Volume 40, Supplement 1, December 2013 ISSN 0140–9883

ELSEVIER

Energy Economics

CONTENTS

Supplement Issue: Fifth Atlantic Workshop in Energy and Environmental Economics
Guest Editors: Carlos de Miguel, Alberto Gago, Xavier Labandeira, Baltasar Manzano

Contents continued on the outside back cover

Includes the Journal of Energy Finance and Development
Available online at www.sciencedirect.com
ScienceDirect

Energy Economics 40 (2013) S108–S118

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

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

Anil Markandya [a], Mikel González-Eguino [b,*], Marta Escapa [c]

[a] Basque Centre for Climate Change (BC3) and IKERBASQUE, Basque Foundation for Science, Spain
[b] Basque Centre for Climate Change (BC3) and University of the Basque Country (UPV/EHU), Spain
[c] University of the Basque Country (UPV/EHU), Spain

ARTICLE INFO

Available online 21 September 2013

JEL classification:
D58
H2
Q5

Keywords:
Environmental fiscal reform
Double dividend hypothesis
Shadow economy
Unemployment
General equilibrium analysis
Spain

ABSTRACT

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 divided 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.

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"[1] 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 possibility of reducing taxes on labour in order to reduce unemployment as a consequence of the environmental fiscal reform. The findings suggest that switching taxation from labour to energy/carbon can increase welfare, employment and reduce emissions but there are disagreements as to the size of these effects[2]; Majocchi (1996) and Markandya (2011) provide surveys of the quantitative studies. There are a great number of different models that focus on different characteristics of the labour market and show different restrictions and conditions that have to be met for a double dividend (in employment) to be found (see Bovenberg and Goulder, 1996; Bovenberg and van der Ploeg, 1998, among others). One relevant point is whether involuntary unemployment is incorporated into the analysis or not (see Carraro et al, 1996; Kosquela and Schöb, 1999; Manresa and Sancho, 2005). In these circumstances there are two possible ways of increasing the demand for labour and reducing unemployment: (i) shifting the tax burden from workers to other groups (people on state benefits, living on capital income or from other countries); and (ii) improving the efficiency of the tax system by shifting taxation from labour to other factors such as capital, energy or carbon.

To date however, this large body of literature on the double dividend hypothesis includes no empirical[3] research on the link between the shadow economy and environmental fiscal reforms. This is an important gap considering that: i) labour taxes affect the decision whether to work in the formal or the informal sector; and ii) informal markets

* Corresponding author at: Basque Centre for Climate Change (BC3), Alameda Urquijo, 4, 4ª 48008 Bilbao, Spain. Tel.: +34 944014690; fax: +34 944054787.
E-mail address: mikel.gonzalez@bc3research.org (M. González-Eguino).

[1] The "tax-interaction effect" is associated with the impacts of environmental policy instruments on the returns to factors of production and the "revenue-recycling effect" is associated with the return to the economy of any revenues generated by an environmental policy instrument.

[2] There is also a debate about the political feasibility of an environmental fiscal reform and the need of gradualism when implementing this type of policies (see De Miguel and Manzano, 2011).

[3] Bovenberg and van der Ploeg (1998) analyse this issue from a theoretical perspective.

0140-9883/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.eneco.2013.09.014

Table 1
Size of the shadow economy in some developed countries, 2005 (% of GDP).

Greece, Italy, Spain, Portugal and Belgium	21–29%
Norway, Sweden, Denmark, Ireland, France, The Netherlands, Germany and Great Britain	12–18%
Japan, Austria, United States and Switzerland	8–10%
Spain (Arrazola et al., 2011)	19–23%

Source: Buehn and Schneider, 2011 and Arrazola et al., 2011.

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 CO_2 tax reform by focusing on the revenue-recycling effect. We compare the effects of using revenues from a CO_2 tax to reduce taxes on labour, 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 in previous studies have traditionally been more optimistic for Spain than for other European countries (see Labandeira et al., 2004; Manresa and Sancho, 2005 or Fæhn et al., 2009), reflecting perhaps greater inefficiencies in the labour market.[4] The studies mentioned show that replacing part of labour taxation by a carbon tax would reduce unemployment and result in either a small loss of welfare or a small gain (as measured by the equivalent variation (EV)).

Our results show that, if the distortions created by the shadow economy are considered, the double dividend hypothesis is more likely: important improvements in welfare can be found with a CGE model if revenues from green (CO_2) taxes are used to reduce taxes on labour. Since the informal labour is not taxed, when the CO_2 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. Thus, via the CO_2 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. This improves efficiency on non-environmental grounds by broadening the factor tax base.

The mechanism that generates the double dividend is not new (to overcome a pre-existing non-environment-related inefficiency in the tax system) and it is well documented (see Bovenberg and Goulder, 1997 or Bento and Jacobsen, 2007). Our main contribution is to include the shadow economy (and informal labour not taxed) as a new source of inefficiency and to estimate how that may increase the double dividend from a green tax reform.

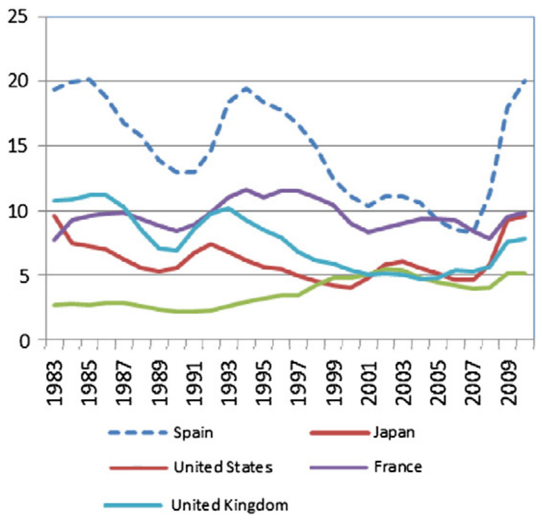

Fig. 1. Unemployment rates in some developed countries, 1983–2010. Source: OCDE (2009).

The paper is structured as follows. Section 2 discusses the relevance of the Spanish case study. Section 3 presents the algebraic model and the specificities of the labour market and Section 4 details the data used for calibration. Section 5 presents the results obtained from the different recycling schemes in the economy and in the environment. Finally, Section 6 concludes with some reflections on where further research is needed and provides some policy recommendations.

2. The shadow economy and unemployment in Spain

It is necessary to clarify what it is meant in this paper by "shadow economy", as there is no single precise and accepted definition of this concept. In fact, several different labels (shadow, informal, underground, irregular, hidden and subterranean) are used in reference to these economic activities. In this paper we follow the definition proposed by the OECD, which considers the shadow economy to include all production activities that are legal[5] but deliberately concealed from public authorities in order to avoid: i) paying taxes or social security contributions; ii) meeting certain legal standards such as minimum wages, maximum hours, safety and health standards; or iii) complying with certain administrative procedures, such as completing statistical questionnaires or other administrative forms. A shadow economy thus implies a shadow or informal labour market. According to the OECD (2009)[6] informal employment is the result of both people being excluded from official jobs and people voluntarily opting out of formal structures.

A comprehensive survey regarding definitions and estimation procedures for the shadow economy can be found in Schneider and Enste (2000) and Schneider (2005, 2011). One of the conclusions of these studies is that the main driving forces of the shadow economy are: i) tax and social security contribution burdens; ii) the lack of 'tax morale' or the intrinsic motivation of individuals to pay taxes; and iii) the intensity of state regulations. The bigger the difference between

[4] A comparison of some studies for Spain can be found in Markandya et al., 2012.

[5] Illegal activities such as drug dealing, crime and human trafficking are not included. Activities such as some household services that legally do not need to be reported to authorities are also excluded.

[6] At the world-wide level, informal jobs are the norm or the normal case: 1.8 billion people work in informal jobs, compared to 1.2 billion who enjoy formal contracts and social security protection (OECD, 2009).

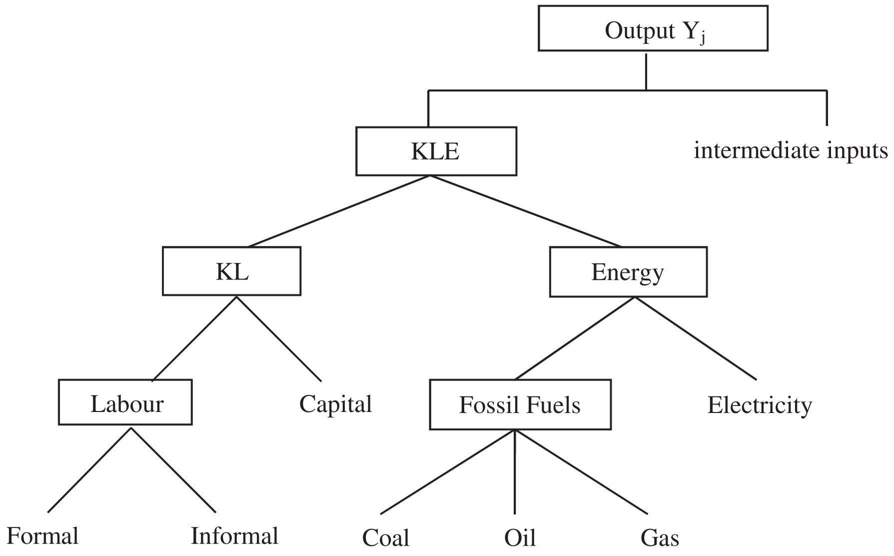

Fig. 2. Output nested CES function structure.

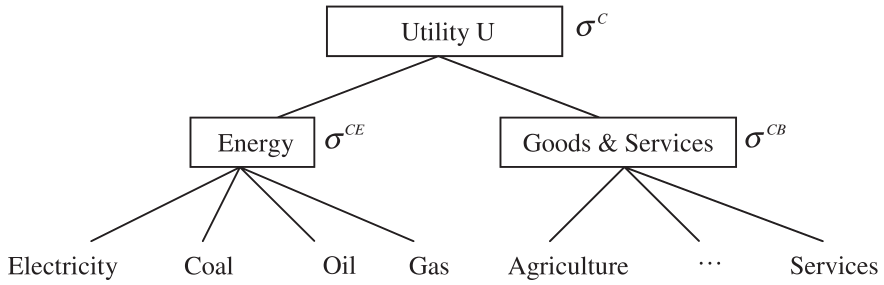

Fig. 3. Utility nested CES function structure.

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[7] 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 CO_2 in some sectors, the main instrument has been the granting of tax

[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).

Table 2
Welfare impacts (%). No mobility ($\sigma_L = 0$) and perfectly flexible wages ($\theta \to \infty$).

	CO_2 emission reduction (%)					
Tax recycling	5%	10%	15%	20%	25%	30%
LST	−0.01	−0.04	−0.09	−0.18	−0.33	−0.54
TaxK	−0.01	−0.03	−0.09	−0.18	−0.32	−0.53
TaxL	0.00	−0.03	−0.08	−0.17	−0.31	−0.52

Table 3
Welfare impacts (%). Mobility ($\sigma_L = 5$) and flexible wages ($\theta = 0.1$).

	CO_2 emission reduction (%)					
Tax recycling	5%	10%	15%	20%	25%	30%
LST	−0.22	−0.52	−0.91	−1.43	−2.10	−2.96
TaxK	−0.21	−0.51	−0.91	−1.43	−2.10	−2.96
TaxL	1.05	2.02	2.89	3.65	4.27	4.72

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 and supplies goods and services; and (4) the "Rest of the World", an aggregate that brings together foreign sectors. Primary factors, which are fixed, are capital and labour (formal and informal). All goods are assumed to be homogenous and perfectly mobile between sectors, but labour and capital are only mobile domestically. There can also be mobility between the formal and informal labour markets.

Producers operate under full competition and maximise profit subject to given prices and current technology. Under constant returns to scale net profits are zero; the value of output must equal the value of all inputs used. Fig. 2 shows the nested-CES production function structure used in this model. The value of the elasticities of substitution between different inputs can be found in the Appendix A.

Consumers have an initial endowment of factors and maximise utility subject to the budget constraint; the value of income must equal the total value of expenditures. Fig. 3 shows the nested-CES utility function. The income obtained from labour (formal and informal), capital and direct transfers from the government is equal to consumption, savings and the payment for CO_2 emissions from households. We assume that savings are a fixed proportion of income and they are used to finance investments and foreign trade deficit.

The government obtains its income through taxes on capital, formal labour and CO_2 emissions.[9] 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 CO_2 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[10] 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 (L_j) by sectors is modelled through a CES function as follows:

$$L_j = \left(\delta_j L_j^{F(1-1/\sigma_L)} + \left(1-\delta_j\right) L_j^{I(1-1/\sigma_L)}\right)^{1/(1-1/\sigma_L)} \tag{16}$$

where L_j^F and L_j^I is formal and informal labour, δ_j is the benchmark share of formal employment for sector j and σ_L is the constant elasticity of substitution between formal and informal labour. When the value of σ_L 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 σ_L *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),

[9] Total CO_2 emissions are the sum of emissions from production sectors and consumers. These emissions are associated via coefficients with consumption of coal, oil and gas. We tax all sources of CO_2 emissions to guarantee cost-effectiveness, although in a real-policy context a CO_2 tax could vary from sector to sector and also between producers and consumers.

[10] There is no labour–leisure choice in the model so all unemployment is involuntary.

Table 4
Economic impacts of alternative tax recycling (15% CO_2 reduction).

	LST	TaxK	TaxL
General (% change in volumes)			
Welfare	−0.91	−0.91	2.89
GDP (including shadow economy)	−0.83	−0.83	2.62
Official GDP	−1.55	−1.55	7.65
General (values in %)			
(S) Shadow Economy (base = 20%)	20.9%	20.9%	14.5%
(U) Unemployment (official, base = 20%)	21.4%	21.4%	16.5%
(Ur) Unemployment (real, base = 10.9%)	12.3%	12.4%	10.8%
Tax Burden (base = 14.5%)	14.6%	14.6%	13.3%
Private consumption (% change in volumes)			
Agriculture	−0.99	−1.81	1.17
Energy	−2.67	−3.04	0.53
Industry	−1.68	−2.09	1.95
Construction	−0.62	−0.70	3.70
Transport	−1.65	−1.23	1.76
Services	−0.32	−0.21	3.74
Energy consumption by source (% change in volumes)			
Coal	−34.39	−34.38	−37.11
Oil	−9.63	−9.52	−9.10
Gas	−1.76	−2.20	0.72
Electricity	−2.77	−2.92	0.06
Emissions (% change in volumes)			
CO_2 emissions	−15.00	−15.00	−15.00
CO_2 tax (€/tCO_2)	33.91	33.83	46.23
Prices (% change)			
Capital price index	−2.15	−0.08	0.75
Formal labour price index	−0.43	−0.44	0.66
Informal labour price index	−1.53	−1.55	2.26

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:

$$\frac{w_F}{P} = \left(\frac{u}{\bar{u}}\right)^{-\theta} \tag{17}$$

where w_F is the formal wage, u is the unemployment rate, $\bar{u}$ is the unemployment rate at the benchmark, θ is an elasticity parameter that measures the sensitivity of the wage rate to the unemployment rate and P is the consumer goods price index. θ 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 θ 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 θ 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 θ 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

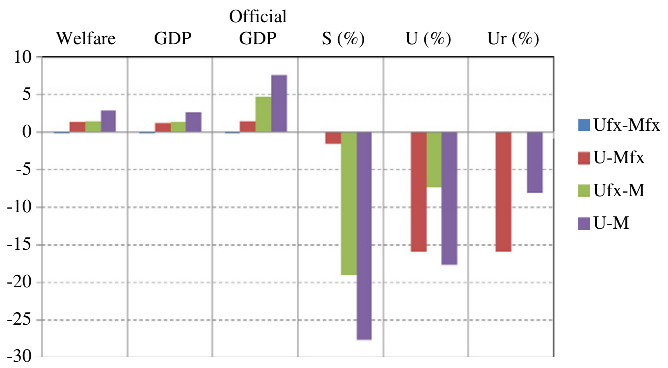

Fig. 4. Effect of TaxL scenario under different labour market conditions (15% reduction in CO_2).

formal and informal wages widens. If unemployment is zero, formal and informal wages (before taxes) should eventually become equal.

$$w_I = w_F(1-u) \tag{18}$$

We also include in the model an endogenous parameter m [12], which measures the mobility rate and determines formal and informal labour supplied in equilibrium:

$$L^F = L_0^F(1-u) + L_0^I(1-m) \tag{19}$$

$$L^I = L_0^I m \tag{20}$$

where L_0^F and L_0^I 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 CO_2 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 economic activity. The selection of sectors under each category and the level of informal labour are based on Hvidtfeldt et al. (2011).[13]

[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 and the value of the elasticity of substitution between formal and informal labour (σ_L) If $\sigma_L = 0$, 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%).

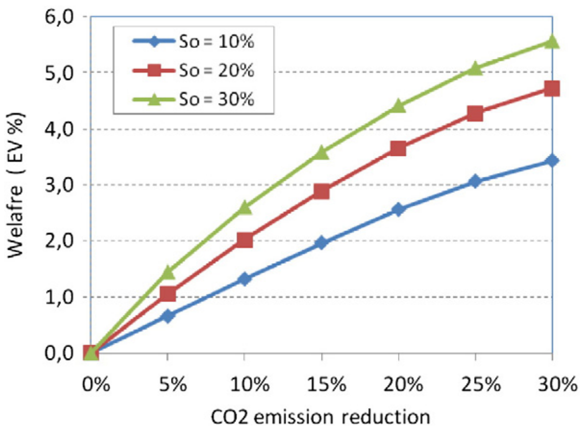

Fig. 5. Welfare impacts (%) for different benchmark sizes of the shadow economy.

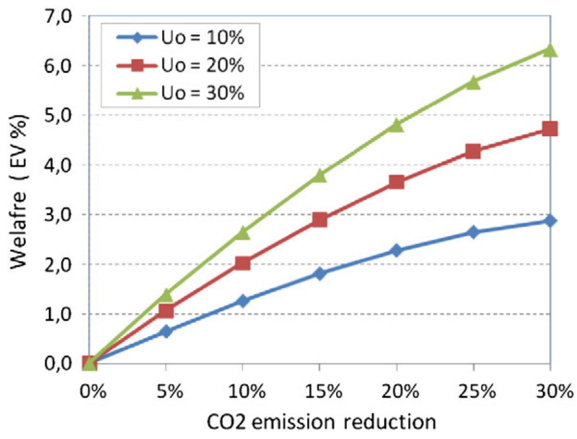

Fig. 6. Welfare impacts for different benchmark official unemployment rates.

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 CO_2 taxes set to reduce emissions by amount ranging from 5% to 30%. The revenues from CO_2 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 ($\sigma_L = 0$) 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 CO_2 emissions and by around 0.54 for a reduction of 30%. A very small weak 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 distortionary 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 ($\sigma_L = 5$). 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 CO_2 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 on formal labour (TaxL scenario) increases 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 CO_2 tax (and the CO_2 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 CO_2 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 CO_2 emissions. It can be observed that if labour taxes are reduced, welfare will increase by 2.8%, GDP by 2.6% 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.

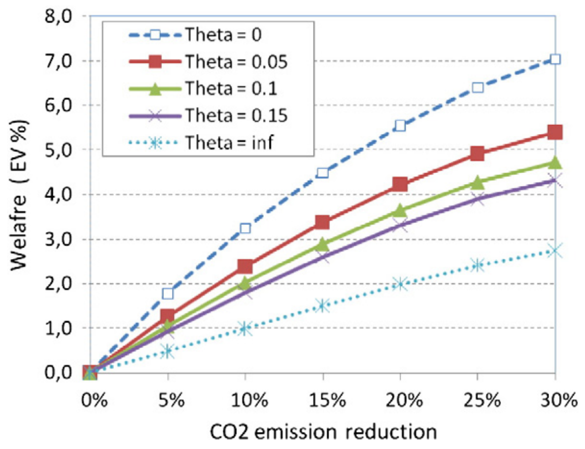

Fig. 7. Welfare impacts for different values of labour market flexibility (θ).

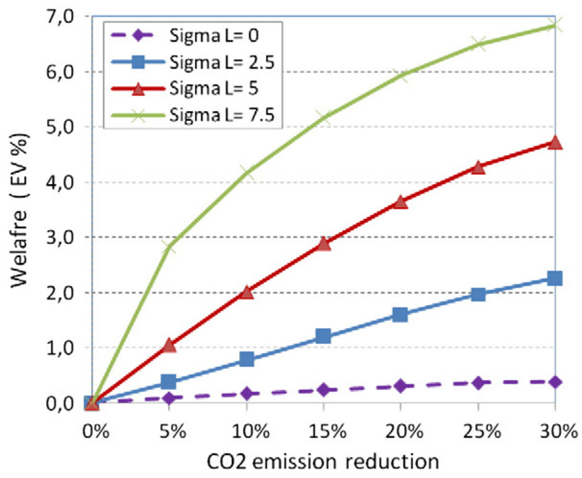

Fig. 8. Welfare impacts for different values of the elasticity of substitution between formal and informal labour (σ_L).

activity is explained by the reduction of both "official" unemployment (from 20% to 16.5%) and "real" unemployment (from 10.9% to 10.8%),[17] 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 CO_2 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 reduced more than gas and electricity. The results also show a shift from highly CO_2-intensive sectors (Energy, Industry and Transport) towards less CO_2 emission-intensive sectors (Services). The CO_2 taxes required to reach the CO_2 targets are around €33/tCO_2 in the LST and TaxK scenarios, and €46/tCO_2 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 CO_2 taxes increase the (relative) price of energy increases and, therefore, the prices of other production factors (labour and capital) decrease.[18] 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 ($\theta \rightarrow \infty$ and benchmark unemployment is fixed (Ufx)) or not (U).

The results in the blue bar (mobility not allowed ($\sigma_L = 0$) and unemployment fixed ($\theta \rightarrow \infty$)) 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[19] 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 those 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 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_o), size of official unemployment (U_0), unemployment flexibility (θ), and substitutability between formal and informal labour (σ_L). We also explore an alternative sectoral distribution of the shadow economy (δ_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).[20] 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 CO_2 emission reduction targets in the case of reducing labour taxes (TaxL). As analysed extensively in previous sections, welfare increases with an increasing CO_2 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 is and the lower the shadow economy (the red line) the lower the welfare increase is. For a CO_2 reduction of 15%, the welfare in the benchmark increases by 2.9%, but it increases by 2.0% 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 CO_2 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 CO_2 reduction of 15% the welfare in the benchmark case increases by 2.9%, 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.

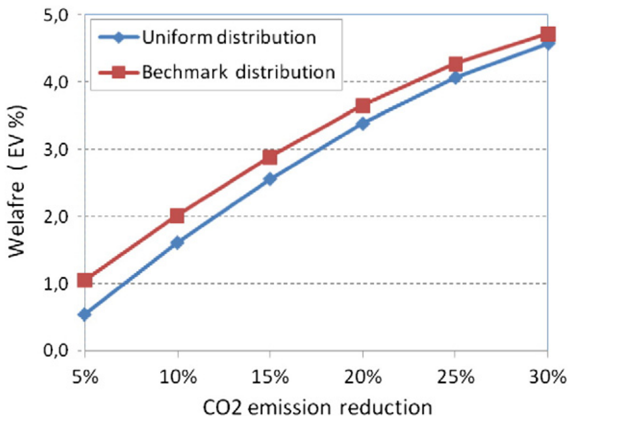

Fig. 9. Welfare impacts for different distributions of the shadow economy between sectors (δ_j).

5.3.3. Wage curve elasticity parameter (θ)

In this section we analyse the impact on welfare of different values of the wage curve elasticity parameter (θ). 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 θ The greater the value of this parameter the lower the welfare gain is. For a CO_2 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.[21] Finally, although

[20] To perform this sensitivity analysis two new different Input–Output Tables were constructed where the sum of the row of the “informal labour” sector is increases/decreases to obtain the shadow economy desired.

[21] 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 (σ_L)

In this section we analyse the impact on welfare of different values of elasticity of substitution between formal and informal labour (σ_L). 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. 8 shows the welfare effects (EV%) for different values of σ_L The greater the value of this parameter, the greater the welfare gain is. For a CO_2 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 (δ_j)

Finally, we explore how the sectoral distribution of the shadow economy (parameter δ_j) 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 CO_2 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 CO_2 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 Bovenberg 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 CO_2 tax reform are analysed by focusing on the revenue-recycling effect of using revenues from a CO_2 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 one of the best options is to replace taxes on labour by taxes on energy/CO_2. 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-Plana 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.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	C	G	I	M	X	Total
Agriculture	46157	−1	−17744	−4941	−1	−29880	−1488	−310	−3142	−12496	0	−871	33456	−8739	0
Coal	−15	984	−100	−4	−1887	−362	0	−5	−75	−195	0	−14	1678	−5	0
Oil	−940	−30	25372	−29	−3072	−4791	−484	−6496	−2842	−8355	0	−219	9369	−7483	0
Gas	−54	−1	−500	7774	−3146	−1940	−20	−147	−1053	−3200	0	−1	2399	−111	0
Electricity	−719	−88	−73	−29	26402	−7720	−526	−1676	−9426	−6219	0	−10	502	−418	0
Industry	−10406	−239	−308	−17	−1530	261044	−54468	−9293	−68376	−115409	−7033	−55744	191306	−129527	0
Construction	−271	−4	−32	−16	−435	−1836	200192	−2190	−20687	−28831	0	−145897	16	−9	0
Transport	−1190	−52	−813	−26	−1145	−25228	−3535	103128	−28295	−33748	−2087	−216	10501	−17294	0
Services	−4040	−79	−1313	−240	−3901	−61133	−22551	−21955	781145	−454975	−162173	−42363	27811	−34233	0
LF	−5058	−301	−391	−198	−1270	−57164	−40779	−18002	−211258	334421	0	0	0	0	0
LI	−3035	−30	−39	−20	−127	−11433	−24467	−3600	−126755	169506	0	0	0	0	0
K	−19559	−60	−3227	−2115	−9099	−41994	−36758	−30947	−231806	375565	0	0	0	0	0
TAXK	0	−3	−702	−68	−284	0	−2454	−3208	−18210	0	24929	0	0	0	0
TAXL	−870	−96	−130	−71	−505	−17563	−12662	−5299	−59220	0	96416	0	0	0	0
TAXLS	0	0	0	0	0	0	0	0	0	−49948	49948	0			
Savings	0	0	0	0	0	0	0	0	0	−245335	0	245335	0	0	0
XD	0	0	0	0	0	0	0	0	0	79219	0	0	−277038	197819	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Source: INE (2009a) and own work.

Table A2
Sectoral output and production factors, 2005.

	Input–output table	Formal labour		Informal labour		
	Sectoral codes	(M€)	(%)	(M€)	(%)	Category
Agriculture	1–3, 5–7	5058	(1.5%)	3035	(1.8%)	High
Coal	4	301	(0.1%)	30	(0.0%)	Low
Oil	8	391	(0.1%)	39	(0.0%)	Low
Gas	10	198	(0.1%)	20	(0.0%)	Low
Electricity	9	1270	(0.4%)	127	(0.1%)	Low
Industry	11,12–39	57164	(17.1%)	11433	(7.0%)	Medium
Construction	40	40779	(12.2%)	24467	(14.9%)	High
Transport	46–52	18002	(5.4%)	3600	(2.2%)	Medium
Services	41–45, 53–73	211258	(63.2%)	126755	(77.3%)	high
Total		334421	(100%)	164073	(100%)	

Source: INE (2009a) and own work.
Note: the sectors with low, medium and high participation of informal labour are classified following Hvidtfeldt et al. (2011). It is assumed that 10 (low), 20 (medium) and 60% (high) of labour is not declared in those sectors and therefore can be classed as informal labour. In total, the shadow economy accounts for 20% of official GDP in 2005.

Table A3
Sectoral CO_2 and other local pollutant emissions, 2005.

	Sectoral codes	CO_2 (kton)
Agriculture	AB + CA.2 + CB	12192
Coal	CA.1	338
Oil	DF	19952
Gas	E.2	235
Electricity	E.1	109186
Industry	E.3 + D − DF	93557
Construction	F	5316
Transport	I	35402
Services	G + H + J + K + L + M + N + O + 95	12354
Households		76357
Total		364888

Source: INE (2009b) and own work.

Table A4
Sectoral CO_2 disaggregation by different sources in %, 2005.

	Coal	Oil	Gas
Agriculture	3	96	1
Coal	–	97	3
Oil	30	–	70
Gas	0	100	–
Electricity	55	25	20
Industry	10	70	20
Construction	0	97	3
Transport	0	100	0
Services	0	80	20
Households	3	75	22
Total	22	58	20

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

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

σ^{Y}	Elasticity of substitution between material inputs and Capital–Labour–Energy	0
σ^{KLE}	Elasticity of substitution between Capital–Labour and Energy	0.25
σ^{KL}	Elasticity of substitution between Capital and Labour	1
σ^{L}	Elasticity of substitution between Formal and Informal Labour	5
σ^{E}	Elasticity of substitution between Electricity and Fossil Fuels	0.5
σ^{F}	Elasticity of substitution between Coal, Oil and Gas	1
σ^{A}	Elasticity of substitution between domestic and imported goods	3
σ^{T}	Elasticity of transformation between domestic goods and exports	3
σ^{C}	Elasticity of substitution between consumption of energy and non energy goods	0.5
σ^{CE}	Elasticity of substitution in consumption of energy goods	1
σ^{CB}	Elasticity of substitution in consumption of non energy goods	1

Source: MIT-EPPA Babiker et al. (2001). The value for σ^{L} is our own.

References

Ahn, N., de la Rica, S., 1997. The underground economy in Spain: an alternative to unemployment? Appl. Econ. 29, 733–743.
Arrazola, M., Hevia, J., Mauleón, I., Sánchez, R., 2011. Estimación del volumen de economía sumergida en España. Cuadernos de Información Económica 220, 81–88.
Babiker, M.H., Reilly, J.M., Mayer, M., Eckaus, R.S., Sue Wing, I., Hyman, R.C., 2001. The MIT emissions prediction and policy analysis EPPA model: revisions, sensitivities, and comparisons of results. MIT Joint Program on the Science and Policy of Global Change, Report 71, Cambridge, Massachusetts.
Bajada, C., Schneider, F., 2009. Unemployment and the shadow economy in the OECD. Rev. Economique 60, 1011–1033.
Bento, A., Jacobsen, M., 2007. Ricardian rents, environmental policy and the double dividend hypothesis. J. Environ. Econ. Manag. 53, 17–31.
Blanchflower, D.G., Oswald, A.J., 1995. An introduction to the wage curve. J. Econ. Perspect. 9, 153–167.
Blanchflower, D.G., Oswald, A.J., 2005. The wage curve reload. IZA WP 1665, pp. 1–47.
Bovenberg, A.L., Goulder, L.H., 1996. Optimal environmental taxation in the presence of other taxes: general equilibrium analyses. Am. Econ. Rev. 86, 985–1000.
Bovenberg, A.L., Goulder, L.H., 1997. Costs of environmentally motivated taxes in the presence of other taxes: general equilibrium analyses. Natl. Tax J. 50 (1), 59–87.
Bovenberg, A.L., van der Ploeg, 1998. Tax reform, structural unemployment and the environment. Scand. J. Econ. 100 (3), 593–610.
Buehn, A., Schneider, F., 2011. Shadow economies around the world: novel insights, accepted knowledge, and new estimates. Int. Tax Public Financ. 1–33.
Carraro, C., Galeotti, M., Gallo, M., 1996. Environmental taxation and unemployment: some evidence on the double dividend hypothesis in Europe. J. Public Econ. 62, 141–181.
De Miguel, C., Manzano, B., 2011. Gradual green tax reforms. Energ. Econ. 33 (1), 50–58.
Eurostat, 2005. Energy and Environment Statistics. European Statistic Office.
Fæhn, T., Gómez-Plana, A.G., Kverndokk, S., 2009. Can a carbon permit system reduce Spanish unemployment? Energ. Econ. 31 (4), 595–604.
Feld, L.P., Schneider, F., 2010. Survey on the shadow economy and undeclared earnings in OECD countries. Ger. Econ. Rev. 112, 109–149.
González-Eguino, M., 2011. The importance of the design of market-based instruments for CO_2 mitigation: an AGE analysis for Spain. Ecol. Econ. 70, 2292–2302.
Goulder, L.H., 1995. Environmental taxation and the double dividend: a reader's guide. Int. Tax Public Financ. 2, 157–184.
Goulder, L.H., 2013. Fiscal interactions and climate change policy. Energy Econ. 35 (2).
Harris, J.R., Todaro, M., 1970. Migration, unemployment and development: a two sector analysis. Am. Econ. Rev. 60 (1), 126–142.
Hvidtfeldt, C., Jensen, B., Larsen, C., 2011. Undeclared work and the Danes, University Press of Southern Denmark, English summary reported. Rockwool Foundation Research Unit, Copenhagen, Denmark.
INE, 2009a. Contabilidad Nacional de España. Base 2000. Marco input–output. Tabla simétrica, Año 2005.Instituto Nacional de Estadística (www.ine.es).
INE, 2009b. Cuentas satélite sobre emisiones atmosféricas. Año 2005. Instituto Nacional de Estadística (www.ine.es.).
Kosquela, E., Schöb, R., 1999. Alleviating unemployment: the case for green tax reform. Eur. Econ. Rev. 43, 1723–1746.
Labandeira, X., Labeaga, J.M., Rodríguez, M., 2004. Green tax reforms in Spain. Eur. Environ. 14, 290–299.
Majocchi, A., 1996. Green fiscal reform and employment: a survey. Environ. Resour. Econ. 8, 375–397.
Manresa, A., Sancho, F., 2005. Implementing a double dividend: recycling ecotaxes towards lower labour taxes, Energ. Policy 33, 1577–1585.
Markandya, A., Gonzalez-Eguino, M., Escapa, M., 2012. Environmental fiscal reform and unemployment in Spain. In: Kreiser, L.A. (Ed.), Critical Issues in Environmental Taxation. Edward Elgar Publishing.
Markandya, A., 2011. Environmental taxation: what have we learnt in the last 30 years? Riv.Polit. Econ. 9, 11–58.
OECD, 2009. Is informal normal? Towards more and better jobs. OECD, París.
Pearce, D., 1991. The role of carbon taxes in adjusting to global warming. Econ. J. 101, 938–948.
Rapanos, V., 1995. The effects of environmental taxes on income distribution. Eur. J. Polit. Econ. 11 (3), 487–501.
Rutherford, T., Light, M., 2002. A general equilibrium model for tax policy analysis in Colombia. The MEGATAX Model, Working paper.
Schneider, F., 2011. The shadow economy and shadow economy labor force: what do we not. know? IZA WP 5769.
Schneider, F., Enste, D., 2000. Shadow economies: size, causes and consequences. J. Econ. Lit. 38, 77–114.
Schneider, F., Buehn, A., Montenegro, C., 2010. Shadow Economies All over the World: New Estimates for 162 Countries from 1999 to 2007. World Bank (WP).
Schneider, F., 2005. Shadow economies around the world: what do we really know? Eur. J. Polit. Econ. 21 (3), 598–642.
Shoven, J., Whalley, J., 1992. Applying General Equilibrium. Cambridge University Pres.