The joint impact of carbon emissions trading and tradable green certificates on the evolution of liberalized electricity markets: The Spanish case

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Abstract

The growing concern for the impacts of climate change is driving many countries towards the implementation of both carbon reduction and renewable electricity promotion policies. However, the joint long-term impact of these policies on liberalized electricity sectors has not been analyzed thoroughly. In this paper we take a look at how the European

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Union ETS and a tradable green certificate system for the promotion of renewable energies may affect the Spanish electricity sector in the long term. The analysis has been carried out with a generation-expansion model which accounts for possible oligopolistic behavior of generation firms. Results are interesting in that the combination of both carbon reduction and renewable promotion policies may result in lower costs than carbon reduction policies alone, with the added benefit of increased renewable deployment. Therefore, there may be a sort of double-dividend in this combination which might be interesting to exploit.

1 Introduction

Climate change policies have clearly been escalating in the political agenda in the recent years. The growing concern for the impacts of climate change, as recently updated by the IPCC (IPCC, 2007) is driving many governments to take action on reducing greenhouse gas emissions. Among the many policies available for achieving reductions, the most popular up to now have been setting up emission trading markets, carbon taxes, and also the promotion of renewable energies.

Emissions trading was contemplated under the Kyoto Protocol as one of the mechanisms available to reduce the cost of complying with reduction targets. However, it was not until the European Union implemented its Emissions Trading Scheme or ETS (EU Directive 2003/87/EC) that these markets really took flight. The relatively successful European experience
has also prompted other countries to consider this mechanism: the US Senate, for instance, is currently considering several bills for the introduction of such a scheme, and other countries are doing the same. The implementation of these markets is also making carbon taxes redundant, and so the countries which featured them are abandoning this instrument.

Renewable energy (RE) promotion policies, on the other hand, have a longer history. In fact, they were devised as a way to reduce energy dependency, and therefore it was around 1973 when they started to be considered. However, the following decrease in oil prices in the 80s made them not necessary to the policy maker, and it was not until the 90s when they made a strong comeback. Since then, these policies have been used extensively, not only in the US and Europe, but also in many other countries, as a multi-purpose instrument: renewable promotion helps reduce carbon emissions, but also energy dependency, and contribute to the development of local industry.

The relevance of these two policies has attracted a lot of attention from researchers and policy makers, and has resulted in many studies. The impact of emissions trading policies has been analyzed from a macro point of view (see e.g. Huntington and Weyant (2004) for a thorough review), and also from the point of view of the electricity sector (which is one of the most relevant players in the carbon emissions market). Here, studies such as the GETS initiative by Eurelectric (2004), Sijm et al (2006), Smale et al (2006)
or Linares et al (2006) have produced very interesting insights. More examples of these studies are included in this volume.

As for the impact of renewable energy promotion policies, they have also been closely examined. For the sake of concision, we will only cite the studies by Ford et al (2007), Fischer (2006), Menanteau et al (2003) or Amundsen and Mortensen (2001).

However, an interesting fact is that, since both types of policies address the same type of issues, there may be important interactions between them, and therefore their impact may have to be assessed together to account for that.

Indeed, an emissions trading scheme will indirectly encourage investments in “clean” technologies such as gas, nuclear energy and renewables, while penalizing investments in other “dirtier” technologies such as coal. This indirect incentive for renewables may interact significantly with current support schemes for renewable energies. Although it is debatable whether the support for renewables accounts for their carbon reduction benefits or for their local positive externalities (which most of the times is not so clear; see, e.g., Komor and Bazilian (2005) or Bergmann et al (2006)), it is possible that the implicit carbon tax may in fact be double-counting the carbon externality of renewables, because of the slow adjustment of support schemes. This brings out the problem of how to avoid this double-counting and of how to combine regional regulations such as the ETS Directive and national ones such as RE support schemes.
Some analyses have already been carried out on the expected consequences of carbon trading mechanisms on renewable support schemes. For instance, Boots (2001) or Jensen and Skytte (2003) have assessed the interaction between carbon trading and tradable green certificates using analytical models. Del Río et al. (2005) have looked at the impact of clean development mechanisms and joint implementation on the deployment of renewable electricity in Europe, although again from an analytical point of view. Hindsberger et al. (2003) or Unger and Ahlgren (2006) used a simulation model to obtain quantitative results for the Nordic electricity and energy sectors respectively also under a tradable green certificate system.

The objective of this paper is to contribute to this analysis, by simulating the joint impact of carbon emissions trading and renewable electricity promotion policies on a liberalized electricity market. Compared to the previously mentioned studies, our approach offers two clear advantages: on the one hand, it is expected to be more realistic, by being able to simulate the oligopolistic behavior of the players in the electricity market; on the other hand, it provides a long-term view, since it simulates the evolution of the electricity system up to 2020.

An earlier paper (Linares et al, 2007b) used this approach for the Spanish electricity sector. However, the description of the sector was too stylized, since the focus was much more on the theoretical interactions than on the real impact. Here we try to present much more realistic results, by
incorporating as much as possible all the current existing policies and conditions affecting the sector. Of these, the major one may be the regulation of SO2, NOx and particulate emissions, which is expected to drastically affect the evolution of the sector in the medium term.

Section 2 describes briefly the model used for the analysis. Section 3 presents the scenarios considered for the simulation, and section 4 shows the major results. Finally, section 5 provides the conclusions and recommendations from the study.

2 The simulation model

The simulation model used for this study is an oligopolistic, long-term generation expansion model developed at Instituto de Investigación Tecnológica, Comillas University. Here only a brief overview is provided. For a full mathematical formulation, see Linares et al (2007a).

The electricity market is modeled as one in which, in the short term, firms compete in quantity of output as in the Conjectural Variations (CV) approach wherein generators are expected to change their conjectures about their competitors' strategic decisions, in terms of the possibility of future reactions (García-Alcalde et al, 2002 and Day et al, 2002). In the long-term electricity market, firms compete in generating capacity as in the Nash game. Conceptually, the structure of this model corresponds to various simultaneous optimizations –for each firm, the maximization of its profits subject to its particular technical constraints–. These optimization problems
they are linked together through the electricity price and the emissions permit price resulting from the interaction of all of them. The general structure of the model is shown in Figure 1 (explained below).

<table>
<thead>
<tr>
<th>Optimization Program of Firm 1</th>
<th>Optimization Program of Firm e</th>
<th>Optimization Program of Firm E</th>
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<tr>
<td>maximize: $\Pi_f(q_f)$</td>
<td>maximize: $\Pi_e(q_e)$</td>
<td>maximize: $\Pi_r(q_r)$</td>
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<tr>
<td>subject to: $h_f = 0$</td>
<td>subject to: $h_e = 0$</td>
<td>subject to: $h_r = 0$</td>
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<tr>
<td>$g_f \leq 0$</td>
<td>$g_e \leq 0$</td>
<td>$g_r \leq 0$</td>
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<tr>
<td>$p^e = f^e \left( \sum q^e_i \right)$</td>
<td>$p^o = f^o \left( \sum q^o_i \right)$</td>
<td>$\sum q^o \geq Q^p$</td>
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</table>

Electricity Market | Allowances Market | Green certificates Market

**Figure 1. Mathematical structure of the market equilibrium model.**

The objective of each generation firm $f$ is to maximize its profit $\Pi$ defined as market revenues minus operating costs, investment costs and cost of purchasing emission allowances, the decision variable being the amount of electricity generated $q$, and the new capacity investments. The sets of constraints $h$ and $g$ ensure that each company’s optimization program provides decisions $q$ that will be technically feasible. For the sake of the clarity and computational tractability, generating units have been grouped into equivalent plants according to its technology.

The link between the electricity market and every firm’s optimization program is the demand function that relates the demand supplied by every
generator $q^*_j$ to the electricity price $p^*$. It is assumed in this model that the electricity market price at each load level is a linear function $f^*(\cdot)$ of the total demand (see left hand side of Figure 1).

The carbon allowance market is modeled as a perfectly competitive one. So the clearing price of the market $p^*$ will be the crossing of the allowances’ aggregated demand curve with the whole supply curve. The whole supply curve is set to be a constant quantity of allowances determined by the government while the aggregated demand curve is the sum of demands of all sectors covered by the emissions trading scheme at every allowance price.

Part of the aggregated demand function is unknown, since for the electricity sector, this demand will depend on the utility they get by means of emission allowances (which in turn depends on electricity prices and costs, and therefore is endogenous to the model). The rest of sectors are much more difficult to model in the same way, because of their disaggregation and lack of data. However, this same disaggregation allows assuming that they will behave as price-takers in the emissions market, and therefore they may be modeled as a competitive fringe, with a demand function corresponding to their marginal abatement costs. Therefore, the residual supply curve considered in the emission allowance market is obtained by subtracting the total demand function for all these sectors to the whole supply curve (total amount offered by the government).
Then the emission allowance market is modeled by the residual supply function that relates the allowances purchased by every firm $q_f^p$ to the allowance price $p^n$. It is assumed that the price is a linear function $f^p(\cdot)$ of the purchases (see box of Allowances Market in Figure 1).

Finally, the green certificate market is also modeled as a perfectly competitive one, and therefore is represented by a global restriction on the amount of renewable electricity that has to be produced: the sum of all renewable electricity produced by all firms $q^{re}$ has to be larger than the quota set by the government $Q^R$ (see right hand side of Figure 1).

The model assumes that firms make their capacity-expansion decisions as in a Nash equilibrium. Formally, the investment market equilibrium defines a set of capacities such that no firm, taking its competitors’ capacities as given, wishes to change its own capacity unilaterally (Ventosa et al, 2002). Thereby, each firm chooses its new maximum capacity so that its own profit is maximized. The Nash assumption implies that firms’ investment decision-making occurs simultaneously as it is modeled.

To summarize, the whole model, which is a CV-market sub-model plus a Nash-expansion planning sub-model, subject to the environmental restriction of the carbon allowances and tradable green certificates markets, defines the operation, the investment, allowances purchases and pricing of both electricity, allowances and green certificates that simultaneously satisfy the first-order optimality conditions of all firms.
This market equilibrium problem can be stated in terms of a Linear Complementarity Problem (Rivier et al, 2001) by means of setting the first-order optimality Karush-Kuhn-Tucker conditions associated to the set of maximization programs.

3 Description of scenarios

In order to analyze the joint impact of carbon emissions trading and renewable energy promotion policies on the electricity sector, we will run the model for four different scenarios: a base or reference case; a case in which emissions trading, but no renewable energy promotion policy is simulated; another one in which renewable energy promotion policies but no emissions trading is considered; and finally, a case in which both policies are modeled together.

3.1 Reference case

The reference case consists in simulating the operation and investment in the Spanish electricity market, under oligopolistic conditions, and without any renewable promotion or carbon emissions reduction mechanisms (we have considered the existing premiums for renewable generation, but only for already existing facilities).

The basic parameters which define the base case are described below. For a more extensive description of the Spanish electricity system, see e.g. Crampes and Fabra (2005).
3.1.1 **Temporal scope**

The simulation has been carried out for a 20-year period (2008-2027). However, in order to avoid strange results due to tail and start-up effects, only the middle 13 years have been considered (2008-2020). Each of these years is disaggregated into five demand levels. The duration of these levels is defined in the following section.

For modeling the emissions market, super-periods have been defined, corresponding to the periods set by the European ETS. The first super-period then is 2005-07, and the rest are five-year periods.

3.1.2 **Electricity demand**

The duration of each demand level, as well as the demand for year 1 of the simulation and its price are shown in Table 1. Demand for 2005 has been taken from REE (2005).

<table>
<thead>
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<th>Table 1: Demand characteristics per level.</th>
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<td>The slope of the demand curve is 60 €/MWh·MW, and the demand growth rate is 2.5%. This growth rate is lower than that experienced in the last years (around 5-6%). However, it seems reasonable to assume that this rate will probably be moderated when the long-term is considered, and in fact those are the assumptions of the Spanish Ministry of Industry (MINER, 2002).</td>
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3.1.3  Firm structure

We have represented the six major firms participating in the Spanish electricity market, plus an additional firm representing new entrants and also another firm which represents the special regime existing in Spain in 2004 (basically, renewables and cogeneration).

Large firms are characterized by a certain slope in their supply curve, which represents the variation of price as a function of the power generated by the firm (or, to put it in other way, the capability of the firm to influence market prices by modifying its offered power). These values have been obtained from García Alcalde et al (2002).

3.1.4  Electricity generation technologies

All the power plants belonging to the generators have been aggregated into one group per technology and firm, in order to reduce the size of the model. The existing technologies considered have been nuclear (NCL), fuel-oil (FO), natural gas (GN), gas combined cycles (ECCGT), domestic coal (HLL), imported coal (CI), brown lignite (BRL), black lignite (BLL), regulating hydro (REG), run-of-the-river hydro (FLU), pumping units (BOMB), biomass (EBIO), cogeneration (ECOG), mini hydro (EMINH), wind (EEOL), and solar (ESOL).

In addition, future technologies have been considered for the new investments: supercritical coal (CSC), advanced nuclear (NCLAV), gas combined cycles (CCGT), three types of biomass (BIO1: energy crops, BIO2:
agricultural waste, and BIO3: forest waste), three types of wind depending on the wind speed of the site (EOL1, EOL2, EOL3), offshore wind (EOLOFF), mini hydro (MINH), cogeneration (COG), and solar thermal (SOLT). Their parameters are presented below. It should be remarked that costs for the different technologies may be a bit out of date, but, since the focus of the paper is not on prediction of prices but on interaction of policies, we consider this is not a critical point.

The cost function used in the model is a binomial function \( c = ax + bx^2 \), where \( a \) corresponds to the linear variable cost and \( b \) to the quadratic variable cost.

Table 2: Parameters for current thermal power plants

Table 3. Parameters for renewables and cogeneration power plants

Table 4. Parameters for current hydro power plants

Table 5 Parameters for new technologies

It should be remarked that, under the base case, no new nuclear investments are allowed due to the current problems with public acceptance and financing.

3.1.5 **Investment related data**

Related to the investment decisions of firms, two relevant factors exist beside the investment cost: the discount rate and the maximum investment capacity.
The discount rate considered has been a 9%. As for the maximum investment, we have assumed that for each super-period the investment capacity of each firm is limited to a quantity equivalent to a number of gas combined cycles, which depends on the size of the firm (from 3 to 5 for the existing firms, and only 1 for the new entrants).

3.1.6 Limits for SO$_2$, NO$_x$ and TSP emissions

As mentioned before, due to its large relevance, we have also modeled the European Directive 2001/80 on atmospheric emission limits from large combustion plants. This Directive has been translated into Spanish legislation by Royal Decree 430/2004.

This Royal Decree establishes that there will not be individual limits for power plants, but rather a National Reduction Plan. Existing power plants must comply with a global annual emissions limit from 2008 onwards (although those plants operating less than 20,000 hours up to 2015 are exempted). There are limits for SO$_2$, NO$_x$ and particulate matter.

The precise limits and the implementation methodology have not yet been fixed, so some assumptions had to be made. For our simulation we have considered that all fuel-oil and gas power plants, plus 477 MW of domestic coal and 320 MW of black lignite will be exempted, since they will operate less than 20,000h (that is, they will not be required to reduce their pollutant emissions). The rest of existing plants will be incorporated into the National Reduction Plan, for which the following global caps have been
assumed. This means that, for most of the existing power plants, the total amount of pollutants emitted cannot exceed those reflected in Table 3.6.

Table 6: Emission limits for existing power plants

For new power plants, the emission limits will be set for each individual power plant. We have assumed that the future power plants to be installed will comply with these limits.

It should be noted that the implementation of this Directive has a large influence in the evolution of CO$_2$ emissions from the Spanish electricity sector, by encouraging the phase out of several high-emitting facilities and by exacting changes in the operation of the remaining ones.

3.2 Alternative scenarios

As already mentioned, in order to analyze the joint impact of carbon emissions trading and renewable energy promotion policies on the Spanish electricity sector, we have built scenarios in which these policies are modeled, both separately and jointly.

3.2.1 Carbon emissions trading policies

The carbon emissions trading policy simulated is the European ETS. Therefore, there is a cap on the total amount of carbon emissions, translated
into a certain amount of tradable allowances. The price for the allowances is generated endogenously by the model.

The amount of allowances distributed is that established by the Spanish National Allocation Plan (RD 60/2005), that is, 160 Mt. However, the Plan only covers the period 2005-07. From 2008, the government envisages that emissions should not be higher than those of 1990 incremented in a 24%, so the total amount of allowances from 2008 to 2014 will be 147.8 Mt. This 24% increment is larger than the 15% increase allowed by the Kyoto commitments. However, the Spanish government assumes that the differential will be covered by Certified Reduction Units from Clean Development Mechanisms (7%), and by carbon sinks (2%).

It has to be noted that this is the whole amount of allowances distributed among all sectors covered by the Directive. However, only the electricity sector has been modeled in detail. The rest of sectors have been modeled, as described in Section 2, as a competitive fringe, where their demand function is the aggregated marginal abatement cost curve for all these sectors in Spain, and has been obtained from the PRIMES model (Capros et al, 2001).

Of course, since the Directive sets up a European market, allowing trade between countries (and from 2008 on, the emissions market will become global rather than European), the expected results for the allowance price may be different than those simulated here. Since the size of the market when enlarged to a European or global scale will be much larger,
abatement opportunities may increase and therefore the expected price of the allowance should be lower.

However, the precise modeling of this European or global market (by including many sectors and countries into the model) runs at odds with the detailed specification of the electricity system provided by our model, because of computing requirements, and therefore a compromise had to be made. Therefore, the balance in this exercise has been driven towards more detail in the electricity sector, assuming that some detail will be lost in the emission permit market. However, we would not expect very large differences between Spanish and European allowance prices, since the Spanish energy technologies and the energy mix are similar to the European average, so the marginal abatement costs curves (which ultimately define the price of the allowance) would be expected to be similar. Therefore, we consider it more advisable to simulate just the Spanish market with no trade, assuming that the real allowance price may be somewhat lower.

Finally, about the allocation of allowances: the objective of this paper is not to look at the distribution of costs and benefits among firms, so allocation is therefore not relevant.

3.2.2 Renewable energy promotion policies

Regarding renewable energy promotion policies, two options are mostly used: price systems (premiums) and quota systems (usually
associated with tradable green certificates). Although the first are more widespread, due to their seemingly better performance (Menanteau et al, 2003), its modeling as an exogenous premium for deciding on generation expansion is somewhat short-sighted. Indeed, premiums are not static, but rather based on implicit quota objectives set by regulators. Therefore, we consider that they should be modeled anyway as quota systems, since that allows for an endogenous generation of the premium.

Therefore, the renewable energy policy considered has been a tradable green certificate system, through which a renewable quota of 17.5% of the total electricity production is reached in 2010 and maintained, according to the European Directive 2001/77 on renewables.

4 Results

In this section, the major results for the scenarios described above are presented. The scenarios are: REF (reference case), ETS (only emissions trading), TGC (only tradable green certificates) and ETSTGC (both emissions trading and tradable green certificates).

Again, we must underline that the prices and costs as such are not indicative, since they are based on assumptions that are not necessarily realistic. The focus of the paper is on the comparison of the different policies, and therefore figures should be considered on a relative, not on an absolute, basis. This is specially relevant for electricity market prices and green certificate prices, and also for the costs of the system.
Table 7: Electricity market price (€/MWh)

As expected, prices increase with the introduction of an ETS, and decrease with a TGC scheme (since the amount of “conventional” energy bid into the system decreases, and so does the marginal price). However, we see that this latter effect is not very pronounced, possibly due to the fact that it is always the same technology which sets the marginal price.

The increase of prices due to the introduction of an ETS is significant: up to 40% in 2012, and more than 300% in 2020. This can be explained by the large increase in demand considered, while the amount of allowances is held constant.

As for the joint impact, we see that the combination of ETS and TGC policies result in significantly lower prices than under the ETS alone. This may be explained by two factors: first, the decrease in marginal prices by the introduction of more renewable energy, which has already been mentioned. And a second factor is the decrease of emission allowance prices again because of the increase of renewables. The two factors combined produce a significant price reduction compared to the ETS-only case, which as we shall see will have consequences on costs for the consumers.

It may be noted that there are significant jumps in prices in 2013 and 2018. This is due to the jump in carbon prices, which will be explained below.
Table 8: Emission allowance price (€/t)

Emission allowance prices increase over time, basically due to the increase in electricity demand, which makes it harder to meet the constant emission constraint. But, as we mentioned before, we see that when the two policies are combined, there is a reduction in allowance prices. This effect has already been identified in the literature (see e.g. Linares et al, 2007b), and is basically due to the fact that when renewables are forced into the system, they contribute to emission reductions at a zero cost (since they are already paid for by the tradable green certificate), and hence reduce the marginal cost of emissions reduction (which is where the emission allowance price comes from). Another way of explaining this is that part of the permit price is being incorporated into the green certificate price.

Although it is not the objective of our exercise to simulate precisely allowance prices, it is interesting to note that prices reflect quite well the current behavior of the allowance market in the short term.

We may also note that there are significant jumps in the allowance prices between trading periods (2013, 2018). This is due to our consideration of different trading periods (which of course may be modified), and to the fact that we do not consider banking between them. Banking would produce smoother price increases, as well as longer trading periods.
The green certificate price, as previously explained, is the difference between the renewable energy marginal cost and the electricity market price, that is, the degree of support required by the marginal renewable energy producer to recover his long-term costs. It only appears when associated to a renewable quota. Here green certificate prices are lower than current ones, based on two facts: first, we are considering quite low investment costs for new renewables; second, we are not introducing a risk premium into the certificate price. Again, since our focus here is on a stylized comparison of policies, we do not find these assumptions too critical.

The interesting effect to be observed is that, when an emissions trading system is implemented, the certificate price is reduced, because the electricity price increases and therefore there is less need for external support. This results even in negative prices for the certificate around 2018 (when the allowance price increases much and so the electricity price).

First, we should point out that the evolution of CO2 emissions under the reference scenario, although significant, is probably much lower than that corresponding to the increase in demand. This is basically due to the impact of the Large Combustion Plant Directive, which implies the decommissioning of most of the most polluting (and CO2-emitting) plants in
Spain. Therefore, there is already a large reduction implied in that reference scenario.

As for the impact of the different policies: we see that an ETS has a significant impact, keeping emissions around 85 Mt per year, while a TGC does not really reduce to that level (indeed, a TGC policy alone such as the one considered here would not be able to achieve the goals set under the Kyoto Protocol for Spain). When the two policies are combined, again we see an interesting effect: on the one hand, we should see a reduction compared to the ETS case, because of the larger participation of renewables into the system. But on the other hand, let’s not forget that the combination of policies also produced a reduction in the price of the carbon allowance (and therefore a reduction in the incentive to abate emissions). So the final effect is not, as might have been expected, a larger abatement than the one under ETS, but rather a similar one (although of course there will be differences in costs and renewable energy development, which will be analyzed later).

Table 11: Installed power in 2020 per technology (MW)

In this table (table 11) we may understand most of the evolution of emissions mentioned above: we see that under an ETS, there is a large investment in gas combined cycles, but also some investment in renewables, in order to achieve the reductions required. These technologies basically replace coal power plants (both new and existing). When a TGC is introduced alone, the investment in gas decreases compared to the reference case, since most of the effort goes to comply with the renewable obligation.
And, what happens when we combine both policies? We see here that is a mixture of ETS and TGC. The investment in gas is a bit higher, as well as the investment in renewables, but only marginally. This explains why emissions are only marginally reduced compared to the ETS-only case.

Finally, a very interesting issue: the costs of the different policies. We will compare here production and consumer costs. Production costs are those borne by generating units (basically, investment, O&M, and fuel costs) and consumer costs are those paid by consumers for their electricity (we use here as a proxy the wholesale price instead of the tariff or retail price, since it is the one which will vary depending on the policy). We also calculate firms' profits as the difference between consumer costs and producer costs (although this is of course an approximation, it gives a hint about the increase or decrease of profits from one case to another).

Table 12: Production and consumer costs, and generating firms’ profits (M€, net present value 2005-2020)

As we may see, production costs increase when the different policies are introduced. The introduction of ETS increases production costs 40%, as well as consumer costs 41% (thus increasing also firms’ profits, what is something interesting to point out). The introduction of green certificates also increase costs, but to a lower extent (around 10%). This is clearly because the reduction in marginal prices compensates for the increase in costs due to the larger introduction of renewables. This is why some authors
have proposed that TGCs alone might be a cheaper alternative for emissions reduction. However, we should take into account: first, that renewable promotion policies also have a cost (the green certificate cost), and second, that they are not enough for achieving significant carbon reductions. Therefore, it seems that this mechanism cannot be considered alone for that purpose.

Finally, the combination of both reduces costs compared to the ETS-only case. Therefore, it seems that the combination is an interesting option, moreover given that, as just mentioned, renewables promotion systems by themselves, which are cheaper than the emissions trading system, are not able to achieve the required emissions reduction.

5 Conclusions

This paper has analyzed the joint impact of carbon reduction and renewable energy promotion policies on liberalized electricity markets, and has shown some interesting results from which some conclusions may be drawn.

But before, it should be reminded that the analysis has been carried out at a national level, due to the difficulties in modeling in detail the European electricity market and its environmental policies, as already mentioned in the introduction. Anyway, the conclusions mentioned below are easily generalized to the regional scope.
Concerning the interaction of instruments, we see that the reduction of carbon emissions only through renewables promotion is very complicated under the current growth of demand, even in a high-renewable-potential country as Spain. And on the other hand, carbon trading systems, although able to stimulate renewables growth, are quite costly for consumers.

However, we observe that the combination of policies produces a reduction in electricity market prices compared to the ETS system alone, which is finally translated into a global reduction in the costs paid by the consumer (including the green certificate costs), while still producing significant emissions reductions and renewable electricity deployment.

This also reduces the windfall profits received by producers due to the introduction of the ETS system. Anyway, this assertion should be made with caution, since there may be in different contexts difficulties for this pass through (in countries with regulated tariffs). Therefore, it will be the regulator the one finally adjusting firms’ benefits by modifying the tariff. This of course depends on the allocation method chosen (see Linares et al, 2006 for an analysis of the effect of allocation on profits).

Therefore, we may conclude that the combination of carbon reduction and renewable promotion policies is a very interesting one, in that it helps achieve the required carbon reductions at a lower cost, while at the same time promoting renewable development. Therefore, there may be a sort of double-dividend in this combination which might be interesting to exploit.
The only drawback of this combination is that, since consumer costs decrease there will be a lower long-term signal for consumers to reduce energy consumption, and this is a clearly negative outcome for the long-term sustainability of the system.

As a final comment, it has to be remarked that this exercise has been carried out under the assumption that the electricity sector is a closed one (except for the exchange of emission permits), and therefore, real effects may be somewhat different from those shown here. For instance, there may be substitution effects between energy sources when their relative prices are modified. In order to simulate these effects a general equilibrium model would be required.

References


