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Competition and environmental policies in an electricity sector ☆

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ABSTRACT

We study the impact of competition and environmental policy (feed-in tariff vs. the EU ETS) on investment, CO_2 emissions and welfare in an electricity sector. We consider different market structures (a planner who maximises social welfare vs. duopoly) and two types of consumers (those whose behaviour depends on the weather vs. those whose behaviour does not). The demand specification is innovative and takes incompressible consumption into account.

Given the costs and demand functions, we find that competition can increase CO_2 emissions, as is highlighted by Mansur (2007). In duopoly, the EU ETS seems to be the only efficient policy for reducing CO_2 emissions but also to increase the share of production based on renewable energy sources. The retained feed-in tariff policy seems to be the most expensive policy in terms of "social welfare". Even if this policy seems to increase "social welfare", feed-in tariffs increase the CSPE, which is paid for by consumers in the form of higher electricity prices and only benefits new entrants. It is also less effective in terms of emission reduction.

1. Introduction

On 23 January 2008, the European Commission adopted the "Energy-Climate Change" package, which mandates the implementation of the European Council's decisions made in March 2007. At that time, the leaders of the European Union agreed on the reduction of at least 20%[1] of CO_2 emissions for the European Union (EU) by 2020 compared to 1990 levels, a share of at least 20% renewable energy sources (RES) in the total energy consumption of the EU in 2020 (and a share of biofuels in the energy consumption of vehicles) and a non-binding aim of a 20% increase in energy efficiency. Objectives for individual nations, which are still to be defined, should (but will not necessarily) take into account the current mix of energy and the potential of different member states to meet certain goals.

Imposing quotas is the first European means to achieve the objective of reduction of greenhouse gas (GHG) emissions. In 1997, the EU ratified the Kyoto Protocol, which sets legally binding targets for industrialised countries to stabilise the CO_2 concentration in the atmosphere. To achieve the objective of reducing GHG emissions, the EU has implemented a marketplace for CO_2 emission quotas: the European Union Greenhouse Gas Emission Trading Scheme (EU ETS). In January 2005 the EU ETS began to operate as the largest multi-country, multi-sector GHG emission trading scheme worldwide, based on Directive 2003/87/EC.

On the other hand, feed-in tariffs are the most frequently used policy for promotion of RES as it was established by the European Commission survey (2005). The aim of this policy is to internalise external effects and stimulate technical change. Comparisons of policies promoting RES,[2] of which are two different approaches based either on price (i.e., feed-in tariffs) or quantity (i.e., tradable quotas), often conclude that feed-in tariffs incur substantial excess costs in terms of public subsidies compared to tradable green quotas (cf. Böhringer et al., 2007; Menanteau et al., 2003). This excess cost can be interpreted as the price tag that policy makers have to attach to reach objectives[3] other than the goal. Consequently, in theory the United Kingdom scheme (quota and auction mechanisms) should be a lower cost mechanism than the German one (feed-in tariffs). In

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[1] This could even be 30% if an international agreement is reached.

[2] The European Commission also refers, without reaching a conclusion, to a goal of energy security for these policies promoting RES.

[3] That is, reduce additional market failures.

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practise,[4] however, this is not the case, as Butter and Neuhoff (2008) confirmed by focusing on the technology of onshore wind energy.

Both intuitively and following the EU's analysis of the impact of its "Energy-Climate Change" package, these two binding goals required by this package are linked, as the promotion of RES should lead to a reduction in CO_2 emissions. However, what is the real impact of these two instruments of environmental policies on CO_2 emissions?

To answer this question, we evaluate the impact of these policies (feed-in tariffs and quotas on emissions of CO_2) on investment decisions and production. We study two shadow market structures: a regulated monopoly and a duopoly.

The regulated monopoly maximises collective welfare, which is defined as the consumers' surplus and the producer's profit with or without different weights (see Mas-Colell et al., 1995, page 837 for more details). In the absence of competition and considering an annual load-duration curve, power is generated according to a chosen capacity mix to meet demand at a minimal cost. Chaton (1997) determines optimal investment in thermal power plants in a two-period model. This model explicitly accounts for the nature of the electric demand through the load-duration curve and considers emission constraints. An extension proposed by Chaton and Doucet (2003) adds an additional period to the model and explicitly takes electricity trading into account. However, this type of model assumes inelastic price demand. We remove this assumption in our model.

A duopoly is composed of the incumbent and other producers who we have aggregated. We assumed an advantage for the incumbent. This advantage reflects, among other things, the following facts: the incumbent already has capacities for which capital costs have already been mostly recovered, and it already has more customers (who appreciate being supplied by the incumbent and do not want to make any effort to be supplied by another producer, taking into account the costs of this change, cf. Loomis and Malm, 1999). We develop a model without environmental policy, a second one constrained by CO_2 quotas and a third one integrating feed-in tariffs. Madlener et al. (2005) consider the impact of environmental constraints on investment decisions of firms that adopt profit-maximising behaviour in the competitive market. Kumbaroğlu et al. (2008) extend this model by considering learning curves for renewable energy technologies. Additionally, Pineau and Murto (2003) focus on investment decisions and competition in the long run. They question the competitive nature of European markets and compare the maximisation of profits in the contexts of competition and oligopoly. They also assume that supply is constrained by limited technologies (nuclear and hydro power) due to social and political considerations and the restricted availability of sites. The supply responds to a demand that is split between base and peak load periods for 80% vs. 20% of the time. Finally, Genc and Sen (2008) add a specification that competition takes place in wholesale markets, where large user customers (e.g., industrials) pay market prices, while end-user customers pay fixed regulated prices.

Reinaud (2003) studies the impact of the EU ETS on electricity prices, showing that in imperfect competition the electricity price does not totally include the CO_2 emission price. Mansur (2007) finds that observed pollution reductions can be attributed to firms exercising market power based on evidence from the Pennsylvania, New Jersey, and Maryland Interconnection, a restructured wholesale electricity market opened to competition in 1999. It is thus important to take care of the industrial structure in addition to complying with environmental constraints. Moreover, in a competitive situation, it would be advisable to integrate the consumer's behaviour. We thus propose models that consider the behaviour of producers who face heterogeneous demand. We assume that producers supply two types of consumers in each of these market structures: consumers whose demand depends on the weather and those whose demand is not dependent on the weather. The specification that we used on demand allows, among other things, the consideration of seasonality ignored in articles that deal with both competition and environmental policies.

Costello (2006) calculates average US energy net elasticities for price and weather. Due to the specificity of the US market, monthly electricity net demand elasticities are highlighted with respect to cooling degree-days. Indeed, many authors (see, for example, Chaton, 1997; Chaton and Doucet, 2003; Madlener et al., 2005) consider only annual load-duration curves and ignore the impact of prices on demand. Other authors consider this impact (such as Genc and Sen, 2008) but totally ignore the seasonal nature of the request. Some (see Pineau and Murto, 2003) only assume two types of demand[5]: baseload and peak-load demands. This environment may lead some to use only two technologies (without taking into account intermittent energy). Such reasoning is too coarse for analysis of environmental policy. As a result, one of our goals is to develop a model with active demand that reflects this seasonality but also reflects the impact of prices on consumer's behaviour. The difficulty then lies in determining the size parameters of the demand function. If, for example, you are interested in the French case, data to calibrate the demand are not available, as the market has been totally open since July 2007 and regulated tariffs still exist. We thus need to resort to some assumptions that may thereafter be unreal.

Our numerical dynamic optimisation models determine annual investment levels and the monthly generation[6] of different technologies/monthly consumption. We can deduce CO_2 emissions as well as prices, producers' profits and consumers' surplus. In Section 2, we expose the main modelling assumptions. In Section 3, we applied these models over the period 2006–2021 using French public data (cf. DGEMP, the Ministry's Direction in charge of Energy). The example of France can be considered uninteresting due to the current low-carbon energy mix resulting high nuclear share.[7] Therefore, the results obtained may not be representative for other EU members. However, although the electricity sector emits relatively less pollutants in France than in other European countries,[8] the analysis of both policies, i.e., feed-in tariffs and emission allowances on the EU ETS, is shown to be rewarding. Indeed, we conclude that these two policies can have contradictory effects in terms of CO_2 emissions and can thus generate a conflict of interest when they are implemented together. This infeasibility can be avoided by relaxing the constraints of individual issues, either through trade allowances or by abandoning feed-in tariffs (which should be a transitional measure because of increasing maturity of green technologies). The current energy mix leads to infeasibility. Indeed, the policy of feed-in tariffs generates increased investment in wind and solar energy. This growth of intermittent energy sources is interesting when it is associated with fossil-fuelled technologies. In

[4] Mitchell et al. (2006) argue that the German scheme is more effective at increasing the share of renewables than the English one because it more effectively reduces risk for RES producers.

[5] The demand specification is often linear.

[6] This is so that we do not detail peak load and baseload demand.

[7] The energy mix into fossil fuels (gas, oil, coal and lignite), f; nuclear, n and hydro, h: Poland (f: 96%; h: 1%; n: 0%); Germany (f: 62%; h: 3%, n: 24%); United Kingdom (f: 71%; h: 1%; n: 20%); Netherlands (f: 78%, h: 0%; n: 4%); Spain (f: 58%; h: 7%; n: 19%); Italy (f: 70%; h: 9%; n: 0%); Belgium (f: 36%; h: 0%; n: 55%); France: (f: 9%; h: 9%; n: 78%); Sweden: (f: 2%; h: 47%; n: 45%) Source: Lighbucket, 2008. Carbon emissions from electricity generation, by country [online document]. [Accessed 17 May 2010]. Available at http://lightbucket.wordpress.com/2008/10/22/carbon-emissions-from-electricity-generation-by-country/.

[8] As a result, in 2007, the values of the national averages for CO_2 emissions by MWh electric for various countries are the following: # Sweden: 50 kg CO_2/MWh; # France: 80 kg CO_2/MWh; # Finland: 295 kg CO_2/MWh; # Belgium: 317 kg CO_2/MWh; # Italy: 429 kg CO_2 /MWh; # Spain: 487 kg CO_2/MWh; # Netherlands: 548 kg CO_2/MWh; # United Kingdom: 557 kg CO_2/MWh; # Germany: 612 kg CO_2/MWh; # Poland: 1002 kg CO_2/MWh. (source: Lighbucket, 2008. Carbon emissions from electricity generation, by country [online document]. [Accessed 17 May 2010]. Available at http://lightbucket.wordpress.com/2008/10/22/carbon-emissions-from-electricity-generation-by-country/).