The Environmental and Economic Effects of a New Carbon Tax in Portugal: A Dynamic General Equilibrium Model Assessment (*)

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Abstract

We consider the environmental, economic, and budgetary effects of a new carbon tax indexed to the carbon price in the EU-ETS market in the context of a dynamic general equilibrium model of the Portuguese economy. We show that the careful recycling of the carbon tax revenues to finance reductions in the personal income tax, in the social security taxes and increases in investment tax credits, in particular when these changes are connected to energy efficiency promoting activities, allows for the carbon tax reform to yield three dividends – reduction in emissions, improvement in economic conditions, and improvements in the budgetary position. By doing so we show that it is possible to design a carbon tax reform that is politically feasible as it satisfies the main constraints of the domestic economy – the quest for growth and for fiscal consolidation – and can accommodate the legitimate interests and needs of different social players–the focus on environmental goals by environmental groups, the concerns with households distributional issues by consumer advocacy groups, and with international competitiveness by business groups.

Keywords: Carbon Taxation, Economic Performance, Budgetary Consolidation, Three Dividends, Portugal.
JEL Classification: D58, H63, O44.

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1. Introduction

The last 20 years in Portugal have been marked by substantial changes in the energy sector and in carbon dioxide emissions from fossil fuel combustion activities, the bulk of greenhouse gas emissions from energy activities and about 70% of total greenhouse gas emissions in the country. These emissions grew 57% between 1990 and 2005 at which time emissions reached their maximum level over the 20 year period of 64.1 Mt CO_2. The introduction of natural gas in the late 1990s, the effective promotion of renewable energies as well as the European Union Emissions Trading System (EU-ETS)have allowed for a 25% reduction in emissions between 2005 and 2012 – in part driven by weak economic conditions and the financial crises of recent years – to current levels of 45.3 Mt CO_2. Following these positive outcomes Portugal, together with the member states of the European Union, has set forth an ambitious program to reduce emissions by 40%, relative to 1990 levels, in 2030 [see, for example, EU (2013)].

One of the cornerstones of current efforts is the possibility of introducing a new carbon tax in the country. Indeed, the government has recently appointed a commission to study and make specific proposals in terms of environmental fiscal reform in Portugal and one of the most emblematic ideas proposed is the introduction of a carbon tax [see, Comissão Para a Reforma Fiscal Ambiental (2014)]. Because of the current economic and budgetary conditions in Portugal, with the country just now leaving the direct control of the troika – the International Monetary Fund, The European Central Bank and the European Commission – no analysis of the impact of such a carbon tax on emission would be complete without a full consideration of its economic and budgetary impacts.

The purpose of this paper is to discuss the environmental, economic and budgetary impact of such a new carbon tax in Portugal.We focus on the issue of the multiple dividends of a carbon tax [see, for example, Pereira and Pereira (2014b)]. Clearly a carbon tax would reduce emissions and thereby generate a first dividend, an environmental dividend. It would, however, in and of itself negatively affect economic performance and possibly even budgetary consolidation.These negative side effects of the carbon tax can, however, be mitigated or even reversed in the context of revenue neutral tax reform where the carbon tax revenues are recycled in a way that alleviates distortions in other tax margins. In terms of the second dividend, the economic dividend, a weak realization of this dividend means an improvement in employment or output over the losses observed the case of a carbon tax without recycling while a strong realization refers to an actual improvement in economic performance in absolute terms compared to the pre-carbon tax situation. In terms of the third dividend, a budgetary dividend, the weak and strong realizations assume similar meanings. Specifically, a strong realization of the third dividend refers to an overall reduction in the public debt to GDP position compared to the pre-tax situation. Because of the terms of the policy debate in Portugal – the quest for growth and the ongoing need for fiscal consolidation – our focus in this paper is on identifying situations yielding the strong realization of the second and third dividends.

Theenvironmental, economic, and budgetary effects of a new carbon tax are analyzed in the context of a dynamic general equilibrium model of the Portuguese economywhich incorporates endogenous growth and a detailed modeling of public sector activities. The model incorporates fully dynamic optimization behavior, endogenous growth, and a detailed modeling of the public sector activities, both tax revenues and public expenditures. Previous versions of this model have been used to evaluate the impact of tax policy [see Pereira and Rodrigues (2002, 2004)], social security reform [see Pereira and Rodrigues (2007)], and energy and climate policy [see Pereira and Pereira (2013, 2014a, 2014b, 2014c)].

This model brings together two important strands of the taxation literature [see the above applications of this model for a detailed list of the references]. On one hand, it follows in the footsteps of computable general equilibrium modeling. It shares with this literature the ability to consider the tax system in great detail. This is important given the evidence that the costs and effectiveness of climate policies are influenced by existing tax distortions [see Goulder (1995) and Goulder et al (1999)]. On the other hand, it incorporates many of the insights of the endogenous growth literature. In particular, it recognizes that public policies have the potential to affect the fundamentals of long term growth and not just for generating temporary level effects [see Xepapadeas (2005)].

The impact of climate policy on economic performance has been a central part of the policy debate [see, for example, Nordhaus (1993a, 1993b), Babiker et al. (2003), Dissou (2005), Stern (2007), Rivers, (2010), and Morris et al. (2012)]. In addition, we have witnessed a growing concern over mounting public debt in recent years and the need to promote fiscal sustainability. In this context, CO_2 taxes and auctioned emissions permits have emerged as potentially important fiscal policy instruments for increasing public revenues [see, for example, Metcalf and Weisbach (2008), Galston and MacGuineas (2010), Metcalf (2010) and Nordhaus (2010)].

The interactions between climate policy, economic growth and the public sector account are fundamental since they correlate to some of the most important policy constraints faced by energy-importing economies in their pursuit of sound climate policies: the need to enact policies that promote long-term growth and fragile public budgets. As EU structural transfers have shifted towards new members, countries such as Ireland, Greece, and Portugal have been forced to rely on domestic public policies to promote real convergence. This poses a challenge since growing public spending, pro-cyclical policies, and more recently, falling tax revenues have contributed to rapidly increasing levels of public debt and a sharp need for budgetary consolidation.

Finally, it should be mentioned that although this paper is an application to the Portuguese case and is intended to be directly relevant from the perspective of policy making in Portugal, its interest is far from parochial. Naturally, climate and energy are at the center of the policy concerns and objectives in the EU [see, for example, European Commission (2014a, 2014b)] and as such all EU countries need to deal, albeit in different degrees, with these issues. In addition, there is a growing chorus of institutional voices urging the different countries in the direction of environmental fiscal reform [see, for example Eurogroup (2014), IMF (2014), OECD (2014), Parry at al. (2014), and World Bank (2014)]. Furthermore, from the perspective of policy evaluation the interactions between climate policy, economic growth and the public sector account are fundamental since they correlate to the most important policy constraints faced by less developed energy-importing economies in their pursuit of sound climate policies: the need to enact policies that promote long-term growth and fragile public budgets.

This paper is organized as follows. In section 2 we present the dynamic general equilibrium model as well as its implementation and the details of the reference case. In section 3, we discuss the environmental, economic, and budgetary effects of a carbon tax under the assumption that the tax revenues it generates are recycled in a lump-sum manner. In section 4,we consider the carbon tax under a variety of revenue recycling mechanisms to identify strategies that mitigate or reverse any potential negative economic and budgetary effects of the tax. In section 5, we present sensitivity analysis with respect to the assumed level of carbon taxation. Finally, in section 6, we provide a summary of the results, present detailed policy recommendations, and highlight some of the shortcomings of this analysis.

2. The Dynamic General Equilibrium Model of the Portuguese Economy

In this section we present the dynamic general equilibrium model of the Portuguese economy in very general terms. Complete model documentation with detailed descriptions of the model equations, parameters, data, calibration, and numerical implementation, can be found in Pereira and Pereira (2012).

We consider a decentralized economy in a dynamic general-equilibrium framework. All agents are price-takers and have perfect foresight. With money absent, the model is framed in real terms. There are four sectors in the economy – the production sector, the household sector, the public sector and the foreign sector. The first three have an endogenous behavior but all four sectors are interconnected through competitive market equilibrium conditions, as well as the evolution of the stock variables and the relevant shadow prices. All markets are assumed to clear.

The trajectory for the economy is described by the optimal evolution of eight stock and five shadow price variables - private capital, wind energy capital, public capital, human capital, and public debt together with their shadow prices, and foreign debt, private financial wealth, and human wealth. In the long term, endogenous growth is determined by the optimal accumulation of private capital, public capital and human capital. The last two are publicly provided.

2.1. The Production Sector

Aggregate output is produced with a Constant Elasticity of Substitution (CES) technology, linking value added and primary energy demand. Value added is produced according to a Cobb-Douglas technology exhibiting constant returns to scale in the reproducible inputs – effective labor inputs, private capital, and public capital. Only the demand for labor and the private capital stock are directly controlled by the firm, meaning that if public investment is absent then decreasing returns set in. Public infrastructure and the economy-wide stock of knowledge are publicly financed and are positive externalities. Primary energy demand is produced according to a CES technology using crude oil inputs and non-transportation energy sources. The production of non-transportation energy is defined according to a Cobb-Douglas technology using coal, natural gas and wind energy inputs.

Private capital accumulation is characterized by a dynamic equation of motion where physical capital depreciates. Gross investment is dynamic in nature with its optimal trajectory induced by the presence of adjustment costs. These costs are modeled as internal to the firm - a loss in capital accumulation due to learning and installation costs - and are meant to reflect rigidities in the accumulation of capital towards its optimal level. Adjustment costs are assumed to be non-negative, monotonically increasing, and strictly convex. In particular, we assume adjustment costs to be quadratic in investment per unit of installed capital.

The firms' net cash flow represents the after-tax position when revenues from sales are netted of wage payments and investment spending. After-tax net revenues reflect the presence of a private investment and wind energy investment tax credits, taxes on corporate profits, and Social Security contributions paid by the firms on gross salaries.

Buildings make up a fraction of total private investment expenditure. Only this fraction is subject to value-added and other excise taxes, the remainder is exempt. The corporate income tax base is calculated as revenues from the sale of output net of total labor costs and net of fiscal depreciation allowances over past and present capital investments. A straight-line fiscal depreciation method over theperiods allowed for depreciation allowances is used and investment is assumed to grow at the same rate at which output grows. Under these assumptions, depreciation allowances simplify proportional to the difference of two infinite geometric sums.

Optimal production behavior consists in choosing the levels of investment and labor that maximize the present value of the firms' net cash flows subject to the equation of motion for private capital accumulation. The demands for labor and investment are obtained from the current-value Hamiltonian function, where the shadow price of private capital evolves according to the respective co-state equation. Finally, with regard to the financial link of the firm with the rest of the economy, we assume that at the end of each operating period the net cash flow is transferred to the consumers.

2.2. The Energy Sector

We consider the introduction of CO_2 taxes levied on primary energy consumption by firms. This is consistent with the nature of the existing policy environment in which CO_2 permits may now be auctioned to firms. Furthermore, evidence suggests that administrative costs are substantially lower the further upstream the tax is administered. By considering taxation at the firm level, the additional costs induced by CO_2 taxes are transmitted through to consumers and consumer goods in a fashion consistent with the energy content of the good. Not levying the CO_2 tax on consumers therefore avoids double taxation of the carbon content of a good.

The energy sector is an integral component of the firms' optimization decisions. We consider primary energy consumption by firms for crude oil, coal, natural gas and wind energy. Primary energy demand refers to the direct use of an energy vector at the source in contrast to energy resources that undergo a conversion or transformation process. With the taxation of primary energy consumption by firms, costs are transmitted through to consumers and consumer goods in a fashion consistent with the energy content of the good.

Primary energy consumption provides the most direct approach for accounting for CO_2 emissions from fossil fuel combustion activities. Carbon is released from fossil fuel upon combustion. Together, the quantity of fuel consumed, its carbon factor, oxidation rate, and the ratio of the molecular weight of CO_2 to carbon are used to compute the amount of CO_2 emitted from fossil fuel combustion activities in a manner consistent with the Intergovernmental Panel for Climate Change (2006) reference approach. These considerations suggest a linear relationship between CO_2 emissions and fossil fuel combustion activities.

Fossil fuels are hydrocarbons defined by the relative amounts of carbon and hydrogen in each molecule. In the combustion reaction, the compound reacts with an oxidizing element such as oxygen. Thus, the amount of carbon relative to hydrogen in the fuel will determine the fuels carbon emissions factor, the amount of carbon emitted per unit of energy. The molecular weight of carbon dioxide CO_2 is 44/12 times greater than the weight of the carbon alone (the molecular weight of carbon is 12 and that of oxygen is 16 which give CO_2 a weight of 44 moles and carbon of 12 moles). The fuel's CO_2 emission factor can be computed from the product of its carbon emission factor, in tons of oil equivalent, the fraction of carbon oxidized and the ratio of the molecular weight of carbon dioxide to carbon. Crude oil yields 3.04 tCO_2 for each ton of oil equivalent consumed, coal yields 3.78 tCO_2 for each ton of oil equivalent consumed and natural gas yields 2.34 tCO_2 for each ton of oil equivalent consumed.

Aggregate primary energy demand is produced with a CES technology in which crude oil, and non-transportation fuels are substitutable at a rate less than unity reflective of the dominance of petroleum products in transportation energy demand and the dominance of coal, natural gas and, to a lesser extent, wind energy, in electric power and industry. Non-transportation fuels are produced with a Cobb-Douglas technology recognizing the relatively greater potential substitution effects in electric power and industry. The accumulation of wind energy infrastructure is characterized by a dynamic equation of motion where the physical capital, wind turbines, depreciates and investment is subject to adjustment costs as private capital. Wind energy investment decisions are internal to the firm while coal, natural gas and oil are imported from the foreign sector.

Optimal primary energy demand is derived from the maximization of the present value of the firms' net cash flows as discussed above. In turn, the demand for coal and natural gas are defined through the nested dual problem of minimizing energy costs given the production function and optimal demand for these energy vectors in electric power and industry. Finally, the variational condition for optimal wind energy investment and the equation of motion for the shadow price of wind energy are defined by differentiating the Hamiltonian with respect to wind energy investment and its stock.

2.3. Households

An overlapping-generations specification was adopted in which the planning horizon is finite but in a non-deterministic fashion. A large number of identical agents are faced each period with a probability of survival. The assumption that the probability of survivalis constant over time and across age-cohorts yields a perpetual youth specification. Without loss of generality, the population, which is assumed to be constant, is normalized to one. Therefore, per capitaand aggregate values are equal.

The household chooses consumption and leisure streams that maximize intertemporal utility subject to the consolidated budget constraint. The objective function is lifetime expected utility subjectively discounted. Preferences are additively separable in consumption and leisure, and take on the CES form. A lower probability of survival reduces the effective discount factor making the household relatively more impatient.

The budget constraint reflects a value-added tax on consumption and states that the households' expenditure stream discounted at the after-tax market real interest rate cannot exceed total wealth. The loan rate at which households borrow and lend among themselves is greater than the after-tax interest rate reflecting the probability of survival.

Total wealth is age-specific and is composed of human wealth, net financial worth, and the present value of the firm. Human wealth represents the present discounted value of the household's future labor income stream net of personal income taxes and workers' social security contributions. The household's wage income is determined by its endogenous decision of how much labor to supply out of a total time endowment and by the stock of knowledge or human capital that is augmented by public investment in education. Labor earnings are discounted at a higher rate reflecting the probability of survival.

A household's income is augmented by net interest payments received on public debt, profits distributed by corporations, international transfers, and public transfers. On the spending side, debts to foreigners are serviced, taxes are paid and consumption expenditures are made. Income net of spending adds to net financial wealth. Under the assumption of no bequests, households are born without any financial wealth. In general, total wealth is age-specific due to age-specific labor supplies and consumption streams.

Assuming a constant real interest rate, the marginal propensity to consume out of total wealth is age-independent and aggregation over age cohorts is greatly simplified and moreover allows us to write the aggregate demand for leisure as a function of aggregate consumption.

2.4. The Public Sector

The equation of motion for public debt reflects the fact that the excess of government expenditures over tax revenues has to be financed by increases in public debt. Total tax revenues include personal income taxes, corporate income taxes, value added taxes, and social security taxes levied on firms and workers. All of these taxes are levied on endogenously defined tax bases. Residual taxes are modeled as lump sum and are assumed to grow at an exogenous rate.

The public sector pays interest on public debt and transfers funds to households in the form of pensions, unemployment subsidies, and social transfers, which grow at an exogenous rate. In addition, it engages in public consumption activities and public investment activities in both public capital and human capital.

Public investments are determined optimally, respond to economic incentives, and constitute an engine of endogenous growth. The accumulations of human capital and public capitalare subject to depreciation and to adjustment costs that are a fraction of the respective investment levels. The adjustment cost functions are strictly convex and quadratic.

Public sector decisions consist in choosing the trajectories for public consumption, public investment in human capital and public investment in public capital that maximize social welfare, defined as the net present value of the future stream of utility derived from public consumption, parametric on household private consumption-leisure decisions. The optimal choice is subject to three constraints, the equations of motion of the stock of public debt, the stock of public capital, and the stock of human capital. The optimal trajectories depend on the shadow prices of public debt, public capital, and human capital stocks, respectively. Optimal conditions are defined for public debt, for public consumption, for public investment, and for investment in human capital.

In the implementation of the model for this paper, and to allow us to focus on the marginal effects on the public debt to GDP ratio that are directly related to the revenue-neutral carbon tax reform, the public sector is assumed to follow a passive form of behavior in which all main types of public spending – public consumption and the two types of public investment – grow at the endogenously determined GDP growth rate. This way public sector behavior still affects long term growth but does so in a passive and accommodating form as opposed to actively pursuing long term economic growth through endogenous changes in public spending. This is a formulation that is more in keeping with the current terms of the policy debate in Portugal, where budgetary concerns prevent the consideration of a more pro-active approach on the part of the public sector.

2.5. The Foreign Sector

The equation of motion for foreign financing provides a stylized description of the balance of payments. Domestic production and imports are absorbed by domestic expenditure and exports. Net imports incorporate payments by firms for fossil fuels and are financed through foreign transfers and foreign borrowing. Foreign transfers grow at an exogenous rate. The domestic economy is assumed to be a small, open economy. This means that it can obtain the desired level of foreign financing at a rate which is determined in the international financial markets. This is the prevailing rate for all domestic agents.

2.6. The Intertemporal Market Equilibrium

The intertemporal path for the economy is described by the behavioral equations, by the equations of motion of the stock and shadow price variables, and by the market equilibrium conditions. The labor-market clearing condition incorporates an exogenous structural unemployment rate. The product market equalizes demand and supply for output. Given the open nature of the economy, part of domestic demand is satisfied through the recourse to foreign production. Finally, the financial market equilibrium reflects the fact that private capital formation and public indebtedness are financed by household savings and foreign financing.

We define the steady-state growth path as an intertemporal equilibrium trajectory in which all the flow and stock variables grow at the same rate, g, while market prices and shadow prices are constant. There are three types of restrictions imposed by the existence of a steady-state. First, it determines the value of critical production parameters, like adjustment costs and depreciation rates given the initial capital stocks. These stocks, in turn, are determined by assuming that the observed levels of investment of the respective type are such that the ratios of capital to GDP do not change in the steady state. Second, the need for constant public debt and foreign debt to GDP ratios implies that the steady-state public account deficit and the current account deficit are a fraction g of the respective stocks of debt. Finally, the exogenous variables, such as public transfers or international transfers, have to grow at the steady-state growth rate.

2.7. Dataset, Parameter Specification, and Calibration

The model is implemented numerically using detailed data and parameters sets. Data are from the Statistical Annex of the European Community (European Commission, 2012), the Portuguese Ministry of Finance (2012) and the Portuguese Directorate General for Geology and

Energy (2012). The decomposition of the aggregate variables follows the average for the period 2000-2013 for macroeconomic data as well as for the energy variables. This period was chosen to reflect the most recent available information and to cover several business cycles, thereby reflecting the long-term nature of the model.Public debt and foreign debt, as well as the stocks of capital, reflect the most recent available data.

Parameter values are specified in different ways. Whenever possible, parameter values are taken from the available data sources or the literature. This is the case, for example, of the population growth rate, the probability of survival, the share of private consumption in private spending, and the different effective tax rates.

All the other parameters are obtained by calibration; i.e., in a way that the trends of the economy for the period 2000-2013 are extrapolated as the steady-state trajectory. These calibration parameters assume two different roles. In some cases, they are chosen freely in that they are not implied by the state-state restrictions. Although free, these parameters have to be carefully chosen since their values affect the value of the remaining calibration parameters. Accordingly, they were chosen either using central values or using available data as guidance. For instance, the elasticity of substitution parameters are consistent with those values often applied in climate policy analysis [see, for example, Manne and Richels (1992), Paltsev et al. (2005) and Koetse et al. (2008)]. The remaining calibration parameters are obtained using the steady-state restrictions.

2.8 Establishing the Reference Case

To generate the reference case based on the calibrated steady state version of the model we consider the evolution of the international fossil fuel prices as well as the trends in domestic energy efficiency gains. Both are important drivers of emission reductions and both can have significant impacts in the economic and budgetary performance of the economy. More importantly, together they frame the effort, in terms of the level of the carbon tax,needed to achieve emission goals [For a comprehensive discussion on the relative role of international fossil fuel prices, energy efficiency and carbon taxation in achieving environmental targets in Portugal see Pereira and Pereira (2014d)].

We begin by recognizing that Portugal is a small-open energy-importing economy, and therefore, we consider the projected evolution of the fossil fuel prices – oil, coal, and natural gas - in international markets. We follow the central fossil fuel price scenario forecasts used by the Portuguese Commission for Environmental Fiscal Reform [see Comissão para a Reforma da Fiscalidade Verde (2014)] developed in great detail in Sena (2014).

The fossil fuel price scenario is based primarily on two sources: The European Commission and futures markets – namely the Intercontinental Exchange. These two sources differ both in their temporal scope as well as the magnitude of expected price changes. In general, the EC forecasts suggest higher prices than futures markets. The central fuel price assumptions are based on an average of the EC forecast and futures market data appended with growth in prices derived from the EC forecast. All fossil fuel prices show an upward trend with prices of coal and natural gas increasing by 20% and 26% in 2030 relative to 2013 levels. The increase in the price on crude oil is less pronounced, with just an 11% increase. Accordingly, the price of coal increases relative to natural gas and both the prices of coal and natural gas increase substantially relative to crude oil.

We also consider the fact that improving energy efficiency is widely regarded as a key mechanism for lowering the energy-intensity and carbon-intensity of the economy. Energy efficiency goals have been formalized in a number of EU directives. Most notable is EC Directive 2009/28/EC which sets a legally binding target of increasing energy efficiency by 20% by 2020 relative to 1990 levels and the current working assumptions of energy efficiency gains in primary energy consumption of 21% by 2030 compared to 2007 levels [see, for example, European Commission (2013)]. These targets imply an annual increase in energy efficiency of near 1%.

The energy intensity of the Portuguese economy, that is, energy use per Euro of GDP, a good measure of the overall productivity of energy resources in the economy, grew through the 1980s and 1990s at an average annual rate of 1.6%. In fact, the energy intensity of the economy reached its maximum value in 1999, reaching again similar values in 2005 despite a modest annual decline of 0.4% per year between 2000 and 2004. Since 2005, the energy intensity of the economy has been declining suggesting improvements in efficiency and, more generally, in the productivity of energy resources in the economy. Between 2005 and 2009, the energy intensity of the Portuguese economy fell by an average of 1.6 percent per year. More recently, in 2011 and 2012, the energy intensity of the Portuguese fell by 0.7%and 1.7%, respectively. For the decade, the energy intensity of the economy fell at an average annual rate of 1.0%, consistent with the targets set out by the European Commission.

3. The Effects of a Carbon Tax: Preliminary Discussion and Results

In this section we discuss the choice of the level for the carbon tax and then identify the environmental, economic, and budgetary effects of this carbon tax in its simplest form–with the revenues returned to households in a lump sum manner.

3.1 On the Choice of a Carbon Tax Indexed to the EU-ETS Carbon Price

The choice of the carbon taxlevel is a delicate matter. There are now about fifteen countries which have introduced or are about to introduce carbon taxes. The levels and scope of taxation vary widely from a low of about 1.5 Euros per ton of CO_2 in Japan and about 7 Euros per ton in Iceland – covering 50% and 70% of domestic emissions respectively, to near 115 Euros in the United Kingdom and 125 Euros in Sweden although these cover only about 25% of emissions in those countries. In about two-thirds of the countries, taxes range between 10 and 35 euros per ton and cover between 35% and 70% of emissions, [for details, see, for example, World Bank (2014)].

Another reference point for the price of carbon emissions is given by the market price for carbon in the European Union Emissions Trading System(EU-ETS). The average price for CO_2 emissions allowances observed in the EU-ETS between 2006 and 2011 was 15 euros per ton. During this period, the price of carbon reached a maximum of 34 Euros per ton. Prices, however, have shown a great degree of volatility, having in recent year reached rather low levels over weak demand - 8 Euros per tCO_2 in 2012, 4.7 Euros in 2013 and an average of about 6.0 Euros in 2014.

Given this evidence,a reasonable reference pointwould be a carbon tax of 15-17 Euros per tCO_2. This tax level is consistent with the recommendation in a recent report by the European Environmental Agency [see Anderson et al. (2013)] and is also indicative of the efforts required to meet domestic targets [see Pereira and Pereira (2013)]. This is also the average reference price for the sectors covered by the EU-ETS for the period from 2015 to 2030 [see, for example, European Commission (2014d)].

The choice of the level of carbon taxation in Portugal isfurther complicated by the fact that part of the economy – corresponding to about 37% of the CO_2 emissions – is currently already covered by the EU-ETS, and therefore already facing a price signal for carbon emissions. Accordingly, a new carbon tax would only apply to the sectors not already participating in this market–firms and sectors not covered by the EU-ETS would face a price signal through the carbon tax while those firms and sectors participating in the EU-ETS would face a price signal through the carbon market.

The question remains that the two carbon price signals – the carbon tax and the carbon price in the EU-ETS –would in general be different, which is not an efficient way of dealing with the issue. Furthermore, with the current low EU-ETS market price, a meaningful carbon tax would likely be higher than the current carbon market price. In this case, the participating sectors which are typically the most polluting would face a lower carbon price, again an undesirable outcome from an efficiency perspective. The option of levelling the two signals by imposing a high carbon tax level on non EU-ETS sectors and simultaneously introducing a matching tax surcharge on the EU-ETS sectors was not deemed politically feasible domestically or legally unquestionable at the EU level.

The remaining option was to index the carbon tax to the carbon price in the EU-ETS market, although this means starting with a very low carbon tax of around 6 Euros per tCO_2. This was the option adopted by the Environmental Fiscal Reform Commission [see CRFV (2014b)]. This policy option has two possible and related advantages. First, given the projected evolution of the carbon prices in the EU-ETS this value is expected to increase significantly over time [see again European Commission (2014d)]. This expected evolution would allow for a smooth transition into a significantly higher carbon price in the economy.Second, for the period until 2030, the expected evolution of the carbon price in the EU-ETS would roughly be equivalent to a flat annual tax of 17 euros per tCO_2, a level of taxation that is within the scope of what would be desirable for Portugal.

In this paper, and unless otherwise indicated, the carbon tax level is indexed to the EU-ETS price and therefore follows the path for the forecasts for the EU-ETS carbon price presented in European Commission (2014d). Specifically, carbon prices are projected to reach 10 euros per tCO_2 by 2020 and 35 euros by 2030. We assume they remain at this level thereafter. Furthermore, and without exceptions, only the sectors not participating in the EU-ETS are subject to this carbon tax. This means that only the revenues from this carbon tax with general but not universal applicability are considered and in no case do we consider the revenues for example from permit auctions for the EU-ETS participants.

3.2 The Effects of an Indexed Carbon Tax without Revenue Recycling

We consider now the environmental, economic, and budgetary effects of the indexed carbon tax as described above. We consider the carbon tax in its simplest form,that is, where tax revenues are distributedthrough lump-sum transfers to households. Such a tax generally leads to favorable results in terms of emissions, a first dividend, but unfavorable outcomes in terms of economic impacts, and sometimes even in terms of the budgetary impacts, that is, no second or third dividend. Results are presented in Table 1.

A CO_2 tax works primarily through two mechanisms. First, by affecting relative prices, the CO_2 tax drives changes to the firms' input structure that affects the marginal productivity of factor inputs. Second, the CO_2 tax increases energy expenditure and reduces the firms' net cash flow, household income and domestic demand. These substitution and scale effects are central in understanding how carbon taxation affects energy consumption, emissions, economic performance and the public sector account.

The CO_2 tax increases the price of fossil fuels relative to renewable energy resources and changes the relative price of the different fossil fuels to reflect their carbon content. This has a profound impact on the energy sector, driving a reduction in fossil fuel consumption of 11.92% and an increase in the stock of wind energy infrastructure of15.56% by 2030. The impact of CO_2 taxation on aggregate fossil fuel demand, however, masks important changes in the fuel mix. In particular, we observe a 33.21% reduction in coal consumption while crude oil falls by 8.55% and natural gas by 3.20%. As such, the CO_2 tax stimulates a shift in the energy mix which favors wind energy at the expense of coal. Ultimately, CO_2 emissions are 13.13% lower in 2030 than in the reference scenario, which corresponds to about 18.3% of the emissions observed in 1990.

CO_2 taxation, by increasing energy system costs, has a negative impact on the firms' net cash flow which limits the firms' demand for inputs. Employment falls by 0.31% in 2030, less than the reduction in private investment of 2.15% and the associated drop in private capital of 1.16% and certainly substantially less than the drop in fossil fuel demand. This is consistent with an overall reduction in input levels coupled with a shift in the firms' input structure away from energy inputs and an increasing role for capital and especially labor.

Given the reductions in factor demand, it is no surprise that CO_2 taxation has a negative impact on economic growth and activity levels. The reduction in the firms' net cash flow has a direct impact on household income since it is an integral part of total wealth. This drives down private consumption and initiates an important dynamic feedback between income, consumption and production. As a result, private consumption falls by 0.68%. The net effect of this interaction is a reduction in GDP levels of 0.92% by 2030.

We observe a reduction in exports and imports, in particular of fossil fuels. By 2030, fossil fuel imports are 10.66% lower than the reference levels. The reduction in domestic demand, coupled with the reduced expenditure on imported energy resources stemming from demand adjustments, suggests that foreign debt to GDP levels fall by 3.67% in 2030 relative to reference levels.

The carbon tax in this simple implementation affects fiscal consolidation negatively. Results suggest that the indexed carbon tax leads to a 1.74% increase in the public debt to GDP ratio by 2030 – equivalent, using 2014 values as a reference point, to a 2.2 percentage point increase in the public debt to GDP ratio. This effect is due fundamentally to a moderate reduction in public expenditures coupled with a small increased in overall tax revenues.

On the expenditure side, and given that all forms of public spending are modelled as exogenous and growing at the ongoing GDP growth rate, we observe a reduction in overall spending of 0.91% in 2030. This closely follows the evolution of GDP itself, the small differences being induced by the evolution of interest payments on outstanding public debt. On the revenue side, a reduction in income, consumption and private inputs results in contracting tax bases. Accordingly, we observe a reduction personal income tax receipts of 0.82%, in corporate income tax revenue of 1.01%, in value added tax receipts of 0.88% and in social security contributions of 1.39%.These reductions are offset by the CO_2 tax receipts. As a result, total tax revenue in absolute terms is 0.34%greater in 2030.

Table 1
Effects of an Indexed Carbon Tax
withlump sum recycling

(Percent change with respect to reference scenario)

	2020	2025	2030	2050
Energy				
Total Energy Demand	-3.26	-5.72	-7.80	-6.86
Demand for Fossil Fuels	-5.04	-8.78	-11.92	-11.32
Crude Oil	-3.10	-6.04	-8.55	-8.44
Coal	-16.67	-25.36	-33.21	-29.84
Natural Gas	-0.67	-2.47	-3.20	-3.52
Investment in Wind Energy	21.18	25.15	24.03	17.50
Wind Energy Infrastructures	6.80	11.61	15.56	18.35
Carbon Dioxide Emissions from Fossil Fuel Combustion	-5.68	-9.70	-13.13	-12.37
Economy				
Growth Rate of GDP (Percent Change over Previous Period)	0.94	0.91	0.92	0.94
GDP	-0.17	-0.54	-0.92	-1.55
Private Consumption	-0.67	-0.67	-0.68	-0.71
Private Investment	-1.49	-1.97	-2.14	-2.35
Private Capital	-0.42	-0.79	-1.16	-1.96
Imported Energy	-3.92	-7.55	-10.66	-11.46
Foreign Debt/GDP	-1.70	-2.78	-3.67	-5.90
Labor Markets				
Employment	0.15	-0.08	-0.31	-0.57
Wages	-0.47	-0.76	-1.03	-1.17
Public Sector				
Public Debt/GDP	0.51	1.07	1.74	3.96
Public Expenditures	-0.23	-0.57	-0.91	-1.48
Public Consumption	-0.23	-0.57	-0.91	-1.48
Public Investment	-0.23	-0.57	-0.91	-1.48
Investment in Human Capital	-0.23	-0.57	-0.91	-1.48
Public Capital	-0.05	-0.17	-0.37	-1.15
Human Capital	-0.01	-0.02	-0.06	-0.29
Tax Revenues	0.19	0.32	0.38	-0.08
Personal Income Tax (IRS)	0.15	-0.29	-0.82	-1.27
Corporate Income Tax (IRC)	0.20	-0.33	-1.01	-1.83
Value Added Tax (IVA)	-0.73	-0.83	-0.88	-0.99
Social Security Contributions (TSU)	-0.33	-0.86	-1.39	-2.01

4. On the Effects of an Indexed Carbon Tax with Revenue Recycling

As an overall evaluation of the simple implementation of the indexed carbon tax – that is an implementation without recycling of its revenues – we can say that such a tax achieves significant reductions in emissions, a significant first dividend. This comes, however, at a cost of a clear reduction in economic activity and a small deterioration of the public sector position, that is, the second and third dividends, naturally, do not materialize. In this section, we consider the issue of recycling of the revenues of the carbon tax in the search of strategies leading to the realization of these second and third dividends.

4.1 The Different Recycling Mechanisms

The undesirable effects of the carbon tax in its simplest form can conceivably be eliminated or even reversed through careful recycling of tax revenues generated by the tax on CO_2 emissions.In all cases, and in keeping with the institutional and political terms of the debate on this issue we assume that all recycling strategies satisfy strict tax revenue neutrality on impact, that is, the revenues generated by the carbon tax are used to finance concomitant reductions in other tax margins. Since the framing assumption is of tax revenue neutrality and not of general budgetary neutrality we do not consider other possible recycling strategies that would involve using the carbon tax revenues to increase different types of public expenditure.

We consider four revenue recycling mechanisms,that is, four different tax margins to be alleviated by the use of the carbon tax revenues – value added tax(*Impostosobreo Valor Acrescentado*, IVA), personal income tax(*ImpostosobreosRendimentos de PessoasSingulares*, IRS), social security contributions (*Taxa Social Única*, TSU)and an investment tax credit (*Crédito Fiscal aoInvestimento*, CFI) in the context of the corporate income tax. These four alternative recycling strategies cover the main economic mechanism to generate the mitigating effects – demand-driven (IVA), employment-driven (IRS and TSU), and investment-driven (CFI) mechanisms. In addition to these four mechanisms in isolation, we also consider mixed recycling strategies which combine some of these individual mechanisms.

In addition to the four individual recycling cases and their judicious combination, we consider the effects of recycling when part of the recycled revenues are targeted specifically at the promotion of energy efficiency. An analysis of the Portuguese energy system using the TIMES_PT model [see Seixas and Fortes (2014)] suggests that energy efficiency improvements equivalent to an average annual savings in primary energy consumption of 2.5-2.9% between 2015 and 2030 are cost-effective in the absence any further climate policy. This means that there are technologies available which are in the best interest of the different economic agents to adopt based on cost considerations independent of environmental concerns or public incentives. Furthermore, with just 57 measures in energy efficiency enacted from 1990 to 2011, Portugal ranks 18 in the EU in terms of the numbers of measures adopted [see, for example, European Economy (2014)]. This evidence suggests that Portugal has significant room for improvement in terms of energy efficiency. Moreover, EU-level mandated energy efficiency targets are becoming increasingly stringent and demanding and therefore steps in this direction are going to be critical in the next couple of decades.

A key issue when considering the targeting activities that promote energy efficiency is the determination of the levels of investment necessary to induce specific energy efficiency gains. It is in fact well understood that the mere presence of energy efficiency opportunities that are cost-effective is far from enough to lead to their adoption. Typically, public incentives in the form of subsidies for example are necessary.

As a reference point we use the value of 400 million euros in investment as the amount necessary to generate a 1,000 ktoe of energy efficiency savings. This value is based on the average cost of avoided energy consumption at the industrial price in the US of $13.8 per MMBTU presented in the abatement cost structure in McKensey Global Energy and Materials (2009). This unit value when duly applied to the Portuguese case implies that a persistent annual increase in energy efficiency of about 1% of the total primary energy consumption at the cost of a yearly investment of 85-100 million Euros. To put these figures in perspective, carbon tax revenues would start at around 160 million euros and would under our indexed tax increase to about 850 million Euros in 2030. This means that the resources required for these levels of investment necessary to induce annual gains in energy efficiency of up to 1% are readily available.

4.2 On the Effects of the DifferentIndividual Recycling Mechanisms

The effects of the four individual recycling strategies are presented in the top panel of Table 2. We start with the case of using the revenues from the carbon tax to finance a reduction in the value added tax, IVA. This is a demand driven case, as the carbon tax revenue are used to stimulate private consumption activities by offsetting value added tax revenues. The resulting CO_2 tax revenues can finance an average 3.4% reduction in the value added tax rate relative to the status quo over the next 15 years.

The IVA recycling strategy yields a small improvement in economic performance over the lump sum recycling case, generatingin the long term a weak realization of the second dividend - GDP falls by 0.71% while employment increases by 0.08% in 2030 (employment falls by -0.25% in 2050). This small improvement in GDP and in employment outcomes relative to the lump sum case reflects the small distortions associated with indirect taxation. In turn, in terms of public debt, we do observe by 2030 a realization of the weak form of the third dividend (strong form by 2050), that is, an increase in the debt to GDP ratio of 1.18% (reduction in indebtedness of -0.47% by 2050)vis-a-vis the reference scenario.

The personal income tax, IRS, and the social security contributions, TSU, recycling cases are employment driven mechanisms**.** These allow us to evaluate labor demand and supply responses to reductions in the tax burden on households and firms.The CO_2 tax revenues finance on average either a 4.8% reduction in the personal income tax rate, or a 3.6% reduction in social security contributions rate over the next 15 years relative to the status quo.

Table 2
Effects of an indexed carbon taxunder different recycling mechanisms
(Percent change with respect to reference scenario)

	Carbon Dioxide Emissions		Employment		GDP		Foreign Debt /GDP		Public Debt /GDP	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
No Additional Energy Efficiency Gains										
Lump Sum	-13.13	-12.37	-0.31	-0.57	-0.92	-1.55	-3.67	-5.90	1.74	3.96
Value Added	-12.97	-12.36	**0.08**	-0.25	-0.71	-1.53	-5.47	-8.47	1.18	**-0.47**
Personal Income Tax	-12.62	-11.56	**0.54**	**0.46**	-0.25	-0.44	-0.53	-1.38	0.55	2.10
Social Security Contributions	-12.77	-11.82	**0.29**	**0.12**	-0.45	-0.79	-1.90	-3.70	**-0.51**	**-3.01**
Investment Tax Credit	-12.60	-10.41	-0.37	**0.18**	-0.22	**1.13**	3.48	8.27	0.45	2.11
Additional Energy Efficiency Gain of 0.25%										
Value Added	-14.07	-13.38	**0.07**	-0.24	-0.64	-1.40	-4.99	-7.78	0.91	**-1.07**
Personal Income Tax	-13.73	-12.60	**0.52**	**0.46**	-0.18	-0.32	-0.14	-0.83	0.30	1.47
Social Security Contributions	-13.87	-12.85	**0.27**	**0.13**	-0.38	-0.67	-1.49	-3.11	**-0.75**	**-3.56**
Investment Tax Credit	-13.71	-11.48	-0.38	**0.19**	-0.15	**1.23**	3.81	8.65	0.19	1.50
Additional Energy Efficiency Gain of 0.5%										
Value Added	-15.13	-14.35	**0.06**	-0.23	-0.57	-1.27	-4.53	-7.12	0.65	-1.65
Personal Income Tax	-14.80	-13.60	**0.50**	**0.46**	-0.12	-0.21	0.23	-0.31	0.05	0.87
Social Security Contributions	-14.94	-13.84	**0.26**	**0.14**	-0.31	-0.55	-1.10	-2.55	**-0.99**	**-4.09**
Investment Tax Credit	-14.78	-12.51	-0.38	**0.19**	-0.08	**1.32**	4.13	9.02	**-0.05**	0.91
Additional Energy Efficiency Gain of 1.0%										
Value Added	-17.13	-16.19	**0.04**	-0.21	-0.43	-1.03	-3.68	-5.90	0.16	**-2.73**
Personal Income Tax	-16.82	-15.48	**0.47**	**0.46**	**0.00**	**0.00**	0.92	0.67	**-0.41**	**-0.26**
Social Security Contributions	-16.95	-15.71	**0.23**	**0.15**	-0.18	-0.33	-0.37	-1.50	**-1.43**	**-5.09**
Investment Tax Credit	-16.79	-14.46	-0.38	**0.20**	**0.04**	**1.49**	4.72	9.70	**-0.51**	**-0.21**

NB – Strong realizations of the second and third dividends are highlighted in boldface.

Overall, these two employment driven policies generate larger improvements in economic performance and larger reductions in the costs of climate policy than do the IVA recycling strategy.Indeed, they both generate strong second dividends in terms of employment and weak dividends in terms of GDP. They result in a 0.25% reduction in GDP for the IRS case and 0.45% for the TSU case, in both cases a weak realization of the second dividend. In turn, both the IRS and TSU recycling policies yield a strong realization of the second dividend as it pertains to employment as they generate gains of 0.54% and 0.29%, respectively, by 2030. Finally, the IRS case yields a weak realization of the third dividend with an increase of 0.55% in the debt to GDP ratio while the TSU case leads to a strong realization with a 0.51% reduction in the debt to GDP ratio.

Finally, we consider the case of the investment tax credit recycling, CFI, in which CO_2 tax revenues are used to promote private investment. The resulting tax revenues could be used to finance an investment tax credit worth on average over the next 15 year 10.1% of the IRC revenues.

The CFI policy stimulates private investment, yield only weak forms of the second dividend by 2030 with a decrease in employment of 0.37% and in GDP of 0.22%. By 2050, however, employment increases by 0.18% and GDP by 1.13%, in both cases a strong realization of the second dividend. Furthermore, we also observe a realization of the third dividend in its weak form as public debt to GDP increases by 0.45% in 2030.

The results for these policies in which part of the revenues to be recycled are channeled to energy efficiency activities generating annual gains of 0.25%, 0.5% and 1.0% are reported in the three bottom panels of Table 2. In general terms we observe that the use of these funds for energy efficiency purposes has a substantial effect on CO_2 emissions. While reductions are in the 10.4-13.0% range in the absence of any further energy efficiency gains, they reach the 14.5-17.1% range when an additional efficiency gain of 1% is achieved. This means that naturally from an environmental perspective this use of the revenue is very important as it substantially deepens the emission reductions.

Equally important from our standpoint is the fact that allocating funds under the different recycling mechanisms to assist with the deployment of energy efficiency technologies activities yields also substantial improvements in both economic and budgetary performance under each of the four different mechanisms. This in the sense that there is a strengthening of the weak realization of both the second and third dividends – the losses induced under the lump sum case are greatly mitigated, and for a more robust performance of 1% in terms of energy efficiency, we actually observe a strong realization of the second and third dividend for the IRS and the CFI cases.

4.3 On the Effects of Mixed Revenue Recycling Strategies

The differences with respect to the economic and budgetary effects among the employment driven policies, the IRS and TSU policies,and the investment driven policy, CFI, suggest that combining these two types of policies may alleviate some of the short term employment losses in the capital investment financing policies – as well as the negative long term budgetary effects while encouraging long term growth through investment in physical capital. We leave out the IVA recycling case as it fails to substantially mitigate the negative economic effects of the carbon tax in terms of either employment or output, compared to the lump sum case, the same being the case, albeit to a lesser degree, in terms of the budgetary effects. As such, the positive effects of the IVA recycling relative to the lump sum case are consistently dominated by the positive effects of the three remaining mechanisms.

We consider, for the purpose of illustration, three mixed strategies based on TSU, IRS and CFI recycling. In the first the revenues of the carbon tax are evenly split between funding IRS reductions and CFI; in the second, they are evenly split between financing reductions in the TSU and CFI; and, in the third, evenly split between the two employment driven mechanisms, IRS and TSU recycling policies, on one hand and the CFI on the other.

Table 3
Effects of an indexed carbon taxundermixed recycling mechanisms

(Percent change with respect to reference scenario)

			Carbon Dioxide Emissions		Employment		GDP		Foreign Debt /GDP		Public Debt /GDP	
CFI Share	**TSU Share**	**IRS Share**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
No Additional Energy Efficiency Gains												
0.50	0.00	0.50	-12.61	-10.97	**0.08**	**0.32**	-0.23	**0.37**	1.56	3.62	0.48	2.07
0.50	0.50	0.00	-12.68	-11.10	-0.05	**0.16**	-0.33	**0.19**	0.88	2.48	**-0.05**	**-0.47**
0.50	0.25	0.25	-12.64	-11.04	**0.02**	**0.24**	-0.28	**0.28**	1.22	3.05	0.22	0.80
Additional Energy Efficiency Gain of 0.25%												
0.50	0.00	0.50	-13.72	-12.03	**0.07**	**0.33**	-0.16	**0.47**	1.92	4.09	0.23	1.45
0.50	0.50	0.00	-13.79	-12.15	-0.06	**0.16**	-0.26	**0.29**	1.25	2.96	**-0.30**	**-1.05**
0.50	0.25	0.25	-13.75	-12.09	**0.01**	**0.24**	-0.21	**0.38**	1.58	3.53	**-0.03**	0.20
Additional Energy Efficiency Gain of 0.5%												
0.50	0.00	0.50	-14.79	-13.04	**0.06**	**0.33**	-0.10	**0.57**	2.26	4.52	**-0.02**	0.85
0.50	0.50	0.00	-14.86	-13.17	-0.06	**0.17**	-0.20	**0.40**	1.60	3.42	**-0.53**	**-1.61**
0.50	0.25	0.25	-14.82	-13.10	**0.00**	**0.25**	-0.15	**0.49**	1.93	3.97	**-0.28**	**-0.38**
Additional Energy Efficiency Gain of 1.0%												
0.50	0.00	0.50	-16.80	-14.96	**0.04**	**0.33**	**0.02**	**0.76**	2.89	5.34	**-0.48**	**-0.27**
0.50	0.50	0.00	-16.87	-15.08	-0.08	**0.18**	-0.07	**0.59**	2.25	4.28	**-0.98**	**-2.67**
0.50	0.25	0.25	-16.84	-15.02	-0.02	**0.26**	-0.02	**0.68**	2.57	4.81	**-0.73**	**-1.47**

NB – Strong realizations of the second and third dividends are highlighted in boldface.

In the case of simply recycling the carbon tax revenues without targeting additional energy efficiency improvements we now observethe **s**trong realization of the second dividend for both employment and GDP (in the longer term), the strongest case being the combination of CFI and IRS recycling. In turn, the strong realization of the third dividend also materializes with the mixed ITC and TSU recycling policy. Accordingly, even at this level, mixed strategies allow for the realization of the three dividends.

With recycling linked to increasing energy efficiency gains, thesecond dividend becomes generally stronger for both employment and GDP. From this perspective again the best outcomes come from a mixed strategy of CFI and IRS recycling. The third dividend as well becomes more pervasive as energy efficiency gains increase, particularly when these exceed a 0.5% gain. From this perspective the best outcome come from mixed CFI and TSU recycling. Overall the realization of the three dividends is a frequent outcome when considering simple mixes of recycling strategies with any degree of energy efficiency gains.

4.4 Effects of Partial Revenue Recycling

Although recycling the CO_2 tax revenue is important from both and economic and budgetary perspective, it is important to recognize that other considerations – such as environmental concerns, distributional considerations, and competitiveness concerns – may lead to a reduction in the amount of the revenue that can be productively recycled. Furthermore, aside from the natural tendency for politicians to prefer these additional revenues without strings attached there are institutional barriers for direct earmarking. The implementation of the recycling strategies will therefore, inevitably, be fraught with uncertainty.

Table 4
Effects of Partial Revenue Recycling
(Mixed Recycling Strategies with Additional Energy Efficiency Gain of 1.0%)

(Percent change with respect to reference scenario)

	Carbon Dioxide Emissions		**Employment**		**GDP**		**Foreign Debt /GDP**		**Public Debt /GDP**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
50% CFI - 50% IRS										
25%	-17.12	-15.87	-0.17	-0.27	-0.41	-0.56	-1.46	-3.00	**-2.70**	**-11.05**
50%	-17.01	-15.56	-0.10	-0.07	-0.27	-0.12	0.01	-0.16	**-1.96**	**-7.45**
75%	-16.91	-15.26	-0.03	**0.13**	-0.12	**0.32**	1.47	2.62	**-1.22**	**-3.85**
100%	-16.80	-14.96	**0.04**	**0.33**	**0.02**	**0.76**	2.89	5.34	**-0.48**	**-0.27**
50% CFI - 50% TSU										
25%	-17.13	-15.90	-0.20	-0.31	-0.44	-0.60	-1.62	-3.27	**-2.83**	**-11.65**
50%	-17.05	-15.62	-0.16	-0.15	-0.32	-0.20	-0.31	-0.71	**-2.22**	**-8.65**
75%	-16.96	-15.35	-0.12	**0.01**	-0.19	**0.20**	0.98	1.81	**-1.60**	**-5.66**
100%	-16.87	-15.08	-0.08	**0.18**	-0.07	**0.59**	2.25	4.28	**-0.98**	**-2.67**
50% CFI - 25% TSU - 25% IRS										
25%	-17.13	-15.88	-0.19	-0.29	-0.42	-0.58	-1.54	-3.14	**-2.77**	**-11.35**
50%	-17.03	-15.59	-0.13	-0.11	-0.29	-0.16	-0.15	-0.43	**-2.09**	**-8.05**
75%	-16.93	-15.30	-0.08	**0.07**	-0.16	**0.26**	1.22	2.22	**-1.41**	**-4.76**
100%	-16.84	-15.02	-0.02	**0.26**	-0.02	**0.68**	2.57	4.81	**-0.73**	**-1.47**

NB – Strong realizations of the second and third dividends are highlighted in boldface.

Here we analyze the effects of leakage in the amount of carbon tax revenues actually recycled under the mixed strategies under considerations to determine how such leakage may affect the ability of such strategies to generate simultaneously desirable environmental, economic, and budgetary outcomes. We focus on the case with the most favorable outcomes – the mixed cases with a 1% gain in energy efficiency where all mixed strategies yield the three dividends. We consider cases in which only 25%, 50% and 75% of the revenues are actually recycled and the remainder is distributed as a lump-sum.

Naturally, partial recycling of the CO_2 tax revenues reduces the positive effects of each policy relative to the lump sum case, as less of the recycled revenues are allocated to alleviate distortions in other tax margins. From the standpoint of the realization of the second and third dividend the results are very clear. Although the realization of the third dividend is not compromised by the partial recycling, the realization of the second is. In fact, in all cases no realization of the strong dividend occurs for example when only 50% of the revenues are recycled. The realization of the second dividend disappears when leakage of the recycling revenues reaches about 30-35% (revenues recycled are 65-70% of total). The message is clear. If the objective of the recycling is to allow for a carbon tax to yield the three dividends, then most carbon tax revenues have to be recycled.

5. On the Effects of Alternative Tax Levels

Our focus on a carbon tax indexed to the central EU-ETS carbon market price projections has allowed for a detailed assessment of the mechanisms through which the tax can affect environmental outcomes, economic performance and the public sector account and has allowed us to assess the relative effects of different revenue recycling policies. From a broader perspective – associated with the choice among energy technologies or economic and political considerations – it is important to examine the impact of alternative levels of taxation. We consider, first a case in which we assume that the current prices observed in the EU-ETS carbon markets, that is, a 6 Euros per tCO_2, remain in effect indefinitely. Then, we consider an alternative in which prices in the carbon markets would immediately jump to levels projected for 2030, that is, a tax of 35 Euros per tCO_2. These two cases provide a natural lower and upper bound on the effects of the indexed tax.

Naturally such dramatic alternatives in the level of carbon taxation have significant impact on the realization of the first dividend. The emission reductions are greatly reduced in the case of a steady 6 Euro tax although not greatly amplified in the case of a steady 35 Euro tax, reflecting a pattern of decreasing marginal benefits of carbon taxation.

Table 5
Effects of aconstant carbon tax of 5 Euros per tCO2

(Percent change with respect to reference scenario)

			Carbon Dioxide Emissions		Employment		GDP		Foreign Debt /GDP		Public Debt /GDP	
CFI Share	TSU Share	IRS Share	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
No Additional Energy Efficiency Gains												
0.50	0.00	0.50	-2.75	-2.28	0.04	0.06	**0.06**	**0.11**	0.50	0.70	0.21	0.57
0.50	0.50	0.00	-2.77	-2.31	0.02	0.03	**0.04**	**0.08**	0.42	0.52	**-0.04**	**-0.09**
0.50	0.25	0.25	-2.76	-2.29	0.03	0.05	**0.05**	**0.09**	0.46	0.61	0.09	0.24
Additional Energy Efficiency Gain of 0.25%												
0.50	0.00	0.50	-4.01	-3.46	0.03	0.07	**0.12**	**0.22**	0.88	1.21	**-0.03**	**-0.03**
0.50	0.50	0.00	-4.03	-3.48	0.01	0.04	**0.10**	**0.19**	0.79	1.04	**-0.29**	**-0.68**
0.50	0.25	0.25	-4.02	-3.47	0.02	0.05	**0.11**	**0.20**	0.83	1.13	**-0.16**	**-0.35**
Additional Energy Efficiency Gain of 0.5%												
0.50	0.00	0.50	-5.23	-4.59	0.02	0.07	**0.18**	**0.32**	1.23	1.70	**-0.27**	**-0.60**
0.50	0.50	0.00	-5.24	-4.61	0.00	0.05	**0.16**	**0.29**	1.15	1.53	**-0.53**	**-1.24**
0.50	0.25	0.25	-5.23	-4.60	0.01	0.06	**0.17**	**0.31**	1.19	1.61	**-0.40**	**-0.92**
Additional Energy Efficiency Gain of 1.0%												
0.50	0.00	0.50	-7.52	-6.73	0.01	0.09	**0.30**	**0.52**	1.89	2.61	**-0.73**	**-1.68**
0.50	0.50	0.00	-7.53	-6.75	-0.02	0.06	**0.28**	**0.49**	1.81	2.44	**-0.98**	**-2.31**
0.50	0.25	0.25	-7.52	-6.74	0.00	0.07	**0.29**	**0.50**	1.85	2.52	**-0.85**	**-2.00**

NB – Strong realizations of the second and third dividends

Table6
Effects of aconstant carbon tax of 35 Euros per tCO2

(Percent change with respect to reference scenario)

			Carbon Dioxide Emissions		Employment		GDP		Foreign Debt /GDP		Public Debt /GDP	
CFI Share	TSU Share	IRS Share	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
No Additional Energy Efficiency Gains												
0.50	0.00	0.50	-12.02	-10.28	**0.23**	**0.32**	**0.27**	**0.52**	2.60	3.66	1.30	3.38
0.50	0.50	0.00	-12.11	-10.41	**0.11**	**0.17**	**0.15**	**0.34**	2.14	2.70	**-0.07**	**-0.13**
0.50	0.25	0.25	-12.07	-10.34	**0.17**	**0.25**	**0.21**	**0.43**	2.37	3.18	0.61	1.62
Additional Energy Efficiency Gain of 0.25%												
0.50	0.00	0.50	-13.15	-11.34	**0.21**	**0.32**	**0.33**	**0.62**	2.94	4.11	1.04	2.75
0.50	0.50	0.00	-13.23	-11.47	**0.10**	**0.18**	**0.21**	**0.45**	2.49	3.18	**-0.31**	**-0.72**
0.50	0.25	0.25	-13.19	-11.41	**0.16**	**0.25**	**0.27**	**0.54**	2.72	3.65	0.36	1.02
Additional Energy Efficiency Gain of 0.5%												
0.50	0.00	0.50	-14.23	-12.37	**0.20**	**0.33**	**0.39**	**0.72**	3.27	4.55	0.79	2.14
0.50	0.50	0.00	-14.31	-12.49	**0.09**	**0.18**	**0.28**	**0.55**	2.83	3.63	**-0.55**	**-1.28**
0.50	0.25	0.25	-14.27	-12.43	**0.15**	**0.26**	**0.33**	**0.64**	3.05	4.09	0.12	0.43
Additional Energy Efficiency Gain of 1.0%												
0.50	0.00	0.50	-16.27	-14.31	**0.18**	**0.33**	**0.50**	**0.91**	3.88	5.36	0.32	1.00
0.50	0.50	0.00	-16.35	-14.42	**0.07**	**0.19**	**0.39**	**0.74**	3.45	4.48	**-1.00**	**-2.34**
0.50	0.25	0.25	-16.31	-14.36	**0.13**	**0.26**	**0.45**	**0.82**	3.66	4.92	**-0.34**	**-0.67**

NB – Strong realizations of the second and third dividends are highlighted in boldface.

In terms of the effects on employment and GDP, we observe that the gains from the mixed recycling strategies increase with the carbon tax rate. The strong realization of the second dividend is more likely when there are greater carbon tax revenues available for reducing distortions at the other tax margins. In a sense the opposite pattern occurs in terms of the strong realization of the third dividend. While for a lower tax level, virtually all cases, certainly all cases with energy efficiency gains, lead to a reduction in the debt to GDP ratio, for a higher tax rate reductions in the debt to GDP ratio only occur under the mixed ITC and TSU case as well as for the ITC and TSU/IRS case with higher energy efficiency gains. This is understandable since public spending by assumption evolves proportionally to the now increasing GDP growth rate. Overall, while lower carbon tax rates make it easier for the second and third dividends to be simultaneously achieved, still even a very high carbon tax consistently allows for the realization of the triple dividend when recycling is coupled with modest gains in energy efficiency

6. Summary and Final Remarks

Our results highlightthe environmental, economic and budgetary impact of the introduction a carbon tax indexed to the carbon market price in the EU-ETS. The tax introduction of a carbon tax in its **simplest form**, alone – absent accompanying revenue recycling policies – reduces CO_2 emissions significantly but has a negative effect on economic performance both in terms of output and employment.Furthermore, because of its contractionary effects it would result in a small increase in the public debt to GDP ratio. In this form, a carbon tax would yield the desired first dividend, environmental improvements, but no second or third dividend, no economic or budgetary advantages, quite the opposite. In the current economic and policy situation in which improving the economic performance is a central objective and budgetary consolidation an ongoing concern, there is no way such a tax would stand a change of being adopted.

It is possible, however, to design a revenue neutral fiscal reform package that can produce three dividends. The introduction of a CO_2 tax with accompanying reductions in distortionary tax rates can reduce emissions while producing long term economic and budgetary effects that are positive or, at a minimum, neutral. The realization of the second and third dividend depends on the judicious use of the revenues generated by the carbon tax.

The revenue recycling policies that appear most promising in terms of yielding simultaneously the three dividends are those that use the revenue raised from the tax on CO_2 emissions to finance private investment tax credits and a reduction in social security contributions and the personal income tax rate in particular when these reductions are linked to energy efficiency improving activities.Recycling the tax revenues through a mixture these three mechanisms produces important changes in the cost structure of our economy, increasing the costs of energy while reducing the costs associated with labor and capital inputs. They allow for the reduction in energy consumption and emissions and at the same time allow for the decline in the costs of labor and capital to spur economic activity, thereby increasing the tax bases and tax revenues, that is, they allow for the realization of the three dividends as both the economy and the budgetary situation will be better after the carbon tax than before.Naturally, allowing for the**leakage** of a meaningful amount of carbon tax revenues away from the purposes of financing reductions in other tax margins linked with energy efficiency gains would seriously hinder the ability of the recycling strategies to mitigate and invert the potential negative economic effects of the tax itself.

The recycling of carbon tax revenues as suggested here, aside from yielding the three dividends, something critical for it to be even considered politically feasiblehas several other advantages which make the adoption more likely by creating a framework for neutralizing some of the legitimate concerns and related special interests surrounding the issue of environmental tax reform.

First, the focus of energy efficiency is fundamental from an economic and budgetary perspective. It is also important to accommodate the concerns of environmental groups whose focus in terms of environmental fiscal reform seems to be exclusively on the first dividend – the environmental benefitsof the reform and on the environmental ethical view that carbon tax funds should be used exclusively for environmental purposes. In this sense, the fact that a significant part of the carbon tax revenues is to be allocatedto activities that are designed to promote energy efficiency is likely to alleviate these concerns.

Second, it is understood that often a carbon tax leads to distributional concerns as low income households may potentially suffer disproportionately from the tax. It is important that these concerns not be addressed through exemptions for the tax, thereby neutralizing the price signal and environmental benefits associated with the tax. These distributional concerns can be fully addressed within the context of reform in the personal income tax while maintained the price signal associated with the tax. This recommendation is consistent with that of international institutions such as the OECD and the IMF, among others. Thus, the potential to recycle the CO_2 tax revenue through reduction in the personal income tax rate discussed above, beyond its efficiency effects, can also serve this function by differentiating the reduction in the personal income tax rate in a manner that supports low income households.

Third, it is also understood that the carbon tax may create some concerns in a country critically dependent on improving its international competitiveness. It is important not to address these concerns through exemptions to the carbon tax so as not to reduce the environmental effectiveness of the proposed fiscal reform. These concerns can be addressed through a reduction in labor costs by reducing social security contributions or in the context of the provision of corporate income tax deductions for investments in private capital. In particular, both the adjustments to the firms' social security contributions as well as incentives for private investment can be differentiated by sector in order to address concerns about competitiveness in energy intensive industries.

Finally, recycling carbon tax revenues by financing reductions in social security contributions – while desirable from an economic perspective in terms of its effect on output and employment (functioning in much the same way as fiscal devaluation) – must be accompanied by mechanisms to ensure that this reduction would never have a negative effect on the long term sustainability of social security accounts.Furthermore, caution is required in implementing this strategy to avoid the problems of political economy and the constitutional challenges to changes in social security that are not linked to a comprehensive reform of the social security system.

Despite its detail and policy relevance, the analysis presented in this paper suffers from two important shortcomings, which could be understood as directions for future research. First, it is an aggregate model and therefore does not accommodate sectorspecific issues pertaining to the energy and the environment. In particular, it does not allow for a differentiation between the sectors that participate in the EU-ETS carbon market, responsible for about 37% of the CO2 emissions, and those which do not. Furthermore, it does not allow for discrimination between tradable and non-tradable sectors a distinction that is becoming more important as the country strives to promote international competitiveness as a strategy for long-term growth.

Second, the model does not contemplate the differential effects across different income groups of the introduction of the carbon tax. The welfare effects of the CO_2 tax among different household groups is directly driven by the share of consumers' expenditure devoted to energy goods. As gasoline, electricity and other household energy sources are necessary goods – the demand for these goods increases at a less than proportional rate than income – the expenditure shares for energy are greater among lower income households. As a result, the welfare losses induced by the carbon tax are typically greater among lower income households. The regressive nature of the carbon tax can be addressed through the appropriate adjustments to the personal income tax in the context of the fiscal reform as suggested above.

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