \gamma} = \frac{\gamma}{\alpha + \gamma}, \end{aligned} \quad (16)$$

so that the competitive equilibrium allocations at the optimal tax menu are given by (6)-(13) for  $\{\tau^*, t_E^*\}$ .

Figure 1 displays a numerical example that illustrates the welfare level achieved (at point A) by this optimal tax menu  $\{\tau^*, t_E^*\}$ . Specifically, we delineated the *aggregate welfare function* at each distorting tax burden ( $\tau$ ) keeping the environmental tax at the optimal tax level ( $t_E^*$ ), i.e. the picture displays the function  $U(\tau; t_E^*)$  for any  $\tau \leq 1$  (dotted line).

#### 4.2. The non-environmental public intervention scenario: The (constrained) optimal tax menu without environmental taxation

In this section, we consider the *non-environmental public intervention* scenario with a benevolent government restricted to choose a constrained-optimal taxation scheme  $(\tau; \bar{t}_E)$  by applying the Ramsey rule with no environmental taxation, i.e.  $\bar{t}_E = 0$ . Formally,

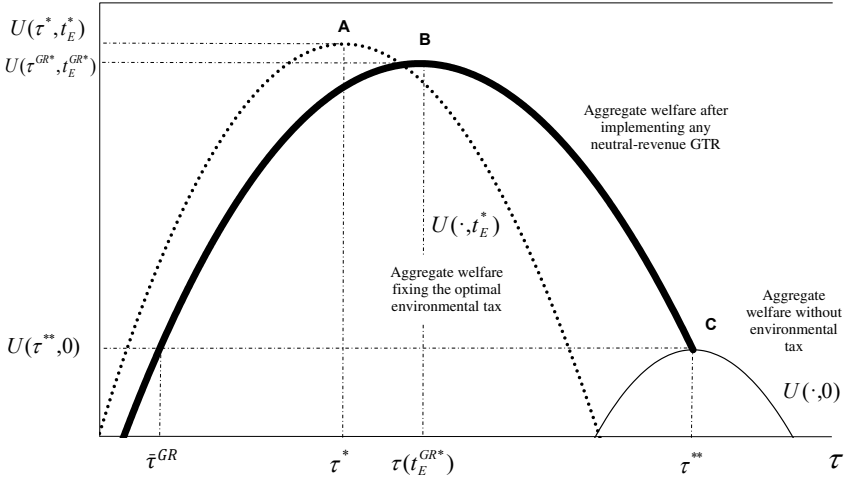
$$U(\tau, t_E) = \max_{\tau, t_E} \sum_{h=1}^H U^h(\tau, t_E), \text{ s. t. } t_E = 0 \quad (17)$$

In our simple model, the Ramsey rule tax ratio is found from the first-order condition  $\partial U^h(\tau^{**}, 0)/\partial \tau = 0$  (see Appendix 2); that is,

$$\tau^{**} = 1 - \frac{\alpha}{\alpha + \gamma} \frac{D}{\frac{K_2}{1+C} - D\beta} = \frac{\gamma}{\alpha + \gamma} + \frac{\alpha}{\alpha + \gamma} \left[ 1 - \frac{(1+C)D}{\phi B(1-\beta) + (1+C)D} \right], \quad (18)$$

so that the competitive equilibrium allocations are given by (6)-(13) for  $\{\tau^{**}, 0\}$ . Observe that the constrained-optimal tax burden of distorting taxes (with  $\bar{t}_E = 0$ ) is higher than the optimal one,  $\tau^{**} > \tau^*$ . This means that a benevolent government, deprived of environmental taxation tools, can still partially mitigate the negative externality by increasing the consumption tax ( $t_c^{**}$ ), the income tax ( $t_w^{**}$ ) or both with respects its optimal level, to decrease individual and aggregate consumption and, then, reduce production and pollution.

**Figure 1**  
**A NUMERICAL EXAMPLE OF WELFARE LEVELS FOR ALTERNATIVE TAX MENUS**



Source: Own elaboration.

Note: The vertical axis represents the aggregate households' welfare for each tax burden of distorting taxes  $\tau$  (horizontal axis). The lower the distorting tax burden  $\tau \in [0, 1]$ , the lower the distortionary taxes. There are three functions displayed: (i) the social welfare function  $U(\tau, t_E^*)$  fixing the environmental tax at its optimal level  $t_E^*$  (represented by the dotted line), a function that reaches a maximum at A for  $\tau^* = \frac{\gamma}{\alpha + \gamma}$ ; (ii) the social welfare function  $U(\tau, 0)$  where no environmental tax is considered ( $t_E = 0$ ) (represented by the solid narrow line), a function that reaches a maximum at C for  $\tau^{**} = \tau^* + \frac{\alpha}{\alpha + \gamma} \left[ 1 - \frac{(1+C)D}{\phi B(1-\beta) + (1+C)D} \right]$ ; and, (iii) the value of the social welfare function after implementing any revenue-neutral GTR starting from point C—that is, by setting any environmental tax and then reducing the distorting tax burden according to the revenue-neutral constraint (19)—, a function represented by the solid thick line. The point B represents the maximum welfare level available. The distorting tax burden  $\bar{\tau}^{GR}$  represents a GTR such that  $U(\bar{\tau}^{GR}, t_E^{GR}) = U(\tau^{**}, 0)$ ; thus, beyond this threshold, households are worse off after implementing a GTR with respect to the non-environmental tax scenario. The parameterization for this numerical illustration is the following:  $\alpha = 1/4$ ,  $\beta = 0.5$ ,  $A = 0.5$ ,  $B = 0.5$ ,  $C = 2/3$ ,  $D = 1$ ,  $H = 20$ ,  $\gamma = 5/3$ ,  $\phi = 4/3$ , and  $T = 1$ , so that  $t_E^* = 1$ ,  $\tau^* = 0.6$ ,  $\tau^{**} = 0.5$ .

Figure 1 also illustrates the welfare level achieved (at point C) by the optimal tax menu  $\{\tau^{**}, 0\}$  at this non-environmental public intervention scenario. Specifically, we delineated the aggregate welfare function at each tax burden of distorting taxes ( $\tau$ ) without environmental tax at the optimal tax level ( $\bar{t}_E = 0$ ), i.e. the solid narrow line displays the function  $U(\tau; 0)$  for any  $\tau \leq 1$ . Accordingly, the solid narrow line is represented at the right-hand side of the dotted line since the distorting tax burden is higher, and the highest welfare level achieved is below that found at the *full (optimal) public intervention* scenario (dotted line).

#### 4.3. The constrained GTR public intervention scenario: A revenue-neutral green tax reform

The advocates for GTR heavily rely on their efficiency gains. Specifically, the revenue of an environmental tax can be recycled to mitigate other distorting taxes, in particular, labour and income taxes (see Dresner *et al.*, 2006, p.897) –in terms of our model, decreasing the tax burden of distorting taxes  $\tau$ . The (expected) result is an increase in aggregate welfare, which would justify a GTR implementation and its social and political acceptance.

In this section, we consider the *constrained GTR public intervention* scenario after implementing a revenue-neutral GTR. Our departure point in real policymaking is the *non-environmental public intervention* scenario (see Section 4.2), with a benevolent government designing a constrained, optimal taxation scheme with no environmental tax  $\{\tau^{**}, 0\}$ . At some moment in time, the benevolent government decides the tax menu must be modified to implement a revenue-neutral GTR, after recognizing the existence of a negative externality (i.e., pollution) because voter demands or as a policy tool to accomplish any international environmental agreement (e.g., the Paris agreement against Climate Change). This revenue-neutral GTR consists strictly on setting any environmental tax ( $t_E^{GR}$ ) and recycling the environmental revenues to reduce distorting taxes ( $\tau^{GR}$ ), *keeping the government budget balanced* (i.e., keeping the government spending at their initial level):

$$P_x(\tau^{GR}, t_E^{GR})G_x(\tau^{GR}, t_E^{GR}) = P_x(\tau^{**}, 0)G_x(\tau^{**}, 0), \quad (19)$$

with  $P_x(\tau, t_E) = 1$  being the numerarie. Formally, for each environmental tax  $t_E^{GR}$ , we can find at (19) the corresponding tax burden of distorting taxes

$$\tau(t_E^{GR}) = \tau^{**} + (1 - \tau^{**}) \left[ 1 - \frac{1}{1 - (1 - \beta) \left[ 1 - \frac{1 + C}{1 + C(1 + t_E^{GR})} \right]} \right] \quad (20)$$

for any  $t_E^{GR} \geq 0$ , that keeps the government budget unchanged. Observe that the implementation of any GTR in our setting entails that as the environmental tax increases, the distorting tax decreases, i.e.  $\tau'(t_E^{GR}) < 0$  for any  $t_E^{GR} > 0$ .

We have delineated in Figure 1 the aggregate welfare function at any combination distorting-environmental taxes  $\{\tau^{GR}, t_E^{GR}\}$  that satisfies (20), represented by the solid thick line. Spe-

cifically, the picture displays the function  $U(\tau(t_E^{GR}), t_E^{GR})$  for any  $t_E^{GR} \geq 0$ . The Figure illustrates that there exists a myriad of revenue-neutral GTR, so the choice of the environmental tax  $t_E^{GR}$  might contribute to other constraints (e.g., optimal tax prescriptions, Pigouvian norm or any other political constraint). Observe that, although not all these revenue-neutral GTR are welfare improving with respects the *non-environmental public intervention* scenario (Section 4.2) as displayed in the figure,<sup>14</sup> the implementation of a *marginal* revenue-neutral GTR results –perhaps not surprisingly– in a marginal increase in household’s welfare, since  $\lim_{t_E \rightarrow 0} dU(\tau(t_E^{GR}), t_E^{GR})/dt_E^{GR} > 0$ . And that is the case for the optimal tax menu  $\{\tau^{GR*}, t_E^{GR*}\}$  picked out by a benevolent government maximizing the aggregate social welfare function subject to a balanced public budget (19).<sup>15</sup> As the picture shows, the welfare level achieved (at point B) by the optimal tax menu  $\{\tau^{GR*}, t_E^{GR*}\}$  is higher than that achieved at the optimal tax menu  $\{\tau^{**}, 0\}$  in the non-environmental public intervention scenario (at point C).

Note also that the optimal tax burden of distorting taxes is lower than the constrained-optimal tax burden of distorting taxes,  $\tau^{GR*} < \tau^{**}$ , thus located at the left-hand side in the graph. Indeed, Figure 1 illustrates a well-known telnet supported by the proponents of the GTR literature: the implementation of a revenue-neutral GTR that introduces an environmental tax is accompanied by a mitigation of distorting taxes –i.e., in terms of our model, by a decrease in the distorting tax burden,  $\tau(t_E^{GR}) < \tau^{**}$  for any  $t_E^{GR} \geq 0$ .

In this case, at the *non-environmental public intervention* scenario with a benevolent government deprived of environmental taxation tools, the higher the welfare parameter  $\phi$ , the greater the distorting burden tax  $\tau^{**}$  in (18) to reduce production and pollution. Observe that as the environmental taxation becomes feasible, an increase in  $t_E$  should reduce distorting taxes –i.e., reduce the distorting tax burden,  $\tau$ . But a neutral-revenue GTR requires an additional constraint, as the budget revenue must remain constant, see condition (19). Then the new environmental revenue,  $t_E^{GR}E$ , fully offset a decrease in the revenue from distorting taxes to fully satisfied the neutral-revenue GTR condition, in such a way that a lower distorting tax burden  $\tau$  will be required to satisfy constraint (19).

#### 4.4. Is full recycling the better way?

In this section, we explore the role played by revenue-neutral GTR in achieving an optimal tax menu. Initially, we departed from a (constrained) optimal tax scheme  $\{\tau^{**}, 0\}$  chosen to maximize citizens’ welfare represented by point C in Figure 1 –i.e., the *non-environmental public intervention* scenario (see Section 4.2). Then, we considered the implementation of a revenue-neutral GTR in the *constrained GTR public intervention scenario* (see Section 4.3) and the resulting optimal neutral-revenue GTR  $\{\tau^{GR*}, t_E^{GR*}\}$ , which yields a level of welfare represented by point B in Figure 1. Here, a key issue arises: is this optimal revenue-neutral GTR tax menu really optimal so that it represents the closest target available for policymakers to the first-best tax  $\{\tau^*, t_E^*\}$ ?, that is, the one found at the full public intervention scenario (see Section 4.1) and represented by point A in Figure 1. The following Theorem 1 states that the answer is negative.

**Theorem 1.**—*Consider a constrained optimal taxation scheme with no environmental tax,  $\{\tau^*, 0\}$ . Then, no revenue-neutral GTR achieves the first-best tax menu,  $\{\tau^*, t_E^*\}$ , which otherwise it can be attained with a non-revenue-neutral GTR.*

The proof is simple (see Appendix 3): there exists no set of positive parameters satisfying  $\tau(t_E^*) = \tau^*$  in (20). The intuition of this result stems from the core of the revenue-neutral GTR proposal: the revenue from environmental taxation is required to be recycled to alleviate distorting taxes *keeping the public budget unchanged*, according to equation (19). This requirement sets a constraint on the benevolent government decisions, a restriction absent when choosing the first-best tax menu. Thus, a revenue-neutral GTR does not provide the best outcome, namely the closest to the optimal one (see Figure 1); that is, the maximum welfare level available as represented by the solid thick line is always below some other greater welfare levels that can be achieved without the revenue-neutral constraint and at lower distorting tax burden, as represented by the dotted line. This conclusion might jeopardize some arguments from proponents of implementing any revenue-neutral GTR.

To sum up, GTR with full recycling of extra revenues restrict the benevolent government choices so as to dismiss the best targets otherwise available for policymakers. Therefore, a relaxation on this full recycling condition, as represented by the third generation of GTR, may provide better economic outcomes (closer to the best target).

## 5. Conclusions and Policy Implications

Environmental and energy-related taxes are usually regarded by both policymakers and economists as promising instruments for easing political constraints. On the one hand, they may raise sizeable revenues to confront fiscal stress episodes in some European countries, facing a scenario of economic crisis and growing public deficits. On the other hand, they may reinforce existing energy efficiency policies aiming to improve the environmental and energy security (on price uncertainty and in the geopolitics realm). However, some academics might be reluctant to departures from revenue-neutral GTR (budget neutrality adjustments) as something undesirable for the general goal of efficiency improvements of the tax system: policymakers should not devise environmental and energy-related taxes as a pretext to raise extra revenue.

In this paper, we have assessed the convenience of revenue-neutral restrictions in GTR on efficiency basis. Our results provide theoretical support to the third generation of GTR, which proposes to give up revenue-neutral constraints and to design GTR schemes with extra revenues recycled to fiscal consolidation. It advocates for a “dynamic approach to revenue-neutrality”, and thus it is aligned with statements from the European Environment Agency and the European Commission, or with close arguments stated by the OECD (2010), such as “the prospective need for fiscal consolidation increases the presumption that environmental objectives like reducing greenhouse gas emissions should be addressed through measures that raise revenues”. Those recommendations have been implemented in some recent legal European experiences.

Observe that our finding differs from Goulder (2013)'s reflections when asserting that "it is more efficient to rely on green taxes rather than other taxes for the additional revenue, provided that the environmental tax is not too large" (p.9). His analysis is based on the standard approach to assessing the convenience of GTR starting from the assumption that the government needs to increase fiscal revenues. He compares a new menu of distorting taxes satisfying the increased fiscal needs with GTR able to achieve the same budget level "[a]nd thus the difference between the costs of the green tax (with no recycling) and the ordinary tax is simply the revenue-recycling effect" (Goulder, 2013, p.9). Our paper, however, considers a different scenario with a government introducing a new tax for environmental purposes (see Section 4.3). In our case, revenue neutrality conditions on GTR constrain the policy maker's degrees of freedom to select (better) available combinations of public policies.

Perhaps the most relevant consequence of this work concerns policy recommendation. Our results suggest that introducing additional taxes to mitigate external effects should lead policymakers to fully reconsider the tax menu instead of being self-restricted to recycling schemes on green tax revenues (e.g., by keeping the existing level of public expenditure). In fact, the findings of this paper shed doubts on any policy prescription proposed by the literature of revenue-neutral GTR, mainly grounded on achieving political support (e.g. the promise of no additional fiscal burdens).

Several final comments are in order. First, we are assuming (for modelling convenience) that the departure point for policymakers is an optimal taxation system without any environmental consideration (thus, without environmental taxes).<sup>16</sup> Once the environmental tax is introduced, a revenue-neutral GTR is unable to transform an inefficient tax system into an optimal one (or even one closer to being optimal). However, if we realise that real-world politicians are constrained by multiple restrictions —e.g., distributional concerns, vote restrictions, international competitiveness— the usual starting point for policymakers used to be a suboptimal tax system. This observation makes the achievement of an optimal tax menu after implementing a revenue-neutral GTR even more unlikely.

Second, although our paper recommends giving up the neutral recycling scheme of GTR to enhance the efficiency of the tax scheme, our findings do not represent straightforward support for increased government expenditures funded with new revenue from environmental taxation. Our simple model shows that it could easily be the reverse: an optimal tax system may require a decrease, instead of an increase, in government expenditure.<sup>17</sup>

Finally, it should be kept in mind that the objective of this work is not to present a complete analysis of the third generation of GTR in the realm of optimal taxation. Instead, we just present theoretical support against revenue-neutral constraints on GTR as a policy choice to achieve an optimal tax menu.

## Appendix 1. Agents' problems and competitive equilibrium with public intervention

### A1.1. The household problem

The representative household  $h$  chooses her consumption of the clean and dirty good,  $x^h$  and  $y^h$ , and the leisure hours  $l^h$  that maximizes her welfare (1) subject to the budget constraint (2), and taking as given the relative prices  $P_y/P_x$ , the real wage  $w/P_x$  and the level of pollution ( $E$ ) and the real public expenditure ( $G$ ).<sup>18</sup> From the first-order conditions, together with the budget constraint (2), we find the demand function for household  $h$  the clean and dirty good,  $x^h$  and  $y^h$ ,

$$\left( x^h \left( \frac{P_y}{P_x}, \frac{w}{P_x}; \tau \right), y^h \left( \frac{P_y}{P_x}, \frac{w}{P_x}; \tau \right) \right) = \left( \frac{w}{P_x} \frac{\alpha\beta}{1-\alpha} (1-\tau), \frac{w}{P_x} \frac{P_x}{P_y} \frac{\alpha(1-\beta)}{1-\alpha} (1-\tau) \right); \quad (\text{A1})$$

and the (inelastic) demand for leisure hours  $l^h$

$$l^h \left( \frac{P_x}{P_y}, \frac{w}{P_y}; \tau \right) = 1 - \frac{\alpha}{1-\alpha}. \quad (\text{A2})$$

Two comments on (A2) is in order. First, due to the linearity of the leisure time in the utility function, the individual demand for leisure is perfectly inelastic: it does not depend on prices. This means that our simple setting can be reinterpreted as a model with fixed individual supply of labour, independent on the wage rate.

Second, the individual demand for leisure sets an upper bound on the value of the utility parameter  $\alpha$ , as the demand is non negative provided  $\alpha \leq 1/2$ . Yet, reasonable calibrated values for this utility parameter fall below this threshold. As an illustration, if a household works for 8 hours, i. e.  $1/3$  of total available time, so that household's leisure time becomes  $l = 2/3$ , then a calibrated value for  $\alpha$  is  $1/4$ .

### A1.2. The firm's problems at each industry

#### A1.2.1. The problem of a firm producing the intermediate good $E$

Any firm producing the intermediate good chooses the level of input labour  $N_E$  and the level of output  $E$  to maximize profits, subject to the linear technology and given prices and wages; that is,

$$\begin{aligned} \pi_E &= \max_{E, N_E} P_E E - w N_E \\ \text{s. t. } E(N_E) &= \frac{B}{C} N_E, \end{aligned} \quad (\text{A3})$$

with  $P_E$  denoting the price of the intermediate good. The first-order condition is

$$P_E = w \frac{C}{B}. \quad (\text{A4})$$



### A1.2.2. *The problem of a firm producing the clean good X*

Any firm producing the “clean” good chooses the level of input labour  $N_X$  and the level of output  $X$  to maximize profits, subject to the linear technology and given prices and wages; that is,

$$\begin{aligned} \pi_X &= \max_{X, N_X} P_X X - w N_X \\ \text{s.t. } X &= X(N_X) = D N_X. \end{aligned} \quad (\text{A5})$$

The first-order conditions are

$$P_X D = w. \quad (\text{A6})$$

### A1.2.3. *The problem of a firm producing the dirty good Y*

Any firm producing the “dirty” good chooses the level of inputs labour  $N_Y$  and the pollutant intermediate good  $E$ , together with the level of output  $Y$  to maximize profits, subject to the Leontief technology and given prices and wages; that is,

$$\begin{aligned} \pi_Y &= \max_{Y, N_Y, E} P_Y Y - w N_Y - P_E (1 + t_E) E \\ \text{s.t. } Y &= Y(N_Y, E) = A \min \left\{ N_Y, \frac{1}{B} E \right\}. \end{aligned} \quad (\text{A7})$$

The optimal condition requires the optimal combination of inputs, so that

$$E = B N_Y. \quad (\text{A8})$$

This means that the pollutant firm problem turns out to maximize

$$\pi_Y = \max_{Y, N_Y, E} P_Y A N_Y - w N_Y - P_E (1 + t_E) B N_Y. \quad (\text{A9})$$

The first-order condition is

$$P_Y A = w + P_E (1 + t_E) B. \quad (\text{A10})$$

### A1.3. *The competitive equilibrium with public intervention*

The functional forms assumed greatly simplify the supply side of the commodity markets and the demand side of the labour market, as all become perfectly elastic. From (A6) we can find the equilibrium real wage at the infinitely elastic labour demand

$$\frac{w^*}{P_X^*} = D \frac{A - B t_E}{1 + C}, \quad (\text{A11})$$

and, if we substitute equilibrium wages in the previous expression onto (A4) we find  $P_E^*/P_X^* = CD/B$ . Finally, substituting these equilibrium prices into (A10), we can find the equilibrium relative prices

$$\frac{P_Y^*}{P_X^*} = \frac{D}{A} [1 + C(1 + t_E)]. \quad (\text{A12})$$

Recall that the price of the clean commodity has been normalized to one, i. e.  $P_x^* = 1$ , so (3) is found.

Now, substituting these prices onto the demand functions (A1) and (A2), we can find the equilibrium allocations, that depends on the tax menu

$$(x^{h*}(\tau, t_E), y^{h*}(\tau, t_E)) = \left( \frac{\alpha\beta}{1-\alpha} D(1-\tau), \frac{\alpha(1-\beta)}{1-\alpha} A \frac{(1-\tau)}{1+C(1+t_E)} \right), \quad (\text{A13})$$

and

$$l^{h*}(\tau, t_E) = 1 - \frac{\alpha}{1-\alpha}. \quad (\text{A14})$$

The clearance conditions at the final commodities are

$$G_x^* + \sum_{h=1}^H x^{h*} = X^*(\tau, t_E) = DN_x, \quad (\text{A15})$$

$$\sum_{h=1}^H y^{h*} = Y^*(\tau, t_E) = AN_y. \quad (\text{A16})$$

From (A9), we can find the equilibrium labour quantity at the pollutant industry

$$N_y^*(\tau, t_E) = \frac{\alpha(1-\beta)}{1-\alpha} H \frac{(1-\tau)}{1+C(1+t_E)}. \quad (\text{A17})$$

This means, from (A8), that the equilibrium level of pollution becomes

$$E^*(\tau, t_E) = BN_y^*(\tau, t_E) = \frac{\alpha(1-\beta)}{1-\alpha} HB \frac{(1-\tau)}{1+C(1+t_E)}, \quad (\text{A18})$$

so, from the intermediate good technology, the equilibrium labour quantity at the intermediate industry becomes

$$N_E^*(\tau, t_E) = \frac{E^*C}{B} = \frac{\alpha(1-\beta)}{1-\alpha} HC \frac{(1-\tau)}{1+C(1+t_E)}. \quad (\text{A19})$$

From (5), after substituting the equilibrium relative prices  $P_y^*/P_x^*$  and  $P_E^*/P_x^*$ , the demand functions for the individual households (A13), and the optimal equilibrium level of pollution  $E^*(\tau, t_E)$ , we find the optimal public expenditure expenditure

$$G_x = \frac{\alpha}{1-\alpha} HD(1-\tau) \left[ \frac{Ct_E(1-\beta)}{1+C(1+t_E)} + \frac{1}{(1-\tau)} - 1 \right]. \quad (\text{A20})$$

Finally, from (A8) we can calculate the equilibrium labour quantity at the non-pollutant industry

$$N_x^*(\tau, t_E) = \frac{\alpha H}{1-\alpha} (1-\tau) \left[ \frac{Ct_E(1-\beta)}{1+C(1+t_E)} + \frac{1}{(1-\tau)} - (1-\beta) \right]. \quad (\text{A21})$$

## Appendix 2. Optimal Tax Problem: First order conditions

$$\frac{\partial U^h(\tau^*, t_E^*)}{\partial \tau} = \frac{\alpha}{\tau} + \gamma \frac{D\beta - \frac{K_2}{1 + C(1 + t_E)}}{D - D\beta(1 - \tau) - K_2 \frac{1 - \tau}{1 + C(1 + t_E)}} = 0 \quad (\text{A22})$$

$$\frac{\partial U^h(\tau^*, t_E^*)}{\partial t_E} = -\frac{\alpha(1 - \beta)C}{1 + C(1 + t_E)} + \gamma \frac{\frac{K_2 C}{[1 + C(1 + t_E)]^2} (1 - \tau)}{D - D\beta(1 - \tau) - K_2 \frac{1 - \tau}{1 + C(1 + t_E)}} = 0 \quad (\text{A23})$$

## Appendix 3. Proof of Theorem 1

To prove that departing from a tax menu  $\{\tau^{**}, 0\}$  a revenue-neutral GTR do not become the tax menu into the optimal one,  $\{\tau^*, t_E^*\}$ , we will show that the distorting tax ratio in (20) can never satisfy  $\tau(t_E^*) = \tau^*$ .

Assume it can be satisfied. Then,

$$\tau^* = \tau(t_E^*) = \frac{\alpha}{\alpha + \gamma} \frac{1}{1 + \frac{\phi B(1 - \beta)}{[1 + C(1 + t_E^*)]^D}} = \tau^* + \frac{1}{1 + \frac{\phi B(1 - \beta)}{[1 + C(1 + t_E^*)]^D}}. \quad (\text{A24})$$

Since the second ration is lower than 1, we reach a contradiction as the second member is strictly lower than  $\tau^*$ , a contradiction that proves Theorem 1.

## Notes

1. See for instance “Global megatrend 7: Intensified global competition for resources” and “Global megatrend 10: Increasing environmental pollution” in the series of global megatrends published by the European Environment Agency (EEA, 2011). The acceptance of this reality represents one of the main fundamentals for the Green Growth initiative under the patronage of the OECD. <http://www.oecd.org/greengrowth/>.
2. For instance, Denmark, Germany, Finland, Norway, Sweden, Netherlands and the UK.
3. We agree with Dresner *et al.* (2006) when asserting that: “The most common definition of ETR [GTR], which we also adopt here, is the use of the revenue from environmental taxes to reduce distortionary taxes, in particular, taxes on labour.” (p. 897).
4. The burden from environmental taxes is becoming an important source of revenue in some countries. Hagemann (2012) attributed as high as 1.8 % of GDP to the contribution of greenhouse gas emission charges as part of fiscal consolidation in most European countries.
5. For instance, Clinch *et al.* (2006) explain this (orthodox) view when asserting: “In an ideal world, the recycling of all the revenues to the exchequer would be the best approach. This would be because, in this world, there would be no government failure (the best projects would be chosen) and tax revenues would be allocated optimally across the entire economy including an optimal level of expenditure on environmental projects. Then it would simply be a matter of raising tax revenue in the least distorting manner by raising as much as possible by taxing ‘bads’ such as pollution. In this case, allocating any extra funds for environmental purposes would be a waste of valuable funds.” (p. 964-5). Later on, Clinch *et al.* (2006) explain that “Some combination of hypothecating a proportion of revenues to environmental projects moving towards a shift in the tax burden away from labour and onto environmental ‘bads’ is probably the best approach given that it is likely to be more socially and politically acceptable and, if the appropriate balance is struck, need not result in any significant economic losses.” (p. 698).
6. See for instance the reviews by Speck *et al.* (2011), Goulder (2013) or Gago *et al.* (2014, 2016).
7. By “revenue recycling” we mean a *revenue-neutral GTR*.
8. See for instance the seminal work of Sandmo (1975), and others such as Bovenberget and Goulder (1996), Ligthart and van der Ploeg (1999), Kim (2002) and Ballard *et al.* (2005). For a general survey, see for instance Bovenberg and Goulder (2002).
9. Most of the optimal taxation literature is concerned with the characterization of an optimal tax system, which also accounts for correcting external effects present in the economy (see for instance the seminal work by Sandmo, 1975).
10. Proposals in this literature, however, are surrounded by some controversies (see for instance Giménez and Rodríguez, 2010).
11. This parametrization is irrelevant for the findings of the paper. Yet, this simple specification allows us to find closed-form solutions.
12. We use the term “distorting taxes” for any tax except the environmental one, because the purpose of the last one is to internalize the market distortions stem from environmental external effects. This is actually the basis of Giménez and Rodríguez (2010) for contesting the usual definition of the second dividend which usually includes the primary cost generated by environmental taxes and its assimilation to an “efficiency cost”. However, Giménez *et al.* consider that they do not represent efficiency cost, because “these distortions in consumption patterns or input choice (primary costs) are desirable on environmental grounds” (Bovenberg and Goulder, 2002; p. 1501). Accordingly, Giménez and Rodríguez design alternative definitions for the first and the second dividends in order to isolate the “true” efficiency effects of the GTR.
13. Our setting could easily consider that the government produces its own input from labour, with labour costs funded with tax revenue. Yet, if the technology is linear, it will not affect the closed-form solutions.

14. Figure 1 shows that there exist a range of environmental tax rates for which a revenue-neutral GTR decreases households' welfare with respect that achieved by the constraint-optimum at the *non-environmental public intervention scenario*,  $\tau^*$ . Specifically, this is the case for high enough environmental taxes whose corresponding distorting tax burden  $\tau$  obtained after implementing a revenue-neutral GTR is lower than  $\bar{\tau}^{GR} = \bar{\tau}^{GR}(\bar{t}_E^{GR})$  with  $U(\bar{\tau}^{GR}(\bar{t}_E^{GR}), \bar{t}_E^{GR}) = U(\tau^*, 0)$ .
15. Since there exists a functional relationship between the distorting tax burden and the environmental tax  $\tau(t_E^{GR})$ , as shown by equation (19), the optimal environmental tax can be found by maximizing  $\max_{t_E^{GR}} U(t_E^{GR}) = \max_{t_E^{GR}} U(\tau^{GR}(t_E^{GR}), t_E^{GR})$ .
16. This tax menu without any environmental tax exists because of a specific reason (lack of knowledge of environmental impacts, etc.). Thus, with complete information, we should say it is not an optimal tax system strictu sensu as long as any environmental externality is absent (see section 4.1).
17. Recall that under a non-environmental tax scenario (from Section 4.2), the distorting tax is higher to finance a higher government expenditure. This higher public spending increases households' welfare to mitigate the negative pollutionary externality. At the time the environmental tax tool is available, the pollutionary externality is reduced –thus, increasing household's welfare–, and, hence, the distorting tax can be reduced as a lower government expenditure is needed (in terms of welfare) to mitigate a lower level of the environmental externality.
18. Although households are the owners of firms, we will not considering the firms' profits as an additional source of income for households to compute the household demands. This is done for simplicity: as each firm operates in a competitive market, in equilibrium no firm exhibits positive economic profits, so  $\pi^h = 0$ .

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**Resumen**

Las Reformas Fiscales Verdes [RFV] han sido inicialmente concebidas como una propuesta de política para resolver simultáneamente varios objetivos de política. Los recientes episodios de tensiones fiscales han desafiado esta visión. En este artículo, estudiamos un elemento clave de interés para los responsables políticos: tomando como punto de partida un sistema fiscal que no incluye un impuesto medioambiental, ¿se obtendría un menú impositivo óptimo si se implementase una RFV neutral en recaudación? Nuestro trabajo ilustra en un ejemplo simple y parametrizado, que la respuesta es negativa. Este resultado se separa de la visión convencional y provee un soporte teórico a la tercera generación de RFV.

*Palabras clave:* reformas fiscales verdes, neutralidad de los ingresos, fiscalidad óptima.

*Clasificación JEL:* H23, Q48.