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ENVIRONMENTAL QUALITY AND INEQUALITY: THE IMPACT OF REDISTRIBUTION ON DIRECT HOUSEHOLD EMISSIONS IN ITALY

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Environmental quality and inequality: The impact of redistribution on direct household emissions in Italy

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Abstract

This paper investigates the relation between income distribution and direct households emissions in Italy. Our results seem to confirm some recent works analyzing the income-pollution relationship in other countries. Indeed, our empirical analysis shows that decreasing inequality would lead to higher aggregate emissions, whereas increasing inequality would reduce environmental problems. By going into a deeper discussion of such results, we identify some weaknesses of the framework proposed by the literature and show that changes in the shape of emission intensities distribution might lead to opposite conclusions.

JEL classifications: Q01; Q56; D12

Keywords: Emissions, Income inequality, household consumption

1 Introduction

The literature on the links between public policy design and environmental quality is now well established, yet some issues, such as income redistribution, lack a full understanding. We focus on the impact of income distribution on environmental degradation. Indeed, recent literature suggests that income distribution can significantly affect environmental pressure. The existence of a potential trade-off between reducing inequality and controlling pollution implies that redistributive policies may have unintended consequences on aggregate emissions. Empirical evidence, however, is mixed. This paper adds to the existing literature by investigating the income-pollution relationship in Italy, with specific reference to how income distribution affects aggregate emissions related to direct household consumption.

Even though the relation between income and environmental quality has been widely explored in the 1990s ([2]), only few works have emphasized the importance of income distribution in explaining environmental outcomes (see, for instance, [3]; [9]; [8]; [7]; [5]; [4]). In a political-economy framework, Boyce (1994) [3] sets forth the hypothesis that the extent of an environmentally degrading activity depends on the balance of power between those who benefit from the activity and those who bear the costs. When the winners are more powerful than the losers, more environmental degradation will occur. Indeed, greater equality of incomes leads to lower levels of environmental degradation. This conclusion has been challenged by other authors. Heerink *et al.* (2001) [5], for instance, finds that higher inequality reduces environmental pollution according to several indicators analyzed on a cross-section of different countries. Their result is based on the argument that an aggregate analysis omitting a measure of income dispersion as an explanatory variable will result in biased estimates when the pollution-income relationship is non-linear at the individual level. Specifically, if there is a concave (convex) relation between income and environmental pressure, an income redistribution from the rich to the poor leads to a higher (lower) environmental damage. Then there is no way to determine a priori if an income equalization policy is beneficial or not for the environment, since the outcome depends on the shape of the income-pollution relation. To account for the non-linearity bias, in Heerink *et al.* (2001) [5] the Gini coefficient is included in the regression equations which estimate the overall impact of income inequality on the environment. In the same line, Brännlund and Ghalwash (2008) [4] estimate a structural model for consumer demand in order to assess how changes in income distribution affect aggregate emissions through changes in household consumption baskets. On the basis of cross-sectional data for Sweden, they conclude that the pollution-income relationship is strictly concave for all types of pollutants they consider, implying that an income equalization would lead to higher emissions.

In this work we aim at contributing to this recent debate. Specifically, following [4], we want to test if the same pollution-income relationship may exist also in Italy. To this end, we firstly estimate a consumer demand system for Italian households, in order to derive income elasticities at micro-level. Then we calculate direct emissions related to household consumption and evaluate emission changes due to an income redistribution. We focus on four different pollutants: carbon dioxide (CO_2), sulphur oxides (SO_x), nitrogen oxides (NO_x) and particulates (PM_{10}), the main polluting agents produced by final household consumption. Our main conclusions support the idea that redistribution reducing (increasing) inequality implies larger (smaller) direct emissions from households. Such conclusion is, however, shown to depend crucially on the assumed shape for emission intensities distribution.

More specifically, as in [4], emission intensity is a constant (i.e. it does not vary with income, consumption etc.). We provide a specific counter-example where the emission intensity parameters are increasing in income, and show that the above result might well be reversed. Though we do not support the "increasing emission intensities" assumption as more (or less) credible than the "constant emission intensities" one, our conclusion does underline the need of more empirical evidence on actual emission intensity in various countries.

The rest of the paper is organized as follows. In Section 2 we discuss the income-pollution relationship and present the empirical model. Section 3 describes consumption and emission data, whereas Section 4 provides the main results of our empirical analysis. Finally, section 5 shows a relevant counterexample, while concluding remarks are given in Section 6.

2 The income-pollution relationship

Households' consumption implies emissions of several pollutants. Such emissions can be related either "directly" to the consumption of certain goods or "indirectly" through their production. Obviously, any change in consumption patterns due to an income change has an impact on environmental quality. The sign of this impact, however, is rather ambiguous. Rising incomes, for instance, may increase the demand for some polluting goods (such as heating and transport); at the same time, richer households may reduce their demand or rely on modern (and less polluting) appliances. It implies that the relation between income and environmental degradation may be non-linear at the household level. As a result, an income redistribution reducing (or increasing) the degree of inequality in the population may affect aggregate emissions in an ambiguous way.

Following [4], we assume that emissions produced by a household i are a function of the household income (Y_i). The average level of emissions per household ($\bar{E}$) can then be expressed as:

$$\bar{E} = \frac{1}{n}\sum_{i=1}^{n} f\left(Y_i\right) = f\left(\bar{Y}\right) + \frac{1}{n}\sum_{i=1}^{n}\left\{f\left(Y_i\right) - f\left(\bar{Y}\right)\right\}$$

where $\bar{Y}$ is the average household income. The way in which an income redistribution affects aggregate emissions will depend on the properties of the function f ([5]). If the function f is strictly convex, reducing inequality will lower average emissions; on the contrary, if the function f is strictly concave, aggregate emissions will be increased as a result of an equalizing redistribution. As shown in [4], non-linearities in the income-pollution function can be introduced *via* the income-consumption relationship. In [4], the shape of the income-pollution function depends on the derivative of the income elasticity with respect to income. Accordingly, a consumer demand system is estimated in order to evaluate how changes in income distribution affect the environmental quality through changes in the households' consumption bundles.

Given the Quadratic Almost Ideal Demand System (QUAIDS) specification ([1]), which allows for the presence of non-linearities in the demand model, estimating the household income elasticity requires to estimate the following expenditure share equation system (equation 7 in [4], where the subscript t for time has been dropped):

$$s_{ij} = \tilde{\boldsymbol{\alpha}}_j^{\prime}\mathbf{d}_i + \boldsymbol{\beta}_j^{\prime}\mathbf{d}_i \ln\left(\frac{Y_i}{P}\right) + \boldsymbol{\delta}_j^{\prime}\mathbf{d}_i \ln\left(\frac{Y_i}{P}\right)^2 + \upsilon_{ij} \qquad j = 1, ..., k \qquad (1)$$

where s_{ij} is the budget share for good j and for household i. Household characteristics are summarized by a vector of dummy variables ($\mathbf{d}_i$), while

υ_{ij} is the residual term. It follows that the income elasticity is given by:

$$\varepsilon_{ij} = \frac{1}{s_{ij}} \left[\boldsymbol{\beta}_j' \mathbf{d}_i + 2\boldsymbol{\delta}_j' \mathbf{d}_i \ln \left(\frac{Y_i}{P} \right) \right] + 1 \qquad j = 1, ..., k \tag{2}$$

In other terms, the quadratic logarithmic specification implies that the income elasticity depends on the income level, meaning that some goods may be considered as necessities at some income levels and luxuries at others. The household income elasticity estimation allows for estimating the effect of an income change on the demand for the various goods.

Whereas the income-consumption relation is non-linear, emissions are considered as a linear function of household consumption. The change in aggregate emissions due to an income change can then be calculated as:

$$\frac{\partial E_m}{\partial Y} = \sum_{j=1}^{k} \frac{\partial x_j}{\partial Y} \frac{\partial E_m}{\partial x_j} = \sum_{j=1}^{k} \frac{\partial x_j}{\partial Y} \theta_m \tag{3}$$

where m indicates the type of pollutant and $\partial E_m / \partial x_j$ is the emission intensity for each substance (total emissions per unit of real consumption of each good). Following [4], we assume $\frac{\partial E_m}{\partial x_j} = \theta_m$ for pollutant m, i.e. emission intensities are constant. In section 5 we will discuss the implications of such assumption.

3 Data

To estimate the income-pollution relationship in Italy we need data on both household consumption expenditure and emissions associated to each kind of consumption good.

The expenditure data are taken from the Italian Household Budget Survey (IHBS) for 2005, including a random sample of 24107 households throughout the country. This survey, which is conducted by the National Institute of Statistics (ISTAT), is one of the most comprehensive sources of microdata on consumption behavior in Italy, yielding detailed information on family expenditures as well as on household socioeconomic and demographic characteristics.

Both non-durable and durable consumption data are provided in the survey. Nevertheless, since data on direct emissions are available only for certain categories of goods, as will be explained later on, we restrict our analysis by considering only expenditure on non-durables (see Figure 1). This is coherent with [4], where it is assumed a two-stage process in the income allocation between durables and non-durables[1].

For non-durables and services, household expenditures are collected over a one-week period and then expressed on a monthly basis. The collection of information on a seven-day period introduces some room for undetected infrequency of purchases. It means that an observed zero expenditure does not necessarily mean that the household does not have such expenditure, but simply that such good has not been purchased in the considered period[2].

Emission data are provided by the 1990-2006 time series of NAMEA (National Accounting Matrix including Environmental Accounts), produced by ISTAT. This database includes the emissions of eighteen air pollutants broken down by economic activity and households' consumption expenditure. Specifically, "direct" emissions (i.e. related to direct households' consumption) are divided among three main sources: transport (within which only expenditure on fuels and lubricants for personal transport equipment can be related to emissions[3]), heating (including expenditure on electricity, gas and

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[1] For further details, see [4].

[2] In order to not introduce distortions in households' behavior, we simply drop households (records) reporting a zero value for some budget share. The final number of observations is then equal to 17689 households.

[3] COICOP (Classification of Individual Consumption According to Purpose) code

other fuels[4]) and other expenditures (among which only activities related to varnishing and solvent use produce emissions). "Indirect" emissions (i.e. those obtained by using emission data from the production side) cannot be directly related to household' consumption expenditures. Accordingly, in this work we focus on direct emissions of carbon dioxide (CO_2), sulphur oxides (SO_x), nitrogen oxides (NO_x) and particulates (PM_{10}), the main polluting agents produced by final consumption. Furthermore, for guaranteeing data compatibility, we consider emissions for 2005.

Expenditure shares for each good as well as emission shares and intensities in 2005 are reported in Table 1. Transport and heating represent almost the same proportion of total households' expenditure and contribute for almost the half of total CO_2 and PM_{10} emissions. Transports are the main responsible for NO_x pollution, while heating produces the largest contribution of SO_x emissions.

Table 1 about here

4 Empirical results

In this Section we empirically analyze the income-pollution relationship in Italy, by showing how an income redistribution affects environmental quality in the considered year. Accordingly, we firstly estimate the household demand model and then use the parameter estimates to calculate income elasticities.

To estimate the demand model, we consider the system defined above (eq. 1) for the three goods related to direct emissions (transport, heating, other expenditures). As the prices of the goods are equal across households in

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07.2.2.

[4] COICOP code 04.5.

the year, they can be considered as a constant in the regressions. Prices can then be included in the intercept term $\tilde{\alpha}$. Given the categories of commodities we are considering, only two typologies of household characteristics, namely household composition and the area of residence, have been deemed relevant in affecting consumer behavior. Accordingly, regressions include three dummy variables for household composition (couple without children, couple with one child, other family types - households with two children or more and single parents), and one geographical dummy variable for households living in the North/Centre of Italy[5].

Finally, and coherently with recent works[6] (see, for instance, [6] and [10]), total expenditure on non durable goods has been used as a proxy of household income.

The demand system has been estimated by using the Seemingly Unrelated Regressions (SURE) model, which allows for disturbances to be correlated across observations. In our case, since explanatory variables are the same in all equations, parameter estimates (coefficients) are identical either by estimating each equation separately with ordinary least squares or estimating all equations simultaneously with SURE. The SURE estimate, however, produces more efficient standard errors, and allows for testing non linearities in the model specification. Such test is crucial in our setting, since the quadratic specification significantly affects the shape of the income-pollution relationship. The likelihood-ratio test applied on our expenditure data suggests that the hypothesis of linearity can be rejected. The SURE estimation results for the demand system (eq. 1) are provided in Table 2.

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[5] Our reference category is represented by households including only one person, living in the South.

[6] In these works, total consumption expenditure is considered as a good proxy for permanent or lifetime income.

Table 2 about here

The parameter values estimated from the demand model are then used to calculate households' income elasticities of each expenditure component (eq. 2). Resulting average elasticities, i.e. evaluated at the mean budget share and the mean total expenditure, are provided in Table 3. It follows that both heating and transport are normal goods and can be considered as necessities, since elasticities are respectively lower and equal to one.

Table 3 about here

On the basis of estimated income elasticities, we can investigate the relationship between pollution and income by examining how a change in the income distribution may affect aggregate emissions.

We consider the empirical distribution of households' total expenditure in 2005. Given the observed distribution (Figure 1), it can be assumed that total expenditure follows a lognormal distribution, i.e. $\ln y \sim N(m, s)$, where m is the mean and s is the standard deviation[7]. In order to determine the impact of an income change on aggregate emissions, we replicate the exercise carried out in [4] and simulate a change in the expenditure distribution. Specifically, we increase/decrease the value of s in the lognormal distribution while adjusting the value of m to keep average expenditure unchanged. In this way we simulate a rise/reduction of the overall inequality, compared to the reference case. Results are displayed in Table 4.

Figure 1 about here

Table 4 about here

The low variance case corresponds to a standard deviation $s(low) = 0.5s$,

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[7] The estimated mean and standard deviation are respectively equal to 6.849 and 0.492. Given this values for the lognormal distribution, the mean ($\bar{y}$) and standard deviation (σ) for y are equal to 1064.86 and 557.67.

whereas the high variance case is defined by $s(high) = 1.5s$ (corresponding standard deviation values for y are indicated with σ in Table 4). The change in the degree of inequality is expressed by the coefficient of variation, defined as the ratio between the standard deviation and mean expenditure.

Changes in the income distribution imply changes in households' consumption patterns on the basis of estimated income elasticities (eq. 2); changes in consumption in turn affect the emissions of each pollutants, according to eq. 3. As Table 4 reveals, a reduction in the degree of inequality would lead to an increase in the level of aggregate emissions for all types of pollutants, whereas a higher inequality would reduce total pollution. The magnitude of these changes is particularly relevant for SO_x, which is mainly related to fuel consumption for heating. Our results then confirm similar results for other countries (see [4] and [7], for instance), suggesting that also in Italy a trade-off between reducing income disparities and controlling polluting emissions seems to exist.

5 Discussion

Results shown in section 4 mimic those obtained in [4] using Swedish data: with reference to CO2, SO2, PM10 and NOx, the pollution–income relationships are all strictly concave, at least in a close neighbourhood of observed income and pollution. The result that more equalization of income will lead to higher direct households emissions may have particularly strong policy implications. It is therefore important to further investigate the robustness of the result. The aim of this section is to show that such result is, at least in the Italian household framework and with reference to direct emissions, not robust to changes in the underlying assumption. More specifically, removing away the constant emission intensities hypothesis is likely to lead to substantially different implications. A flavour of such conclusion might be obtained if we assume that emission intensities are a function of income, i.e. $\theta_m = \theta_m(Y)$, and modify (3) to account for such a change:

$$\frac{\partial E_m}{\partial Y} = \sum_{j=1}^{k} \frac{\partial x_j}{\partial Y} \theta_m + \sum_{j=1}^{k} x_j \frac{\partial \theta_m}{\partial Y} \tag{4}$$

Comparing (3) with (4) it is clear that a redistribution reducing inequality might, in principle, lead to a decrease in emissions. This might happen when θ_m increases with income, so that resitributing to the poor implies a decrease in the environmental impact of household consumption. In Table 5, we report the change in CO2 emissions stemming from the same redistribution exercise performed in Table 4. The differnce among the two tables lies in the assumed behavior for θ_{CO2}: in Table 4 it is constant, while in Table 5 it is increasing and convex in income. The shape of the $\theta_{CO2}(Y)$ function is calibrated so that total CO2 emissions before redistribution are the same. Clearly, moving from Table 4 to Table 5 results are completely reversed, and reducing inequality improves direct households emissions and vice versa.

Table 5 about here

The assumption of an increasing and convex relationship between emission intensities and income might of course appears as arbitrary as the assumption of constant emission intensities. A clear consequences of our exercise is, however, to show that the knowledge of the precise shape of θ_m is crucial to obtain robust results.

6 Concluding remarks

This paper rests on the recent literature focusing on the relevance of income distribution for correctly interpreting the income-pollution relationship.

Specifically, our work is based on the analysis carried out in [4], where the link between consumption and pollution is empirically assessed for Sweden. By replicating their analysis for Italy we obtained similar results for the income-pollution relation. Specifically, our empirical analysis shows that an income redistribution reducing inequality would lead to higher emissions, whereas an increased inequality scenario would mitigate environmental problems.

According to our present results, then, also in Italy reducing inequality and abating emissions objectives go in opposite directions, suggesting the unpleasant conclusion that a higher inequality scenario can be beneficial for the environment. Nevertheless, such result (confirmed by other works, as noted above) follows from some intrinsic limitations of the empirical framework proposed by the literature, the most important being the assumption of a linear relation between emissions and consumption. By relaxing this hypothesis and also extending the analysis for considering durable goods and services, the income-pollution relationship can change direction, as it is the case when emission intensity is increasing in income. A full understanding of the relationship between inequality and households direct emissions requires therefore a more precise knowledge of the links between emission intensities and other relevant economic variables, such as income, consumption etc. Once more, the rather limited interest on redistributional issues in the current literature is no longer justifiable.

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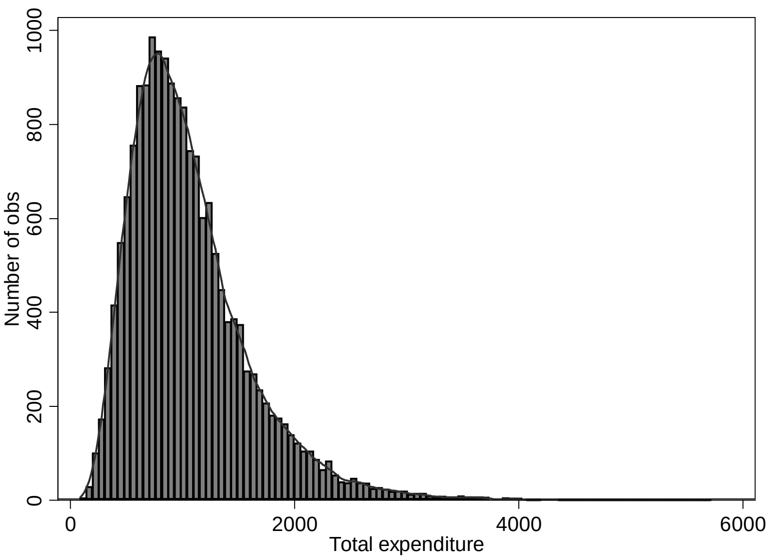

Figure 1 - Distribution of total expenditures on non-durable goods in 2005

Table 1 - Budget and emission shares (year 2005)

	Budget share	Emission share				Emission intensities			
		CO_2	NOx	SOx	PM_{10}	CO_2	NOx	SOx	PM_{10}
Transport	14.0	46.7	75.2	6.4	45.8	1.79818	0.00573	0.00003	0.00050
Heating	13.0	52.8	24.8	93.6	54.2	1.87047	0.00174	0.00039	0.00055
Others	73.0	0.5	-	-	-	0.00077	-	-	-
Sum	100.0	100.0	100.0	100.0	100.0				

Note: Percentage of total expenditure and total emissions. Emission intensities are in tons/euro. The contribution of "other expenditures" to direct emissions is negligible for CO2 and is not reported for other pollutants.

Table 2

Parameter estimates from the demand model in 2005
(t-ratio within parentheses)

	Heating	Transport
Intercept of the expenditure equation		
Constant	1.24 (5.62)	0.36 (1.48)
Couple	-1.13 (-4.23)	0.02 (0.07)
Ch1	-0.88 (-2.95)	-0.40 (-1.22)
Other_fam type	-0.57 (-2.35)	-0.07 (-0.27)
North_centre	-0.21 (-1.22)	0.49 (2.57)
Linear expenditure coefficients		
Constant	-0.31 (-4.57)	0.02 (0.32)
Couple	0.36 (4.4)	-0.05 (-0.52)
Ch1	0.28 (3.16)	0.08 (0.79)
Other_fam type	0.19 (2.6)	-0.03 (-0.35)
North_centre	0.06 (1.17)	-0.13 (-2.31)
Quadratic expenditure coefficients		
Constant	0.02 (3.98)	-0.01 (-1.25)
Couple	-0.03 (-4.51)	0.006 (0.85)
Ch1	-0.02 (-3.3)	-0.003 (-0.39)
Other_fam type	-0.01 (-2.74)	0.005 (0.88)
North_centre	-0.004 (-1.02)	0.009 (2.07)

Notes: Couple, without children; Ch1, couple with 1 child; Other_fam type, couple with more than 1 child, single parent, other family types.

Table 3
Estimated demand elasticities

	Budget elasticity
Heating	1.0551 (.025)
Transport	0.9448 (.018)

Note: Standard error are in parentheses

Table 4 - Aggregate emissions in different income distribution scenarios

	Low variance	Reference	High variance
Std deviation (s)	0.25	0.49	0.74
Std deviation (σ)	242.7	557.67	1055.13
Coefficient of variation	0.23	0.52	0.99
CO_2	10138.46 (+3.66%)	9780.10	9327.27 (-4.63%)
NO_x	22.85 (+2.21%%)	22.36	21.66 (-3.11%)
SO_x	0.96 (+6.71%)	0.90	0.83 (-7.82%)
PM_{10}	2.89 (+3.73%)	2.78	2.65 (-4.70%)

Note: Emissions are in thousands of tons.

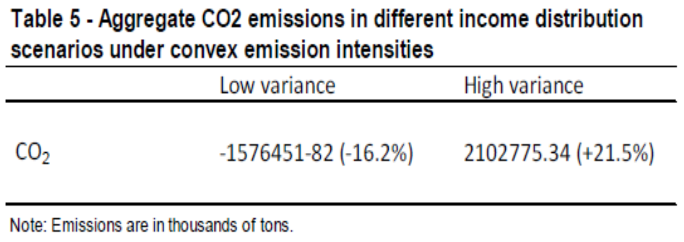

Table 5 - Aggregate CO2 emissions in different income distribution scenarios under convex emission intensities

	Low variance	High variance
CO_2	-1576451-82 (-16.2%)	2102775.34 (+21.5%)

Note: Emissions are in thousands of tons.