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# How to make a carbon tax reform progressive: The role of subsistence consumption\*

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## Abstract

This letter analyzes the distributional effects of a carbon tax reform when households must consume carbon-intensive goods above a subsistence level. The reform is progressive if revenues are recycled as uniform lump-sum transfers, in other cases it is regressive.

*JEL classification:* D30, D60, E62, H22, H23

*Keywords:* Carbon tax reform, distribution, revenue recycling, inequality, non-homothetic preferences

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# 1 Introduction

Mitigating climate change requires substantial reductions in carbon emissions, which can be achieved most cost-effectively by carbon pricing (Tietenberg, 1990). An important obstacle to introducing carbon pricing are distributional concerns: Pricing emissions in developed countries is often believed to harm the poorest part of the population due to the higher share of their income these households spend on carbon-intensive goods (Grainger and Kolstad, 2010; Fullerton, 2011; Combet et al., 2010).

Grainger and Kolstad (2010) show, for the case of the US, that there is a subsistence level for most carbon-intensive goods and that a price increase in these goods is the main driver behind the regressivity of carbon taxes. This mechanism, has received scarce attention in the theoretical literature on the distributional implications of carbon tax reforms.

Analyzing the distributional effects of a carbon tax reform while accounting for a subsistence level of carbon-intensive goods is the purpose of the present note. We use a stylized analytical model that features two consumption goods, one of which is assumed to be carbon-intensive. Households differ only in their productivity and must consume a minimal amount of the carbon-intensive good to survive. We are only concerned with the short-term distributional effects of a carbon tax reform, i.e. how setting a price on carbon impacts inequality<sup>1</sup>, which we believe to be decisive for political decision making.

We find three main results. First, when the tax revenue is returned to the households via linear income tax cuts, or in proportion to their productivity, the overall effect of the tax reform is regressive. Second, for the case of uniform lump-sum recycling, the overall effect of the tax reform is progressive. Finally, we show that when setting the subsistence level of carbon-intensive consumption to zero, regressive policies appear to be distribution-neutral.

Previous literature either relies on large numerical models (Rausch et al., 2010, 2011) or on rather specific modeling assumptions (Fullerton and Monti, 2013; Chiroleu-Assouline and Fodha, 2014).<sup>2</sup> In fact, there seems to be some disagreement in the theoretical literature on the extent to which the regressivity of a carbon tax can be reduced by the recycling of its revenues: Fullerton and Monti (2013) show that in a model with household heterogeneity in skills, “returning all of the revenue to low-skilled workers is still not enough to offset higher product prices.” (p. 539) On the other hand, Chiroleu-Assouline and Fodha (2014) demonstrate that an environmental

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<sup>1</sup>This permits us to abstract from major factors usually discussed in the context of climate policy, such as environmental damages and structural change.

<sup>2</sup>A parallel strand of literature studies the interplay of carbon and income taxes in optimal taxation frameworks (Cremer et al., 1998; Jacobs and De Mooij, 2015; Klenert et al., 2016). Optimal carbon tax reforms under equity constraints are analyzed by Kaplow (2012).

tax can always be designed to be Pareto-improving if the revenue is used for a progressive reform of the wage tax. They use a model in which pollution is a by-product of capital and hence interpret a capital tax as an environmental tax. Households differ in skill level and age. Both studies mention a subsistence level of polluting consumption as at least partially responsible for the regressivity of a carbon tax, but refrain from modeling it by means of non-homothetic preferences.

A large body of literature confirms that low income households spend a larger percentage of their income on carbon-intensive goods than high income households, notably on heating, electricity and food (see e.g. Grainger and Kolstad 2010; Flues and Thomas 2015 and Wier et al. 2001).<sup>3</sup> In the following we analyze the distributional impacts of a carbon tax reform when this mechanism is modeled explicitly.

## 2 The model

We use a two-sector model in which  $N$  households are distinguished by their productivity. Households need to consume a minimum amount of the polluting good. Since we only consider the short term (i.e. structural change is negligible), we use a static model. Furthermore we assume that commodity prices are fixed. Sources-side effects, which are likely to be progressive (Dissou and Siddiqui, 2014), are hence ignored and all the tax burden is assumed to rest on the consumers.<sup>4</sup>

**Households:** The households are distinguished only by their productivity  $\phi_i$ ,  $i = 1 \dots N$ . Each household is endowed with one unit of a production factor. A share  $l_i$  of the production factor is used at home and can be interpreted as leisure. For the remaining share  $(1 - l_i)$ , the household receives a rental rate  $w$ , so the households' incomes  $I_i$  are given by

$$I_i = \phi_i w (1 - l_i) (1 - \tau_w^0 + \tau_w). \quad (1)$$

Here  $\tau_w^0$  denotes the income tax before the carbon tax reform and  $\tau_w$  is a potential (linear) income tax reduction financed by carbon tax revenues. We normalize the household productivities so that  $\sum_{i=1}^N \phi_i = 1$ .

Households derive utility from the consumption of clean goods  $C_i$ , polluting goods  $D_i$  and leisure  $l_i$ . They have identical non-homothetic preferences (due to the minimum-consumption requirement  $D_0$  for the polluting commodity) and maximize utility, given by

$$U(C_i, D_i, l_i) = C_i^\alpha (D_i - D_0)^\beta l_i^\gamma, \quad (2)$$

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<sup>3</sup>This might not be the case for developing countries, see Sterner (2011).

<sup>4</sup>For a study that also includes sources-side effects, see our more extensive numerical analysis (Klenert et al., 2016). However, accounting for potentially progressive effects of endogenous prices below would likely make our result from Proposition 2 stronger, while the effect on the result from Proposition 1 is unclear.

with  $\alpha, \beta, \gamma > 0$ . We assume that  $\alpha + \beta + \gamma = 1$  to obtain more tractable formulas, but our findings also hold for  $\alpha + \beta + \gamma \neq 1$ . The utility function is not defined for  $D_i < D_0$ . The budget equation is given by

$$C_i \cdot p_C + D_i \cdot p_D \cdot (1 + \tau) = I_i + L_i, \quad (3)$$

with  $\tau$  denoting a tax on the polluting commodity and  $L_i$  a lump-sum transfer. We assume constant commodity prices.

Maximizing utility (2) subject to the budget constraint (3) yields the first-order conditions of the households, which can be transformed to obtain explicit expressions for  $C_i$ ,  $D_i$  and  $l_i$ :

$$C_i = \frac{\alpha}{p_C} (\phi_i w (1 - \tau_w^0 + \tau_w) + L_i - D_0 p_D (1 + \tau)), \quad (4)$$

$$D_i = \frac{\beta}{p_D (1 + \tau)} (\phi_i w (1 - \tau_w^0 + \tau_w) + L_i - D_0 p_D (1 + \tau)) + D_0, \quad (5)$$

$$l_i = \frac{\gamma}{\phi_i w (1 - \tau_w^0 + \tau_w)} (\phi_i w (1 - \tau_w^0 + \tau_w) + L_i - D_0 p_D (1 + \tau)). \quad (6)$$

**Government:** The (non-optimizing) government has a fixed spending requirement  $G$ , which is financed by the (pre-existing) income tax  $\tau_w^0$ . Additional revenue can either be returned to the households via lump-sum transfers  $L_i$  or via reductions in the income tax  $\tau_w$ . The government's budget constraint thus reads:

$$G + \sum_{i=1}^N L_i + \sum_{i=1}^N \phi_i w (1 - l_i) \tau_w = \tau \cdot D \cdot p_D + \sum_{i=1}^N \phi_i w (1 - l_i) \tau_w^0. \quad (7)$$

### 3 Results

We analyze the distributional implications of three carbon tax reforms. Each reform consists of a carbon tax combined with a revenue recycling-scheme. We consider recycling through (i) lump-sum transfers in proportion to household productivities, (ii) linear income tax reductions and (iii) uniform lump-sum transfers.

We show in Proposition 1 that in the first and second case, inequality increases. In the third case, inequality is reduced (Proposition 2). Finally, we demonstrate in Proposition 3 that recycling the revenues as in the first and second case is distribution-neutral when the subsistence level of polluting consumption equals zero.

We consider the utility ratio of two households as a measure of the distributional impacts of the carbon tax reform, since analyzing the income

ratios would not capture the necessity of consuming at least an amount  $D_0$  of the polluting commodity. We verified numerically that our findings also hold when the Gini coefficient in utility is used as a measure of inequality.<sup>5</sup>

The ratio of the indirect utilities of households  $i$  and  $j$  is:

$$\begin{aligned}\frac{U_i}{U_j} &= \frac{C_i^\alpha (D_i - D_0)^\beta l_i^\gamma}{C_j^\alpha (D_j - D_0)^\beta l_j^\gamma} \\ &= \left(\frac{\phi_j}{\phi_i}\right)^\gamma \left(\frac{(\phi_i w(1 - \tau_w^0 + \tau_w) + L_i - D_0 p_D(1 + \tau))}{(\phi_j w(1 - \tau_w^0 + \tau_w) + L_j - D_0 p_D(1 + \tau))}\right)\end{aligned}$$

We denote by  $(U_i/U_j)^{\text{BT}}$  the ratio of utilities before taxes,  $(U_i/U_j)^{\text{AT-P}}$  the case of a tax with the revenues recycled in proportion to each household's productivity  $\phi_i$ ,  $(U_i/U_j)^{\text{AT-T}}$  the case of a tax with the revenues recycled via linear income tax reductions and  $(U_i/U_j)^{\text{AT-U}}$  the ratio of utilities after taxes with uniform lump-sum recycling of the revenues:

$$\left(\frac{U_i}{U_j}\right)^{\text{BT}} = \left(\frac{\phi_j}{\phi_i}\right)^\gamma \left(\frac{\phi_i w(1 - \tau_w^0) - D_0 p_D}{\phi_j w(1 - \tau_w^0) - D_0 p_D}\right), \quad (8)$$

$$\left(\frac{U_i}{U_j}\right)^{\text{AT-P}} = \left(\frac{\phi_j}{\phi_i}\right)^\gamma \left(\frac{\phi_i(w(1 - \tau_w^0) + \tau p_D D) - D_0 p_D(1 + \tau)}{\phi_j(w(1 - \tau_w^0) + \tau p_D D) - D_0 p_D(1 + \tau)}\right), \quad (9)$$

$$\left(\frac{U_i}{U_j}\right)^{\text{AT-T}} = \left(\frac{\phi_j}{\phi_i}\right)^\gamma \left(\frac{\phi_i w(1 - \tau_w^0 + \tau_w) - D_0 p_D(1 + \tau)}{\phi_j w(1 - \tau_w^0 + \tau_w) - D_0 p_D(1 + \tau)}\right), \quad (10)$$

$$\left(\frac{U_i}{U_j}\right)^{\text{AT-U}} = \left(\frac{\phi_j}{\phi_i}\right)^\gamma \left(\frac{\phi_i w(1 - \tau_w^0) + \tau D p_D \frac{1}{N} - D_0 p_D(1 + \tau)}{\phi_j w(1 - \tau_w^0) + \tau D p_D \frac{1}{N} - D_0 p_D(1 + \tau)}\right). \quad (11)$$

**Proposition 1.** *The incidence of a tax on the polluting good is regressive if the revenues are recycled*

- (a) *in proportion to each household's productivity  $\phi_i$  (i.e.  $L_i = \phi_i \tau p_D D$  and  $\tau_w = 0$ ).*
- (b) *via linear income tax cuts  $\tau_w$  (i.e.  $\tau_w w \sum_{i=1}^N \phi_i(1 - l_i) = \tau p_D D$  and  $L_i = 0$ ).*<sup>6</sup>

<sup>5</sup>These results are available upon request.

<sup>6</sup>Some argue that using carbon tax revenues for rebates in a pre-existing income tax system does not only reduce pollution but also enhances efficiency (Goulder, 1995; Bovenberg, 1999). Proposition 1 (b) implies that reaping such an additional benefit might come at the cost of increased inequality (at least if the tax cut is linear).

The before-taxes utility ratio given in Equation (8) is proportional to the sum of a utility-increasing ( $\phi_k w(1 - \tau_w^0)$ ) and a utility-reducing term ( $-D_0 p_D$ ) with  $k = i$ , divided by the same sum with  $k = j$ . In the proof we show that recycling the carbon revenue as in Equations (9) and (10) increases the utility-reducing term more strongly than the utility-increasing term, which makes the policy regressive.

*Proof.* For the proof of part (a), it suffices to demonstrate that  $(U_i/U_j)^{\text{AT-P}} < (U_i/U_j)^{\text{BT}}$  for  $\phi_j > \phi_i$ .

By introducing the auxiliary variables  $A$  and  $B$  we transform Equation (9) into

$$\left(\frac{U_i}{U_j}\right)^{\text{AT-P}} = \left(\frac{\phi_j}{\phi_i}\right)^\gamma \left(\frac{\phi_i A(1 + \frac{B}{A}) - D_0 p_D(1 + \tau)}{\phi_j A(1 + \frac{B}{A}) - D_0 p_D(1 + \tau)}\right), \quad (12)$$

with  $A = w(1 - \tau_w^0)$  and  $B = \tau p_D D$ .

Similarly  $(U_i/U_j)^{\text{BT}}$  can be transformed:

$$\left(\frac{U_i}{U_j}\right)^{\text{BT}} = \left(\frac{\phi_j}{\phi_i}\right)^\gamma \left(\frac{\phi_i A - D_0 p_D}{\phi_j A - D_0 p_D}\right).$$

We can ignore the constant term  $(\phi_j/\phi_i)^\gamma$  which appears in both utility ratios. It hence suffices to work with the second term. In both the numerator and the denominator of Equation (12), a positive and a negative term remain. The positive term increases in  $B/A$ , which increases the utility ratio (and thus decreases inequality). Similarly, the negative term ( $-D_0 p_D$ ) increases in  $\tau$ , which decreases the utility ratio (and thus increases inequality). We can infer from this expression directly that the distributional effect of a carbon tax reform is neutral if  $B/A = \tau$ , since in that case the term  $(1 + \tau)$  can be eliminated from the fraction and we get  $(U_i/U_j)^{\text{AT-P}} = (U_i/U_j)^{\text{BT}}$ . The distributional effect of a tax reform is regressive if  $B/A < \tau$  and vice versa. It thus remains to show that  $B/A < \tau$ . By inserting the expressions for  $A$  and  $B$ , we get

$$\frac{B}{A} = \frac{\tau p_D D}{w(1 - \tau_w^0)} < \tau.$$

By rearranging, we obtain:

$$p_D D < w(1 - \tau_w^0).$$

The term on left-hand side of this inequality represents total spending on polluting goods (before the tax reform), the term on the right-hand side stands for total income when aggregate leisure is zero (before the tax reform). Since by assumption  $\phi_i$  is strictly smaller than  $\phi_j$ , households with  $j > 1$  always consume positive amounts of leisure and of the clean good. Total spending on polluting goods hence must be lower than total income (when

no leisure is consumed) and the inequality above holds. This implies that  $(U_i/U_j)^{\text{AT-P}} < (U_i/U_j)^{\text{BT}}$ , and closes the proof of part (a).

The proof of part (b) is analogous to that of part (a), using  $B = w\tau_w$  instead. What remains to show is that  $B/A < \tau$ . By inserting the expressions for  $A$  and  $B$  we get:

$$\frac{B}{A} = \frac{\tau_w}{(1 - \tau_w^0)} < \tau. \quad (13)$$

For revenue recycling through income tax cuts, the sum of all income tax rebates equals the total carbon tax revenue:  $\tau_w w \sum_{i=1}^N \phi_i(1 - l_i) = \tau p_D D$ . We use this relationship to eliminate  $\tau_w$  from Equation (13) and obtain:

$$\frac{B}{A} = \frac{\tau p_D D}{(1 - \tau_w^0) w \sum_{i=1}^N \phi_i(1 - l_i)} < \tau.$$

By rearranging, we get:

$$p_D D < (1 - \tau_w^0) w \sum_{i=1}^N \phi_i(1 - l_i).$$

The term on the left-hand side of this inequality stands for total spending on polluting goods (before the tax reform), the term on the right-hand side for total income (before the tax reform). For the same reason as in the proof of part (a), this inequality holds.  $\square$

**Proposition 2.** *The tax reform is progressive for uniform lump-sum redistribution of the revenues (that is  $L_i = L = \tau p_D D/N$  for  $i = 1, \dots, N$  and  $\tau_w = 0$ ).*

The intuition behind the subsequent proof is similar to the intuition behind the proof of Proposition 1: in the case of a carbon tax with uniform lump-sum recycling, a positive (utility-enhancing) and a negative (utility-reducing) term are added to the numerator and the denominator of the before-taxes utility ratio  $(U_i/U_j)^{\text{BT}}$ . Since the transfers are uniform, these terms are constant across households. We demonstrate that the sum of both terms is positive, which reduces inequality.

*Proof.* Two terms are added to both the numerator and the denominator of the before-taxes utility ratio  $(U_i/U_j)^{\text{BT}}$  to obtain the after-taxes utility ratio  $(U_i/U_j)^{\text{AT-U}}$ :  $-D_0 p_D \tau < 0$  stands for a decrease in utility due to the tax on subsistence consumption and  $\tau p_D D/N > 0$  stands for an increase in utility due to the revenue recycling. Adding up these two terms yields:

$$\tau p_D D/N - D_0 p_D \tau = p_D \tau (D/N - D_0) > 0.$$

This expression is strictly bigger than zero since we assume that  $\tau, p_D > 0$  and  $\phi_i < \phi_j$ . Therefore all agents with  $j > 1$  have a level of polluting



consumption that is higher than the subsistence level  $D_0$ , so the average level of polluting consumption,  $D/N$ , is always higher than the subsistence level  $D_0$ . The proof is then completed by using the elementary relation

$$m < s \Rightarrow \frac{m}{s} < \frac{m+t}{s+t}, \quad \text{for } t > 0 \quad \text{and } m, s > 0,$$

with  $m = \phi_i w(1 - \tau_w^0) - D_0 p_D$ ,  $s = \phi_j w(1 - \tau_w^0) - D_0 p_D$  and  $t = -D_0 p_D \tau + \tau D p_D / N$ .

□

**Proposition 3.** *For a subsistence level of polluting consumption of zero ( $D_0 = 0$ ), the revenue-recycling mechanisms examined in Proposition 1 are distribution-neutral.*

Proposition 3 demonstrates that it is only our assumption of a subsistence level of polluting consumption that drives the results of Proposition 1. The result presented in Proposition 2 is independent of the level of  $D_0$ .

*Proof.* Setting  $D_0 = 0$  in Equations (8), (9) and (10) yields the desired result.

□

## 4 Conclusion

In this note we demonstrate conceptually that carbon-intensive subsistence consumption is the key to understanding the distributional effects of a carbon tax reform. We confirm that such a reform is regressive if revenues are recycled by lump-sum transfers that are in proportion to the households' productivities, and if revenues are recycled via linear income tax cuts. By contrast, a carbon tax reform can be made progressive by recycling the revenues as *uniform* lump-sum transfers. No additional assumptions are required to obtain our analytical results, which makes the modeling strategy transparent and our results robust.

Several extensions of our framework are conceivable, but go beyond the scope of this letter. Examples include non-linear income tax reductions, price effects and taxing emissions instead of output. We treat these cases in a numerical study (Klenert et al., 2016). Moreover, long-term consequences of a carbon tax reform would need to be studied in a model with structural change so that a decarbonization of the economy is possible.

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