The impact of income inequality on public environmental expenditure with green consumerism*

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Abstract

This article analyzes the impact of income inequality on environmental policy in the presence of green consumers. We first develop a model with two main ingredients: citizens with different income capacities have access to two commodities whose consumption differs in terms of price and environmental impact, and they vote on the environmental policy. In this setting, a unique political equilibrium exists in which the population is split into two groups that differ in the type of good, conventional vs. green, they consume. The analysis shows that a change in the level of inequality induces variations in both the size and composition of these two groups of citizens. In turn, this determines whether or not more inequality stimulates public policy. We then conduct an empirical investigation on a panel of European countries over the period 1996–2019. We find the existence of a reversed-$J-$shaped relationship between inequality and public environmental spending. This outcome can be explained by the combination of a composition effect, affecting the green group, and a substitution effect between private green consumption and public environmental spending.

Keywords: income distribution, inequality, green consumption, environmental public expenditure.

JEL classification: Q58, H23, D31, D72

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1 Introduction

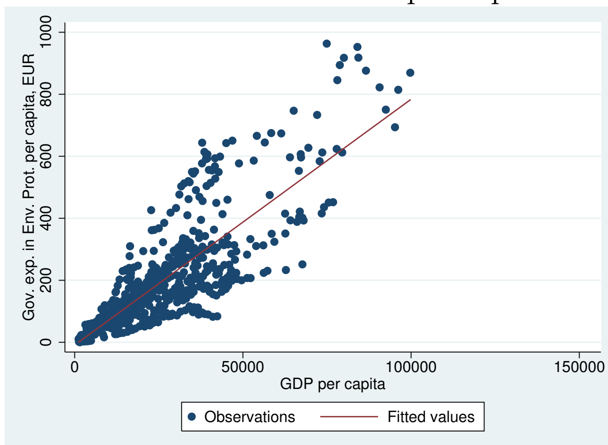
This paper addresses the old and important question of the link between income distribution, especially income inequality, and public policy. Since the early 2000s, and to a greater extent more recently, the issue has regained attention as it has become necessary to think about the design of policies capable of responding to the many environmental challenges modern societies face while being socially acceptable. As perfectly noticed by Stiglitz (2014), there is a two-way relationship between environmental policy and income distribution. Scholars' contributions on this topic are naturally divided into two distinct focal areas. Some examine the distributional impact of environmental policy (Aubert and Chiroleu-Assouline, 2019 and Jacobs and van der Ploeg, 2019), while others try to understand how income distribution shapes environmental policy (Boyce, 1994, Magnani, 2000 and subsequent contributions). This paper falls within the second category and has been motivated by the following observations, based on recent data collected in Europe. First, we observe a positive correlation between GDP per capita and general government expenditure in environmental protection per capita (EPPC) (see Figure 1).[1] This is in line with the intuition and supported by most of the arguments put forward to explain the decreasing part of the environmental Kuznets curve (EKC).[2] In particular, as people become richer, one expects that the demand for environmental protection rises.

Second, and more interestingly, the relationship between income inequality and environmental policy does not seem to be monotonic (see Figure 2). We turned to the existing literature for an explanation and came to two conclusions. First, even though this topic has been investigated for twenty years, the literature is relatively sparse both on theoretical (Magnani, 2000, Eriksson and Persson, 2003, Kempf and Rossignol (2007) and empiri-

[1]Hereafter, we focus on public environmental expenditure as an indicator of environmental policy. Information about data collection is explained in detail in Section 5.

[2]The EKC is the inverted $U-$shaped relationship linking income per capita to some measures of pollution. It was detected in the early 90s and has been a subject of lively debate since then.

Figure 1: General EPPC and GDP per capita 1996–2019.

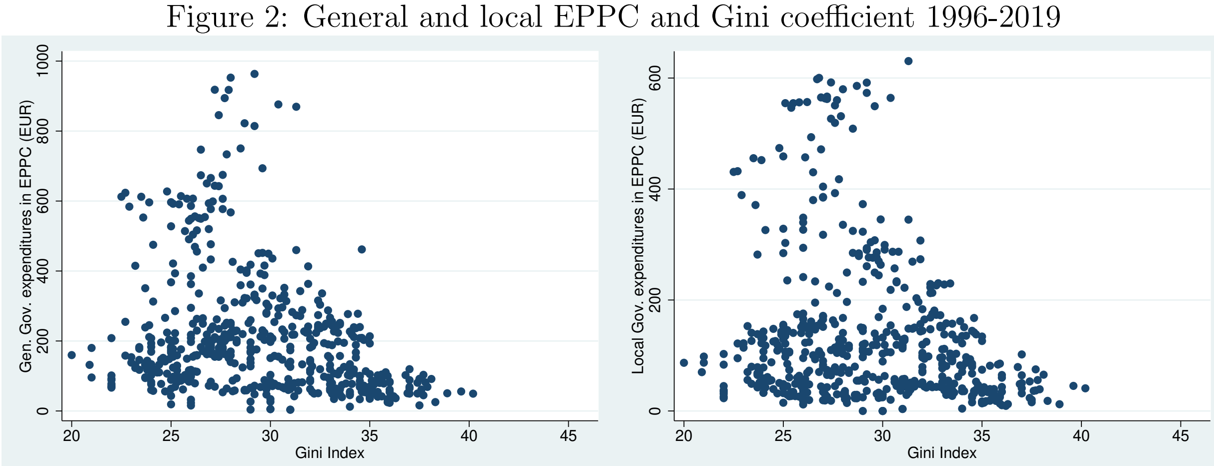


Source: Authors from the Eurostat data set, period 1996–2019.

Sample size: 692 observations for 31 European countries.

cal (Magnani, 2000, Grunewald et al., 2017, Martínez-Zarzoso and Phillips, 2020) grounds. Second, existing theories conclude the existence of a negative relationship between inequality and environmental policy, which tends to be validated empirically.[3] In other words, the literature proves unable to explain the stylized facts presented above.

Figure 2: General and local EPPC and Gini coefficient 1996-2019



Source: Authors from the Eurostat dataset, period 1996–2019. Sample size: 621 observations for 31 European countries.

[3]See Section 2 for a literature review on this topic and others connected to our work.

This paper aims to fill this gap by providing a theoretical explanation of these stylized facts and by examining their empirical validity. Our approach is novel in that it relies on the interaction between private green consumption and the collective decision on environmental public expenditure. Green consumerism—the fact that some people display a preference for the green version of some good (food, cars, etc.)—has not been considered by the above literature so far, as it is a relatively new phenomenon. Its impacts on policy making are only beginning to be analyzed (Ambec and Donder, 2020). Moreover, taking account of green consumption allows us to conduct an analysis that is very much in line with other literature assessing the link between the income distribution and the collective choice on the provision of a public good, like the public funding of education (de la Croix and Doepke, 2009, Arcalean and Schiopu, 2016, Melindi-Ghidi, 2018).

To investigate how this original mechanism shapes the relationship between inequality and environmental public spending, we first develop an original political economy model that combines the following ingredients. The economy comprises citizens who display heterogeneity in income, take consumption decisions, and care about the environment. Citizens exhibit green consumerism, that is, a preference for green goods.[4] Green consumption does not find its origin in its ability to perfectly internalize its environmental impact. It is better explained by other private motives like being healthier and the existence of the warm-glow effect (Andreoni, 1990). In other words, there exists an environmental externality of consumption. Preferences are also defined over environmental quality that is determined by private green consumption and public expenditure. Indeed, the public policy consists of taxing citizens' income and using the resulting revenue to finance environmental public expenditure. This public policy is the outcome of a voting procedure. Finally, we account for the existence of a price premium: green goods are more expensive

[4]These goods include organic food, energy-saving household appliances, hybrid and electric vehicles, etc.

than their conventional/neutral counterparts.

In the political equilibrium, the income tax is associated with a critical income level that splits the population into two groups, those who consume the green good and those who do not. We then assess how the statistics of the income distribution shape environmental spending. In line with the intuition and stylized fact reported in Figure 1, we find that public environmental expenditure unconditionally increases with the average income, keeping the standard deviation constant. Considering a mean preserving spread (MPS), conclusions are less clear-cut as we find that an increase in inequality induces a decrease in environmental expenditure if and only if the equilibrium tax is lower than a critical threshold. Green consumerism is the key mechanism underlying this outcome. A variation in the level of inequality changes the size and composition of both groups. This, in turn, affects both the marginal benefit and each group's marginal cost of the policy and, consequently, the outcome of the electoral process. We carefully dissect the mechanisms at stake and interpret results that remarkably reproduce stylized facts (Figure 2). Last but not least, we identify a sufficient condition, depending on the environmental concern and price premium, for income inequality having a negative impact on environmental policy.

To obtain more insight into the link between income distribution and environmental spending, we then perform an empirical analysis using a sample covering 31 European countries over the period 1996–2019. By adopting a fixed-effect model with robust standard errors, we analyze the impact of mean income and inequality, as measured by the Gini index, on both general and local government expenditure in environmental protection. As expected, we find that GDP per capita is positively correlated with public environmental spending. In addition, empirical results show the existence of a reversed-Jshaped relationship between inequality and environmental policy, thereby confirming the non-monotonic nature of that relationship, first highlighted in Figure 2 and then pointed out by the theoretical analysis.[5] The intuition of the result draws on our theory: an MPS is associated with thicker tails and finer middle of the income distribution. More rich people mean more green consumption, which is good for the environment and calls for less public spending. Fewer middle-income people imply the opposite, provided that part of the middle class buys green. When inequality is already high, and average income is low, the threshold income is low as well, which means that many middle-income people consume the green good, and the negative effect on green consumption prevails. People then ask for more public environmental expenditure as compensation.

The paper is organized as follows. Section 2 reviews the related literature with a focus on our contribution to it. Section 3 presents the model. Section 4 is devoted to the equilibrium analysis and assesses the impact of the income distribution on public policy. Section 5 is dedicated to the empirical analysis. Section 6 concludes.

2 Related literature

The link between environmental policy and income distribution has been examined recently (see among others, Aubert and Chiroleu-Assouline, 2019 and Jacobs and van der Ploeg, 2019). This strand of literature deals with the impact of environmental tax reform on the different income groups that compose society. It also addresses the optimal design of environmental taxes when distributional effects are considered. It is finally interested in the efficiency of the economic and fiscal system.[6]

[5] Results are robust to the use of "environmental taxation" as an alternative dependent variable.

[6] Papers on environmental taxation generally conduct their analyses in second-best microeconomic frameworks. They assume that the population is heterogeneous in terms of income capacities and sometimes in terms of exposure to environmental damages. When it comes to the preferences, they often consider non-homothetic utility functions defined over two types of goods, clean vs. polluting, both featuring the same price. The latter good is named this way because its consumption causes a polluting externality. The public policy combines an income tax with a linear tax on the dirty good, whereas fiscal revenues can be recycled through lump-sum transfers, public spending, or used to reduce distortionary tax.

In the coming analysis, we look at the problem another way by asking how income inequality can shape environmental policy. Economists have long debated this question. Dating back to the seminal paper of Boyce (1994), the literature provides a series of arguments explaining why (more) inequality is bad for the environment. In a recent survey, Berthe and Elie (2015) classify these arguments into two categories depending on whether they involve individual behaviors and how they relate to environmental pressure or emphasize collective decision making. Central to all this discussion is the idea that potential conflicts exist in societies among social and income groups, typically the poor vs. the rich, especially regarding the demand for environmental protection, and that these conflicts are exacerbated by inequality. The authors do, however, note that there is no theoretical nor empirical consensus on this topic.

A few formal studies of the impact of inequality on environmental policy also exist. The most prominent contribution to this line of research is Magnani (2000). The author develops a simple political economy model where individuals' preferences are defined over consumption and environmental quality. The government enhances environmental quality thanks to public expenditures that are financed by an income tax (accounting for the marginal cost of public funds). People vote on the tax rate. Focusing on majority voting, Magnani (2000) shows the existence of a negative relationship between inequality and environmental policy. In her model, the key mechanism that explains this negative link is the dependence of individuals' environmental preferences on relative income. Subsequent contributions (Eriksson and Persson, 2003, Kempf and Rossignol, 2007) also build majority voting models and reach the same unambiguous conclusion, even though they consider different mechanisms.[7]

[7] Eriksson and Persson (2003) consider a uniform distribution of individuals who care about consumption and pollution in Stokey (1998)'s static model. Individual consumption is equal to the product of a collectively chosen pollution standard and production, which is an increasing and convex transformation of the individual type. They capture an increase in inequality by an increase in the gap between the median voter's production and the average voter's production and show that when this gap increases, the

This literature is thus unable to explain the situation depicted in Figure 2. This is where the first contribution of our paper lies. We propose a new theory based on the substitution between public environmental spending and private green consumption. Considering green consumption echoes the observation that nowadays, a growing number of people display a willingness to pay (WTP) for green goods and a willingness to accept (WTA) a price premium compared to their neutral counterparts (McFadden and Huffman, 2017, Poder and He, 2017). Ambec and Donder (2020) are the first to analyze the impact of green consumerism on environmental policy. Our approach differs from theirs as they assume that the proportion of green consumers in the economy is exogenous and do not deal with the heterogeneity of income distribution. Compared to the above-mentioned literature, our approach is also more general because we pay a great deal of attention to the interplay between individual and collective decisions.[8] Finally, we depart from the literature by using a probabilistic voting model. Thus, our paper has also a connection with the political economy literature on public goods provision, especially with recent contributions on private education *vs.* public schooling (de la Croix and Doepke, 2009, Arcalean and Schiopu, 2016, Melindi-Ghidi, 2018). Compared to majority voting, probabilistic voting shifts the political power from the poorer to the wealthier people, who are also those who consume green goods, in the determination of the political outcome.[9]

On empirical grounds, the literature on the link between income inequality and environmental policy is sparse.[10] Its main contribution lies in the validation of the negative

median voter asks for a less stringent standard. Kempf and Rossignol (2007) build an endogenous growth model *a la* Barro (1990) in which pollution arises from production. The government levies a tax on income that is used to finance both environmental (abatement) and productive (infrastructure) spending. The median voter must choose how to allocate the fiscal revenue between these two types of expenditure. More inequality induces the median voter to support growth at the expense of the environment.

[8]Papers in the literature deal with the collective decision dimension only.

[9]See the discussion on probabilistic voting models in Section 4.1.

[10]The literature examining the link between inequality and pollution or environmental degradation indicators is more substantial (see among others, Torras and Boyce, 1998, Heerink et al., 2001 and Baek and Gweisah, 2013). However, it is also more distant from our problem. Indeed, people vote to choose public policies (public spending, taxation) rather than the level of pollution for many reasons, observability

link between inequality and indicators of environmental policy, although there seems to be a dependence of the results on the level of income. Magnani (2000) measures inequality by the Gini index, whereas environmental policy is captured by public R&D expenditure to protect the physical environment. Working with a panel data set for OECD countries over the period 1980–1991, the author shows a negative correlation between income inequality and environmental policy.[11] Vona and Patriarca (2011) follow the lead of Magnani (2000). They also study OECD countries and consider a more recent and longer period (1985-2005). They focus on environmental innovations like green R&D and the production of environmental patents, especially by the public sector. Their empirical results highlight that inequality negatively influences the diffusion of innovations in countries with high per-capita incomes. The dependence on GDP results can be explained by the methodology used in these papers. The regressions include a second-order polynomial in the GDP and an interaction term between the GPD and the Gini index. This typically falls within the EKC empirical literature tradition.[12]

Our contribution to the empirical literature is two-fold. First, we use a more recent and broader data set, focusing on European countries, and a more exhaustive variable to capture environmental public expenditure.[13] Second, based on stylized facts, we adopt (and justify) an empirical strategy that accounts for the potential non-monotonicity of the impact of inequality on environmental policy.[14] We estimate an equation that includes a

and measurement issues being the most important ones.

[11]These results appear to be valid for high-income countries only.

[12]Note that such a dependence also appears in recent papers assessing the relationship between income inequality and environmental degradation, for the very same reason. For instance, Grunewald et al. (2017) find that the relationship between income inequality and CO_2 emissions depends on income levels: at higher (lower) levels of income, higher income inequality increases (decreases) CO_2 emissions.

[13]This variable includes all public expenditure related to the environment, such as waste management, water management, pollution abatement, protection of biodiversity, and also R&D environmental protection expenditure. It is measured both locally and at the national scale. See Section 5.1 for details.

[14]Figure 1 reveals that all European countries are located on the increasing part of the EKC: a linear term should be enough to obtain insight into the relationship between GDP and environmental policy. Figure 2 suggests the nature of the relationship between inequality and environmental policy.

second-order polynomial in the Gini index, not in the GDP. This is in sharp contrast with the literature (but similar to Martínez-Zarzoso and Phillips, 2020).

3 Model

The fundamental ingredient of our model is the (income) heterogeneity of the population. Our work is closely connected to the literature on environmental taxation because of the issue at stake, even if we adopt a different (yet complementary) perspective. In the modeling approach, we share with them the general shape of preferences. In particular, we work with a non-homothetic utility function, account for the environmental impact of consumptions, and assume the existence of a consumption externality. However, the similarity ends there. In the main, we adapt and extend de la Croix and Doepke (2009)'s framework, which is representative of the political economy literature on the public funding of education.

We consider two types of commodities that differ in terms of their environmental impact. We work with an index of environmental quality, Q, with reference level normalized to 0. This level is defined in relation to a business-as-usual level of pollution taken as given. The first commodity, whose consumption is denoted by c, is environmentally neutral, whereas the second, d, is environmental-friendly. Consuming good d has a positive side-effect on the environment. Typical examples of consumptions that improve environmental quality along some, possibly different, dimensions are organic food (quality of soils, etc.) and electric vehicles (atmospheric pollution). In addition to the consumption channel, environmental quality can be increased through environmental expenditure by the government. Overall, citizens take environmental quality as given, which means that a positive consumption externality exists.

The population is constant with its size normalized to 1. The continuum of individuals differ with respect to the wage rate. Wages are distributed on the support $[w_m, \infty)$, with $w_m > 0$, according to density and cumulative distribution functions $f(w)$ and $F(w)$. Like Arcalean and Schiopu (2016), we make use of a Pareto distribution: $F(w) = 1 - \left(\frac{w_m}{w}\right)^k$, $f(w) = kw_m^k w^{-(1+k)}$ with $k > 2$, and pay attention to its two main statistics, the average, μ, and standard deviation, σ.

Following the discussion conducted in the Introduction, people exhibit a WTP (or WTA a price premium) for green goods. At the same time, however, it is difficult to assign this WTP(A) to an environmental awareness whereby they would be able to evaluate the impact of their (consumption) decisions on the environment. From a modeling viewpoint, this leads us to represent preferences by a utility function with three components: the two consumptions and the level of environmental quality, taken as given. For the sake of the analysis, we choose a quasilinear representation of the non-environmental utility combined with a linear environmental benefit. We also assume that people display the same preferences, with utility function:[15]

$$U(c, s, Q) = u(c, d) + \beta Q = \frac{\gamma}{\alpha}(c)^{\alpha} + d + \beta Q \tag{1}$$

where $\alpha \in (0, 1)$ and $\gamma, \beta > 0$ are the relative weight of respectively, non-green (or environmentally neutral) consumption and the environment in the preferences. Consumption decisions are subject to the budget constraint:

$$(1 - t)w = c + \pi d \tag{2}$$

where $t \geq 0$ is the (linear) income tax, and π is the (relative) price of the green good. As Nyborg et al. (2006), we impose $\pi > 1$, which is a reasonable assumption for the category

[15] Our results would remain qualitatively the same with Stone–Geary preferences in consumption (like in Aubert and Chiroleu-Assouline, 2019), and a (strictly) concave function for the environmental benefit. However, the resolution and comparative statics would require an unnecessarily complicated algebra.

of goods concerned. Indeed, focusing on organic products, the United States Department of Agriculture (USDA, see Coleman-Jensen et al. (2017)) gets an estimate for the price premium— the price of organic products relative to that of conventional alternatives—that ranges from 7% to 82%. Liu (2014) also measures a differential of about 17% between the mean price of hybrid cars and of conventional cars sold in the US.

In the same vein as de la Croix and Doepke (2009), we consider a generic income tax whose purpose is to finance the public provision of environmental quality, or environmental public spending, G. In addition, the government follows a balanced budget rule: $G = \int_{w_m}^{\infty} twf(w)dw = t\mu$. Public spending is adding to private consumption of the green good to determine the realized level of environmental quality: $Q = G + \int_{w_m}^{\infty} df(w)dw$.

The sequence of events is as follows: citizens first elect a government that pre-commits to a policy platform $\{t, G\}$. Once elected, the government sets the tax rate. People then choose their consumption levels, which finally results in a level of environmental spending and quality. We assume perfect foresight which especially means that when political parties choose their strategy in the electoral competition, they perfectly anticipate people's reaction to the public policy. This is a typical Stackelberg game that can be solved backwards by first determining individual decisions as a function of policies and then choosing policies that take this dependency into account.[16]

This baseline model serves as a vehicle for the coming analysis where our main goal is first to establish that the problem above has a solution—a political equilibrium—and next to examine how the equilibrium features, especially the public policy, change when the main characteristics of the income distribution, average and standard deviation, vary.

[16] de la Croix and Doepke (2009) consider the other timing where individuals "move first," before the policy is chosen. They provide the argument that, unlike public policy, decisions on fertility and education cannot be revised frequently. In our setting, we can support the suggested timing by providing the exact opposite argument because we are dealing with consumption decisions. Moreover, this timing is similar to the one arising in second best analyses of environmental taxation (Jacobs and van der Ploeg, 2019).

4 Theoretical investigation

4.1 Political equilibrium

Let us start with individual decisions. Environmental quality enters utility as a pure externality: each consumer takes environmental quality as given when they maximize (1) subject to (2), and $c, d \geq 0$. Solving for this program, we identify a critical income level

$$\tilde{w}(t) = \frac{(\gamma\pi)^{\frac{1}{1-\alpha}}}{1-t}, \text{ with } \tilde{w}'(t) = \frac{\tilde{w}(t)}{1-t} > 0, \tag{3}$$

that determines whether or not a consumer purchases the green good. In fact, a consumer devotes a positive amount of resources to green consumption if and only if she earns enough money, that is, $w > \tilde{w}(t)$. For an interesting problem, this threshold must belong to (w_m, ∞). This defines two boundaries, t^m and t^M, with $t^m = 1 - w_m^{-1}(\gamma\pi)^{\frac{1}{1-\alpha}} < 1 = t^M$. The lower bound t^m can be positive or negative, which does not matter for the analysis.

Whatever the tax rate $t \in (\max\{0, t_m\}, t_M)$, the population can be split into two groups, respectively labeled by N and G (for "non green" *vs.* "green" consumers). Membership to a particular group is determined by the individual's income. It is a member of group N whenever $w \in (w_m, \tilde{w}(t))$, otherwise she belongs to G (for $w \in (\tilde{w}(t), \infty)$). So wealthier people form group G, whereas poorer folks are part of group N. This dichotomy is in line with, for instance, descriptive statics provided by Liu (2014) that illustrate that demand for hybrid cars essentially arises from people who belong to the upper income classes. Decisions made by individuals within each group are summarized by the following equations (we use a superscript letter for decisions):

$$\text{Group } N: \quad d^n = 0, \; c^n(w,t) = (1-t)w, \tag{4}$$

$$\text{Group } G: \quad d^g(w,t) = \pi^{-1}\left((1-t)w - (\gamma\pi)^{\frac{1}{1-\alpha}}\right), \; c^g = (\gamma\pi)^{\frac{1}{1-\alpha}}. \tag{5}$$

A member of group N cannot afford the green good and thus devotes her entire income to purchasing the environmentally neutral and cheaper good. By contrast, a green consumer spends a constant amount of money on the neutral good and the extra money goes to the green good. Note that the quasilinear utility explains why c^g is constant. This is innocuous for the analysis. Hereafter, we will make use of the indirect utility functions:

$$\begin{aligned} v^g(t,w) &= \pi^{-1}\left((1-t)w - (\gamma\pi)^{\frac{1}{1-\alpha}}\right) + \tfrac{\gamma}{\alpha}(\gamma\pi)^{\frac{\alpha}{1-\alpha}}, \\ v^n(t,w) &= \tfrac{\gamma}{\alpha}((1-t)w)^{\alpha}. \end{aligned} \tag{6}$$

Both decrease with the tax rate, and the larger the income, the larger the marginal disutility from taxation.

The level of environmental quality is obtained by adding environmental public expenditure, which is financed by the income tax (under the balanced budget rule), and aggregate private consumption of the green good:

$$Q(t) = t\mu + \int_{\tilde{w}(t)}^{\infty} d^g(w,t)f(w)dw. \tag{7}$$

Environmental quality is increasing and convex function of the tax rate. Increasing the tax has two opposite effects on Q: higher tax means more public expenditure for a given tax base, which is good for the environment. However, it diverts consumers away from the green good, which negatively affects Q. The overall effect remains positive, however.

With all this information in hand, we can turn to the analysis of the electoral competition. To deal with this issue, we consider a probabilistic voting model as in de la Croix and Doepke (2009), Arcalean and Schiopu (2016), and Melindi-Ghidi (2018). By "smoothing" the payoffs of parties involved in the political game, probabilistic voting generally ensures the existence of a Nash equilibrium in situations where the majority voting rule does not.The key point with probabilistic voting is that it introduces "noise" in the outcome of the electoral process. Indeed, it is assumed that in addition to the policy platforms the different candidates offer, voters' preferences also depend on a non-policy outcome of the election. In the literature, this additional concern is typically associated with an ideology. In the end, for any policy platform, a party does not know the exact number of voters who will support it. Indeed, contrary to standard (majority) voting models, individuals belonging to the same economic group do not have the same ideological preferences. The best a party can do is to evaluate its vote share, which is defined as the sum of probabilities that people in each group vote for it multiplied by the relative group size.[17] A party's objective is then to choose the platform that maximizes its vote share. As in a two-party electoral competition, parties' decision problems are symmetric; one generally focuses on the symmetric Nash equilibrium in pure strategies of the zero-sum game. It is then easy to show that parties' equilibrium policies maximize the following utilitarian social welfare function:

$$\int_{w_m}^{\tilde{w}(t)} (v^n(t,w) + \beta Q(t))\theta(w)f(w)dw + \int_{\tilde{w}(t)}^{\infty} (v^g(w,t) + \beta Q(t))\theta(w)f(w)dw,$$

with $v^n(.)$, $v^g(.)$ and $Q(.)$ defined in (6) and (7), and where $\theta(w)$ represents the political power of a voter with income w. For simplicity, we assume away this particular dimension of the problem by considering that citizens share the same political power, that is, $\theta(w) = 1$ for all w.[18] This implies that the only weights that matter in the objective function, denoted by $W(t)$, are given by the relative size of each group, and this function reduces to:

$$W(t) = \int_{w_m}^{\tilde{w}(t)} v^n(t,w)f(w)dw + \int_{\tilde{w}(t)}^{\infty} v^g(w,t)f(w)dw + \beta Q(t).$$

[17]If there are two parties A and B, then the probability that an individual votes for party A is an increasing function of the difference of utility levels brought by each party once elected. This function is a cumulative distribution function that captures how ideology is distributed in society.

[18]It is not the aim of the paper to account for this additional source of heterogeneity. It would be an interesting extension of the present work, however.

On may note that its first derivative,

$$W'(t) = \beta Q'(t) + \int_{w_m}^{\tilde{w}(\tau)} \frac{\partial v^n(w,t)}{\partial t} f(w)dw + \int_{\tilde{w}(t)}^{\infty} \frac{\partial v^g(w,t)}{\partial t} f(w)dw, \tag{8}$$

illustrates the simple trade-off faced by the economy when collectively deciding public policy. Increasing the tax rate induces a marginal environmental benefit, hereafter MB (first term). However, it also comes with marginal costs because of the decrease in the indirect utility of both groups, resulting from the decrease in consumptions, denoted respectively by MC^n and MC^g (last two terms).

Solving for the political equilibrium requires searching for the tax that maximizes $W(t)$. We first identify a threshold, t^c, with

$$t^c = 1 - wm^{-1}(\gamma\pi)^{\frac{1}{1-\alpha}} \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1}{\alpha-k}},$$

such that $W''(t) < 0 \Leftrightarrow t > t^c$. Without loss of generality, this critical tax rate is assumed to be positive. Then, we can establish the following existence result (see the Appendix A.1):

Proposition 1. *A necessary and sufficient condition for the existence of a unique political equilibrium associated with policy platform* (t^*, G^*) *is* $W'(t^c) > 0$. *This is equivalent to imposing*

$$\pi > \underline{\pi}(\beta) \equiv \beta^{-1} \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1-\alpha}{k-\alpha}}. \tag{9}$$

The existence condition (9) can be interpreted in terms of two critical parameters of the current analysis, the environmental concern β and the relative price of green goods, π. Indeed, the threshold $\underline{\pi}(\beta)$ is decreasing in β. It is difficult to obtain a precise estimate of the environmental concern. Following a tradition that finds its origin in sociology, scholars run surveys that include a series of questions to elicit respondents' WTP for environmental protection, knowledge about environmental issues, and so on and so forth. In the end, they build an environmental concern index and study its main drivers.[19] They reach a consensus regarding the most important determinant of environmental concern, that is, the level of wealth. When it comes to the representation of the utility function, one may argue that as individuals prioritize consumption, the relative weight of the environment should be lower than one. From a more aggregate perspective, findings of this literature strongly suggest that on average, environmental concern should be the highest in the richest countries. Taking $\beta \in (0, 1)$, we obtain that $\underline{\pi}(\beta) > 1$. Intuitively, people should care enough about the environment, and the price of the green good should be high enough (but the higher β, the less stringent the condition on π) for them to be willing to incur the cost of the public provision of environmental quality. A political equilibrium of this sort is then more likely to arise in relatively rich countries, like the OECD and EU member states.

The equilibrium tax t^* is defined implicitly only. However, it is quite easy to check that t^* is increasing in both β and π. On the one hand, a larger β means that the population cares more about the environment, which raises the incentive to tax incomes in order to finance public expenditure on the environment. On the other hand, a larger π makes green consumption costlier, thereby lowering it. Thus, taxation and public provision of the environment should increase as compensation.

The next section is devoted to a comprehensive comparative statics exercise.

4.2 Impact of a change in the income distribution

We want to explain how public policy changes as a response to the two important statistics of the income distribution, which are the average and standard deviation. Intuition suggests that taxation and environmental public expenditure should be higher, the larger the average income. The outcome is no as obvious in terms of the impact of σ. The main purpose

[19]For an interesting work representative of this line of research, see Franzen and Meyer (2009).

of this section is then to understand the impact of inequalities on the public provision of environmental quality.

We proceed in two separate steps to address these issues. We assess the change in the equilibrium tax resulting from 1/ a variation in the average income, taking the standard deviation as given, and 2/ a variation of the standard deviation taking the average income as given. Our analysis, summarized in the Appendix A.2, leads to the following results:

Proposition 2.

- *An increase in the average income translates into an increase in the equilibrium tax, t^*, for a given standard deviation.*
- *There exists a critical tax rate $t^s \in (t^c, 1)$ such that an increase in the standard deviation induces a decrease in the equilibrium tax, t^*, for given average income, if and only if $t^* < t^s$.*

Not surprisingly, we find that countries with a high average income levy a larger fiscal revenue to finance environmental quality than countries with lower average incomes. This outcome is very much in line with stylized facts reported in Figure 1. A change in μ has repercussions on all the components of marginal welfare (8), especially on the MB through a tax base effect (see the first terms in (7) and (8)). Dissecting the various channels through which μ impacts $W'(t^*)$ would be an interesting yet unnecessary exercise. Indeed, the comparative statics result is unambiguous, and the analysis would share many similarities with what comes next, which is the most important study of the impact of σ on public policy.

Hereafter we focus on the interpretation of the impact of inequalities, captured by the standard deviation.[20] A change in the standard deviation affects marginal welfare by

[20] In fact, working with a constant mean, a variation of σ exactly corresponds to a variation of the coefficient of variation, that is a measure of the level of inequality. It is different yet positively correlated to the Gini index. See also the discussion in Section 5.

changing both the distribution of the population between the two groups (size effect) and the composition of each group (composition effect).

Denote the size of group $I = G, N$ as N^i with $i = g, n$, given that $N^g = 1 - N^n$, and $\tilde{w}^* = \tilde{w}(t^*)$, $\tilde{w}^s = \tilde{w}(t^s)$. The overall impact of a marginal change in σ can be decomposed into three terms:

$$\frac{\partial^2 W(t^*)}{\partial t \partial \sigma} = \frac{\partial MB}{\partial \sigma} - \left[\frac{\partial MC^g}{\partial \sigma} + \frac{\partial MC^n}{\partial \sigma}\right],$$

with

$$\begin{aligned}
\tfrac{\partial MC^g}{\partial \sigma} &= \tfrac{\pi^{-1}\tilde{w}^*}{k-1}\left(-\tfrac{N^g}{k-1}\tfrac{\partial k}{\partial \sigma} + k\tfrac{\partial N^g}{\partial \sigma}\right), \ \tfrac{\partial MB}{\partial \sigma} = -\beta \tfrac{\partial MC^g}{\partial \sigma}, \\
\tfrac{\partial MC^n}{\partial \sigma} &= \tfrac{\pi^{-1}\tilde{w}^*}{k-\alpha}\left[-\tfrac{\alpha}{k-\alpha}\tfrac{\partial k}{\partial \sigma}\left(\left(\tfrac{w_m}{\tilde{w}^*}\right)^{\alpha} - 1 + N^n\right) + k\tfrac{\alpha}{\tilde{w}^*}\left(\tfrac{w_m}{\tilde{w}^*}\right)^{\alpha-1}\tfrac{\partial w_m}{\partial \sigma} + k\tfrac{\partial N^n}{\partial \sigma}\right],
\end{aligned}$$

and $\frac{\partial w_m}{\partial \sigma}, \frac{\partial k}{\partial \sigma} < 0$.

We observe that MB and MC^g move the opposite direction in a proportional way. It means that these two components add up to change marginal welfare. Let us focus on the marginal cost components, starting with MC^g. The sign of $\frac{\partial MC^g}{\partial \sigma}$ is determined by the aggregation of the composition effect (the first term between the parentheses, which is positive) and the size effect (the second term). The composition effect works as follows. The interval of incomes associated with the green group is invariant, but the density of people at each income level within this interval is affected by the variation of σ. Now, the density increases for the highest income levels.[21] Given that the disutility of taxation (resulting from the decrease in green consumption) is larger, the larger the income, this composition effect tends to increase MC^g. The size effect may add to or, on the contrary, alleviate the composition effect depending on whether the size of group G increases as a result of the increase in the level of inequalities. As to group N, the same two effects are at play, but the composition effect features another component. Indeed, the lower bound

[21]It may or may not decrease for income levels close to the threshold, $\tilde{w}^*$, that determines the division of the population into groups N and G at the equilibrium.

of the interval of incomes corresponding to that group, w_m, decreases due to the increase in σ. According to this additional part (the second term between the parentheses in the expression of MC^n, which is negative), and other things being equal, more people located are around the lower income levels as σ increases. This pushes toward a lower MC^n. Let us call it the dispersion effect, which is part of the composition effect.

Given the expressions above, a particular comparative statics result can be obtained *via* different combinations of the sign of $\frac{\partial MC^g}{\partial \sigma}$ and $\frac{\partial MC^n}{\partial \sigma}$. It is unclear a priori what is the relevant case to consider. We can ease the discussion simply by imposing: $\pi < \exp^{\frac{k-1}{k}}$. So we set an upper bound on the price of the green good. For example, taking $k = 3$, $\exp^{\frac{k-1}{k}} \approx 1,95$: we ask the price of the green goods to be less than twice the price of the equivalent non-green goods. This assumption seems acceptable given the figures we provided earlier for organic food and hybrid vehicles.

In this situation, $\frac{\partial MC^g}{\partial \sigma} < 0$, which implies $\frac{\partial N^g}{\partial \sigma} < 0$. Green consumers become less numerous, and the size effect dominates the composition effect. As a result, their (positive) contribution to the marginal cost of taxation shrinks (remember that green consumption, d^g, is decreasing in the tax). Their (negative) contribution to the marginal benefit also shrinks for the very same reason. Measuring the impact of a change in σ on the cost borne by group N is less simple. The relative size of group N increases, so the size effect is positive. In addition, their density at any income level in the interval $(w_m, \tilde{w}^*)$ decreases ($\frac{\partial f(w)}{\partial \sigma} < 0$), whereas this interval expands thanks to the dispersion effect. Overall, it is unclear whether the composition effect is positive or negative. At this point, the ranking between the critical levels $\tilde{w}^*$ and $\tilde{w}^s$ becomes important.

In Proposition 2, we prove that when the equilibrium tax is reasonably high, $\tilde{w}^* > \tilde{w}^s$, the composition effect is negative and strong enough to offset, partly or totally, the size effect for group N. In other words, either MC^n decreases, or it increases but overall we have:

$$\left|\frac{\partial MC^n}{\partial \sigma}\right| < \left|\frac{\partial MC^g}{\partial \sigma} - \frac{\partial MB}{\partial \sigma}\right|.$$

This is all driven by the dispersion effect that finds full expression when the threshold $\tilde{w}^*$ is sufficiently high (compared to w_m). We can conclude that $\frac{\partial W'(t^*)}{\partial \sigma} > 0$: t^* should increase when the standard deviation goes up. When $\tilde{w}^* < \tilde{w}^s$, we reach the opposite conclusion.

The statement in Proposition 2 is interesting because it highlights that the impact of inequalities on public policy varies, depending on a country's characteristics. This finding quite remarkably echoes the stylized fact reported in Figure 2. However, it is fair to say that in its current version, Proposition 2 does not allow us to draw more insightful conclusions because t^* and t^s are both endogenous variables whose ranking is a priori undetermined. We thus need to investigate further to identify some condition that provides us with a clear-cut policy message. This is precisely the purpose of the next corollary that brings together the results of Propositions 1 and 2.

Corollary 1. *From the existence condition (9), we obtain:*

$$\lim_{\pi \to \underline{\pi}(\beta)} t^* = t^c.$$

By construction, we have $t^c < t^s$. In that situation, an increase in inequality induces a reduction of the equilibrium tax, t^*, and of the resulting public provision of environmental quality, G^*, for given average income. By a continuity argument, the same conclusion holds true for π higher than, but close enough to, the threshold $\underline{\pi}(\beta)$.

Remember that from the discussion following Proposition 1, the threshold $\underline{\pi}(\beta)$ is larger than 1 and decreasing in β.[22] In addition, the critical level t^s identified in Proposition 2 does not depend on π. These points support the following conclusion. In countries

[22]The former property holds for β low enough and is always satisfied for $\beta \in (0, 1)$.

where people display sufficient concern for the environment (β high enough, which, in turn implies $\underline{\pi}(\beta)$ low enough), and where the relative price of green goods is above 1 but remains moderate, we expect that a higher level of inequality negatively impairs the public provision of environmental quality.

Thus far, the analysis has unveiled the important forces that drive environmental policy changes due to a variation of the level of inequality. Although the overall impact of inequality on taxation and environmental spending can be characterized in the special case of Corollary 1, the general impact remains ambiguous (Proposition 2 and following discussion). In addition, the sufficient condition of Corollary 1 involves parameters whose values in the different countries are poorly known. To uncover how inequality affects environmental policy, we must then perform an econometric analysis. Of course, we should ultimately check that our simple theory provides a meaningful explanation of the obtained empirical results.

5 Empirical analysis

This section aims at examining the general link between income distribution and environmental policy. In our model, public environmental expenditures are monotonically increasing in the tax rate. Therefore, we can work with either variable and select the former due to data availability and modeling options. We first provide a short description of the panel data set we use in the empirical investigation. We then describe our econometric models and go over the main results.

5.1 Data description

We build our dataset using data from Eurostat, the statistical office of the European Union and from the Environmental Performance Index (EPI).[23] Values for environmental protection expenditures include many items and ensure a high degree of international comparability. The database captures all government expenditures in terms of waste management, water management, pollution abatement, protection of biodiversity and landscape, R&D environmental protection, and others.[24]

In the coming analysis, we consider two main dependent variables that are extracted from the category *government expenditure in environmental protection*. As first dependent variable, we take *general government* environmental protection expenditures. To account for different types of political systems, we deal with a second dependent variable that corresponds to environmental protection expenditure by *local governments*. In Section 5.4, we will also consider a third dependent variable as a robustness test: *total environmental taxation*.[25]

We express the dependent variable in per-capita terms because the variable Q, introduced in the model, also represents the average environmental quality when population size is normalized to 1. The main explanatory variables are the GDP per capita in current euros and the Gini index, taken from the European Union Statistics on Income and Living Conditions Survey (EU-SILC). In Section 4.2, we assessed the impact of income inequality on environmental policy by considering a mean preserving spread,that is, a change in the standard deviation for given average income, that boils down to measuring inequality via

[23]See appendix B for more information on the dataset.

[24]According to the European System of Accounts (ESA), examples of environmental protection expenditures are: *"investments in clean technologies, restoring the environment after it has been polluted, recycling, the production of environmental goods and services, conservation and the management of natural assets and resources."*

[25]Even though the theoretical model does not consider environmental taxation, we look at this outcome variable because we expect that taxation and public environmental spending move in the same directions.

the coefficient of variation (CV). Here we use the Gini index because it is strongly correlated with the CV, and this measure of inequality is the one most commonly used in the literature. We also consider some demographic indicators by adding the variables *density*, measured by habitants per square km, and *population growth* to the database. We include both variables because they are potential determinants of environmental pressure.[26] Finally, we control for the level of environmental quality in the country. More precisely, we introduce two control variables taken from the Environmental Performance Index (EPI) dataset representing both environmental health and ecosystem vitality. To this end, we consider household air pollution from solid fuels (HAD) and biodiversity habitat index (BHV), respectively.[27] Summary statistics, for the main variables are displayed in Table 1 and the distribution of the environmental expenditure levels is shown in Figure 3.

Table 1: Summary statistics

Variable	N. Obs.	Mean	Std. Dev.	Minimum	Maximum
Gen Gov Exp	551	209.05	178.52	3.58	963.32
Loc Gov Exp	553	134.82	133.41	0	630.56
GDP	621	26507.49	18446.82	1758.88	103464.6
Population (millions)	621	18.8	23.9	0.29	83.0
Gini Index	621	29.94	4.66	20	46
HAD	791	74.17	23.63	23.95	100
BHV	813	49.23	11.42	30.25	81.32

Source: Eurostat and EPI datasets over the period 1996 - 2019.

5.2 Specification tests and econometric model

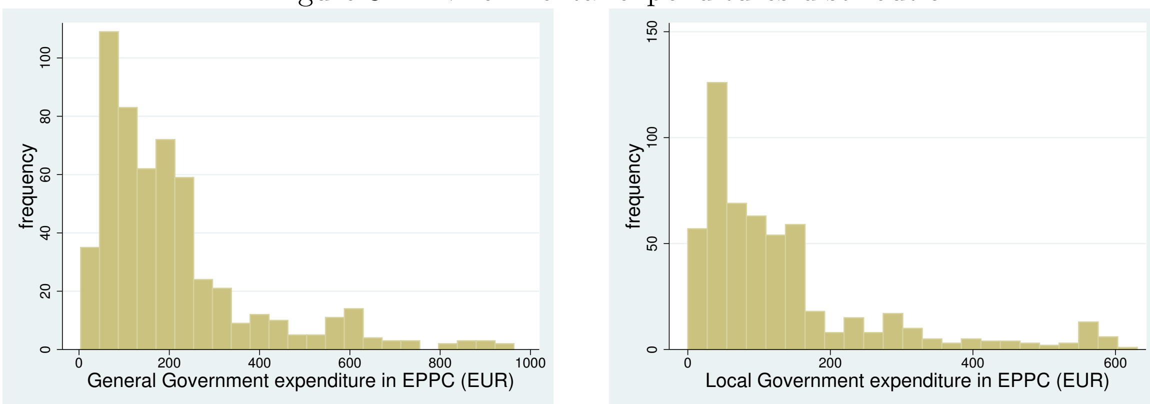
Our basic empirical model is given by the following equation:

$$y_{i,t} = \alpha + \beta_1 Gini_{i,t-k} + \beta_2 Gini^2_{i,t-k} + \beta_3 GDP_{i,t} + \beta_j X'_{i,t} + u_{i,t} \tag{10}$$

[26]Focusing on US cities, Ribeiro et al. (2019) find a positive correlation between population size changes and CO_2 emissions, whereas the correlation is negative for changes in population density.

[27]See appendix B for more information on the EPI dataset.

Figure 3: Environmental expenditures distribution



Source: Authors from the Eurostat dataset, period 1996 - 2019.

where i denotes the cross-sectional unit (country), and t is the time period (year). The variable $y_{i,t}$ is the log of the GDP per capita, $Gini_{i,t-k}$ is the $k-$year lagged Gini index, and $X'_{i,t}$ is a vector of controls, $x_{i,t}$. We take a five-year lag for the Gini index ($k = 5$) to account for causality between income inequality and environmental policy.[28] Gini observations are average values over 5 years. We introduce the lagged Gini-squared in the model to account for possible non-monotonicity, as suggested the stylized facts described in Figure 2 and later confirmed by our equilibrium analysis. As mentioned above, the vector $X'_{i,t}$ controls for density, population growth, environmental health and ecosystem vitality. Parameter α is a common intercept, β_j are coefficients associated with the independent variables, and $u_{i,t}$ is the error term. Table 2 summarizes the transformations we made in the coming regressions, for each country i and period t.

Several approaches can be used with cross-country panel data. Fixed-effect and random-effect models are the most common.[29] We use the following decomposition: $u_{i,t} = \mu_i + \epsilon_{i,t}$, where μ_i is an unobserved individual-specific effect, and $\epsilon_{i,t}$ refers to an idiosyncratic error term. Whether μ_i is treated as a random or fixed effect determines the estimation method.

[28]In Appendix 5.4, we provide the estimation results with the current $Gini_{i,t}$, showing that results are not affected. However, the use of a lagged regressor reduces the number of observations from 621 to 548.

[29]We exclude pooled OLS because F-tests reject equal fixed effects across units for all dependent variables at 1% level .

Table 2: Eurostat data description

Variable	Original Eurostat variable	Transformed variable
Dependent variables		
Gen Gov Exp	Government expenditure on environmental protection by general government in million current euros	$\log\left(\frac{\text{Gov\_10a\_exp\_1}_{i,t}\times 10^6}{\text{Population}_{i,t}}\right)$
Loc Gov Exp	Government expenditure on environmental protection by local government in million current euros	$\log\left(\frac{\text{Gov\_10a\_exp\_2}_{i,t}\times 10^6}{\text{Population}_{i,t}}\right)$
Independent variables		
GDP per capita	GDP in million current euros	$\log\left(\frac{\text{nama\_10\_gdp}(t)\times 10^6}{\text{Population}_{i,t}}\right)$
Gini index lagged	Gini coefficient of equivalized disposable income	$\text{lag\_gini}_{i,t} = \frac{\sum_{j=5}^{10}\text{gini}_{i,t-j}}{5}$
Population density	Population over land cover in total	$\frac{\text{Population}_{i,t}}{\text{Total\_Landcover}_i}$
Population growth	Population change on 1 January	$\frac{\text{Population}_{i,t}-\text{Population}_{i,t-1}}{\text{Population}_{i,t}}$

Source: Authors from the Eurostat dataset.

We run different specification tests, summarized in Table 3, to decide which model better fits with our panel dataset.

First, we run the Hausman specification test (Hausman, 1978). The test rejects the null hypothesis (the preferred model is random effects), which suggests that unobserved country-specific effects are better modeled by a fixed-effect model.[30] Even though the Hausman test is valid under restrictive assumptions and does not support robust standard errors, it clearly indicates the existence of a correlation between the individual errors and the regressors in the model that should be analyzed with a fixed-effects model.

We then check if time dummies among the regressors should be included in the regression. We test if the dummies for all years are equal to 0 and we reject this assumption for both dependent variables at 1% significance level. Inclusion of time dummies is particularly important here, given that environmental policies have been influenced by European and international treaties for the last 25 years, and cannot be fully explained by variations in

[30]Note that we do not include control variables of the database such as gender, land, education, etc., because models with fixed-effects do not allow estimating the coefficients of time-invariant regressors.

observed socio-economic variables at country level. Moreover, introducing both time- and country-invariant fixed effects might adjust for potential omitted-variable bias.

Before moving to the econometric analysis, we should also consider tests for heteroskedasticity, autocorrelation and cross-sectional dependence. The modified Wald test for groupwise heteroskedasticity in fixed-effect models and the Wooldridge test for autocorrelation show that parameters can be consistently estimated using robust or clustered standard errors, that is, by treating each country as a cluster (Wooldridge, 2010). Because the Hausman test does not support robust standard errors, we implement a test of overidentifying restrictions (Sargan-Hansen test) robust to arbitrary heteroskedasticity and within-group correlation (Schaffer and Stillman, 2006). This test again rejects the null hypothesis (the preferred model is random effects) and suggests implementing fixed-effect models at 1% significance level for both outcome variables. We then verify the presence of cross-sectional independence within the residuals using the test of Pesaran (Pesaran, 2020). This test of cross-sectional dependence provides no evidence for rejecting the null hypothesis of no cross-sectional dependence at 5% level. However, because the average absolute correlation of the residuals is quite high for both outcome variables, we decide to perform robustness estimations using Driscoll-Kraay standard errors, usually implemented in the presence of cross-sectional dependence (Hoechle, 2007).

The final check has to do with the model specification. We implement the test developed by Lind and Mehlum (2010) to check for the existence of a non-monotone relationship between our dependent variables and the independent variable measuring income inequality, that is, the Gini index. The null hypothesis is either a monotone or inverted $U-$shaped relationship. The test rejects the null hypothesis for both dependent variables, showing the probable presence of a $U-$shaped relationship between public expenditure on the environment and the Gini index.[31] Finally, the Ramsey regression equation specification error

[31]Results are robust with 5-years lagged and non-lagged Gini index.

(RESET) test (Ramsey, 1969) suggests no evidence of functional form misspecification, confirming that our model is well specified.

Table 3: Specification tests

Test	Gen Gov Exp	Loc Gov Exp
Hausman test H0: random vs. fixed	$\chi^2(7) = 40.67$ $Pr > \chi^2 = 0.0000$	$\chi^2(7) = 62.49$ $Pr > \chi^2 = 0.0000$
Time-fixed effects test H0: No time dummies	$F(18, 381) = 2.87$ $Pr > F = 0.0001$	$F(18, 383) = 2.24$ $Pr > F = 0.0028$
Modified Wald test H0: $\sigma(i)^2 = \sigma^2 \ \forall i$	$\chi^2(28) = 3100.39$ $Pr > \chi^2 = 0.0000$	$\chi^2(28) = 4617.24$ $Pr > \chi^2 = 0.0000$
Wooldridge test H0: no first-order autocorrelation	$F(1, 27) = 30.434$ $Pr > F = 0.0000$	$F(1, 27) = 13.728$ $Pr > F = 0.0010$
Sargan-Hansen test H0: random vs. fixed (robust)	$\chi^2(15) = 884.292$ p-value = 0.0000	$\chi^2(14) = 3342.946$ p-value = 0.0000
Av. abs. value diagonal elements H0: cross sectional independence	$abs = 0.352$ Pr = 0.827	$abs = 0.348$ Pr = 0.635
Test of presence of a U-shape H0: monotone or inverse U-shape	t-value=2.87 $P > \|t\| = 0.0039$	t-value=2.48 $P > \|t\| = 0.0099$
Ramsey Reset test H0: functional form specification	F(2,27)=0.34 $Pr > F = 0.7154$	F(2,27)=0.01 $Pr > F = 0.9894$

Note: to perform the Hausman test, we have scaled the variable population growth (x10) to obtain coefficients on a similar scale.

5.3 Empirical results

5.3.1 General insights

Following the recommendations obtained from the above tests, we estimate the equation (10) considering country fixed-effects (μ_i), time dummies affecting all countries uniformly (λ_t) and robust standard errors clustered by country.

Table 4 summarizes the results when general government expenditures on environmental protection per capita (EPPC) is the dependent variable, whereas Table 5 considers local government expenditures on EPPC as an outcome. In both tables, Column (1) does not incorporate the control variables but includes both the country and time dummies. Column

(2) adds population density. Column (3) accounts for population growth. Column (4) also considers the two environmental quality controls. Column (5) provides estimation results of the model with all the controls using Driscoll-Kraay standard errors.

Table 4: General government expenditures in EPPC

	(1)	(2)	(3)	(4)	(5)
$Gini$	-0.2407**	-0.2336**	-0.2695***	-0.2792***	-0.2792***
	(0.090)	(0.099)	(0.093)	(0.087)	(0.035)
$Gini^2$	0.0041**	0.0040**	0.0045***	0.0046***	0.0046***
	(0.015)	(0.002)	(0.002)	(0.001)	(0.001)
GDP	0.5020	0.4685	0.3389	0.5396*	0.5396**
	(0.296)	(0.324)	(0.341)	(0.292)	(0.201)
$Density$		-0.0006	-0.0017	-0.0022**	-0.0022***
		(0.001)	(0.001)	(0.001)	(0.001)
ΔPop			0.7846*	0.6494**	0.6494***
			(0.443)	(0.256)	(0.208)
HAD				-0.0113	-0.0113***
				(0.010)	(0.002)
BHV				0.1967*	0.1967***
				(0.089)	(0.023)
$Year$	YES	YES	YES	YES	YES
R^2 (within)	0.34	0.33	0.35	0.39	0.39
σ_u	0.53	0.64	0.85	2.60	N/A
σ_e	0.20	0.21	0.21	0.20	N/A
ρ	0.87	0.90	0.94	0.99	N/A
Observations	459	434	434	434	434

Notes: ***p<0.01 **p<0.05 *p<0.10. Cluster-robust (1-4) and Driscoll-Kraay standard errors are in parentheses. All regressions include country fixed effects. Year represents the time fixed effect. The dependent variable and GDP per capita are expressed in log.

The effect of income inequality on environmental policy is captured by the coefficients $Gini$ and $Gini^2$. All specifications exhibit a negative effect of the Gini index on the variables describing the EPPC. A higher Gini index is associated with the following first order effect: it makes the environmental policy less stringent. If we consider general government expenditures in EPPC, the effect is more volatile, because the coefficients vary

Table 5: Local government expenditures in EPPC

	(1)	(2)	(3)	(4)	(5)
Gini	-0.2312**	-0.2061**	-0.2357***	-0.2555***	-0.2555***
	(0.085)	(0.094)	(0.088)	(0.089)	(0.087)
$Gini^2$	0.0041***	0.0037**	0.0042***	0.0044***	0.0044***
	(0.014)	(0.001)	(0.001)	(0.001)	(0.001)
GDP	0.6370***	0.6600***	0.5528*	0.8601***	0.5396**
	(0.205)	(0.236)	(0.287)	(0.224)	(0.259)
Density		-0.0006	-0.0015*	-0.0022**	-0.0022***
		(0.001)	(0.001)	(0.001)	(0.001)
ΔPop			0.6506	0.4256*	0.4256**
			(0.537)	(0.244)	(0.203)
HAD				-0.02019	-0.02019***
				(0.015)	(0.004)
BHV				0.2871***	0.2871***
				(0.080)	(0.042)
Year	YES	YES	YES	YES	YES
R^2 (within)	0.28	0.28	0.29	0.37	0.37
σ_u	0.66	0.67	0.75	3.48	N/A
σ_e	0.22	0.22	0.22	0.20	N/A
ρ	0.90	0.90	0.92	0.99	N/A
Observations	461	436	436	436	436

Notes: ***p<0.01 **p<0.05 *p<0.10. Cluster-robust (1-4) and Driscoll-Kraay standard errors are in parentheses. All regressions include country fixed effects. Year represents the time fixed effect. The dependent variable and GDP per capita are expressed in log.

than the specification with expenditures by local government.

As second-order effects, we find that coefficients of $Gini^2$ are positive but very small for all specifications, and both for general and local government environmental spending. By conducting the simple exercise of computing the ratio $\beta_1/(2\beta_2)$ in columns (4) and (5) in Table 4 (Table 5), we find that the minimum is reached for $Gini = 30.33$ ($Gini = 29.06$). It turns out that more than 50% of our observations are below this threshold, the median being at 29. Considering all the observations and the very low coefficient for $Gini^2$, the interaction between outcome variables and the Gini index should be interpreted as a reversed $J-$shaped rather than an $U-$shaped relationship. This means that an increase in the Gini index is first associated with a decrease in environmental spending at a decreasing rate. From the turning point onwards, the effect becomes positive, although the connection is almost zero. Before we check this claim carefully and provide an intuition about our main result, let us discuss the role of GDP and different controls.

Looking at the effect of the GDP per capita on environmental expenditure, coefficients are positive for both dependent variables in columns (4) and (5). This positive effect is consistent with both the theoretical results and conclusions drawn in the related literature. Results suggests that the effect of GDP per capita on local expenditures is stronger than the model with general government expenditures. The effects of population control variables, population density and growth, on governmental EPPC are given by the coefficients $Density$ and ΔPop, respectively. We find a negative correlation between population density and government expenditures, whereas the correlation turns positive for population growth. This result echoes the findings of Ribeiro et al. (2019) for US cities.

The environmental quality control variables, household air pollution from solid fuels and biodiversity habitat index, are given by the coefficients HAD and BHV, respectively. As expected, the results suggest that the control representing environmental health (HAD) negatively impacts the policy, while the control describing ecosystem vitality (BHV) positively affects the environmental policy. The introduction of the controls increases the significance of the model: the R^2 (within) for general (local) government spending is equal to 0.39 (0.37) with controls, and it is equal to 0.34 (0.28) without. However, the most important feature of the specifications come from the inclusion of time and country fixed effects using robust standard errors. They allow us to control for most unobservable interactions not captured by the model and might account for potential omitted-variable bias.

5.3.2 Shape and origin of the relation between inequalities and public policy

This section aims to validate the exact shape of the relationship between inequality and public expenditure in environmental protection. Then, we will interpret our result along the lines of the theory developed in Section 4.

As mentioned earlier, the test of Lind and Mehlum (2010) rejects the null hypothesis of either a monotone or inverted $U-$shaped relationship. Looking at Figure 2, the data appears to be better fitted by a reversed $J-$shaped rather than a $U-$shaped relationship. According to Haans et al. (2016), several conditions must be met to confirm the existence of a $U-$shaped curve. First, the coefficients associated with both the linear and quadratic variables must be significant. Second, the turning-point should not be "extreme:" it must lie strictly inside the sample. Finally, the slope on both sides of the $U-$shaped curve must be steep enough. Although the first two conditions are verified in our analysis, the third condition is not, because the coefficients associated with Gini^2 are very small, ranging from 0.0037 to 0.0046.

To test the shape of the relationship between the Gini index and public expenditure, we conduct two more regressions on two sub-samples, as suggested by Qian et al. (2010).

The lower (upper) sub-sample comprises the observations with a Gini smaller (greater) than or equal to the turning point, that is, $Gini = 30.33$ for general and $Gini = 29.06$ for local government expenditures, considering all the controls. According to this test, if the $U-$shaped relationship were to be confirmed, we would observe a negative and significant coefficient for the lower sub-sample, and a positive and significant coefficient for the Gini in the upper sub-sample. However, this is not the case, as shown in Table 6.

As expected, for the lower sub-sample of the general government expenditures, coefficients of the Gini are significant regardless of the specification.[32] We also find that coefficients are greater than those obtained when considering the entire sample. The coefficient for the lagged Gini is -0.45 instead of -0.28 in the original regression. The Gini^2 coefficient is again significant and its effect is still very small. However, for local government expenditures, coefficients are significant only for the model with Driscoll-Kraay standard errors (5). This highlights the existence of a bias generated by the sample selection.[33] For the upper sample, that is a Gini equal or larger to the turning point of the supposed U, the coefficients of the Gini index (linear and quadratic terms) are never significant regardless of the outcome variable considered (see Table 6). It follows that if we consider all the sample, the interaction between inequalities and per capita environmental public policy seems better described by a reversed $J-$shaped rather than an inverted $U-$shaped curve.

Now we can provide an explanation of this result that is perfectly consistent with our theory. We will highlight how the starting point, that is, the equilibrium situation "before" a change occurs, affects the analysis of the impact of an MPS on public spending. For that purpose, we first need to acknowledge a strong negative correlation between per capita income and inequality, that is, between μ and σ, in European countries (Pearson correlation

[32] This is true whether we analyze the cluster-robust (4) or the Driscoll-Kraay standard error (5) regressions.

[33] Notice that if we consider the same turning point of $Gini = 30.33$ for both variables, the effect of the Gini turns significant also for local government expenditures and cluster-robust standard errors.

Table 6: $U-$shaped robustness test

	$Gini < 30.33$		$Gini < 29.06$		$Gini \geq 30.33$		$Gini \geq 29.06$	
	Exp. by general gov.		Exp. by local gov.		Exp. by general gov.		Exp. by local gov.	
	(4)	(5)	(4)	(5)	(4)	(5)	(4)	(5)
$Gini$	-0.4479***	-0.4479***	-0.3070	-0.3070**	-0.6313	-0.6313	0.3092	0.3092
	(0.155)	(0.087)	(0.247)	(0.117)	(0.411)	(0.420)	(0.379)	(0.200)
$Gini^2$	0.0080**	0.0080***	0.0054	0.0054**	0.0084	0.0084	-0.0043	-0.0043
	(0.003)	(0.002)	(0.005)	(0.002)	(0.006)	(0.006)	(0.006)	(0.002)
GDP	0.6412	0.6412*	0.1924	0.1924	0.2001	0.2001	0.6746***	0.6746***
	(0.459)	(0.347)	(0.381)	(0.415)	(0.265)	(0.212)	(0.309)	(0.153)
$Density$	-0.0008	-0.0008	-0.0008	-0.0008	-0.0504**	-0.0504***	-0.0196*	-0.0196***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.020)	(0.010)	(0.005)	(0.006)
ΔPop	0.2008	0.2008	0.6412*	0.6412*	0.4688	0.4688**	0.4617	0.4617
	(0.278)	(0.311)	(0.341)	(0.319)	(0.387)	(0.216)	(0.309)	(0.302)
HAD	-0.0065	-0.0065	-0.0217	-0.0217	-0.0956***	-0.0956***	-0.0427**	-0.0427***
	(0.013)	(0.012)	(0.029)	(0.014)	(0.028)	(0.010)	(0.017)	(0.004)
BHV	0.0845	0.0845	0.1120	0.1120	0.2153**	0.2153***	0.2664**	0.2664***
	(0.116)	(0.061)	(0.071)	(0.112)	(0.067)	(0.046)	(0.097)	(0.026)
$Year$	YES	YES	YES	YES	YES	YES	YES	YES
R^2 (within)	0.43	0.43	0.29	0.29	0.52	0.52	0.50	0.50
σ_u	1.38	N/A	1.89	N/A	5.99	N/A	7.51	N/A
σ_e	0.16	N/A	0.18	N/A	0.21	N/A	0.20	N/A
ρ	0.99	N/A	0.99	N/A	0.99	N/A	0.99	N/A
Observations	266	266	229	229	168	168	207	207

Notes: ***p<0.01 **p<0.05 *p<0.10. Cluster-robust (4) and Driscoll-Kraay (5) standard errors are in parentheses. All regressions include country fixed effects. Year represents the time effect. The dependent variable and GDP per capita are expressed in log.

coefficient of -0.421, $p-value = 0.000$). Then, there are two cases to consider: an initially high $\sigma/$ low μ *vs.* the opposite. Hereafter, we discuss the first case; the analysis of the second case follows by symmetry. A low μ means a low equilibrium tax and a low level of public spending. In turn, the income threshold is also low. Thus, rich and middle-income people consume the green good, which tends to "compensate" for the low level of public spending. Therefore, there is a substitution effect at work: green consumption supplants environmental public spending. In this situation, following an MPS, the middle-income class shrinks, whereas the number of people located at both tails of the income distribution rises (there are more rich and more poor people at the same time). This shift affects green consumption as well as environmental expenditure by the substitution effect. Thus, an MPS indeed involves two opposing effects: the decrease in the middle class impairs green consumption, whereas the increase in the number of rich people tends to stimulate it. In this case, because a large part of green consumption comes from the middle-income class, the negative effect should be larger than the positive one. This means that when inequality is already high, following a further increase in inequality, higher public spending is needed to compensate for the lower green consumption.

5.4 Robustness checks

We implement two robustness tests to confirm the empirical results. In the first robustness test, we consider a third dependent variable, which is the total environmental taxation per inhabitant.[34] Overall, we obtain the same qualitative results as those found with environmental expenditure. Proceeding as before, the results of the tests are similar to those we obtained with environmental protection expenditure. However, Pesaran's test indicates cross-sectional dependence at 1% level. Therefore, the accurate model for this outcome variable is the regression with the Driscoll-Kraay standard errors (5), rather than considering robust standard errors (4).

We report in Table 7 the estimated coefficients considering total environmental taxation as the outcome variable. For government environmental spending, coefficients for the $Gini$ and the $Gini^2$ display a significant convex and negative correlation between inequalities and environmental tax. Also, the computed turning point (30.59) is consistent with the previous regressions. The GDP per capita has a positive and significant effect on taxation in all specifications, as suggested by our theoretical results. The coefficients for this outcome variable are around 0.7. As in the previous regressions, introducing the controls increases the quality of the model, as suggested by the value of the within R^2. The model with Driscoll-Kraay standard errors (5) confirms our previous empirical findings, even though the control representing environmental health status (HAD) is now positively correlated with the policy. A plausible explanation is the following: as the regressions

[34] Total environmental taxation is extracted from *env_ac_tax*. It is calculated as: $\log\left(\frac{\text{env\_ac\_tax}_{i,t}\times 10^6}{\text{Population}_{i,t}}\right)$

Table 7: Total environmental taxation

	(1)	(2)	(3)	(4)	(5)
Gini	-0.1344**	-0.1705***	-0.1762***	-0.1632***	-0.1632***
	(0.052)	(0.057)	(0.056)	(0.049)	(0.045)
$Gini^2$	0.0022**	0.0027***	0.0028***	0.0027***	0.0027***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDP	0.7308***	0.6796***	0.6581***	0.6651***	0.6651***
	(0.192)	(0.197)	(0.205)	(0.191)	(0.127)
Density		-0.014	-0.0015	-0.0017**	-0.0017***
		(0.001)	(0.001)	(0.001)	(0.001)
ΔPop			0.1316	0.1819	0.1819
			(0.196)	(0.156)	(0.107)
HAD				0.0088	0.0088*
				(0.009)	(0.004)
BHV				0.0693	0..0693**
				(0.048)	(0.027)
Year	YES	YES	YES	YES	YES
R^2 (within)	0.68	0.70	0.70	0.72	0.72
σ_u	0.27	0.49	0.52	1.015	N/A
σ_e	0.11	0.10	0.10	0.10	N/A
ρ	0.86	0.96	0.96	0.99	N/A
Observations	506	462	462	462	462

Notes: ***p<0.01 **p<0.05 *p<0.10. Cluster-robust (1-4) and Driscoll-Kraay standard errors are in parentheses. All regressions include country fixed effects. Year represents the time effect. The dependent variable and GDP per capita are expressed in log.

show, omitted controls are already captured by the fixed country and time effects. Therefore, the residual mechanisms involved by control variables are quite intricate and differ depending on whether taxation or public expenditure is under scrutiny.

Table 8: Robustness check with Gini not lagged

	Exp gen gov		Exp loc gov		Tot env tax	
	(4)	(5)	(4)	(5)	(4)	(5)
Gini	-0.1865**	-0.1865*	-0.1047*	-0.1047	-0.0735*	-0.0735**
	(0.078)	(0.108)	(0.055)	(0.076)	(0.036)	(0.033)
$Gini^2$	0.0029**	0.0029	0.0016*	0.0016	0.0011	0.0011**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
GDP	1.2613***	1.2613***	1.1868***	1.1868***	0.9268***	0.9268***
	(0.249)	(0.188)	(0.254)	(0.137)	(0.143)	(0.075)
Density	-0.0009	-0.0009	-0.0013	-0.0013***	-0.0016**	-0.0016***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ΔPop	-1.5194	-1.5194	-0.5590	-0.5590	0.5743	0.5743
	(4.802)	(3.330)	(5.220)	(2.945)	(1.869)	(1.246)
HAD	-0.0023	-0.0023	-0.0085	-0.0085	0.0028	0.0028
	(0.015)	(0.006)	(0.013)	(0.005)	(0.008)	(0.004)
BHV	0.2034*	0.2034***	0.2864***	0.2864***	0.0999***	0.0999***
	(0.106)	(0.027)	(0.096)	(0.038)	(0.489)	(0.024)
Year	YES	YES	YES	YES	YES	YES
R^2 (within)	0.66	0.66	0.58	0.58	0.84	0.84
σ_u	2.45	N/A	3.31	N/A	1.29	N/A
σ_e	0.25	N/A	0.23	N/A	0.11	N/A
ρ	0.99	N/A	0.99	N/A	0.99	N/A
Observations	503	503	501	501	527	527

Notes: ***p<0.01 **p<0.05 *p<0.10. Cluster-robust (4) and Driscoll-Kraay (5) standard errors are in parentheses. All regressions include country fixed effects. Year represents the time effect. The dependent variable and GDP per capita are expressed in log. The Gini index is not lagged

The second test consists of removing the 5-year lag for the Gini index. We perform the regressions for the model with controls and both Cluster-robust standard errors (4) and Driscoll-Kraay standard errors (5). The regression results are in Table 8. Because the model with robust standard errors (4) is more appropriate to describe the government expenditure variables, whereas the model with Driscoll–Kraay standard errors (5) is more appropriate to describe the environmental taxation, results are robust and very similar to those obtained with the time lag. Even though the effect of the explanatory variables is much more significant in the model with the Gini lagged, we can safely conclude that the data exhibit the negative and convex effect of inequalities on the environmental policy, as suggested by our theoretical analysis.

6 Conclusion

In this paper, we investigate the nature of the interaction between income distribution and environmental policy. Recent data for European countries especially reveal that the relationship between the Gini index and environmental public expenditure may not be monotone, which is a result that cannot be explained by the existing literature.

Our contribution is first to develop an original political economy model that helps to explain the factors that shape this relationship. Among the key factors is the opportunity for people to choose between conventional and green consumption, and to vote for environmental policy. Both decisions are dictated by individuals' income capacities, while both green consumption and environmental public expenditure enhance environmental quality. Our analysis shows that a change in the level of inequality induces variations in both the size and composition of the two groups of citizens, those who consume green and those who do not. Their respective importance, in turn, determines whether such a change stimulates public policy. We provide some conditions under which it is possible to conclude that inequality impairs environmental policy. But, in general, the impact can go either way.

Second, we conduct a full-fledged empirical investigation of the link between income distribution and environmental policy. The main dependent variable corresponds to the public expenditure on environmental protection. Our data consist of a sample covering thirty-one European countries over the period 1996-2019. We analyze the impact of the

Gini index on public environmental expenditure using of a fixed-effect model with robust standard errors, accounting for the potential non-monotonicity. Results show the existence of a reversed J-shape relationship between inequality and environmental spending. Here we can refer to our theory to provide an intuition of this outcome. As mentioned above, a change in inequality causes a change in the size and composition of the group that consumes the green good, which in turn affects the social demand for public provision of environmental quality according to a substitution effect. When the level of inequality is initially low, an increase in inequality tends to increase green consumption originating from the richest people who become more numerous, which calls for less environmental spending by the government.

A promising future line of research would be the inclusion of different political powers in the hands of the socio-economic groups. It would be interesting to understand how the heterogeneity in political power could affect the outcome of the electoral process and resulting public policy. Such analysis would contribute to the literature discussing how political power and conflict among opposing interest groups affect the design of environmental policy.

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A Appendix

A.1 Proof of Proposition 1

First and second derivatives of $Q(t)$ w.r.t to t:

$$\begin{aligned} &Q'(t) = \mu + \int_{\tilde{w}(t)}^{\infty} \frac{\partial d^g(w,t)}{\partial t} dw \Leftrightarrow Q'(t) = \mu - \pi^{-1} \int_{\tilde{w}(t)}^{\infty} w f(w) dw > 0, \\ &Q''(t) = \pi^{-1} \tilde{w}'(t) \tilde{w}(t) f(\tilde{w}(t)) > 0. \end{aligned} \tag{11}$$

For the Pareto distribution, the marginal benefit and costs of the public policy are:

$$\begin{aligned} MB &= \beta \left[\mu - \frac{k\pi^{-1}\tilde{w}(t)}{k-1} \left(\frac{w_m}{\tilde{w}(t)} \right)^k \right], \\ MC^g &= \frac{k\pi^{-1}\tilde{w}(t)}{k-1} \left(\frac{w_m}{\tilde{w}(t)} \right)^k, \\ MC^n &= \frac{k\pi^{-1}\tilde{w}(t)}{k-\alpha} \left(\frac{w_m}{\tilde{w}(t)} \right)^k \left[\left(\frac{w_m}{\tilde{w}(t)} \right)^{\alpha-k} - 1 \right]. \end{aligned}$$

The relative size of group G, N^g, is equal to: $N^g(\tilde{w}(t)) = \left(\frac{w_m}{\tilde{w}(t)} \right)^k$. So we observe that MC^g is proportional to N^g, while the MB is linearly decreasing in this size.

Using this expression, we get the expression of the marginal value, $W'(t) = MB - (MC^g + MC^n)$:

$$W'(t) = \mu \left[\beta - \pi^{-1} \left(\frac{w_m}{\tilde{w}(t)} \right)^{k-1} \left(1 + \beta - \frac{k-1}{k-\alpha} + \frac{k-1}{k-\alpha} \left(\frac{w_m}{\tilde{w}(t)} \right)^{\alpha-k} \right) \right] \tag{12}$$

First, we have to check that the second order optimality condition holds, given that

$$W''(t) = -\frac{k w_m \pi^{-1}}{1-t} \left(\frac{\tilde{w}(t)}{w_m} \right)^{1-\alpha} \left[\frac{1-\alpha}{k-\alpha} - \left(1 + \beta - \frac{k-1}{k-\alpha} \right) \left(\frac{\tilde{w}(t)}{w_m} \right)^{\alpha-k} \right].$$

We obtain $W''(t) < 0 \Leftrightarrow \tilde{w}(t) > w_m \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1}{k-\alpha}} \equiv \tilde{w}^c$, which is equivalent to

$$t > t^c \text{ with } t^c = 1 - w_m^{-1}(\gamma\pi)^{\frac{1}{1-\alpha}} \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1}{\alpha-k}},$$

and one may note that $t^c > (\leq) 0$ if and only if

$$w_m > (\leq)(\gamma\pi)^{\frac{1}{1-\alpha}} \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1}{\alpha-k}}.$$

We can easily verify that $\lim_{t\to 1} W'(t) = -\infty$. Assuming $t^c > 0$, which boils down to imposing

$$w_m > (\gamma\pi)^{\frac{1}{1-\alpha}} \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1}{\alpha-k}}, \tag{13}$$

a necessary and sufficient condition for existence is: $W'(t^c) > 0$. This is equivalent to:

$$\beta\pi > \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1-\alpha}{k-\alpha}}. \tag{14}$$

Rearranging, the existence condition can be stated as follows: $W'(t^c) > 0 \Leftrightarrow \pi > \underline{\pi}(\beta)$, with

$$\underline{\pi}(\beta) = \beta^{-1} \left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1-\alpha}{k-\alpha}}.$$

A.2 Proof of Proposition 2

First we express the two parameters of the Pareto distribution in terms of the average, μ, and standard deviation, σ:

$$w_m(\mu,\sigma) = \frac{(k(\mu,\sigma)-1)\mu}{k(\mu,\sigma)} \text{ and } k(\mu,\sigma) = 1 + \sqrt{1 + \left(\frac{\mu}{\sigma}\right)^2},$$

and we obtain, after some computations, $\frac{\partial w_m}{\partial \mu}, \frac{\partial k}{\partial \mu} > 0$, and $\frac{\partial w_m}{\partial \sigma}, \frac{\partial k}{\partial \sigma} < 0$.

Next, we differentiate the expression of MB, MC^g and MC^n w.r.t w_m, k, and μ:

$$\begin{aligned}
dMC^g &= \tfrac{\Psi dw_m}{k-1}\left[1 + \tfrac{w_m}{k^2}\left(k\ln\left(\tfrac{w_m}{\tilde{w}^*}\right) - \tfrac{1}{k-1}\right)\tfrac{dk}{dw_m}\right], \\
dMB &= \beta\left(d\mu - dMC^g\right), \\
dMC^n &= \tfrac{\Psi dw_m}{k-\alpha}\left[\tfrac{\alpha}{k}\left(\tfrac{w_m}{\tilde{w}^*}\right)^{\alpha-k} - 1 - \tfrac{w_m}{k}\left(\tfrac{\alpha}{k(k-\alpha)}\left(\left(\tfrac{w_m}{\tilde{w}^*}\right)^{\alpha-k} - 1\right) + \ln\left(\tfrac{w_m}{\tilde{w}^*}\right)\right)\tfrac{dk}{dw_m}\right].
\end{aligned} \tag{15}$$

with $\Psi = k^2\pi^{-1}\left(\frac{w_m}{\tilde{w}^*}\right)^{k-1} > 0$, and $\tilde{w}^* = \tilde{w}(t^*)$.

Hereafter, we conduct the analysis of the impact of a mean preserving spread (change in $d\sigma > 0$ taking $d\mu = 0$ as given). Then we turn to the analysis of a change in μ keeping σ constant.

A.2.1 Mean preserving spread

Under a mean preserving spread, the joint variation of w_m and k satisfies: $\frac{dk}{dw_m} = \frac{k(k-1)}{w_m}$. Using this relationship in the expressions above, we get:

$$\begin{aligned}
\tfrac{\partial MC^g}{\partial \sigma} &= \tfrac{\Phi^\sigma}{k-1}\left[1 + (k-1)\ln\left(\tfrac{w_m}{\tilde{w}^*}\right) - \tfrac{1}{k}\right], \\
\tfrac{\partial MB}{\partial \sigma} &= -\beta\tfrac{\partial MC^g}{\partial \sigma}, \\
\tfrac{\partial MC^n}{\partial \sigma} &= \tfrac{\Phi^\sigma}{k-\alpha}\left[-\left(1 + (k-1)\ln\left(\tfrac{w_m}{\tilde{w}^*}\right)\right) + \tfrac{\alpha(k-1)}{k(k-\alpha)} + \tfrac{\alpha(1-\alpha)}{k(k-\alpha)}\left(\tfrac{w_m}{\tilde{w}^*}\right)^{\alpha-k}\right].
\end{aligned} \tag{16}$$

with $\Phi^\sigma = k^2\pi^{-1}\left(\frac{w_m}{\tilde{w}^*}\right)^{k-1}\frac{\partial w_m}{\partial \sigma} < 0$.

We want to determine the sign of $\frac{\partial^2 W(t^*)}{\partial t \partial \sigma} = \frac{\partial MB}{\partial \sigma} - \frac{\partial MC^g}{\partial \sigma} - \frac{\partial MC^n}{\partial \sigma}$. Rearranging, we obtain:

$$\frac{\partial^2 W(t^*)}{\partial t \partial \sigma} = \Phi^\sigma\left(\frac{w_m}{\tilde{w}^*}\right)^{\alpha-k}\left[G(t) - \frac{\alpha(1-\alpha)}{k(k-\alpha)^2}\right],$$

with,

$$G(t) = \left(\frac{\tilde{w}(t)}{w_m}\right)^{\alpha-k} \left[\left(1+\beta-\frac{k-1}{k-\alpha}\right)\left(\ln\left(\frac{\tilde{w}(t)}{w_m}\right)-\frac{1}{k}\right)+\frac{1-\alpha}{(k-\alpha)^2}\right].$$

As to the features of $G(.)$: We get that $\lim_{t\to 1} G(t) = 0$, and

$$G(t^c) > \frac{\alpha(1-\alpha)}{k(k-\alpha)^2} \Leftrightarrow \frac{1-\alpha}{\beta(k-\alpha)}\left(1+\frac{\beta(k-\alpha)}{1-\alpha}\right)\ln\left(1+\frac{\beta(k-\alpha)}{1-\alpha}\right) > 1,$$

which always holds. Moreover, either $G(.)$ is monotone decreasing on $(t^c, 1)$, or it is bell-shaped. So we can conclude that there exists a unique $t^s \in (t^c, 1)$ such that $G(t^s) = \frac{\alpha(1-\alpha)}{k(k-\alpha)^2}$ and $G(t) > 0 \Leftrightarrow t < t^s$. Put differently, we have shown that

$$\frac{\partial^2 W(t^*)}{\partial t \partial \sigma} < 0 \Leftrightarrow t^* < t^s,$$

which completes the first part of the proof.

A.2.2 Average income variation (constant standard deviation)

Here, it is more convenient to start from the expression of $W'(t)$ given in (12) once we observe that the coefficient in front of the squared brackets is simply μ and that the term between the squared brackets is equal to 0 for $t = t^*$. We have to combine $d\mu > 0$ and $d\sigma = 0$, the latter restriction imposing $\frac{dk}{dw_m} = \frac{k(k-1)(k-2)}{w_m(k-1+k(k-2))}$. After some calculations, we get

$$\frac{\partial^2 W(t^*)}{\partial t \partial \mu} = \Phi^\mu \left[H(t) - \Delta\right],$$

with $\Phi^\mu = \mu\pi^{-1}\left(\frac{\tilde{w}^*}{w_m}\right)^{1-\alpha}\frac{\partial k}{\partial \mu} > 0$,

$$H(t) = \left(\frac{\tilde{w}(t)}{w_m}\right)^{\alpha-k} \left[\left(1+\beta-\frac{k-1}{k-\alpha}\right)\left(\ln\left(\frac{\tilde{w}(t)}{w_m}\right)-\frac{k-1+k(k-2)}{k(k-2)}\right)+\frac{1-\alpha}{(k-\alpha)^2}\right],$$

and

$$\Delta = \frac{(1-\alpha)(k(k-2)-(k-\alpha)(k-1+k(k-2)))}{k(k-2)(k-\alpha)^2} < 0.$$

We immediately observe that $G(t) > H(t)$ for all $t < 1$ and $\lim_{t\to 1} H(t) = 0$. In addition, we have $H(t^c) > \Delta$ because

$$G(t^c) > \frac{\alpha(1-\alpha)}{k(k-\alpha)^2} \Leftrightarrow H(t^c) > \Delta.$$

Given that $H(.)$ is either monotone decreasing or increasing then decreasing on $(t^c, 1)$, we finally conclude that

$$\frac{\partial^2 W(t^*)}{\partial t \partial \mu} > 0 \text{ for all } t,$$

which completes the second part of the proof.

A.3 Mean preserving spread: discussion

Here we provide some elements that help to understand the comparative statics results, for a change in σ.This change negatively affects both the lower bound of the support, w_m, and the parameter, k, of the Pareto distribution $F(w)$.

Differentiating the expression of group G's relative size w.r.t w_m and σ yields:

$$dN^g = N^g dw_m \left[\frac{k}{w_m} + \ln\left(\frac{w_m}{\tilde{w}^*}\right)\frac{dk}{dw_m}\right].$$

Considering a change in the parameters resulting from a change in σ, for a constant μ, we have

$$\frac{\partial N^g}{\partial \sigma} = N^g \frac{\partial w_m}{\partial \sigma}\frac{k}{w_m}\left(1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right)\right),$$

and

$$\frac{\partial f(w)}{\partial \sigma} = \frac{\partial w_m}{\partial \sigma} \frac{k}{w_m} f(w) \left(1 + (k-1)\left(\frac{1}{k} + \ln\left(\frac{w_m}{w}\right)\right)\right).$$

From the last expression, we see that there exists a critical $w^f = w_m \exp^{\frac{1}{k(k-1)}}$ such that $\frac{\partial f(w)}{\partial \sigma} > 0 \leftrightarrow w > w^f$.

Recall that:

$$\frac{\partial^2 W(t^*)}{\partial t \partial \sigma} = \frac{\partial MB}{\partial \sigma} - \left[\frac{\partial MC^g}{\partial \sigma} + \frac{\partial MC^n}{\partial \sigma}\right].$$

We want to sign the expressions in (16) and see how it relates to $t^* \gtrless t^s$. Focusing on the changes in MC^g and MC^n, there are four possible cases:

1. $\frac{\partial MC^g}{\partial \sigma}, \frac{\partial MC^n}{\partial \sigma} < 0$ iff $\frac{1}{k} < 1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right) < \Psi$,
2. $\frac{\partial MC^g}{\partial \sigma} < 0$ and $\frac{\partial MC^n}{\partial \sigma} > 0$ iff $\max\left\{\frac{1}{k}, \Psi\right\} < 1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right)$,
3. $\frac{\partial MC^g}{\partial \sigma} > 0$ and $\frac{\partial MC^n}{\partial \sigma} < 0$ iff $1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right) < \min\left\{\frac{1}{k}, \Psi\right\}$,
4. $\frac{\partial MC^g}{\partial \sigma}, \frac{\partial MC^n}{\partial \sigma} > 0$ iff $\Psi < 1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right) < \frac{1}{k}$,

with $\Psi = \frac{\alpha(k-1)}{k(k-\alpha)} + \frac{\alpha(1-\alpha)}{k(k-\alpha)}\left(\frac{w_m}{\tilde{w}^*}\right)^{\alpha-k} > 0$.

We don't know much a priori about the signs and rankings between those different terms. To start with, let us determine whether $1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right) \gtrless \frac{1}{k}$. We obtain $1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right) > \frac{1}{k} \Leftrightarrow \tilde{w}^* < \tilde{w}^x$ with $\tilde{w}^x = w_m \exp^{\frac{1}{k}}$. Evaluating the expression of $W'(t)$ given by (12) at $\tilde{w}(t) = \tilde{w}^x$, we get

$$W'(t)|_{\tilde{w}(t)=\tilde{w}^x} < 0 \Leftrightarrow \beta(1 - \pi^{-1}\exp^{\frac{k-1}{k}}) < \frac{\pi^{-1}\exp^{\frac{k-1}{k}}}{k-\alpha}\left(1 - \alpha + (k-1)\exp^{\frac{\alpha-k}{k}}\right),$$

and imposing

$$\pi < \exp^{\frac{k-1}{k}},$$

is sufficient to conclude that $\tilde{w}^* < \tilde{w}^x$. Under this (weak) restriction, we know that $\frac{\partial MC^g}{\partial \sigma} < 0$. This also implies $\frac{\partial N^g(\tilde{w}^*;\mu,\sigma)}{\partial \sigma} < 0$ as $\frac{\partial N^g(\tilde{w}^*;\mu,\sigma)}{\partial \sigma} < 0 \Leftrightarrow 1 + (k-1)\ln\left(\frac{w_m}{\tilde{w}^*}\right) > 0 \Leftrightarrow \tilde{w}^* < \tilde{w}^\sigma = w_m \exp^{\frac{1}{k-1}}$ and $\tilde{w}^x < \tilde{w}^\sigma$.

So we know that the increase in σ translates into both a decrease in MC^g and an increase in MB. In this situation, two possibilities remain regarding the evolution of MC^n. They correspond to the cases 1. and 2. listed above. We also know that the relative size of group N increases while the density at each income levels in $(w_m, \tilde{w}^*)$ decreases since while $(\tilde{w}^* <)\tilde{w}^x < w^f$ implies that $\frac{\partial f(w)}{\partial \sigma} < 0$ for all $w < \tilde{w}^*$.

Suppose that equilibrium tax is pretty high so that $\tilde{w}^* > \tilde{w}^s$. A necessary condition for this to occur is $\tilde{w}^s < \tilde{w}^x$. Either MC^n decreases and we can directly conclude that $\frac{\partial^2 W(t^*)}{\partial t \partial \sigma} > 0$ (case 1.). Or, MC^n increases (case 2.). But then, based on the results of Appendix A.2.1, we can conclude that

$$|\frac{\partial MC^n}{\partial \sigma}| < |\frac{\partial MC^g}{\partial \sigma} - \frac{\partial MB}{\partial \sigma}| \Leftrightarrow \frac{\partial^2 W(t^*)}{\partial t \partial \sigma} > 0.$$

Consider next that the tax is low so that $\tilde{w}^* < \tilde{w}^s$. Then we know that MC^n necessarily increases, which places us in case 2. Relying on our previous results, we can furthermore conclude that:

$$|\frac{\partial MC^n}{\partial \sigma}| > |\frac{\partial MC^g}{\partial \sigma} - \frac{\partial MB}{\partial \sigma}| \Leftrightarrow \frac{\partial^2 W(t^*)}{\partial t \partial \sigma} < 0,$$

which ends the discussion.

A.4 Proof of Corollary

This proof is based on the following observation. Unlike the equilibrium tax, the critical level t^s, that determines whether a mean preserving spread stimulates taxation, is independent of π. Noticing that the necessary and sufficient existence condition (14) can be rewritten as:

$$\pi > \underline{\pi}(\beta) = \beta^{-1}\left(1 + \frac{\beta(k-\alpha)}{1-\alpha}\right)^{\frac{1-\alpha}{k-\alpha}}.$$

with $\underline{\pi}'(\beta) < 0$ because $k > 1$, and $\underline{\pi}(\beta) > 1$ for $\beta \in (0, 1)$. Actually, only for very high β would the threshold fall below 1 (and then become irrelevant).

Under this condition, we know that there exists a unique t^* satisfying $W'(t^*) = 0$. Now, simply observe that

$$\lim_{\pi \to \underline{\pi}(\beta)} t^* = t^c,$$

which is by construction lower than t^s. Then, by a continuity argument, we can conclude that in situations where π is close enough to $\underline{\pi}(\beta)$, a mean preserving spread induces the policy maker to reduce the income tax and the public provision of environmental quality.

B Data sources

Data comes from Eurostat (the statistical office of the European Union) and the Environmental Performance Index (EPI),developed from 2006 by the Yale Center for Environmental Law and Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University.

The Eurostat dataset provides the total and local government expenditure by functions and by type of institution. In this dataset there are data for 31 European countries over the period 1996-2019. List of countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK. Variables are extracted from *gov_10a_exp*. According to the European System of Accounts (ESA), general governments are *"institutional units which are non-market producers whose output is intended for individual and collective consumption, and are financed by compulsory payments made by units belonging to other sectors, and institutional units principally engaged in the redistribution of national income and wealth"*. Local government are: *"public administration whose competence extends to only a local part of the economic territory, apart from local agencies of social security funds."* The dataset for total environmental taxation contains 34 countries, with Liechtenstein, Serbia and Turkey in the sample.

From the Environmental Performance Index (EPI) dataset we take two variables from the category environmental health and ecosystem vitality: household air pollution from solid fuels (HAD) and biodiversity habitat index (BHV), respectively. The variable household solid fuels is calculated using the number of age-standardized disability-adjusted life-years lost per 100,000 persons (DALY rate) due to exposure to household air pollution from the use of household solid fuels. The biodiversity habitat index estimates the effects of habitat loss, degradation, and fragmentation on the expected retention of terrestrial biodiversity. The larger the score, the lower the habitat loss or degradation experienced by the country. See https://epi.yale.edu/epi-results/2020/component.