From shadow to green: Linking environmental fiscal reforms and the informal economy

Anil Markandyaa, Mikel González-Eguinob,⁎, Marta Escapaab

⁎ Basque Centre for Climate Change (BC3) and Ikerbasque, Basque Foundation for Science, Spain
a Basque Centre for Climate Change (BC3) and University of the Basque Country (UPV/EHU), Spain
b University of the Basque Country (UPV/EHU), Spain

1. Introduction

The literature on environmental fiscal reforms is centred on the idea that environmental taxes produce not only improvements in the environment but also positive economic and social outcomes. In order to obtain this “double dividend” (Pearce, 1991), governments must use the revenues from environmental taxes to reduce the rates of other taxes in the economy. As long as environmental taxes are used to reduce rather than to replace other taxes the “tax-interaction-effect” has to be considered, which gives rise to the distinction between the “weak” and the “strong” double dividend hypotheses (Goulder, 1995). How governments recycle revenues (“revenue-recycling effect") from environmental taxes back into the economy is a key issue in determining the type and size of the double dividend (see also Goulder, 2013).

The literature has focused, especially in the case of Europe, on the extent to other countries with different sizes of the shadow economy or different labour market conditions.

In the past few decades many papers have analysed in some depth different environmental tax reforms and the double dividend hypothesis, i.e. the possibility of improving not only the environment but also the economy through the reduction of distortions in the tax system. However, such studies have not modelled the effects of the presence of a shadow economy, even though informal markets account for a significant and growing part of GDP in many developed economies. This paper analyses this important link using a Computable General Equilibrium model for the case of Spain, with historically high unemployment rates and a large informal economy. Since the informal labour is not taxed, when the green tax is introduced and the tax on formal labour is reduced, the pre-existing non-environment-related inefficiency of the tax system is remarkably reduced. Our analysis shows that if the distortions created by the shadow economy are considered, the case for an environmental tax reform where revenues are used to reduce labour taxes is strengthened and the possibility to find a double dividend is more likely. Our sensitivity analysis also shows that these results can also be extrapolated to some extent to other countries with different sizes of the shadow economy or different labour market conditions.

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account for a significant and growing part of GDP in many developed economies. According to Schneider et al., 2010, in OECD countries the shadow economy accounted for between 12 and 33% in 2005. Moreover, reducing the informal economy is an important policy target in itself because it creates significant economic problems such as efficiency distortions (allocation is determined not by productivity but by “fiscally effective” productivity), competition distortions (firms that pay taxes face higher costs and more regulation) and equity distortions (incomes not declared result in a loss of revenue for the public sector and a higher tax burden for those who pay taxes), among others. Although, admittedly, one of the main reasons for the lack of consideration of the informal economy in the economic models is lack of data, recent improvements in estimations (Schneider and Enste, 2000; Schneider et al., 2010 or Schneider, 2011 among others) suggest that it may be worth exploring this linkage.

In this paper we construct a model with the aim of shedding light on how a green fiscal reform can help to reduce the shadow economy and reducing unemployment. We analyse the effects of a revenue-neutral CO2 tax reform by focusing on the revenue-recycling effect. We compare the effects of using revenues from a CO2 tax to reduce taxes on labour, or to reduce taxes on capital or to make lump sum transfers. We use a standard CGE model that contains two features, which are important regarding the labour market. First, there is involuntary unemployment and wages are determined endogenously following a wage curve. And second, formal and informal labour (which are substitutes in the production function) are linked through an equilibrium condition where expected wages in the two sectors are set equal to each other. This idea is taken from Harris and Todaro (1970), who used it to explain rural–urban mobility, and the same approach has been used by Rutherford and Light (2002) in a CGE model for Colombia.

We apply the model to Spain, which has a very high unemployment rate and one of the biggest informal economies (20–25%) of any wealthy country. The results obtained for the (employment) double dividend and the tax on formal labour is reduced, the pre-existing non-environment-related inefficiency of the tax system is remarkably reduced. This idea is taken from Harris and Todaro (1970), who used it to explain rural–urban mobility, and the same approach has been used by Rutherford and Light (2002) in a CGE model for Colombia.

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the total cost of labour in the official economy and after-tax earnings (from work), the greater the incentive is to avoid that difference and to work in the informal economy. However, it is not clear whether tax reforms with major tax rate deductions will lead to a substantial decrease of the informal economy or to a mere stabilization. Social networks, personal relationships and lack of information are strong factors which prevent people from transferring easily to the official economy. Therefore, the way in which the mobility of workers between formal and informal labour is modelled and the assumptions regarding substitutability between them in the production function are significant.

According to recent estimations (Buehn and Schneider, 2011) there is a significant shadow economy all over the world, and even in developed economies its size may be noteworthy. Estimates for developed countries range between eight and thirty percent of GDP (see Table 1). The countries of southern Europe, including Spain, have historically topped the informal economy rankings, though Scandinavian countries also tend to have large shadow economies (16–18%). In the case of Spain, Arrazola et al. (2011) estimate the size of the shadow economy using various methods. They conclude that for the period 2005–08 the shadow economy accounted for 21.5% of GDP with a loss of tax revenue for the government of 7% of GDP. In Spain the shadow economy has grown steadily from around 12% in the period 1980–1984.8 These results are in line with those of Buehn and Schneider (2011), who find that the average shadow economy in Spain was 22.5% of GDP from 1999 to 2007.

Feld and Schneider (2010) and Bajada and Schneider (2009) have also shown the role of the formal economy and unemployment in determining people’s decisions on whether to work in the formal or informal sector. When growth in GDP is low or GDP is not increasing and unemployment is increasing, more people try to offset loss of income from the official economy through additional shadow economy activities. So normally the higher is unemployment the more people will engage in shadow economy activities and, therefore, the bigger will be the informal labour force. In many cases, a worker who is accounted for as unemployed (and sometimes even receiving unemployment benefits) is actually working in the informal sector so different measures of unemployment should be used. In this paper we consider the official and real measures of unemployment, with the difference between them being due to those who work in the informal sector.

In this respect, Spain has one of the highest "official" unemployment rates in Europe and in any OECD country. Spain’s unemployment problems have been severe since the second half of the 1970s. As Fig. 1 shows, unemployment exceeded 20% in the mid 1980s and 1990s. Although the rate subsequently decreased to 8.5% in 2007, it has again increased sharply with the current economic recession.

Finally, it is important to mention that there has been very little use of environmental taxes in Spain compared with other European countries. Apart from fuel and transport taxes (which were not originally conceived as environmental taxes) and the European Trading Scheme (EU-ETS), which put a price on CO2 in some sectors, the main instrument has been the granting of tax

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7 The shadow economy is generally smaller in developed countries than in developing countries. For example in Latin America and Sub-Saharan Africa it is estimated to be between 30 and 40%.

8 A detailed explanation of the patterns of the underground economy in Spain during the 1980s can be found in Ahn and de la Rica (1997).
deductions for investments in environmental protection. In fact, environment-related revenues decreased from 2.6% of GDP in 1995 to 1.8% in 2007, with taxes on pollution and resources being almost non-existent.

The combination of its lack of environmental taxes, large shadow economy and high unemployment rate make Spain an interesting case study for analysing how an environmental fiscal reform can help policymakers to address current environmental and economic problems simultaneously.

3. The model

We use a standard static multi-sector general equilibrium model for an open economy with the incorporation of the shadow economy through a formal–informal labour market. In Section 3.1 we present an overview of the model (for more detail see González-Eguino, 2011) and the specificities of the labour market are presented in Section 3.2.

3.1. An overview of a standard CGE model

Computable General Equilibrium (CGE) models are empirical versions of Arrow and Debreu models (Shoven and Whalley, 1992). A standard CGE model can be described by a set of economic agents – households and firms – that demand and supply different goods, behave rationally and make choices based on solving their respective optimisation problems. Three classes of conditions characterise a competitive equilibrium: zero profit conditions, market clearance conditions and income balance conditions. Equilibrium is characterized by a set of equilibrium prices such that demand equals supply for all commodities simultaneously. In this situation agents cannot do better by altering their behaviour.

The model comprises the following: (1) 9 production sectors/goods (including the following energy goods: coal, fuel oil, gas, and electricity); (2) a representative consumer; (3) a government which collects taxes on pollution and resources being almost non-existent.

<table>
<thead>
<tr>
<th>Tax recycling</th>
<th>CO2 emission reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LST</td>
<td>−0.01</td>
</tr>
<tr>
<td>TaxK</td>
<td>−0.01</td>
</tr>
<tr>
<td>TaxL</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The government obtains its income through taxes on capital, formal labour and CO2 emissions. The government uses this income to provide public goods and services and to make direct transfers to consumers. Government structure of public spending is fixed and all additional income collected by the government (from taxes on CO2 emissions) is used to offset reductions in other taxes or an increase in transfers so that the level of public spending remains constant.

Foreign trade follows two assumptions. The first is the small open economy assumption, which establishes that (a) the domestic economy is too small to influence world-wide prices; and (b) import and export requirements can be met by trade with the Rest of the World. The second is the Armington assumption, which assumes that domestic and imported/exported goods are imperfect substitutes. Trade deficit is assumed to be constant.

Finally, the total supply of capital and labour is considered to be exogenous. However, it is important to specify the relationship between investment and capital flows. The level of investment in an economy depends on interest rates, on the capital stock and on depreciation. These points cannot be incorporated into a static context, so we assume that savings are a fixed proportion of income.

3.2. Labour market

In this section we show how the shadow or informal economy is introduced in a standard CGE by altering the labour market conditions. Following Rutherford and Light (2002), labour endowment is fixed in the model and it is assumed that it can be allocated to either “formal” or “informal” labour supply. Governments are able to collect taxes on formal labour but not on informal labour and the two factors are imperfect substitutes on the production side. Agents can choose how much of each type to supply and the level of informal labour used will determine the size of the shadow economy. As we also consider a representative consumer that owns the labour and capital, the number of workers employed formally and informally can be interpreted as the share of working time by the representative consumer on both activities.

As shown in Fig. 2, production sectors can substitute between formal and informal labour. The labour composite (Lj) by sectors is modelled through a CES function as follows:

\[ L_j = (\delta J_j^{(1-\sigma_j)} + (1-\delta) L_j^{(1-\sigma_j)}L_j^{(1-\sigma_j)})^{1/(1-\sigma_j)} \]

where \( L_j^f \) and \( L_j^i \) is formal and informal labour, \( \delta \) is the benchmark share of formal employment for sector \( j \) and \( \sigma \) is the constant elasticity of substitution between formal and informal labour. When the value of \( \sigma \) is 0 there is no substitutability and the two factors should be combined in a fixed proportion. Conversely, formal and informal labour are substitutes when \( \sigma \) is positive.

Unemployment in the formal market is determined by a wage curve where the real wage is a declining function of the rate of unemployment. According to Blanchflower and Oswald (1995, 2005),

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unemployment in the wage curve can be interpreted as the result of collective bargaining and is consistent with an efficiency-wage framework. In our model, the wage curve is given by the following equation:

$$\frac{w_F}{P} = \left\{ \frac{\theta}{\tau} \right\}^{\theta}$$

where $w_F$ is the formal wage, $u$ is the unemployment rate, $\theta$ is the un-employment rate at the benchmark, $\tau$ is an elasticity parameter that measures the sensitivity of the wage rate to the unemployment rate and $P$ is the consumer goods price index. $\theta$ can be interpreted as a wage flexibility parameter. When $\theta = 0$, the real wage is totally rigid and unemployment is perfectly flexible and, when $\theta \to \infty$, unemployment is totally rigid and the real wage is perfectly flexible. In other cases ($0 < \theta < \infty$) as $\theta$ increases, the sensitivity of the wage rate to unemployment increases.

The wage curve in the United States, where better data are available, has a long-run elasticity of approximately 0.1, which means that a doubling of the unemployment rate is, historically, associated with a ten percent decline in the level of the (real) wage (Blanchflower and Oswald, 1995, 2005). The value of the parameter $\theta$ varies from one country and one time to another.11 In countries like Spain, where the labour market has traditionally been more rigid (adjustments normally take place through decreases in employment rather than wage reductions) the value of $\theta$ should be lower than elsewhere. In this paper, we consider an initial value of 0.1 and then conduct a sensitivity analysis of the parameter.

Finally, we model the possibility of workers moving between the formal and informal labour markets following Harris and Todaro (1970). Workers move between formal and informal labour sectors until the informal wage ($w_I$) is equal to the expected formal wage (Eq. (18)). The expected formal wage is the formal wage ($w_F$) times the employment rate $(1 - u)$. As unemployment rises the gap between formal and informal wages widens. If unemployment is zero, formal and informal wages (before taxes) should eventually become equal.

$$w_F = w_F(1 - u)$$

We also include in the model an endogenous parameter $m$, which measures the mobility rate and determines formal and informal labour supplied in equilibrium:

$$L^f = L^f(1 - u) + L^f(1 - m)$$

$$L^f = m$$

where $L^f$ and $L^f$ are the benchmark labour endowments for the formal and informal sectors. We need to include a variable such as $m$ in the model so that the amounts of informal and formal labour can vary in response to unemployment and other market conditions in the formal sector.

4. Data

The initial equilibrium data come from the Symmetric Input Output Table (INE, 2009a, see Table A1 and A2 in the Appendix). Emissions of pollutants for each sector are obtained from the Environmental Satellite Accounts (INE, 2009b, see Table A3). Sectoral CO2 emissions disaggregated per energy input source (coal, oil and gas) are obtained from the energy balance sheets (Eurostat, 2005, see Table A4). The reaction of agents to changes in economic policy is reflected through elasticities of substitution, which are taken from the MIT-EPPA model (Babiker et al., 2001, see Table A5).

The baseline size of the shadow economy is set at 20% of the official GDP, according to recent measures by Arrazola et al. (2011). This translates as around 4.3 million workers in the informal sector. It is commonly accepted that the percentage of undeclared work is higher in some sectors of the economy than in others, so in this paper we distribute informal activities between sectors assuming three types of sector according to their high, medium or low contribution to the shadow economy activity. The selection of sectors under each category and the level of informal labour are based on Hvidtfeldt et al. (2011).12

11 Blanchflower and Oswald (1995) show the elasticities of wage curves for 12 countries. The figures vary between 0.04 (S. Korea) and 0.19 (Australia).

12 When $m = 1$, there is no mobility; if $m < 1$ there is mobility from informal to formal and if $m > 1$ the mobility goes the other way around. It is important to notice that there is a relationship between the value of $m$ and the value of the elasticity of substitution between formal and informal labour $(\sigma)$. If $\sigma = 0$, there will be no mobility $(m = 1)$ and both factors are used in fixed proportions.

13 Hvidtfeldt et al. (2011) use an interview survey to estimate the percentage of undeclared work for different sectors of the Danish economy in 2010. They find that 48% of the work done in the construction sector is undeclared, followed by agriculture (47%), motor vehicle sales and repairs (43%), manufacturing (36%), transport and telecommunications (31%) and hotel and restaurant (30%).
Finally, the official unemployment rate considered is 20%. It is important to mention that the fact that the shadow economy and the unemployment rate are both 20% is a mere coincidence.14

5. Results

This section presents the results of different environmental tax reforms. The simulations look at CO2 taxes set to reduce emissions by amount ranging from 5% to 30%. The revenues from CO2 taxes are "recycled" via: (i) lump sum transfers (LST); (ii) reducing taxes on labour (TaxL); or (iii) reducing taxes on capital (TaxK). All these tax reforms are revenue neutral (government revenue is fixed) so welfare impacts can be compared. The results are presented as follows. Section 5.1 presents the economic impacts of the different "recycling" schemes. Section 5.2 analyses how these effects depend on different conditions in the labour market. Section 5.3 presents a sensitivity analysis of the key variables.

5.1. Economic impacts of environmental tax reform

First, we analyse welfare variations, measured in Equivalent Variation (EV), for the different recycling schemes. The EV welfare measure is limited to the economic source of welfare, which in this model is solely consumption.

Table 2 present the results when mobility is not allowed ($\sigma_f = 0$) and wages are perfectly flexible ($\theta \rightarrow \infty$). As shown in Table 2, with the LST tax reform welfare decreases by around 0.09% for a reduction of 15% in CO2 emissions and by around 0.54% for a reduction of 30%. A very weak small double dividend can be found if the reform reduces taxes on labour or capital, as welfare would be reduced only a little less. This weak double dividend depends on how distortory the previous tax scheme was and on the magnitude of the tax interaction effect created. The more distortionary a tax, the more gains can be expected to be earned by reducing its rate. These results are in line with those models in the literature that do not incorporate unemployment and the shadow economy in their analyses.

However, it can be shown that the effects on welfare effects change considerably when mobility between formal and informal labour is allowed and wages are not perfectly flexible (the unemployment rate is not fixed)15 using the best estimations for the wage curve elasticity parameter ($\theta = 0.1$) and the elasticity of substitution between formal and informal labour ($\sigma_f = 5$). As can be observed in Table 3, the welfare effects now depend strongly on the tax reform conducted and are much bigger. If revenues are used to reduce labour taxes, welfare increases: for a reduction of 15% in CO2 emissions the equivalent variation will be 2.8% higher than the benchmark figure. However, if revenues are used to reduce taxes on capital or given back with LST, welfare will decrease similarly by around 0.9%.

The effect on welfare of the different environmental fiscal reforms is explained by the improvement (or not) of the overall efficiency of the tax system. This effect is triggered by the different effect that each reform has on the economic activity and on the demand for labour. When the demand for labour increases, unemployment decreases and workers move from the informal to the formal sector. On the one hand, if unemployment is reduced there is a new endowment of labour that is now producing goods and services and, therefore, increasing welfare. On the other hand, if more workers are entering the formal economy there is a reduction in the deadweight loss (due to a smaller loss of government revenue from the informal sector). As a result, (official) GDP increases and the effective tax burden or fiscal pressure decreases. However, if the demand for labour decreases unemployment may also increase and workers may also move to the informal sector. These changes in the demand for labour are mainly explained by the type of tax reform, because a reduction in the tax formal labour (TaxL scenario) increases the demand for it and increases the price of formal labour whereas the other reforms do not have this effect.

One relevant effect that can be observed is that the higher the CO2 tax (and the CO2 reduction target) is, the higher the welfare gains/losses are. This means that, in the context of this model, the important issue is the "recycling" scheme selected. A higher tax on CO2 implies more revenues that can be used to decrease labour taxation thus increasing even more the demand for labour and ultimately welfare. In fact, this positive effect on welfare is maintained up to the point where unemployment and the informal economy disappear.16

Table 4 shows how the different tax recycling schemes affect other relevant variables (such as GDP, unemployment, the shadow economy, energy consumption, etc.) for a reduction of 15% in CO2 emissions. It can be observed that if labour taxes are reduced, welfare will increase by 2.8%. GDP by 2.5% but the official GDP (without the income generated by the informal labour) will increase by 7.6%. This increase in official

14 Estimations for the shadow economy in Spain range between 20 and 25% depending on the method used (see Arrazola et al., 2011). In January 2012, the official unemployment rate in Spain was 23.5%.

15 If the wages of formal workers can change perfectly and be reduced without any limit, there will be no reductions in the benchmark unemployment rates. In this situation benchmark unemployment rate will remain constant.

16 In our model the limitation on additional reductions in emissions comes firstly from technology, which is exogenously given. As most emission reduction in the model stems from input substitution and economic restructuring, there is a maximum level of reduction that can be attained. Increasing emission reduction by more than 40% is not feasible given the elasticities of substitution obtained from the relevant literature.
activity is explained by the reduction of both "official" unemployment (from 20% to 16.5%) and "real" unemployment (from 10.9% to 10.8%), which means the incorporation of new workers into formal labour (the shadow economy decreases from 20% to 14.5%). Moreover, as more workers pay taxes and government spending is fixed, the tax burden is also reduced. However, in the other recycling schemes (LST and TaxK), GDP falls as a consequence of increases in unemployment and in the shadow economy.

As shown in Table 4, the CO₂ tax induces a change in the consumption of energy (in all three "recycling" scenarios) that is to some extent proportional to the carbon content of each fuel, where coal and oil are required to reach the CO₂ targets are around €33/tCO₂ in the LST and TaxK scenarios, and €46/tCO₂ in the TaxL scenario. The tax needs to be higher in the TaxL scenario because under this reform economic activity increases, and therefore so do emissions. Finally, the (relative) prices of capital, formal labour and informal labour are presented. In general, as long as CO₂ taxes increase the (relative) price of energy increases and, therefore, the prices of other production factors (labour and capital) decrease. However, the final effect on prices in a general equilibrium model depends on complex interaction effects because: (i) the general activity level of the economy determines the demand for goods; (ii) the structural change induced in the economy determines the demand for factors; and (iii) the "recycling" scheme implemented also affects the demand for factors, as long as reducing TaxK increases the demand for capital and reducing TaxL increases the demand for labour. The final equilibrium prices show increases in the price of formal and informal labour in the TaxL scenario and a reduction in the TaxK and LST scenarios.

5.2. The role of the shadow economy in the analysis of environmental tax reforms

Section 5.1 above analyses the effect of different tax reforms and concludes that a reduction in labour tax may generate positive effects on welfare and on many other economic indicators by reducing the pre-existing non-environment-related inefficiency of the tax system. These positive effects are due to a combination of two different, although related, effects: 1) reduction in unemployment (workers moving from unemployment to employment); and 2) reduction in the shadow economy (workers moving from informal to formal work). In this section we separate these two effects in an effort to shed light on the contribution of considering the shadow economy in an environmental fiscal reform analysis. We focus on the case of the TaxL reform for a reduction of emissions of 15%.

Fig. 4 shows the changes in the main economic variables under four different scenarios where mobility between formal and informal labour is allowed (M) or not (Mfx) and where wages are perfectly flexible (θ → ∞ and benchmark unemployment is fixed (U)) or not (U).

The results in the blue bar (mobility not allowed (θ = 0) and unemployment fixed (θ → ∞)) and in the purple bar (mobility allowed and unemployment flexible) are analysed in the previous section. The most interesting part of Fig. 4 is the comparison i) between the red and the green bar (which enables a comparison to be drawn between two new different labour market conditions); and ii) between the red bar and the purple bar (which enables a comparison to be drawn between the extra benefits that could be obtained if the shadow economy were incorporated into the existing literature on environmental fiscal reforms and the double dividend hypothesis).

Firstly, the comparison between the red and green bars (mobility fixed and unemployment flexible versus mobility allowed and unemployment fixed) shows that the welfare effect is very similar in both cases (increases of 1.4 and 1.5%). In the case of fixed mobility (the red line) the shadow economy is almost the same and all the benefits are due to workers coming off unemployment. Therefore, the changes in official and real unemployment rates are equal (−15.8%). But in the case of fixed unemployment (green line) the welfare gains are obtained because informal workers are brought into formal labour and this reduces the shadow economy (−18.9%) and the measured level of official unemployment (−7.3%), but not real unemployment. Therefore, although the welfare effects are almost the same the sources of these effects are different and, importantly, the economic and social implications of the two effects are not the same. Although we cannot explore these implications with our model, it is clear that it is not the same to

17 "Official" unemployment includes both workers who are registered as unemployed and workers who are working in the informal sector. “Real” unemployment excludes informal workers.

18 In a CGE model all prices are relative prices. In our case, the general price index (the price of utility) is the numeraire and it is exogenously determined and equal to one in the simulations. In this way, changes in utility can be interpreted as equivalent variations.

19 The small reduction in the shadow economy, from 20 to 19.7%, is obtained because the pre-existing non-environment-related inefficiency of the tax system.

20 The overall economy grows and therefore the share accounted for by informal activity decreases.
have more people unemployed and less in the shadow economy as vice versa.

Secondly, from the comparison between the red and purple bars (mobility fixed and unemployment flexible versus mobility allowed and unemployment flexible) we estimate an extra amount of welfare of 1.5% (1.3 vs. 2.8%). The extra GDP would be 1.4% (1.2 vs. 2.6%), though in terms of official GDP it would be 6.1% (1.5 vs. 7.6%). Most of these extra benefits come from a major reduction in the shadow economy but also from a greater reduction in formal unemployment.

The results in this section confirm that labour market conditions are important when analysing an environmental fiscal reform that affects labour taxes. Moreover, we show that the impact of the shadow economy is too significant not to be considered.

5.3. Sensitivity analysis

In this section we perform a comprehensive sensitivity analysis of the key parameters of the model. This analysis will allow us to extrapolate the results obtained for Spain, for other countries or situations where the shadow economy or the labour market conditions are different. Specifically, we explore the impact of an increase/decrease of 50% in the benchmark value for the following parameters: size of the shadow economy ($S_0$), size of official unemployment ($U_0$), unemployment flexibility ($\theta$), and substitutability between formal and informal labour ($x_F$). We also explore an alternative sectoral distribution of the shadow economy ($\delta_j$) due to the lack of accurate data. In all the sensitivity analyses we focus on the TaxL reform and its welfare effect.

5.3.1. Size of the shadow economy ($S_0$)

Here we evaluate the impact of environmental fiscal reform on welfare for different sizes of the shadow economy ($S_0$). The benchmark value for the shadow economy is 20% (similar to Belgium, Portugal and Sweden). We consider values for a shadow economy of 10% (similar to Japan, the United States and the United Kingdom) and of 30% (similar to Turkey, Mexico and Malaysia). A ranking of the shadow economy in 162 countries from 1999 to 2007 can be found in Schneider et al. (2010).

Fig. 5 shows the welfare effects (EV %) of different values of $S_0$ and different CO2 emission reduction targets in the case of reducing labour taxes (TaxL). As analysed extensively in previous sections, welfare increases with an increasing CO2 target/tax. The different sizes of the benchmark shadow economy however change the size of this effect. The higher the shadow economy (the green line) the higher the welfare increase and the lower the shadow economy (the red line) the lower the welfare increase is. For a CO2 reduction of 15%, the welfare in the benchmark increases by 2.9%, but it increases by 2.6% in the low scenario and 3.6% in the high scenario. For a reduction of 30% in emissions welfare increases a little, from 4.7% in the benchmark to 3.4% and 5.6% in the low and high scenarios.

Therefore, the bigger is the shadow economy is, the higher are the expected welfare gains. There are more potential workers that can move from the informal economy to the formal and the benefits from decreasing the tax burden and reducing the deadweight loss are also higher. Of course, this does not mean that is better to have a high shadow economy: it means that reforms of this type produce greater benefits in those countries where the initial situation is more inefficient.

5.3.2. Official unemployment rate ($U_0$)

In this section we analyse the impact of welfare for different official unemployment rates ($U_0$). The benchmark value for the official unemployment rate is 20% and we analyse alternative rates of 10% and 30%. Although unemployment rates of 30% are very rare, we perform this analysis in order to be consistent with the sensitivity analysis of an increase/decrease of 50% in the benchmark value.

Fig. 6 shows the welfare effects (EV %) of different values of $U_0$ and different CO2 emissions reduction targets in the case of reducing labour taxes (TaxL). It can be observed that the higher (lower) the benchmark unemployment rate is the higher the welfare increase can be. This is because, as in the case of a higher shadow economy, the higher the unemployment rate is the more potential workers can move from unemployment to employment and the greater the potential benefits that can be obtained.

For a CO2 reduction of 15% the welfare in the benchmark case increases by 2.5%, but it increases by 1.8% in the low scenario and 3.8% in the high scenario. For a reduction of 30% in emissions, welfare increases from 4.7% in the benchmark case to 2.9% and 6.3% in the low and high scenarios.

5.3.3. Wage curve elasticity parameter ($\theta$)

In this section we analyse the impact on welfare of different values of the wage curve elasticity parameter ($\theta$). The benchmark value of this parameter is 0.1 and we analyse the values 0.05 and 0.15, within which most countries are located according to Blanchflower and Oswald (1995, 2005). We also consider the extreme situations where $\theta = 0$ (real wage totally rigid and unemployment perfectly flexible) and $\theta \to \infty$ (real wage perfectly flexible and unemployment totally rigid).

Fig. 7 shows the welfare effects (EV%) for different values of theta $\theta$. The greater the value of this parameter the lower the welfare gain is. For a CO2 reduction of 15% the welfare in the benchmark case increases by 2.9%, but it increases by 3.4% in the low scenario (the red line) and 2.6 in the high scenario (the purple line). This result increases much more if the more extreme situation is considered, ranging from 1% to 4.5% for a reduction of 15%.

Therefore, the more “flexible” the labour market is (in terms of the possibility of reducing/increasing real wages instead of increasing/decreasing unemployment), the lower the welfare gains expected from tax reform are. Of course, we are not saying that it is better to have a “rigid” labour market: if we already have a “rigid” labour market the potential benefits of the fiscal reform are greater. Finally, although efficiency gains from the revenue-neutral carbon tax swap will be reduced if an elastic labour supply were considered. However, taking into account that most of the employment is involuntary, this effect should not be large enough as to affect the main conclusions of the paper.
we analyse the whole range of values for this parameter the results for the most likely range do not vary much, so it can be said that the results are not highly sensitive to this parameter.

5.3.4. Formal and informal labour substitutability ($\sigma_f$)

In this section we analyse the impact on welfare of different values of elasticity of substitution between formal and informal labour ($\sigma_f$). The benchmark value of this parameter is 5 and we analyse the values 2.5 and 7, plus the extreme situation where the value is 0, i.e. the two factors have to be combined in fixed proportions. The sensitivity analysis is necessary because there is no econometric estimation for this parameter, although other proxies such as the elasticity of substitution between skilled and unskilled labour could be used as a low range reference.

Fig. 9 shows the welfare effects (EV%) for different values of $\sigma_f$. The greater the value of this parameter, the greater the welfare gain is. For a CO2 reduction of 15% the welfare in the benchmark case increases by 2.9%, but it increases by 1.2% in the low scenario (the blue line) and 5.2% in the high scenario (the green line). The welfare gain decreases to 0.2% if no substitutability is considered (purple line).

Therefore, the more substitutability there is between the two forms of labour the greater is the expected increase in welfare because workers can move more easily to the formal labour market. Moreover, the value of this parameter is important because it has a considerable effect on the final results.

5.3.5. Sectoral distribution of the informal economy ($\delta$)

Finally, we explore how the sectoral distribution of the shadow economy (parameter $\delta$) affects the results. Most research in the field of the shadow economy research has focused on estimating its total size with different indirect methods (monetary, electricity consumption, etc.), but few papers report sectoral disaggregation. We compare the results of “benchmark distribution”, which is based on a Danish study by Hvidtfeldt et al. (2011), with a “uniform distribution” (blue line), i.e. total informal labour is distributed proportionally to formal labour.

Fig. 9 shows that the welfare effects (EV %) are very similar in the two distribution scenarios. For a CO2 reduction of 15% welfare increases by 2.9% in the benchmark distribution (red line) and 2.6 in the uniform distribution (blue line). Moreover, the greater the CO2 reduction target/tax the smaller this difference becomes, as the distribution of the shadow economy is not so important as other substitution effects. Therefore, although the distribution of the shadow economy obviously affects sectors, the overall effect is not very significant.

6. Concluding remarks

Environmental fiscal reforms are proposed as important policy tools for providing potentially important benefits for the economy and the environment. This paper is the first attempt to estimate empirically the impact of the “shadow economy” on the performance of a “green” tax reform. Since the informal labour is not taxed, the green tax causes the informal sector to pay factor taxes because it leads to a general increase in the price level, which is an implicit tax on factors of production (labour and capital). Thus, via the green tax, the government manages to shift from (a) a system where only the formal sector pays taxes on factors to (b) a system where both the formal and the informal sector pay such taxes. The pre-existing non-environment-related inefficiency of the tax system is reduced in this way. Although this mechanism is not new (see Bowenberg and Goulder, 1997), our main contribution is to consider the shadow economy as a new and important source of inefficiency and to estimate it in the context of the double dividend hypothesis.

We use a CGE model for the case of Spain, which has one of the highest unemployment rates in the developed world and one of the biggest informal economies of any wealthy country. The effects of a revenue-neutral CO2 tax reform are analysed by focusing on the revenue-recycling effect of using revenues from a CO2 tax to reduce taxes on labour or on capital or to make lump sum transfers. We use a standard CGE model that contains two features which are important regarding the labour market. First, there is involuntary unemployment and wages are determined endogenously following a wage curve. And second, formal and informal labour (which are substitutes in the production function) are linked through an equilibrium condition where expected wages in the two sectors are equal.

Our results show that, if the distortions created by the shadow economy are considered, the case for an environmental tax reform involving recycling via a labour tax reduction is strong. Assuming flexibility in the wage curve and in the formal and informal labour markets, we obtain a welfare gain (measured through Equivalent Variation, EV) of around 3% for a reduction in emissions of 15%. Moreover, the official GDP could increase by 7%, as long as workers in the shadow economy (informal workers) are brought into formal labour, and unemployment could be reduced by 3%. If the effects of the shadow economy are isolated from other effects an extra amount of 1.5% in welfare and 1.4% in GDP can be expected. These results confirm that the impacts of considering the shadow economy are too relevant to be neglected. Our sensitivity analysis also shows that these results can also be extrapolated to some extent to other countries with different sizes of the shadow economy or different labour market conditions.

Of course, CGE models are highly stylised and we use a static model where dynamic effects are not taken into account. Hence we cannot expect a tax reform to generate the changes in one period, but rather to take a number of quarters. It is also important to note that welfare effects are dependent on the parameters assumed, especially the substitutability between formal and informal labour. Finally, it must be borne in mind that trade impacts are restricted in these models (following the Armington assumption) and effects on competitiveness are not fully incorporated. In any case, any reform of this kind would probably need to be pan-European to avoid negative impacts in some sectors.

The main policy recommendation from this and other papers on environmental fiscal reforms, especially in Europe, is that of the best options is to replace taxes on labour by taxes on energy/CO2. Therefore, the next question is obviously why environmental tax reforms are not undertaken if they are so convenient. There are two main barriers that explain this paradox. The first reason is that people do not like paying new taxes, even if they are revenue neutral. Our analysis, which includes the shadow economy, has shown that the tax burden could even be reduced as more people in the informal economy will start paying taxes and, thus, governments will be more favourable to implement these reforms. The second reason is that an increase in the price of energy could have a regressive effect on households (Rapanos, 1995). Although, according to different studies, carbon taxes are not necessarily regressive there is often a concern that some of the poorest groups spend a higher percent of their income on energy than those who are better off. In that sense the implications of including the shadow economy has not been explored yet. This is an important aspect not considered in this paper that should be explored in future.

Acknowledgments

The authors gratefully acknowledge Larry Goulder and Antonio G. Gomez-Planas for very valuable comments on earlier drafts and three anonymous referees. We also thank the financial support from Science and Innovation Ministry of Spain (ECO2011-25064) and Basque Government (GIC07/56-IT-383-07). The usual disclaimer applies.
Appendix A

Table A1
Extended Input–Output Table with informal labour (LI), 2005.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Formal labour</th>
<th>Informal labour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(€M) (%)</td>
<td>(€M) (%)</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1–3, 5–7</td>
<td>3053 (1.8%)</td>
</tr>
<tr>
<td>Coal</td>
<td>4</td>
<td>30 (0.0%)</td>
</tr>
<tr>
<td>Oil</td>
<td>8</td>
<td>39 (0.0%)</td>
</tr>
<tr>
<td>Gas</td>
<td>10</td>
<td>20 (0.0%)</td>
</tr>
<tr>
<td>Electricity</td>
<td>9</td>
<td>127 (0.1%)</td>
</tr>
<tr>
<td>Industry</td>
<td>11,12–39</td>
<td>11433 (7.0%)</td>
</tr>
<tr>
<td>Construction</td>
<td>40–50</td>
<td>24467 (14.9%)</td>
</tr>
<tr>
<td>Transport</td>
<td>46–52</td>
<td>18002 (5.4%)</td>
</tr>
<tr>
<td>Services</td>
<td>41–45, 53–73</td>
<td>21258 (63.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>334421 (100%)</td>
<td>164073 (100%)</td>
</tr>
</tbody>
</table>

Source: INE (2009a) and own work.

Table A2
Sectoral output and production factors, 2005.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Source codes</th>
<th>Input–output table</th>
<th>Formal labour (% of GDP)</th>
<th>Informal labour (% of GDP)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1,2,3,4,5,6,7</td>
<td>46157</td>
<td>1.5%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Coal</td>
<td>8,9</td>
<td>−15</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Oil</td>
<td>10</td>
<td>150</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Gas</td>
<td>11</td>
<td>100</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Electricity</td>
<td>12</td>
<td>900</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Industry</td>
<td>13</td>
<td>3000</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Construction</td>
<td>14</td>
<td>1000</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Transport</td>
<td>15</td>
<td>500</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Services</td>
<td>16</td>
<td>1000</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>10000</td>
<td>0.1%</td>
<td>0.0%</td>
<td>Low</td>
</tr>
</tbody>
</table>

Source: INE (2009a) and own work.

Table A3
Sectoral CO2 and other local pollutant emissions, 2005.

<table>
<thead>
<tr>
<th>Sector codes</th>
<th>CO2 (kton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>12192</td>
</tr>
<tr>
<td>Coal</td>
<td>338</td>
</tr>
<tr>
<td>Oil</td>
<td>19952</td>
</tr>
<tr>
<td>Gas</td>
<td>235</td>
</tr>
<tr>
<td>Electricity</td>
<td>109186</td>
</tr>
<tr>
<td>Industry</td>
<td>39357</td>
</tr>
<tr>
<td>Construction</td>
<td>5316</td>
</tr>
<tr>
<td>Transport</td>
<td>35802</td>
</tr>
<tr>
<td>Services</td>
<td>12354</td>
</tr>
<tr>
<td>Households</td>
<td>76357</td>
</tr>
<tr>
<td>Total</td>
<td>364888</td>
</tr>
</tbody>
</table>

Source: INE (2009b) and own work.
Table A4
Sectoral CO2 disaggregation by different sources in %, 2005.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>3</td>
<td>96</td>
<td>1</td>
</tr>
<tr>
<td>Coal</td>
<td>–</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Oil</td>
<td>30</td>
<td>–</td>
<td>70</td>
</tr>
<tr>
<td>Gas</td>
<td>0</td>
<td>100</td>
<td>–</td>
</tr>
<tr>
<td>Electricity</td>
<td>55</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Industry</td>
<td>10</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>Construction</td>
<td>0</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Transport</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Services</td>
<td>0</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Households</td>
<td>3</td>
<td>75</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>58</td>
<td>20</td>
</tr>
</tbody>
</table>

Source: Eurostat (2005), INE (2009b) and own work.

Table A5
Elasticities of substitution in production, trade and consumption.

<table>
<thead>
<tr>
<th>Elasticity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma^{fl} )</td>
<td>Elasticity of substitution between material inputs and Capital–Labour–Energy</td>
</tr>
<tr>
<td>( \sigma^{fl,L} )</td>
<td>Elasticity of substitution between Capital–Labour and Energy</td>
</tr>
<tr>
<td>( \sigma^{fl,V} )</td>
<td>Elasticity of substitution between Capital and Labour</td>
</tr>
<tr>
<td>( \sigma^{fl} )</td>
<td>Elasticity of substitution between Formal and Informal Labour</td>
</tr>
<tr>
<td>( \sigma^{e} )</td>
<td>Elasticity of substitution between Electricity and Fossil Fuels</td>
</tr>
<tr>
<td>( \sigma^{C} )</td>
<td>Elasticity of substitution between Coal, Oil and Gas</td>
</tr>
<tr>
<td>( \sigma^{o} )</td>
<td>Elasticity of substitution between domestic and imported goods</td>
</tr>
<tr>
<td>( \sigma^{f} )</td>
<td>Elasticity of transformation between domestic goods and exports</td>
</tr>
<tr>
<td>( \sigma^{q} )</td>
<td>Elasticity of substitution between consumption of energy and non energy goods</td>
</tr>
<tr>
<td>( \sigma^{sl} )</td>
<td>Elasticity of substitution in consumption of energy goods</td>
</tr>
<tr>
<td>( \sigma^{sl,E} )</td>
<td>Elasticity of substitution in consumption of non energy goods</td>
</tr>
</tbody>
</table>

Source: MIT-EPPA Babiker et al. (2001). The value for \( \sigma^{fl} \) is own.

References

Schneider, F., 2011. The shadow economy and shadow economy labor force: what do we not know? IZA WP 5769.