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Local air pollution and global climate change taxes: a distributional analysis

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Local air pollution and global climate change are two significant environmental problems which are interrelated. Some recent papers examine them together, but most of the relevant literature has focused either on climate change alone or on the ancillary benefits of mitigating it (in terms of air pollution). In regard to distribution, most publications have focused on the impacts of climate change-related taxes such as excise duties on CO_2, energy or fuels. This paper explores the distributional implications of policies for taxing local air pollution and compares them with climate change taxes. The framework of taxation on air pollution is based on the estimated damage associated with the main local air pollutants, while the climate change framework is based on a CO_2 tax. The case of Spain is examined, using an Input-Output model in combination with a micro-simulation model. The distributional implications of a revenue-neutral tax reform are also explored. We find that taxes on local pollutants are more regressive than those levied on climate change pollutants, because the goods implicitly taxed have a greater weight in the consumer basket of low income groups, even if the tax revenues are recycled.

Key words: Environmental Tax Reform; Distributional Impact; Local air pollution taxes; global climate change taxes

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1. Introduction

Global climate change (GCC) and local air pollution (LAP) are two significant, interrelated environmental concerns. Emissions from the combustion of fossil fuels contribute to both, but the best options for mitigating them may be different. Most of the relevant literature to date has dealt with these two problems separately or has focused mainly on the ancillary benefits in terms of LAP of GCC mitigation policies (see for example OECD, 2001 or Barker & Rosendahl, 2000). However, recently some authors (Xu & Masui, 2009) have started to explore the matter from the opposite side, i.e. to examine the GCC ancillary benefits of LAP mitigation policies, given the slow progress of international agreements on climate change and especially the fact that the health effects of pollution are a more immediate issue for developing countries.[1] Finally, Bollen et al. (2009) have assessed the effects in a cost-benefit analysis framework of tackling these two problems in isolation or in combination. According to their results "LAP control combined with GCC policy creates an extra early-kick-off for the transition towards climate friendly energy supply" (Bollen et al., 2009, page 179).

For many countries, one of the difficulties of implementing GCC policies lies in their distributional implications. The distributional impacts on households of energy and carbon taxes, for example, have been investigated and many studies find that they tend to be regressive, i.e. they affect low income households more. This is observed in early studies such as Poterba (1991) and Pearson & Smith (1991). Poterba (1991) finds regressivity in motor fuel taxes, though it is low when the results are expressed as a proportion of expenditure.[2] Pearson & Smith (1991) also show that a carbon tax in Europe would be regressive, but there are differences from one country to another. More recent papers for a panel of European countries (such as Ekins et al., 2011 and Barker & Köhler, 1998) also find major country-to-country differences. In these studies GCC tax regressivity is caused by home energy use (lighting and heating), but the results become ambiguous when the analysis is focused on motor fuel taxes. The differences between countries are due mainly to differences in the type of tax, consumer patterns, income level and energy and transport infrastructures.[3]

Most studies find regressivity in GCC related taxes, but this conclusion cannot be taken as a rule because it depends on the case study. There are papers that do not find regressivity. For example Labandeira & Labeaga (1999) for Spain, Sterner (2012) for a panel of European countries, and Tiezzi (2005) for Italy.

The degree of substitutability of the goods taxed is essential in explaining welfare impacts. For example, the existence or not of a good public transport network is basic in explaining household motor fuel expenditure. In countries or regions with poor public transport, the tax on motor fuel would be more regressive because the lowest income groups in these regions or countries use more private transport than their peers in regions with good public transport infrastructures. In this way, the tax regressivity is due to the possibility of substitution between public and private transport. In that regard, the relevant literature

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[1] According to WHO estimates, LAP is also one of the leading causes of death in developing countries (WHO, 2009).

[2] The different results between annual income and other proxies of lifetime income are due to the fact that many households belonging initially to the lowest income group are not poor permanently (e.g. students). Other papers show that annual income overestimates distributional effects. See for example Feng et al. (2010), Metcalf (1999), Sterner, (2012), Wier et al. (2005). Only Rausch et al. (2011) fail to find evidence that annual income overestimate distributional impacts. Most of these studies look at snapshots of taxes in one year relative to a proxy for lifetime income, which is often current consumption.

[3] There are other studies that find regressive effects in some countries (e.g. Metcalf et al., 2010 for the US, Wier et al., 2005 for Denmark, Feng et al., 2010 for the U.K., Kerkhof et al., 2008 for The Netherlands, and Brännlund & Nordström, 2004 for Sweden) because the tax is levied on goods which are proportionally consumed more by low income households, especially consumption linked to home energy use.

shows also that tax impacts are higher in rural areas than in urban ones (e.g. Labandeira et al., 2004; Wier et al., 2005; Romero et. al., in press), because urban households have fairly easy access to public transport.

The distributional impacts of these taxes depend also on the use of new revenues. As proposed in the literature on double dividends (see Goulder, 1995), the efficiency of the tax system could be improved if other distortionary taxes such as those on capital or labor, are reduced. However, the revenues could also be used to fund lump-sum transfers to compensate groups who have been left worse off. Rausch et al. (2011) show (using a CGE model for the US) that lump-sum transfers to households are more progressive than lowering income tax, which proves highly regressive.[4] However, there could be a trade-off between efficiency and equity (distributional effects) depending on the revenue-recycling scheme. For example, in countries with an inefficient labor market a reduction in taxes on labor could reduce unemployment and thus have a positive efficiency impact, but the distributional implications may not be positive. Barker & Khöler (1998) show that a reduction in tax on labor is regressive, but recycling via lump-sum transfers is progressive.

To date the relevant literature has concentrated on the distributional implications of GCC policies, but there have been a few papers that have investigated the distributional effects of LAP policies. For example, Parry (2004) assesses the distributional effects of emission permits for CO_2, NOx, and SO_2, and finds that CO_2 permits are more regressive than SO_2 permits but less than NOx ones. Metcalf (1999) assesses the distributional effects of various environmental taxes, and finds that an air pollution tax is less regressive than a carbon tax or a motor fuel tax.[5] Due to this shortage of studies,[6] it is not yet clear what the effect of LAP tax is on the distribution of the tax burden across income groups.

This paper examines and compares in detail the distributional effects of an LAP tax (based on the internalization of the external costs of several pollutants). We also run a compressive comparison with a GCC tax (tax on CO_2).[7] We use an Input-Output model which calculates the price change caused by these taxes as applied to producers, combined with a micro-simulation model that calculates distributional effects on consumers for the case of Spain. We calculate the welfare loss and the deadweight loss by expenditure deciles and also the main progressivity and redistribution indexes such as the Reynolds-Smolensky and Kawani indexes. Finally, we also explore the distributional effects of a revenue-neutral recycling scheme through a reduction in taxes on labor (social security contributions paid by employers).

The rest of the paper is structured as follows: Section 2 presents the methodology and data, Section 3 describes the different tax scenarios proposed, Section 4 presents the results, and Section 5 sets out our conclusions.

[4] Ekins et al. (2011), Barker & Khöler (1998) and Metcalf (1999) also find that revenue recycling through distortional taxes could be more regressive than other types of revenue recycling. Also, Gonzalez (2012) finds that in Mexico and the US recycling through tax cuts on manufacturing is regressive, while recycling through food subsidies is progressive.

[5] But the results of Metcalf (1999) are not definitive because if impacts are studied with lifetime income measures the results are different: with lifetime income measures an air pollution tax is more regressive than a motor fuel tax.

[6] Although, there are work that assess the economic effects of the internalization of the external costs of local air pollution. See for example Kiulia et al. (2013).

[7] Although the environmental taxes must be complemented with other instruments in long term, are successful in short terms (del Río González, 2008).

2. Methods and data

2.1. Methods

The empirical analysis involves two stages: In the first the price changes produced by the environmental tax are studied through an input-output price model. In the second stage a microsimulation model is used to calculate the distributional effects of price changes. This is done with the microsimulation tool developed by Sanz et al. (2003).

2.1.1 Input–Output model

Price changes are assessed through an Input–Output (IO) model. This model assumes that the production technology is linear, i.e. that each sector produces a single good or service under fixed coefficients by combining intermediate inputs, primary factors (labor and capital) and imports. This means that there is no possibility of substitution between inputs and taxes on producers are therefore passed on to consumers (Kerkhof et al., 2008 or Wier et al., 2005). Although this is a strong assumption in the long term, it is reasonable for assessing short-term impacts.

The input-output price model has been used in numerous papers that assess the effects of environmental taxes in Spain. For example, Labandeira & Labeaga (1999) use an input-output model to assess the distributional effects of carbon taxation in Spain. Another example is the paper by Buñuel Gonzalez (2011), which uses an input-output model to calculate the price change from carbon taxation on fuels.

In particular, we use an input-output model based on Leontief's price model with differentiation of imports, so the taxes proposed do not alter import prices.[8] This model is similar to the one used by Buñuel Gonzalez (2011). We also include emissions from the different production sectors[9] and the cost of the associated externality if a tax is levied on it.

The following equation can be used to evaluate the effects on prices:

$$P_j = \sum_{i=1}^{21} p_i a_{ij} + p_{m_i} a_{m_{ij}} + (1 + s_j) w l_j + r k_j + \sum_{z=1}^{21} c_z E_{zj} \tag{1}$$

where P_j is the price of production in sector j, a_{ij} stands for the input-output coefficients, and p_i is the price of production in sector *i*. The term p_{m_i} represents the price of imports, and $a_{m_{ij}}$ is the coefficient that represents imported goods per euro of output. Further, l_j, k_j, and E_{zj} are, respectively, labor, capital, and emissions of pollutant *z* from sector *j*. The terms w, r, and c_z are the price of labor (wage), the price of capital, and the price of pollutant *z*, while s_j is the tax rate of the social security paid per sector. Finally, $\sum c_z E_{zj}$ represents the internalization of the externality or cost generated by each pollutant. When there is no internalization (i.e. no tax on pollutants) its value is zero, but including a tax on a pollutant changes the prices. The size of this effect depends on the level of internalization as it is not necessary to include all social costs.

2.1.2 Microsimulation model

Households may be expected to alter their spending decisions as a result of price changes. A demand model reveals households' behavior and provides a realistic picture of the substitution, own-price and income effects. To assess the distributional effects, a micro-simulation model developed by Sanz et al. (2003) is used.

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[8] The model deals with 21 production sectors. See Appendix 1

[9] See methodology on Environmental Satellite Accounts.

Our micro-simulation model uses an Almost Ideal Demand System (AIDS) designed by Deaton & Muellbauer (1980). The main advantage of AIDS is that it enables a first-order approximation to be made to an unknown demand system. In addition, this model satisfies the consumer axioms and does not impose constraints on the utility function (Sanz et al., 2003). AIDS is based on the assumption that the households will alter their spending decisions as result of price changes as per this equation:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{G}{P}\right) \tag{2}$$

where w_i is the share in expenditure of good i for a particular household, p_j is the price by commodity, P represents the price level, and G is total expenditure. Hence, G/P represents the real expenditure. To satisfy the homogeneity and symmetry constraints required under the theory of consumption, the parameters of this equation are estimated imposing the following conditions (Deaton & Muellbauer, 1980):

$$\sum_{i=1}^{n} \alpha_i = 1 \tag{3}$$

$$\sum_{i=1}^{n} \gamma_{ij} = \sum_{j=1}^{n} \gamma_{ij} = 0 \tag{4}$$

$$\sum_{i=1}^{n} \beta_i = 0 \tag{5}$$

As w_i represents the expenditure share of good i, the sum of w_i should also satisfy the following condition (the micro-simulation model has 16 different consumption groups):

$$\sum_{i=1}^{16} w_i = 1 \tag{6}$$

The performed simulation is based in an indirect tax reform which is equivalent to the price change obtained. This price change is the result calculated with the input-output model. The distributional impacts on the short run effects of the price change are thus examined. The micro-simulation model has 16 different consumption groups, so it calculates the pre- and post-reform price indexes and the sum of the prices of all individual goods weighted by their contribution to the composite category. The pre-reform price for good i is:

$$p_i^0 = \left(1 + t_i^0\right)(z_i) \tag{7}$$

where t_i^0 is the initial VAT rate, and z_i represents the price before tax. Hence the price after tax is

$$p_i^1 = \left(1 + t_i^1\right)\left[\frac{p_i^0}{\left(1 + t_i^0\right)}\right] \tag{8}$$

where t_i^1 is the post-reform VAT equivalent to price change obtained with the input-output model.

Finally, welfare is assessed through Equivalent Variation (EV), which assumes that households reallocate expenditure as result of price change. Given a vector of reference price P_r, the equivalent expenditure is defined as the expenditure level which allows households to achieve a reference level of utility, $v_r(P, G)$, where P and G, respectively, are the effective price and expenditure:

$$V(P_r, G_e) = v_r(P, G) \tag{9}$$

which can be expressed in terms of the expenditure function

$$G_e = e\big(P_r, v_r(P, G)\big) \tag{10}$$

The equivalent variation is then defined as the amount of money that households would be willing to pay to prevent the occurrence of the price change

$$\mathrm{EV} = e(p^1, v^1) - e(p^0, v^1) \tag{11}$$

2.2 Data sources

The input–output model is based on the data from the Symmetric Input–Output Table for 2005 (INE, 2013a). The input–output table is a representation of the uses and resources of the production sectors of the Spanish production system. Measures for the emission of different pollutants per production sector are obtained from the Environmental Satellite Accounts (INE, 2013b). Information on the damage to society caused by air pollution is obtained from CASES (2006).

The basic data used in micro-simulation come from the Spanish Continuous Household Expenditure Survey, EPCF (INE, 2013c). This database provides micro-data which are used for both the estimation and simulation phases of the demand model. The ECPF provides information on consumption patterns as well as some data on household incomes, taxes and household demographic characteristics. It is targeted at 3200 families chosen by sampling techniques, and one eighth of the sample is renewed each quarter. The estimation phase uses ECPF data corresponding to the period from the third quarter of 1985 to the fourth quarter of 1995, whereas the simulation phase uses the 1998 ECPF data as its reference. The information is completed with data from TEMPUS, which provides the price of goods and services consumed by households.

Annual income is often used as a measure of relative well-being for households. However, as detailed before, it is a poor proxy for lifetime income because many low-income households are not poor for life (and vice versa). For example, students tend to have low incomes, but this situation may be transitory. In fact, other papers have shown that the degree of regressivity decreases significantly when other measures of lifetime income are used (Metcalf, 1999; Poterba, 1991). In this study we use expenditure as a proxy of lifetime income, on the grounds that it is a more stable measure than annual income (INE, 2013d) and is widely used elsewhere (see, for example, Parry, 2004). The demand model places the different goods consumed by households in 16 different groups. The goods considered are as per the Classification of Individual Consumption according to Purpose (COICOP). However, the Symmetric Input–Output Table shows the sectoral structure of the economy. The National Classification of Economic Activities (Clasificación Nacional de Actividades Económicas, CNAE) is used to link the different activities with the goods and services in the COICOP.

3. Tax scenarios

The main objective of this study is to compare the distributional effects of local air pollution and global climate change policies. This section presents the two tax scenarios analyzed: a tax on CO_2 (GCC tax) and a Local Air Pollution tax (LAP tax). These taxes are levied on producers and are designed in such a way that the obtained revenues are the same in the two scenarios. The CO_2 tax is used as a benchmark.

Current economic instruments aimed at mitigating Global Climate Change (GCC) focus on CO_2 emissions, because CO_2 is the main contributor to climate change. For this reason, we assess the distributional impacts of a tax on CO_2 aimed at mitigating GCC. Table 1 shows the different CO_2 taxes applied in various European countries[10] and the prices of CO_2 in the European Emission Trading Scheme (EU-ETS). The levied taxes range from €13.5 per ton in Denmark to €108 per ton in Sweden.[11] In the case of the EU-ETS, between January 2011 and December 2012 future prices for 2020 fluctuated between €10.5 and €28 per ton. A look at the damage caused per CO_2, i.e. the social cost of carbon, results in widely varying estimates (Downing et al., 2005) that reflect uncertainties related mainly to damage from climate change and to the difficulties associated with estimating that damage in monetary terms (for a survey see Tol, 2005). For example, according to Nordhaus (2011) the optimal social cost of carbon in 2005 for the US is $12/ton but according to Downing et al. (2005) it could be around $50/ton.

Table 1: Current CO_2 prices/taxes

Country	CO_2 tax (€/ton)
Denmark (2012)	13.5
Finland (2012)	20
Sweden (2012)	108
France (proposal 2011)	17
Max. EU-ETS (2020)	28
Min. EU-ETS (2020)	10.5

Source: adapted from Fuster (2011)

Finally, this study considers a GCC tax of €25 per ton of carbon. This tax is within the range of carbon taxes levied recently in other countries and is also within the expected price range for the EU-ETS in the future. Moreover, this price is similar to the current social cost averaged over various studies as calculated by Tol (2005). Finally, this tax is similar to the taxes on CO_2 applied in other studies for Spain (see Buñuel González, 2011 and Labandeira & Labeaga, 1999). However, it could be changed or increased in the future.

The absolute value of the GCC tax is not so important for a distributional analysis, but it is important that both taxes generate the same revenues. A CO_2 tax of €25 per ton of carbon applied to production sectors would (before any change in the response by producers and consumers is considered) generate revenue to the tune of €7,103M, 0.86% of GDP.

In the case of the LAP tax, we use the external cost or social damage associated with the following main air pollutants: NH_3, NOx, SO_2, NMVOC, and PM_{10} emissions.[12] In 2006, the CASES (Cost Assessment of Sustainable Energy System) Project (Markandya et al., 2010), funded by the European Commission, compiled a complete, consistent assessment of the social cost of these emissions for EU Countries. This project assessed the physical damage caused by these pollutants to human health, crops and buildings/infrastructures and converted it into monetary values. Table 2 shows the social costs per pollutant calculated by CASES for Spain in 2005 in euros per ton. Measurements of this type should be taken with some caution, but they enable taxes to be distributed proportionally between the pollutants. However, full internalization of the external cost of LAP as calculated by CASES would generate more revenue than the GCC tax proposed. Therefore, the LAP tax, equivalent to €25/t of CO_2, represents the internalization of 47.2% of the external costs.

[10] See Fuster (2011) for more details about the carbon tax in the EU.
[11] When it was introduced in 1991 the carbon tax in Sweden was €28/ton, but it is now estimated to be around €108/ton, although some sectors are exempted.
[12] For more information on social damage as calculated by CASES see: http://www.feemproject.net/cases/downloads_presentation.php

Table 2: External cost of local air pollutants in Spain, 2005

	External costs (€/ton)
SOx	4912.2
NOx	3485.0
COVNM	797.3
NH3	5393.9
PM10	16037.5

Source: CASES Project (Markandya et al., 2010)

The tax scenarios proposed are combined with a revenue-neutral tax reform in which the tax revenues from the scenarios are used in full to reduce taxes on labor, specifically social security (SS) contributions paid by employers. There is a large body of literature on improving the efficiency of the tax system (the double dividend hypothesis) with policies of this type (Goulder, 1995) and the objective of this scenario is to assess the distributional effects. To make the reform revenue-neutral, the figure for SS contributions from a tax of €25/t of CO_2 is 7.45%. The tax scenarios are summarized in Table 3.

Table 3: Tax scenarios

Scenarios	Description	Tax Equivalent
GCC tax	Tax on CO2 emissions levied on producers.	€25/t CO2
LAP Tax	Tax on NH3, NOX, SO2, NMVOC, and PM10 emissions levied on producers.	47.2% internalization of external costs
Revenue-Recycling	Reduction in social security contributions paid by employers	7.5% reduction in SS contributions

4. Results

This section presents the results obtained for the two tax scenarios presented in Section 3: the GCC tax and the LAP tax. The impacts on prices obtained with the Input-Output model are presented first, then the distributional effects obtained when those price impacts are factored into the demand model are analyzed. Thirdly, the implications of “recycling” the revenues from each tax scenario are examined, and finally the different aggregate indexes are considered so as to measure the distributional implications consistently and in an overall manner.

4.1 Price impacts

As mentioned above, the input-output model assumes that taxes on sectors are passed on to consumers in the form of higher consumer prices. Figure 1 shows the impact on prices for the five sectors with the highest and lowest impacts on prices changes. Appendix 1 shows all the results for all the sectors.

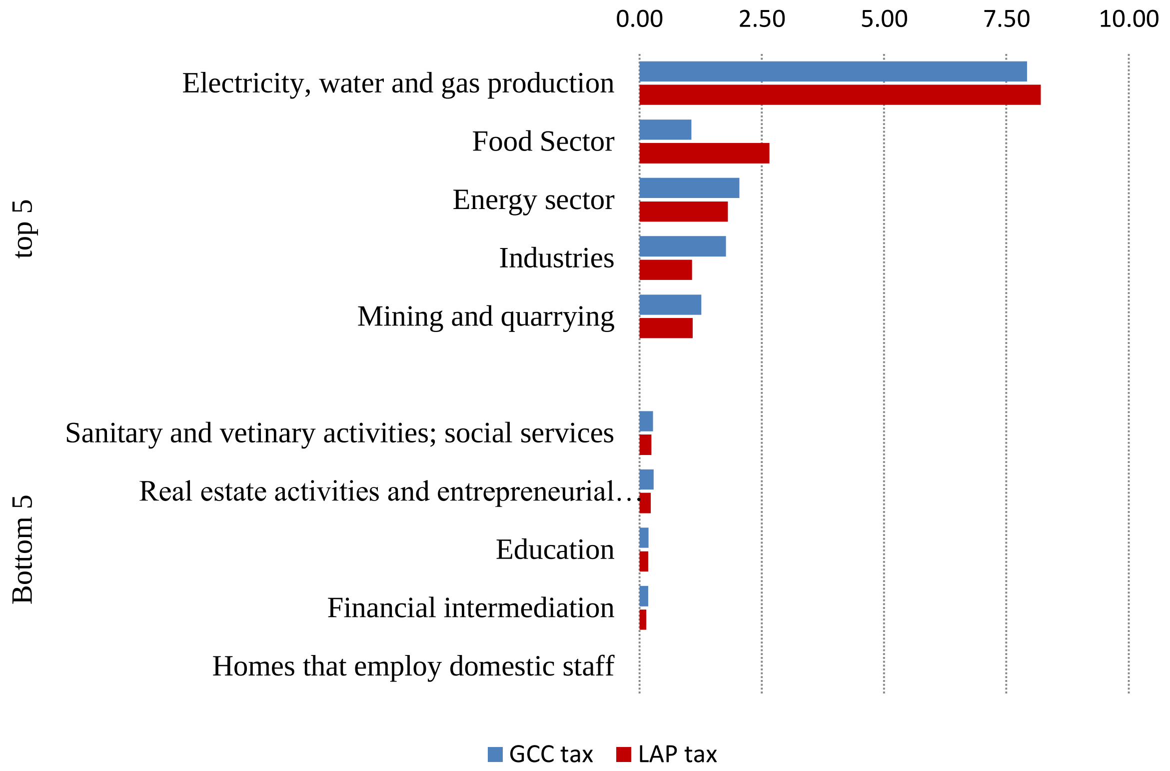

Figure 1: Change (%) in production prices. Top and bottom sectors

Observe that "Electricity, water and gas production", "Energy", "Food", "Industry" and "Mining" are the top five sectors in terms of price impact. These sectors have in common that they are energy-intensive or energy-related. "Electricity, water and gas production" is the sector with the highest impact: it shows a price increase of more than 7.5% in all the tax scenarios. Although all these sectors show similar impacts on prices for the different tax scenarios, there are differences worth mentioning. For example, the price increase for the "Food" sector is higher with an LAP tax than with GCC tax due to emissions of NH_3 produced by animal waste degradation and the use of fertilizer. Similarly, the "Electricity" sector has lower impacts if GCC emissions are considered instead of LAP, due to the large amount of SO_2 emitted by fuel combustion in electricity generation, especially in thermal power stations.

The sectors with the least impact on prices are mainly those that are relatively more labor intensive. "Homes that employ domestic staff", "Education", "Financial intermediation", "Real estate activities" and "Health services" have the lowest price increases, and their impact is almost negligible (see Appendix 1).

The changes observed in the price system can be explained by the direct and the indirect impacts of the tax scenarios. The direct impacts are related to the emissions from each sector (and the subsequent tax imposed) and the indirect impacts are related to the multiplier effects of these direct impacts, which are transmitted to the whole economy through the complex sectorial inter-linkages captured by the Input–Output model. The direct impacts are different for each sector because each tax proposal affects them differently. Consequently, the indirect impacts are also different because each sector thus also affects others in a different way.

Table 4: Cost of tax with respect to production value per sector: top 5 and bottom 5

	Sector	GCC Tax	LAP Tax
Top5			
1	**Electricity, water and gas production**	6.18%	6.46%
2	**Energy sector**	1.70%	1.50%
3	**Food Sector**	0.33%	1.44%
4	**Transport and communications**	0.62%	0.51%
5	**Industries**	0.96%	0.43%
Bottom 5			
5	**Hotel management**	0.01%	0.01%
4	**Financial intermediation**	0.02%	0.00%
3	**Real estate activities and entrepreneurial services**	0.00%	0.00%
2	**Education**	0.00%	0.00%
1	**Homes that employ domestic staff**	0.00%	0.00%

Table 4 shows the cost of the tax with respect to production for different sectors. For example, in the case of the GCC Tax scenario the tax levied on the "Electricity" sector represents 6.1% of the value of its production. A comparison between the sectoral price changes in Figure 1 and Table 4 shows a very close relationship between them. Table 4 shows direct effects on prices, whereas Figure 1 shows the total direct and indirect effects. In general, the activities with the highest direct impacts also have the highest total impacts on prices. One relevant exception is the "Transport" sector, which is ranked 4th in direct prices but only 6th in total impact on prices. Likewise, the sectors with the lowest direct impacts (clean activities) have the lowest effects.

Table 5 shows the total impacts (direct and indirect) of the different tax scenarios on the Consumer Price Index[13] (CPI). Firstly, observe that the two scenarios have exactly the same total direct impact on the CPI: an increase of 0.4%. This is because the two tax proposals were actually designed to obtain the same revenue, so in an Input–Output model context they have the same direct impact on prices. However, as explained above, the indirect effects are different. This is shown in Table 5. The GCC Tax has a lower indirect effect on prices than the LAP tax, because the burden of the LAP tax affects sectors that are located nearer the beginning of the production chain, and whose multiplier effect is therefore greater (e.g. "Electricity"). The total increases in CPI of 0.77% (GCC tax) and 0.92% (LAP Tax) are compatible with the higher impacts on prices shows in some sectors because they represent a small proportion of the economy. It is important to consider the total increases in CPI for the different tax scenarios because they also affect welfare impacts, as shown in the next section.

Table 5. Impacts (%) on CPI of the different tax scenarios

	Direct	Indirect	Total
GCC Tax	0.41	0.36	0.77
LAP Tax	0.41	0.51	0.92

[13] The Consumer Price Index or CPI is calculated by weighting the price (P_j) variation of each sector/good by its share in the budget (w_j): $\Delta \text{CPI} = \sum_j w_j \Delta P_j$

4.2 Distributional effects

This section analyzes the welfare impacts of the different tax scenarios. The scenarios consider a tax with revenues equivalent to €25 per ton of CO_2. Table 6 and Fig. 2, respectively, show the average welfare effects and the welfare effects by expenditure deciles. The first decile (1) represents the lowest tenth of expenditure and the last one (10) the highest. Welfare impacts are measured in terms of equivalent variation (EV) as a percentage of household expenditure. As mentioned above, expenditure can be considered a good proxy for lifetime income. The results show that average welfare loss is €138.17 in the case of the GCC tax and €182.8 for the LAP tax. In other words, the welfare loss is 31% higher with the LAP tax.

Table 6. Average welfare impacts

	Mean Equivalent variation (EV)	Percentage of household expenditure
GCC Tax	-138.17	0.78%
LAP Tax	-182.8	1.04%

Table 6 shows, firstly, that the welfare losses[14] are below 1.05% for all the expenditure deciles in terms of equivalent variation in expenditure. A wide range of impacts for similar levels of environmental taxes is reported in the relevant literature, but these results are within that range and are similar to those obtained by Wier (2005) or Rausch et al (2011). In the case of the GCC tax the welfare loss ranges from €45.67 per household per year in the first decile to €377.02 in the last decile. In the case of the LAP tax the welfare loss is between €73.81 and €440.97, i.e. the households in the top decile suffer a welfare loss eight times greater than that of the bottom decile in the case of a GCC tax, and six times greater in that of the LAP tax.

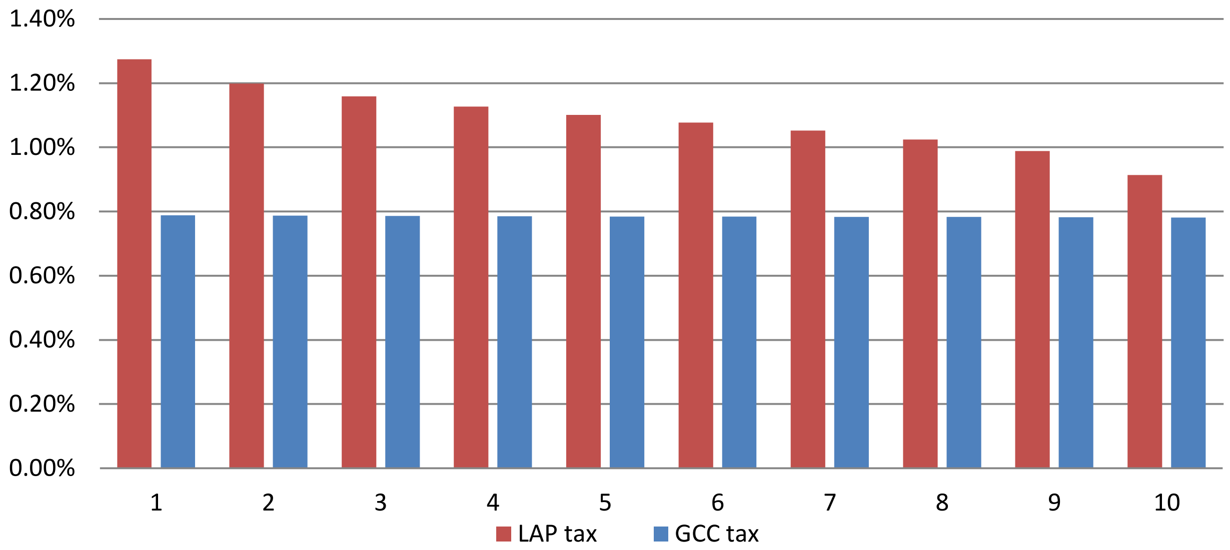

Figure 2: Welfare impacts change (EV, %) by expenditure deciles

[14] It should however be stressed that the benefits of the policy, in terms of increased environmental quality, are not taken into account, and hence the welfare losses only represent the cost side of changes in total welfare.

Table 7. Welfare impacts, equivalent variation in Euros

	Decile									
	1	2	3	4	5	6	7	8	9	10
GCC Tax	-45.67	-72.7	-92.46	-111.1	-129.26	-149.14	-172.24	-202.85	-250.25	-377.02
LAP Tax	-73.81	-110.81	-136.32	-159.49	-181.45	-204.82	-231.31	-265.31	-316.06	-440.97

Secondly, observe that the costs are always lower if the GCC tax is selected and higher with the LAP tax. This can be explained partially by the general price increase that each tax scenario generates (see Table 5). Table 7 shows that the LAP tax has higher costs for all income groups than the GCC tax.

Thirdly, Fig. 2 shows the distributional impacts of the different taxes. Note that the GCC tax shows no regressive effects: in fact it is almost perfectly proportional as the welfare loss is very similar for all expenditure deciles. All income groups lose about 0.8% of welfare in terms of equivalent variation in expenditure. These results are similar to those of Labandeira & Labeaga (1999) who also find no evidence of regressivity for a CO_2 tax in Spain. In the case of the LAP tax, the bottom deciles pay a larger share of their expenditure than the top deciles. For example, the lowest decile would lose about 1.27% of its welfare, whereas the highest decile would only lose around 0.91%. Clearly, the LAP tax is more regressive than the GCC tax in terms of equivalent variation in expenditure. Section 5.4 below uses different standard indexes to measure and confirm this effect more precisely.

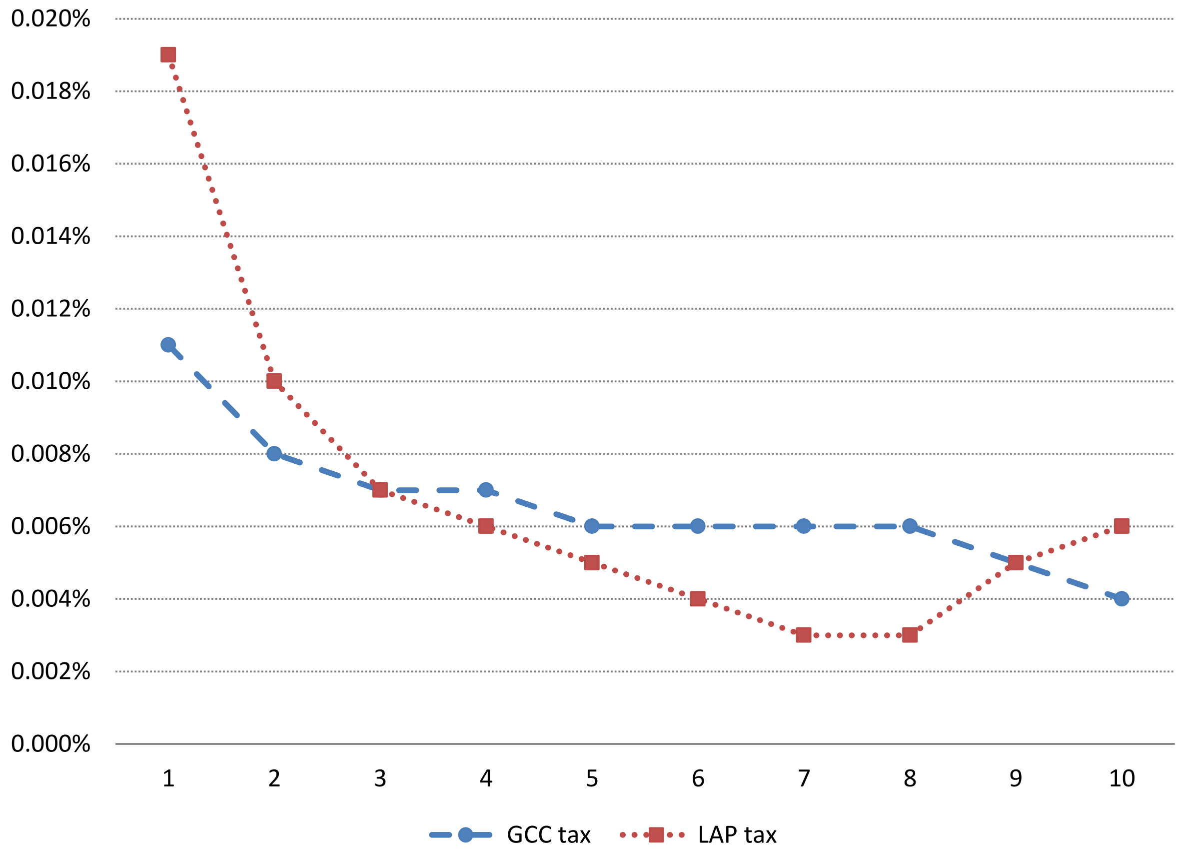

Figure 3: Relative efficiency impacts

Finally, the impact of taxes on GCC and LAP on efficiency is computed using the deadweight loss[15]. Figure 3 shows that the LAP tax is more efficient for the middle income groups because its excess burden is low in the middle expenditure deciles but is very high in the top and bottom deciles. For the GCC tax there is less difference between income groups, so the excess burden is more similar across income.

Consumption patterns are very important if all these results are to be understood. Figure 4 shows how the different expenditure groups spend their incomes: Low income households spend a larger fraction of their available income than high income households on "food" and "housing", in relative terms. The budget share accounted for by expenditure on travel, entertainment, restaurants and hotels increases notably with income. For example, the lowest expenditure decile spends 24% on food and 47% on housing, whereas the highest spends only 12% and 27%, respectively. Conversely, expenditure on transport ranges from 3% in the lowest decile to 18% in the highest.

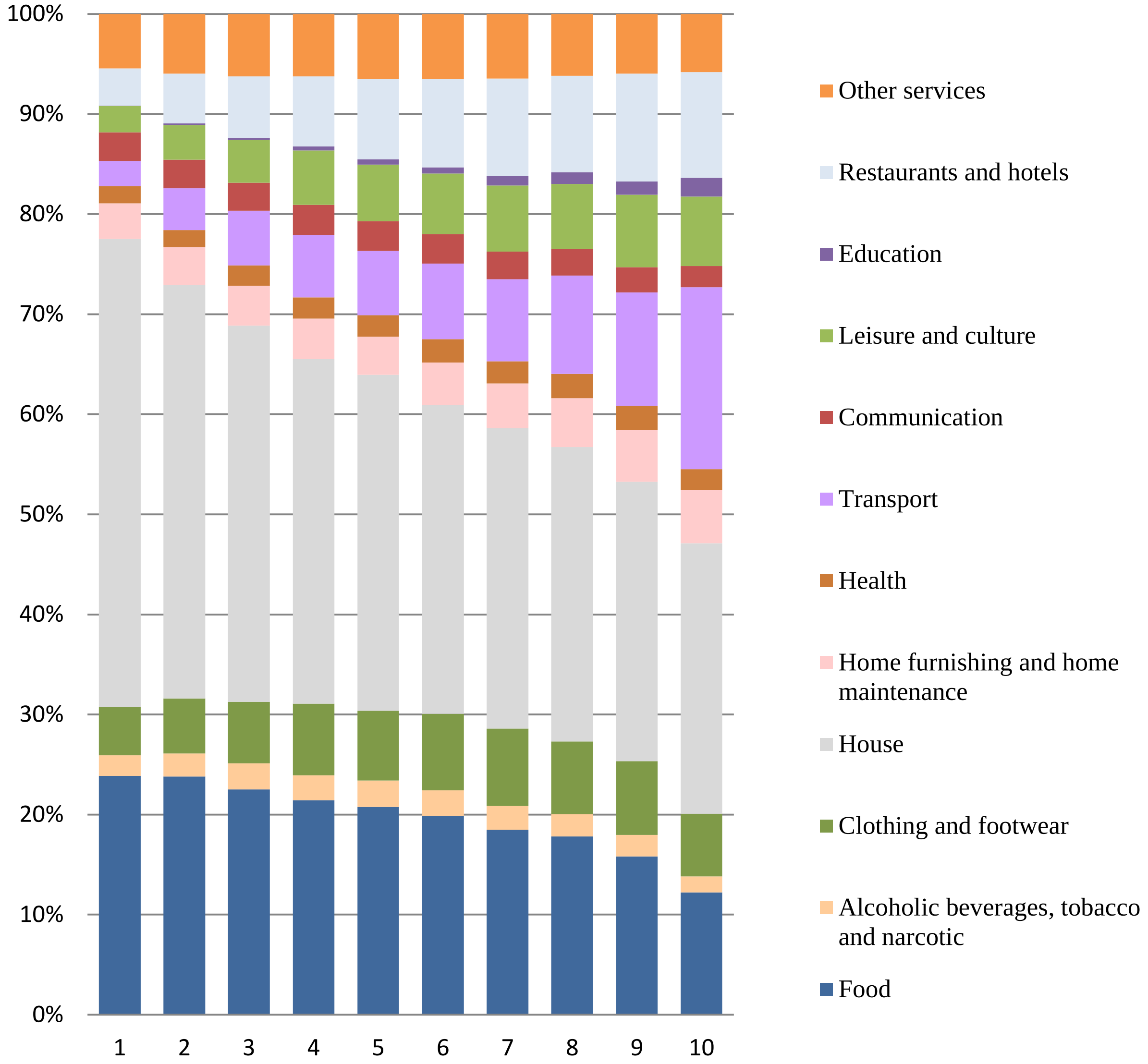

Figure 4: Consumption patterns by expenditure deciles, 2004. Source: The Spanish Continuous Households Expenditure Survey (EPCF). Spanish National Institute of Statistics (INE)

[15] The excess burden is calculated as the difference between equivalent variation (EV) and revenue (R) generated by households (h): $E_{GE} = -\sum_h EV_h - (R_h^1 - R_h^0)$

As stated in the previous section, the LAP tax increases the price for food and energy more than for other sectors. That is why this tax is more regressive than GCC. These results can be summarized by saying that LAP taxes are more regressive than GCC taxes because they have a higher impact on basic necessities and goods that are relatively consumed more by "poorer" households. The regressivity of GCC taxes is offset mainly because "richer" households consumption more of certain other goods that also have significant emission factors, such transport.

4.3 Effects of revenue recycling on income distribution

This second exercise entails a revenue-neutral tax reform in which the tax revenues from the scenarios are used in full to finance a reduction in taxes on labor, and more precisely a reduction in social security contributions paid by employers. The tax reduction needed to offset the new environmental tax is around 7.5% of social security contributions.

Figure 5 shows the further impacts on prices with the revenue-neutral tax reform. The results show that there is still a major increase in energy-intensive sectors: the "Electricity, water and gas production" and the "Energy Sector" undergo large price increases independent of the kind of tax burden imposed, while the "Food Sector" undergoes a large price increase with the LAP tax. However, the important difference now is that those sectors which are non-polluting or "clean" and labor intensive benefit from reductions in their prices. For example, the price changes in "Education" and "Health services" are negative and close to 1%.

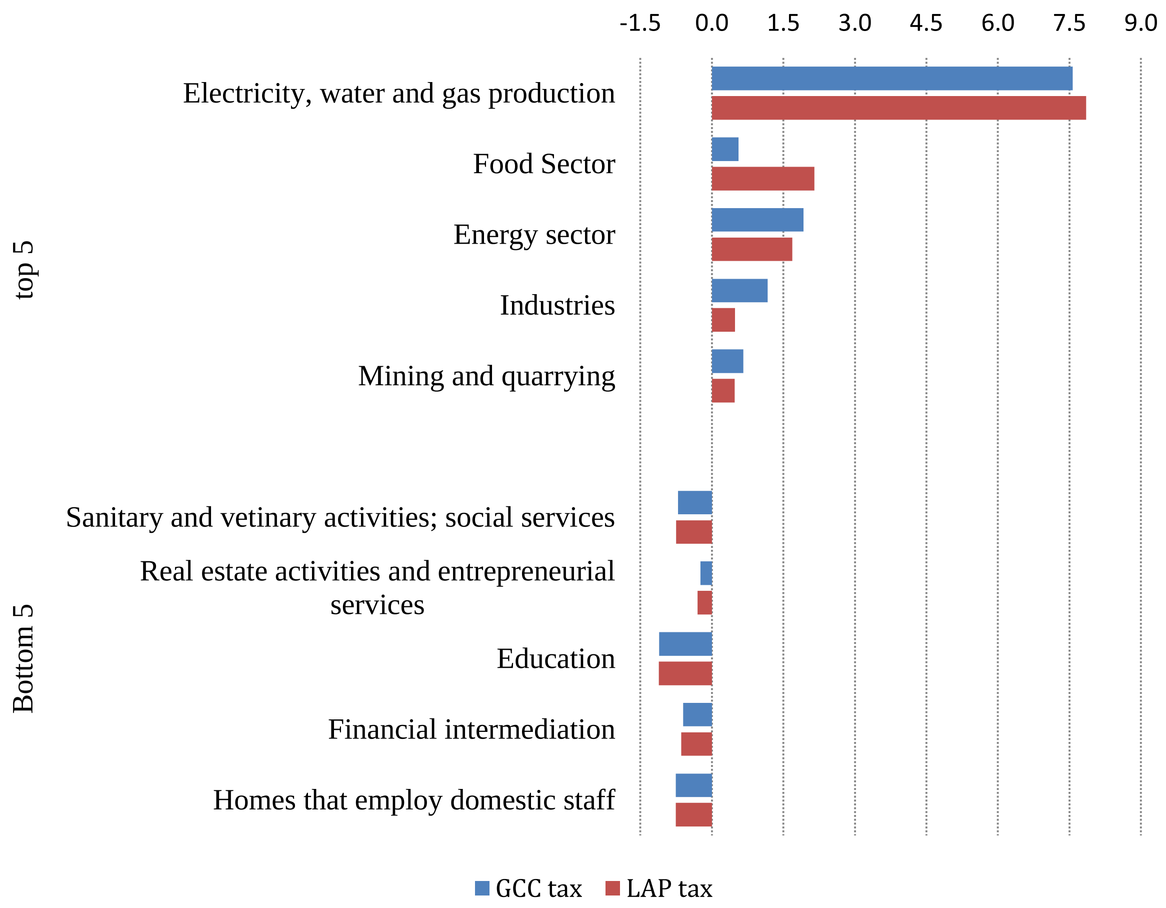

Figure 5: The impact of revenue recycling on price change

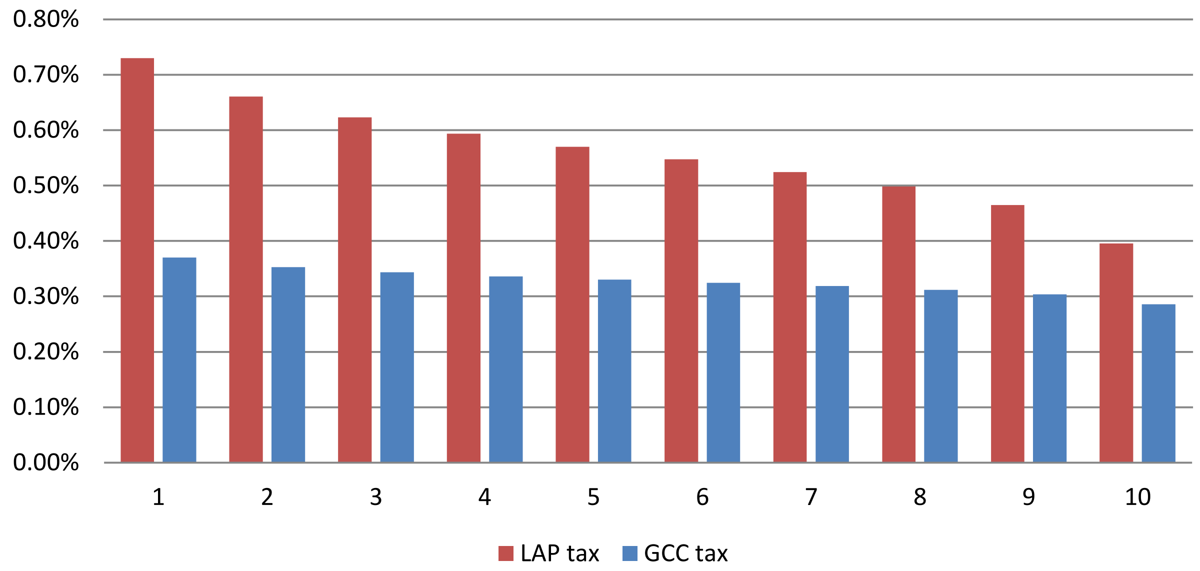

Figure 6: Average welfare impacts after recycling per expenditure group

Figures 6 and 7 show welfare impacts and the excess burden per expenditure decile after revenue recycling. Firstly, it is clear that the welfare impacts are lower after recycling revenue: they decrease by about 0.5% for all income groups and for both tax scenarios.

Revenue recycling through a tax on labor tax can reduce the progressivity of the tax system. Figure 6 reveals that under the GCC tax the differences between different types of household are still very small. However the difference between high and low income groups is larger than before recycling, evidencing that impacts are more regressive with revenue recycling. Under the LAP tax the welfare cost for the highest income group is only 0.35% while that of the lowest group is 0.73%, and the gap between income groups is wider than without recycling.

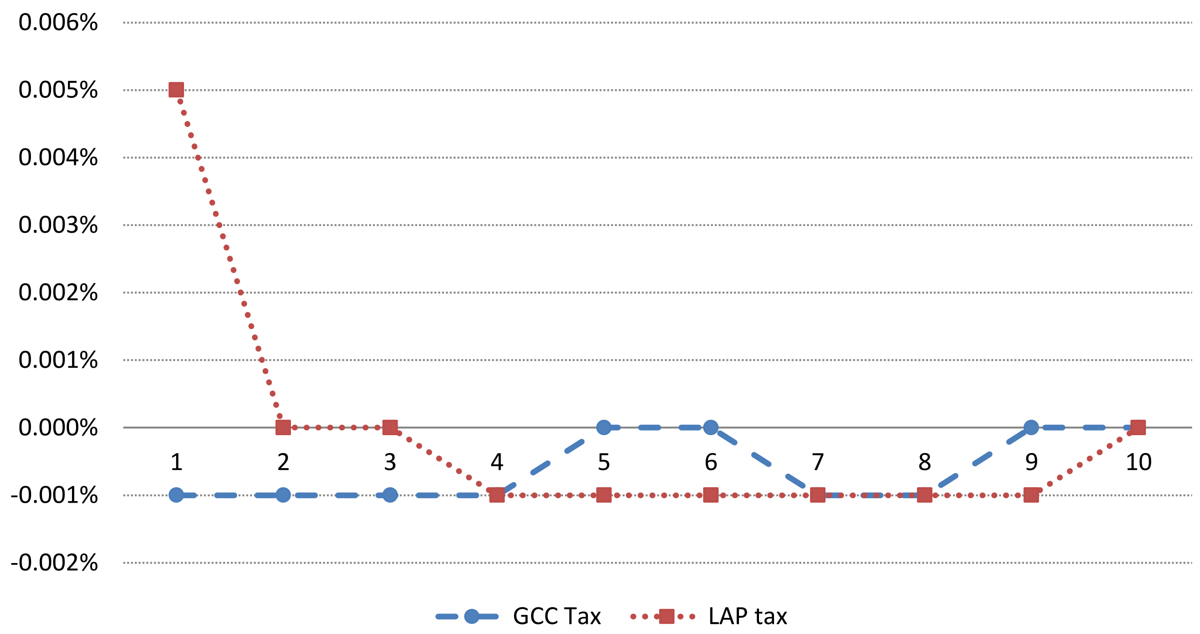

Figure 7: Relative efficiency impacts after recycling revenue

The effects in terms of efficiency of a revenue-neutral tax reform are as follows: the excess burden is reduced considerably for both the GCC tax and the LAP tax. Thus, the fiscal system is more efficient with revenue recycling for most expenditure deciles. These results are in line with the literature on the double dividend hypothesis, where it is reported that welfare cost decreases if the revenues from environmental taxes are recycled through taxes on labor (Goulder, 1995). Our results show that a trade-off between efficiency and equity (distributional effects) can exist when choosing specific revenue-recycling based on low taxes on labor. As shown elsewhere (see for example Rausch et al., 2011), revenue recycling through a distortionary tax has a positive impact on efficiency, but the distributional implications may not be positive.

4.4 Indexes for measuring regressivity

The micro-simulation model calculates a set of indexes which can provide information about the overall distributional effect of the taxes proposed. The Reynolds–Smolensky Index (RS Index) provides information about redistribution, and the Kakwani index is used to measure progressivity. All these indexes are estimated relative to total household expenditure.

Table 8. Progressivity and redistribution effects

	Marginal Reynolds–Smolensky Index	Marginal tax rate	Marginal Kakwani index
1. Pre-reform index	0.00434	0.11379	0.03855
2. Post-reform indexes Without Revenue-Recycling (NRR)			
GCC tax	0.00440 (-0.00006)	0.12064 (-0.00685)	0.03662 (-0.00193)
LAP tax	0.0039 (-0.00044)	0.12301 (-0.00922)	0.0322 (-0.00635)
3. Post-reform indexes With Revenue-Recycling (WRR)			
GCC tax	0.00419 (-0.00015)	0.1171 (-0.00331)	0.03626 (-0.00230)
LAP tax	0.00381 (-0.00053)	0.1192 (-0.00541)	0.03269 (-0.00586)

(Variation of measures of regressivity with respect to the pre-reform index)

Table 8 reports the Reynolds–Smolensky index (RS) and the Kakwani index (K). RS and K indexes are useful to measure the impact of a tax reform in terms of redistribution and progressivity (for more details see Appendix 2). Variation in absolute terms with respect to the situation in the pre-reform scenario is shown in parenthesis. Table 8 shows results for the effects of a reform on GCC and LAP taxes in two cases: (i) without revenue recycling (NRR) and (ii) with revenue recycling (WRR). RS and K indexes have, in the pre-reform and the post-reform scenarios, a positive value. Although positive, the values for both indexes are clearly close to zero in all cases analyzed ($K<0.04$ and $RS<0.0045$). Therefore, we can say that the tax system tends toward proportionality in both scenarios (pre-reform and post-reform) and regardless of the assumptions used (NRR or WRR). However, there are two issues that deserve to be highlighted. First, (negative) changes in K and RS indexes indicate that progressivity and redistribution are in general worse in the post reform scenario (both in NRR and WRR). The only exception is the redistribute effect of a GCC tax in the case of NRR. Second, in global terms, a GCC tax is superior to an LAP tax in terms of progressivity and redistribution, both under NRR or WRR. Finally, a GCC tax is slightly more progressive and redistributive when a NRR is used. By contrast, the result is ambiguous in the case of LAP tax. Specifically, it is slightly more progressive under the WRR assumption and more redistributive with NRR.

The sectors that are most labor intensive produce items that are consumed by high-income households, such as “services” and “leisure-related activities”. By contrast, the basic commodities consumed by poorer households are produced by capital-intensive sectors such as “Industry” and “Energy, water and gas production”. The revenue neutral tax reform simulated reduces social security contributions and, therefore, increases the price of capital-intensive goods, which are normally also highly pollution-intensive, by a relatively greater amount. This is the main reason why the fiscal system is less progressive after revenue neutral tax reform than in the pre-reform system.

Finally, indexes show that the changes in redistribution and progressivity are very low, thus the tax system continues to be proportional or even slightly progressive. In the case of GCC tax, the change in the system is negligible, while LAP tax reduces slightly the progressivity of the system.

5. Conclusions

Local air pollution (LAP) and global climate change (GCC) are two relevant, interrelated environmental problems. Most of the relevant literature has focused on the distributional impacts of climate change-related taxes such as taxes on CO_2, energy and fuel but to date few papers have investigated the distributional effects of LAP policies. Here we conduct a distributional analysis of an LAP tax (based on the internalization of the external costs of several pollutants) and compare it in a compressive way with a GCC tax (tax on CO_2). We use an Input–Output model which calculates the price change caused by these taxes levied on producers, combined with a micro-simulation model that calculates distributional effects on consumers for the case of Spain. We calculate the welfare loss and the deadweight loss by expenditure deciles and also the main indexes such as the Reynolds–Smolensky and Kawani indexes. Finally, we also explore the distributional effects of a revenue-neutral recycling scheme through a reduction on taxes on labor (social security contributions paid by employers).

Our results show that taxes on local pollutants are more regressive than those levied on climate-change pollutants. In fact, the GCC tax tends to be proportional because the energy used in lighting and heating, consumed mainly by low-income households, is offset by the higher spending on transport and energy by high-income households. This is similar to the results obtained by other papers for Spain (see e.g. Labandeira & Labeaga, 1999) and is in line with the emission intensity by income groups in Spain, as shown by Duarte et al. (2012). LAP taxes tend to be more regressive because they largely affect goods that are consumed by low-income households, such as electricity and food. The increase in food prices is a key factor that explains the regressivity of the LAP tax, because this tax indirectly increases more the price of food and because low income households spend a large proportion of their income on food. The welfare loss in the case of a GCC tax is around 0.8% for all the expenditure deciles, but in the LAP tax the welfare decrease ranges from 1.2% for the first decile (the poorest households) to 0.9% for the tenth (the richest households). In any case, the overall effect on distribution in the tax system is very low when the change in the indexes is compared with the pre-reform situation.

As far as recycling is concerned, our results show that the overall welfare loss is reduced notably but the distributional implications do not change much. Indeed they are actually worse, because the average reduction in social security contributions for all sectors reduces the price of some service sectors that are “cleaner” and more labor-intensive because they are consumed relatively more by high-income households. Although the level of progressivity of the tax system does not change much in the LAP tax (where the Kawani index shows better results for progressivity but the Reynolds–Smolensky indexes show worse results for distribution and redistribution), the loss of progressivity is clear for the GCC tax.

Finally, recycling also shows that a trade-off may exist between efficiency (of the tax system) and equity (distribution) especially in the GCC tax scenario.

Some caveats should be made in order to put these results into perspective. First, these are empirical results and they can be extrapolated only to countries with similar production and consumption profiles. The distributional implications of taxes on air pollution or climate change depend very much on the structure of the economy, even if revenues are recycled in different forms. Second, we only consider the distributional effect of environmental taxation and not the welfare loss associated with pollution. There are many studies (see for instance Pye et al., 2006 and Walker et al., 2003) that show that LAP affects low income household locations more. Third, our input–output model cannot capture the full effects that a reduction in taxes on labor could have on employment and, therefore, on welfare. The relevant literature suggests that such tax reforms could have a positive effect especially in those countries, such as Spain, that have highly distorted labor markets and high unemployment levels (see for example Markandya et al., 2013), and that they could be a good option (see OCDE, 2011) for raising new funding to help the fiscal consolidation process in the aftermath of the 2008 economic recession. Finally, we do not analyze other revenue recycling designs such as lump sum transfers or other more specific policies such as, for example, subsidies on public transportation.

The first policy implication of this paper is that although it was thought that LAP taxes might be easier to implement because their effects (mainly on health) are felt more immediately by citizens and by low-income households than those of GCC taxes, this may not be the case if the distributional issue is factored into the policy maker's equation. The second policy implication is that if it is wished to correct the distributional effect of this type of tax reform the standard approach, i.e. reducing taxes on labor, may not improve the distributional effect. However, and this is the third policy implication, given that the overall regressivity of these taxes is low, various specific combinations of policies could be designed to compensate the households or groups that are most affected.

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Appendix 1

Price increases of aggregate sectors groups when a GCC tax or LAP tax is levied on industry in Spain in 2005.

SECTOR		**Without Revenue-Recycling**		**With Revenue-Recycling**	
		GCC tax	**LAP tax**	**GCC tax**	**LAP tax**
Area1	**Food Sector**	1.06	2.66	0.56	2.15
Area 2	**Energy sector**	2.04	1.81	1.92	1.68
Area 3	**Mining and quarrying**	1.26	1.09	0.66	0.48
Area 4	**Electricity, water and gas production**	7.92	8.20	7.57	7.85
Area 5	**Textile**	0.89	0.68	0.17	-0.04
Area 6	**Leather and footwear**	0.70	0.71	0.03	0.04
Area 7	**Industries**	1.77	1.08	1.17	0.48
Area 8	**Machinery**	0.70	0.50	0.01	-0.19
Area 9	**Electrical equipment, electronics and optics**	0.60	0.46	0.07	-0.08
Area 10	**Manufacture of transport material**	0.59	0.44	0.11	-0.04
Area 11	**Construction**	0.63	0.45	-0.16	-0.35
Area 12	**Commerce**	0.56	0.50	-0.13	-0.20
Area 13	**Hotel management**	0.40	0.65	-0.22	0.02
Area 14	**Transport and communications**	1.19	1.01	0.63	0.45
Area 15	**Financial intermediation**	0.18	0.14	-0.61	-0.64
Area 16	**Real estate activities and entrepreneurial services**	0.29	0.23	-0.24	-0.30
Area 17	**Education**	0.18	0.18	-1.11	-1.11
Area 18	**Sanitary and veterinary activities; social services**	0.28	0.24	-0.71	-0.75
Area 19	**Other services and social activities; personal services**	0.54	0.43	-0.15	-0.25
Area 20	**Public services**	0.38	0.34	-0.83	-0.87
Area 21	**Homes that employ domestic staff**	0.00	0.00	-0.76	-0.76

Appendix 2. Indexes for measuring regressivity

The Gini index measures the extent to which the distribution of consumption expenditure among individuals or households within an economy deviates from a perfectly equal distribution. A Lorenz curve plots the cumulative percentages of total expenditure received against the cumulative number of recipients, starting with the poorest individual or household. The Gini index measures the area between the Lorenz curve (*L*) and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. In this way, with a distribution of expenditure, *F*(*x*), the Gini Index can be expressed as follows:

$$F(x) \rightarrow G_x = 1 - 2\int_0^1 L_x(p)dp; \qquad p \in (0,1) \tag{A.1}$$

To assess the redistribution effects of the tax reform, we use the Reynolds–Smolensky (RS) index, which calculates the area between Lorenz curve of expenditure twice, before and after the tax reform:

$$\pi^{RS} = 2\int_0^1 [L_{X-T}(p) - L_X(p)]dp = G_X - G_{X-T} \tag{A.2}$$

The Kakwani index provides information about the progressive effects of tax reforms. This index equals twice the area between the Lorenz curve and the concentration curve of a tax:

$$\pi^K = 2\int_0^1 [L_X(p) - L_T^*(p)]dp = C_T - G_X \tag{A.3}$$

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