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Financing Future Feed-in Tariffs from Currently Installed RES-E Generating Capacity

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Financing Future Feed-in Tariffs from Currently Installed RES-E Generating Capacity [1]

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Abstract

In this paper, we address the issue of how to finance the excess costs of electricity generation from currently installed renewable energy production capacity. We do so using a multi-sector and multi-household dynamic computable general equilibrium model of the Portuguese economy. We consider three issues: the effects of the existence of these excess-costs; the effects of annuitizing such costs; and, the effects of different financing mechanisms. Following the logic of the tariff deficit, we recommend the annuitizing of these excess costs. This strategy can be justified on distributional grounds. We also find that financing through carbon taxation is a better alternative than passing these excess costs through to electricity consumers in the form of higher future electricity prices. This is consistent with the idea that renewable electricity production is not an issue pertaining exclusively to the electricity market but rather a part of the national quest for decarbonization. Finally, we show that there is little reason from an environmental perspective to extend such preferential financing mechanisms to any future renewable capacity installation.

JEL Classification: C68, E62, H23, Q43, Q48.

Keywords: Renewable Financing; Feed-in Tariffs; Tariff Deficit; Electricity; CO2 Taxation; General Equilibrium; Portugal.

Note: This article is sole responsibility of the authors and do not necessarily reflect the positions of GEE or the Portuguese Ministry of Economy.

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1. Introduction

In recent years electricity tariff deficits have emerged in Spain, Portugal, and in some other EU countries such as Bulgaria, France, and Greece [see, for example, Linden eta al. (2014)]. Tariff deficits are shortfalls of revenues in the electricity system, which arise when the tariffs for the regulated components of the retail electricity price are set below the corresponding costs borne by the energy companies. These shortfalls may be permanent or temporary, may or not be officially acknowledged, and may be due to the need of financing renewable energy production, problems with the financing of public services, or induced by regulatory conditions.

The tariff deficit in Portugal is substantial, permanent, officially acknowledged and due to a combination of feed-in tariffs and regulatory issues. Starting in 2007, the total accumulated tariff deficit peaked at the end of 2015 when it reached 5 billion euros. After 2016, it has been declining having reached by the end of 2018 3.7 billion euros, which corresponds to 1.9% of the 2018 GDP [see ERSE (2018)]. Overall, the magnitude of the tariff deficit in Portugal is only second to that of Spain.

In Portugal, an important part of the tariff deficit is due to excess-costs associated with the production of renewable electricity, which renders it, partially, as a mechanism to promote accelerated adoption of renewable energy production. Indeed, in the first seven months of 2019, 52.4% of electricity production in the country was from renewable sources, of which more than half was from wind sources [APREN (2019)]. On the flip side, in 2019 about 34% of the regulated electricity price in low tension reflected general economic costs not associated with either energy or network and distribution costs. Of these, 18% corresponded to excess costs of renewable production occurred in the past and passed through to the tariff deficit [see EDP (2019)]. Accordingly, the existing tariff deficit including its renewable financing component has been priced into the electricity market.

The focus of this paper is on the excess costs of renewable energy production into the next decade implied by current contractual commitments with reference to the renewable production capacity already installed. These excess-costs are estimated to accumulate until 2030 to 8.5 billion euros [see EDP (2018)], which corresponds to 4.3% of the 2018 GDP. This means that just on account of the ongoing contractual obligations with renewable production under this special regime the accumulated tariff deficit may more than double in the next decade. To be noted, these are not excess costs from renewable capacity to be installed in the future. Indeed, most forms of renewable energy production are now competitive by market standards [see, for example, IRENA (2019)].

This leaves open two key policy questions as to what to do with these forthcoming excess costs of renewable production. The first pertains to the issue of the timing of payments of such excess costs. One alternative is to allow the over costs to be passed onto electricity prices as they occur and therefore be borne immediately by electricity customers. Another alternative is to add such excess costs to the tariff deficit and pass them smoothly to electricity prices as annuities. In this case, the excess costs will be borne by electricity customers over time. The argument behind this alternative is to spare for as long as possible households and businesses from the increased electricity prices. And this has been the case over the last decade.

The second policy questions deals with who should bear the burden of the excess costs of renewable production. One alternative is that electricity customers should bear this burden, and this has been the default over the last decade. This is suggested by the fact that renewable energy production is in fact electricity production from renewable sources and, as such, should be paid by electricity customers. Another alternative is that the burden of the renewable energy financing should be levied on the general public. The argument is that renewable energy adoption is a national design and not an electricity market issue and, as such, should not be financed by the electricity customers alone. In addition, levying the excess costs on electricity customers, distorts market conditions against electrification, which is in and of itself a major component of any strategy towards decarbonization. Importantly, the increase in electricity prices is highly regressive [see, for example, Bhattacharya et al., (2017) and Rausch and Mowers (2014)]

From this perspective, it would make sense to finance the excess costs of renewable production through standard public finance mechanisms such as deficit-financing or increased general taxation revenues. These alternatives, however, are not politically plausible given the ongoing budgetary constraints faced by the public sector. This leaves as a particularly appealing alternative, the possibility of financing the excess costs through additional carbon taxation in a revenue neutral manner.

In this paper, we compare the environmental, macroeconomic and distributive effects of annuitizing or not annuitizing these forthcoming renewable excess-costs. In addition, we compare and contrast financing the excess costs by electricity consumers versus financing through a CO2 tax. We address these questions in the context of a multi-sector, multi-household dynamic computable general equilibrium model of the Portuguese economy that builds upon the aggregate dynamic general equilibrium model, known as DGEP. Previous versions of this model are documented in Pereira and Pereira (2014c), and have been used recently to address energy and climate policy issues [see Pereira and Pereira (2014a, 2014b, 2017a, 2017b, 2017c) and Pereira et al. (2016)]. The current version of the model has a detailed description of the tax system. On the production side, it features a fine differentiation of consumer and producer goods, particularly those with a focus on energy products. On the household side, it captures the heterogeneity in income and consumption patterns by considering five differentiated household groups.

General equilibrium models have been used extensively in energy and environmental studies. In general terms, our approach follows in the tradition of the early models developed by Borges and Goulder (1984) and Ballard et al. (2009). In its specifics, however, it is more directly linked to the recent contributions of, for example, Fullerton et al (2012), Goulder and Hafstead (2013), Bhattarai et al. (2016), Tran and Wende (2017), and Annicchiarico et al. (2017). In turn, thematically, this research is close to Timilsina and Landis (2014), Landis and Timilsina (2015), Bohringer et al. (2016), Chatri et.al. (2018), Johansson and Kristromas (2019) on the general issue of the evaluation of the economic effects of feed-in tariffs and, in particular, Behrens et. al. (2016) and Proença and St Aubin (2013), which specifically address the case of feed-in tariffs in Portugal.

This paper is organized as follows. In section 2, we present in very general terms the dynamic model of the Portuguese economy. In section 3, we introduce the simulation design and present and discuss the simulation results pertaining to the two policy questions under consideration. Finally, in Section 4, we provide a summary and the policy implications of our results.

2. The Dynamic Computable General Equilibrium Model

What follows is a very brief and general description of the dynamic computable general equilibrium model of the Portuguese economy. See Pereira and Pereira (2017d) for further details.

2.1 The General Features

The dynamic multi-sector general equilibrium model of the Portuguese economy incorporates fully dynamic optimization behavior, detailed household accounts, detailed industry accounts, a comprehensive modeling of the public sector activities, and an elaborate description of the energy sectors. We consider a decentralized economy. There are four types of agents in the economy: households, firms, the public sector and a foreign sector. All agents face financial constraints that frame their economic choices. All agents are price takers and have perfect foresight.

Households and firms implement optimal choices, as appropriate, to maximize their objective functions. Households maximize their intertemporal utilities subject to an equation of motion for financial wealth, thereby generating optimal consumption, labor supply, and savings behaviors. We consider five household income groups per quintile. While the general structure of household behavior is the same for all household groups, preferences, income, wealth and taxes are household-specific, as are consumption demands, savings, and labor supply.

Firms maximize the net present value of their cash flow, subject to the equation of motion for capital stock to yield optimal output, labor demand, and investment demand. We consider thirteen production sectors covering the whole spectrum of economic activity in the country. These include energy producing sectors, such as electricity and petroleum refining, other EU-ETS sectors, such as transportation, textiles, wood pulp and paper, chemicals and pharmaceuticals, rubber, plastic and ceramics, and primary metals, as well as sectors not in the EU-ETS such as agriculture, basic manufacturing and construction. While the general structure of production behavior is the same for all sectors, technologies, capital endowments, and taxes are sector-specific, as are output supply, labor demand, energy demand, and investment demand. The public sector and the foreign sector evolve in a way that is determined by the economic conditions and their respective financial constraints.

All economic agents interact in different markets. The general market equilibrium is defined by market clearing in product markets, labor markets, financial markets, and the market for investment goods. The equilibrium of the product market reflects the national income accounting identity and the different expenditure allocations of the output by sector of economic activity. The total amount of a commodity supplied to the economy, be it produced domestically, or imported from abroad, must equal the total end-user demand for the product, including the demand by households, by the public sector, its use as an intermediate demand, and its application as an investment good.

The total labor supplied by the different households, adjusted by an unemployment rate that is assumed exogenous and constant, must equal total labor demanded by the different sectors of economic activity. There is only one equilibrium wage rate, although this translates into different household-specific effective wage rates, based on household-specific levels of human capital which obviously differ by quartile of income. Different firms buy shares of the same aggregate labor supply. Implicitly, this means that we do not consider differences in the composition of labor demand among the different sectors of economic activity, in terms of the incorporated human capital levels. Saving by households and the foreign sector equal the value of domestic investment plus the budget deficit.

The evolution of the economy is described by the optimal change in the stock variables – household-specific financial wealth and sector-specific private capital stock, as well as their respective shadow prices. In addition, the evolution of the stocks of public debt and of the foreign debt act as resource constraints in the overall economy. The endogenous and optimal changes in these stock variables – investment, saving, the budget deficit, and current account deficit – provide the link between subsequent time periods. Accordingly, the model can be conceptualized as a large set of nonlinear difference equations, where flow variables are determined through optimal control rules.

The intertemporal path for the economy is described by the behavioral equations, the equations of motion of the stock and shadow price variables, and the market equilibrium conditions. 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 while market prices and shadow prices are constant.

2.2 Calibration

The model is calibrated with data for the period 2005-2014 and stock values for 2015. The calibration of the model is designed to allow the model to replicate as its most fundamental base case, a stylized steady state of the economy, as defined by the trends and information contained in the data set. In the absence of any policy changes, or any other exogenous changes, the model's implementation will just replicate into the future such stylized economic trends. Counterfactual simulations thus allow us to identify marginal effects of any policy or exogenous change, as deviations from the base case.

There are three types of calibration restrictions imposed by the existence of a steady state. First, it determines the value of critical production parameters, such as 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 budget deficit and the current account deficit are a fraction of the respective stocks of debt equal to the steady-state growth rate. Finally, the exogenous variables, such as public or international transfers, have to grow at the steady-state growth rate.

2.3 Numerical Implementation

The dynamic general equilibrium model is fully described by the behavioral equations and accounting definitions, and thus constitutes a system of nonlinear equations and nonlinear first order difference equations. No objective function is explicitly specified, on account that each of the individual problems (the household, firm and public sector) are set as first order and Hamiltonian conditions. These are implemented and solved using the GAMS (General Algebraic Modeling System) software and the MINOS nonlinear programming solver.

MINOS uses a reduced gradient algorithm generalized by means of a projected Lagrangian approach to solve mathematical programs with nonlinear constraints. The projected Lagrangian approach employs linear approximations for the nonlinear constraints and adds a Lagrangian and penalty term to the objective to compensate for approximation error. This series of sub-problems is then solved using a quasi-Newton algorithm to select a search direction and step length.

2.4 The Reference Scenario

The reference scenario provides a trajectory for the economy through 2050. The reference scenario embodies several assumptions regarding climate policy, which are super-imposed on the steady state trajectory used in the calibration of the model. The main assumptions in our reference scenario are as follows. First, we assume that the current levels of carbon taxation persist through 2050. Second, we assume that the major coal fired power plants cease operations at the end of their useful life and no additional coal capacity is installed. Third, we assume that fossil fuel prices follow forecasts given by the IEA (2018).

3. Simulation Design and Simulation Results

3.1 Simulation Design

In Table 1, we present the details of the evolution of the excess-costs of renewable production as estimated by EDP (2018). The evolution of the excess-costs depends critically on the existing levels of CO2 taxation. Naturally, the higher the CO2 taxation levels the lower the excess-cost. Accordingly, there is an important interaction between the levels of carbon taxation and the evolution of the tariff deficit. Under current levels – for carbon taxation between 17 and 23 euros per ton, the excess-costs estimated to occur until 2030 are 8.5 billion euros, which corresponds to 4.3% of the GDP in 2018. The annuitized value would be 725 million euros or 0.363% of the 2018 GDP.

[Table 1]

We consider four policy scenarios divided in two groups of simulations. First, we consider a pair of simulations in which the excess-costs, both under their estimated annual levels [CF1] and as an annuity [CF2], are financed by electricity customers. Second, we consider a pair of simulations in which the excess-costs, both under their estimated annual levels [CF3] and as an annuity [CF4], are financed through a carbon tax. These four policy alternatives allow us to ascertain the effects of the existence of these excess-costs, the effects of annuitizing, and the effects of different financing mechanisms.

3.2 How to Finance the Excess Costs: Actual Costs Versus Annuities

In Tables 2 and 3 we report the simulation results over time. In turn, in Table 4 we report the accumulated effects by 2030. Considering the accumulated effects is rather relevant as the different policies have very different intertemporal patterns of impact depending on whether or not we annuitize the excess-costs.

[Tables 2 - 4]

Considering cases CF1 and CF2, simulation results suggest that, the existence of excess costs – regardless of whether or not we annuitize - leads to an accumulated reduction in CO2 emission reduction of around 2.6%. This reduction, however, comes with a cost in terms of both macroeconomic performance and welfare effects. In terms of the macroeconomic effects, the best scenario would be a loss of 0.63% in GDP and of 0.31% in employment. In terms of the welfare effects, the best scenario would be a loss averaging 0.06%.

The low environmental benefits and the clear efficiency and equity costs of the excess cost of renewable energy production regardless of whether or not they are annuitized cast doubts on the effectiveness and desirability of these policies. Naturally, at this stage they are contractual commitments and therefore cancelling them is not a realistic or expeditious option.

Comparing counterfactual scenarios CF1 and CF2 also indicate that, taking for granted their existence, there are some advantages and some disadvantages of annuitizing the excess costs. For essentially the same accumulated environmental effects, annuitizing is better from a distributional perspective as it leads to lower welfare losses. It is, however, worse from a macroeconomic perspective as the adverse output and employment effects are more pronounced. The fact that annuitizing the tariff deficit is desirable from a welfare perspective hints at the benefits of consumption smoothing.

These general considerations on the desirability of the existence of the excess costs and the issue of whether or not to annuitize are robust to the different alternatives we want to consider as to who bears the burden of these excess costs. This is established by comparing cases CF3 and CF4 in which, the excess costs are financed through CO2 taxation.

3.3 Who Should Pay for the Excess Costs - Electricity Customers Versus Carbon Taxation

We have established that annuitizing the excess costs of renewable production is justified from a distributional perspective and robust as to who bears the burden of the excess costs. We consider now in much greater details the issue of who should pay for these annuities. We consider the most direct financing mechanisms – electricity costs are fully supported by customers and reflected in utility bills – CF2, and compare this policy to CF4, a case in which renewable finance reform is financed through a CO2 tax. We present detailed simulation results in Tables 5-9.

[Tables 5 - 9]

3.3.1 Renewable energy financing reform financed by electricity customers

The CF2 counterfactual case corresponds to the implementation of renewable energy financing reform paid for by electricity customers in the form of higher electricity prices. This policy alternative leads to an increase in energy prices of 2.08%, which leads to a 3.32% decrease in energy demand. The price of domestic electricity itself increases by 6.54%, which leads to a 6.36% reduction in electricity production and a 1.50% decrease in electricity imports. Overall electricity demand decreases by 6.28%. Accordingly, the share of electricity in final energy demand decreases by 3.06%.

In turn, this policy alternative allows for a 2.36% reduction in CO2 emissions, which brings emissions by 2030 to 82.0% of 2010 levels. Similar reductions also occur in N2O emissions and in particular in SF6 emissions. In turn, the air pollutant emissions are also only slightly improved – namely NOx, SO2, CO, and PM – while VOC and NH3 are even less affected.

The macroeconomic effects of this policy alternative are adverse. GDP decreases by 0.86% linked directly on the supply side to the reduction in investment by 0.27% and of employment by 0.41% and on the demand side by a reduction in private consumption of 0.17%. The CPI increases by 0.32%. In turn, foreign debt increases by 0.23% with increased reliance of relatively cheaper foreign goods. Finally, there an increase of 1.43% public debt as a direct result of reduced economic activity.

The industry that is the most affected is naturally electric power. Other sectors that use a significant amount of electricity also see larger effects from the policy stemming from the increase in electricity costs and the subsequent increase in production costs. These sectors include textiles, wood, chemicals, rubber, and in particular, basic metals and equipment.

Finally, overall, there is an aggregate welfare loss of 0.15%. Across the different income groups this loss is felt in a regressive manner. Indeed, the lowest income group suffers a loss of 0.27% while the highest income group loses just 0.10%. Accordingly, the factor of regressivity is 2.7.

3.3.2 Renewable energy financing reform financed by a carbon tax

In simulation CF4, renewable energy financing reform is financed by a carbon tax rather than by the customers of the electric power industry. The carbon tax necessary to finance this policy is 16 euros per ton of CO2.

Under this policy alternative, energy prices increase by 2.41% and decrease energy demand by 2.67%. The price of electricity generation increases by 2.74%, which leads to a 2.39% reduction in production while electricity imports increase by 3.10%. Overall, the share of electricity in final energy demand increases by 0.38%. Compared to CF2, all results in CF4 on the electricity prices and production are smaller and lead ultimately, and unlike in CF2, to higher electricity imports and an increase in the share of electricity in final demand.

CO2 emissions decrease by 12.72%, which means that emissions by 2030 will represent 74.6% of emissions in 2010. Emissions of CH4 and N2O also decrease more substantially while reductions in emissions of SF6 are less pronounced. We see significant reductions in emissions of all pollutants except for NH3. The most significant reductions in emissions in CF4 compared to CF2 – reductions in CO2 emissions are about five times larger under CF4 – are a natural outcome of the CO2 tax financing mechanism which is a much sharper instrument than the mere increase in electricity prices.

This policy alternative leads to a decrease in GDP of 0.99% with private investment decreasing by 0.23% and employment by 0.50%. The CPI increases by 0.41% and private consumptions decreases by 0.20%. Foreign debt increases by 0.50% with higher domestic prices while public debt increases by 1.77% on a reduced tax base. Overall compared to CF2 we observe adverse macroeconomic effects that are of the same order of magnitude – just slightly greater.

The reduction in economic activity observed at the aggregate level hides some interesting industry effects. Now, under CF4, electricity generation shows a less pronounced decrease than under CF2 while the opposite is true with the refining sector. The sectors that were adversely the most under CF2 are now also the ones that are the most adversely affected. To these we now add wholesale and retail trade as well as transportation as showing significant adverse effects.

There is a welfare loss of 0.21%. A pattern of regressivity can be observed as the lowest income group sees a loss of over 0.31% and the lowest income group of 0.15%. The factor of regressivity is 2.0. These adverse effects are marginally larger than under CF2.

3.3.3 Comparing the two financing alternatives

Financing the excess-costs of renewable production through CO2 tax is much more effective from an environmental perspective. A one percentage-point reduction in GDP is consistent with a 13.7 % reduction of emissions under the CO2 taxation versus 4.1% under financing by the electricity consumers. On the other hand, financing the excess costs through CO_2 tax is much less costly from a welfare perspective. A one-percentage point reduction in welfare is consistent with a 44.9 % reduction of emissions under the CO_2 taxation versus 10.4% under electricity consumer finance.

4. Concluding Remarks

In this paper, we address the issue of how to finance the excess costs of renewable energy production from currently installed production capacity. We consider three issues: the effects of the existence of these excess-costs; the effects of annuitizing; and, the effects of different financing mechanisms.

We can summarize our simulation results as follows. First, the environmental effects of financing the excess costs of renewables by electricity customers are only marginally significant while the effects on economic performance, employment, and household welfare are adverse albeit small. Second, the tariff deficit approach can be justified from a distributional perspective as it allows for consumption smoothing and a reduction of the welfare losses of the policy. Third, renewable energy financing reform based on CO_2 taxation has slightly larger adverse economic and welfare effects than financing by customers of electricity but much more substantial environmental benefits. It is also much more cost effective in terms of the relative magnitude of the environmental gains relative to the macroeconomic or welfare losses they induce.

These simulation results, in turn, have important policy implications. First, there are no good reasons to extend any preferential mechanisms to any future renewable capacity installation even if the market conditions would so suggest in the form of higher costs of renewable production. The environmental benefits do not justify the adverse macroeconomic and welfare costs. Second, the welfare benefits justify the use of a tariff deficit approach to address excess costs resulting from electricity generation by currently installed capacity under contractual feed-in tariffs. Third, these excess costs should be financed through CO_2 taxation rather than being passed through electricity customers. That would be a much more cost-effective manner of achieving reductions in emissions.

These results, hint at some important but much more general strategic considerations given the domestic and international environmental policy context. In the path towards decarbonization, the Portuguese authorities have adopted the 2018 IPCC of reducing carbon emission by 45% by 2030 compared to 2010 levels [see IPCC(2018) and APA(2018)]. This requires a comprehensive reform package that is financed by CO_2 taxation to meet 2030 environmental targets and proper recycling of the reminiscent revenues is a much more desirable alternative as it promotes both decarbonization and electrification while promoting desirable economic and welfare outcomes.

Financing of the existing tariff deficit as well as the excess costs currently forecasted into the next decade, should be part of this comprehensive package. This is so because of the macroeconomic and distributional arguments put forth in this paper. It is also so, given the synergies between the future excess costs of renewables and the levels of CO_2 taxation. In fact, the introduction of CO_2 taxation at the levels necessary to reach the IPCC targets will, in and of itself, go a long way to reduce the magnitude of such excess costs of production using currently installed capacity. This is because the excess costs depend on market prices, which in turn depend on the level of CO_2 taxation. The higher the levels of CO_2 taxation the lower the magnitude of the contractual excess costs.

Finally, and although this is an energy policy paper applied to the Portuguese economy and its policy implications directly relevant for the Portuguese case, its interest is far from parochial. The quest for decarbonization is universal. The existence of renewable energy subsidies widespread. The concerns over the macroeconomic and distributional effects of renewable energy finance and environmental policies in general unavoidable if there is some hope of meaningful policies ever being adopted.

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Table 1 - Excess Cost of Renewable Energy Production from Existing Installed Capacity

Unit: Million Euros

	Evolution of 2018 Tariff Deficit	Excess Cost		
		[CO2 tax: 17 -23 Euros]	[CO2 tax: 80 -150 Euros]	[Co2 tax: 115 – 185 Euros]
2018	3,192	-	-	-
2019	2,066	987	643	391
2020	1,211	815	503	261
2021	581	692	344	99
2022	265	591	200	12
2023	134	453	44	0
2024	0	332	22	0
2025	0	289	15	0
2026	0	291	9	0
2027	0	251	0	0
2028	0	225	0	0
2029	0	192	0	0
2030	0	64	0	0
Total Deficit		**8,512**	**5,111**	**4,093**
Annuity		**725**	**435**	**350**

Source: EDP (2018)

Table 2 – Current vs Annuity Payments Financed by Electricity Customers

Percent change from baseline

	2020	2025	2030
CF1: CURRENT – Tariff Deficit financed by electricity customers			
Carbon Tax [Euros per ton of CO2]	0	0	0
Carbon Dioxide Emissions	-6.38	-1.03	-0.17
GDP	-1.46	-0.31	-0.13
Private Consumption	-0.43	-0.07	-0.01
Employment	-0.71	-0.15	-0.04
Households: First Quintile (Lowest Income)	-0.65	-0.10	-0.03
Households: Second Quintile	-0.52	-0.08	-0.02
Households: Third Quintile	-0.42	-0.06	-0.03
Households: Fourth Quintile	-0.37	-0.05	-0.01
Households: Fifth Quintile (Highest Income)	-0.29	-0.04	-0.00
CF2: ANNUITY – Tariff Deficit financed by electricity customers			
Carbon Tax [Euros per ton of CO2]	0	0	0
Carbon Dioxide Emissions	-2.64	-2.49	-2.36
GDP	-0.71	-0.81	-0.86
Private Consumption	-0.07	-0.08	-0.17
Employment	-0.40	-0.44	-0.41
Households: First Quintile (Lowest Income)	-0.16	-0.11	-0.27
Households: Second Quintile	-0.10	-0.11	-0.21
Households: Third Quintile	-0.06	-0.07	-0.16
Households: Fourth Quintile	-0.04	-0.05	-0.14
Households: Fifth Quintile (Highest Income)	-0.01	-0.01	-0.09

Table 3 - Current vs Annuity Payments Financed Though a CO_2 Tax

Percent change from baseline

	2020	2025	2030
CF3: CURRENT - Tariff Deficit financed with CO2 tax			
Carbon Tax [Euros per ton of CO2]	49.00	6.52	1.20
Carbon Dioxide Emissions	-24.13	-6.20	-1.37
GDP	-1.96	-0.42	-0.18
Private Consumption	-0.56	-0.10	-0.01
Employment	-1.01	-0.21	-0.10
Households: First Quintile (Lowest Income)	-0.88	-0.14	-0.02
Households: Second Quintile	-0.76	-0.13	-0.02
Households: Third Quintile	-0.66	-0.11	-0.02
Households: Fourth Quintile	-0.60	-0.10	-0.01
Households: Fifth Quintile (Highest Income)	-0.44	-0.08	-0.01
CF4: ANNUITY – Tariff Deficit financed with CO2 tax			
Carbon Tax [Euros per ton of CO2]	17.75	17.09	16.45
Carbon Dioxide Emissions	-13.26	-12.99	-12.72
GDP	-0.88	-0.96	-0.99
Private Consumption	-0.16	-0.14	-0.20
Employment	-0.49	-0.53	-0.50
Households: First Quintile (Lowest Income)	-0.28	-0.26	-0.31
Households: Second Quintile	-0.23	-0.21	-0.27
Households: Third Quintile	-0.19	-0.17	-0.23
Households: Fourth Quintile	-0.17	-0.15	-0.21
Households: Fifth Quintile (Highest Income)	-0.11	-0.09	-0.15

Table 4 - Current vs Annuity Payments:
Accumulated Intertemporal Effects by 2030

Percent change from baseline

	CF1: Financed by electricity customers - CURRENT	CF2: Financed by electricity customers - ANNUITY	CF3: Financed with CO2 tax - CURRENT	CF4: Financed with CO2 tax - ANNUITY
Carbon Dioxide Emissions	-2.59	-2.55	-11.67	-13.09
GDP	-0.63	-0.77	-0.85	-0.93
Private Consumption	-0.14	-0.06	-0.24	-0.17
Employment	-0.31	-0.42	-0.44	-0.51
Households: First Quintile (Lowest Income)	-0.25	-0.17	-0.35	-0.27
Households: Second Quintile	-0.19	-0.12	-0.30	-0.22
Households: Third Quintile	-0.15	-0.07	-0.26	-0.19
Households: Fourth Quintile	-0.13	-0.05	-0.24	-0.16
Households: Fifth Quintile (Highest Income)	-0.10	-0.01	-0.17	-0.10

Table 5 Annuity Financing of Excess Costs:
Long Run [2030] Effects on Energy Markets

Percent Change from Baseline

	CF2 Financed by electricity customers	CF4 Financed with CO2 tax
Carbon Tax	0	16
Energy Price	2.08	2.41
Electricity Price	6.54	2.74
Electricity Production	-6.36	-2.39
Thermal Generation	-4.95	-6.58
Renewable Energy Systems	-4.90	-0.25
Net Electricity Imports	-1.50	3.10
Energy Demand	-3.32	-2.67
Electricity Demand	-6.28	-2.30
% Electricity in Final Energy Demand	-3.06	0.38

Table 6 Annuity Financing of Excess Costs:
Long Run [2030] Effects on GHG and Air Pollutant Emissions

Percent Change from Baseline

	CF2 Financed by electricity customers	CF4 Financed with CO2 tax
Greenhouse Gases		
CO2 emissions relative to 2010	82.0%	74.6%
Carbon Dioxide – CO_2	-2.36	-12.72
Methane – CH_4	-1.94	-6.10
Nitrous Oxide – N_2O	-2.03	-9.64
Hydrofluorocarbons – HFC	-0.69	-1.06
Perfluorocarbons – PFC	-0.63	-0.93
Sulfur Hexafluoride – SF_6	-6.36	-2.39
Air Pollutants		
Nitrogen Oxides – NOx	-2.21	-14.07
Sulfur Dioxide – SO2	-2.62	-17.42
Volatile Org. Compounds – VOC	-1.75	-4.72
Carbon Monoxide – CO	-3.60	-20.51
Particulate Matter – PM	-4.93	-31.93
Ammonia – NH3	-0.59	-0.85

Table 7 Annuity Financing of Excess Costs:
Long Run [2030] Effects on Macroeconomic Performance

Percent Change from Baseline

	CF2 Financed by electricity customers	CF4 Financed with CO_2 tax
GDP	-0.86	-0.99
Private Consumption	-0.17	-0.20
Investment	-0.27	-0.23
Employment	-0.41	-0.50
Foreign Debt	1.43	1.77
Public Debt	0.23	0.50
CPI	0.32	0.41

Table 8 Annuity Financing of Excess Costs:
Long Run [2030] Effects on Output by Industry

Percent Change from Baseline

	CF2 Financed by electricity customers	CF4 Financed with CO2 tax
Total	-0.86	-0.99
Petroleum Refining	-0.28	-1.89
Electricity	-6.36	-2.39
Biomass	-0.06	0.44
Agriculture	-0.53	-0.80
Mining	-1.40	-1.59
Food products	-0.41	-0.54
Textiles	-1.28	-1.59
Wood, pulp and paper	-1.39	-1.54
Chemicals and pharmaceuticals	-0.96	-1.51
Rubber, plastics and ceramics	-1.35	-2.61
Basic metals and fabricated metal products	-1.76	-2.03
Equipment manufacturing	-2.04	-3.27
Water, sewage and waste management	-0.29	-0.35
Construction	-0.31	-0.31
Wholesale and retail trade	-0.68	-1.08
Transportation	-0.67	-1.67
Accommodation and food services	-0.39	-0.44
Information technology	-0.31	-0.35
Finance and insurance	-0.36	-0.48
Real estate	-0.06	-0.13
Professional services	-0.52	-0.63
Public administration	-0.15	-0.17
Education	-0.08	-0.10
Health	-0.16	-0.23
Other	-0.38	-0.49

Table 9 Annuity Financing of Excess Costs :
Long Run [2030] Household Welfare Effects by Income Level

Percent Change from Baseline

	CF2 Financed by electricity customers	CF4 Financed with CO2 tax
All Households	-0.15	-0.21
First Quintile (lowest income)	-0.27	-0.31
Second Quintile	-0.21	-0.27
Third Quintile	-0.16	-0.23
Fourth Quintile	-0.14	-0.21
Fifth Quintile (highest income)	-0.10	-0.15

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