Carbon Leakage in South-East Europe Regional Electricity Markets under EU ETS

Verena Viskovic, University College London, +44(0)7578619566, verena.viskovic.13@ucl.ac.uk
Afzal S. Siddiqui, University College London and Stockholm University, +44(0)2076791871, afzal.siddiqui@ucl.ac.uk
Yihsu Chen, University of California Santa Cruz, 0018315027184, yishuchen@ucsc.edu

Overview

In the fight against climate change, the EU and many countries/regions around the world have established policies in order to reduce CO_2 emissions levels. For the EU, the guiding principle was laid out in 2007 under the EU 20-20-20 [1] stipulating that, by 2020, EU as whole will lead a 20% reduction in CO_2 emissions compared to 1990 levels, 20% of the energy consumption from renewables, and 20% increase in energy efficiency. Well into reaching its goals for 2020, policymakers are expecting a continuation of CO_2 emissions reduction from electricity generating facilities through the Emissions Trading Scheme (ETS). Since its second phase, the ETS assigns emissions allowances. The allowances can then be traded on regulated exchanges for compliance purposes.

The EU is projected to achieve its goal for 2020, partially because of an economic downturn that has reduced electricity demand and the price of CO_2 emissions allowances. However, one concern that might undermine the effectiveness of ETS is that there are some EU member states that are located on the periphery of the ETS who might be exposed to the risk of carbon leakage. In current context, carbon leakage is defined as the situation in which the reduction in emissions in the ETS region is partially offset by an increase in carbon emissions in the non-ETS regions. So far, carbon leakage has been showed in the context of a two-node stylised example[2] as a result of the introduction of carbon tax. On a more realistic scale, levels of carbon leakage have been compared under different allowance allocation schemes in the California market[3]. To the best of our knowledge, carbon leakage on the periphery of the ETS in power markets has not yet been addressed. Thus, further analysis to address this concern is essential to safeguard the effectiveness of ETS. We apply a bottom-up partial equilibrium framework to study the extent of emissions leakage in South-East Europe using South Eastern European Regional Electricity Market (SEE-REM). In addition to emissions leakage, we also address the impact in terms of generation, transmission flows, electricity prices, CO_2 allowances, and social welfare.

Methods

SEE-REM is a bottom-up model based on game theory where following market players are considered: producers, consumers, and a transmission system operator (TSO). Such models can be implemented computationally both as a single optimisation problem and by formulating it as a complementarity[4] problem where each entity's optimisation is addressed separately.

Producers are modelled as perfectly competitive. Each producer owns a number of generating units, located in different locations that are characterised by their marginal costs of production and CO_2 emissions rates based on different technologies. Moreover, each producer's objective is to maximise its profit and subject to a number of constraints related to maximum generation capacity and energy balance. *Consumers* are represented by the inverse demand function at each node, which could be viewed as the results from solving their utility-maximisation problem. The *TSO*'s profit is given by charging the wheeling fee (transmission) for the power transmitted through the grid. In a sense, it maximises the scarce transmission resources. The TSO's optimisation problem is constrained by the maximum transmission capacity on the lines and Kirchhoff's laws. The flows on the lines are modelled using the DC load flow approximation. Finally, the electricity market is cleared by mass-balance at each location, i.e., equating the difference between sales and generation at a node with imports to that node. The price of CO_2 emissions is exogenous, and it affects the producers through their marginal cost of production.

We consider nine *scenarios* by varying a combination of CO_2 prices and hydropower availability. Of these nine scenarios, one is the baseline scenario (price of allowances is equal to zero) that we use for the purpose of calibration to 2013 actual market data. Two scenarios correspond to two different prices of allowances (€30/ton and €40/ton), two scenarios consider two different levels of hydropower production (based on data from wet and dry years and price of allowances equal to zero), and the final four scenarios are the interaction between different prices of CO_2 allowances and hydropower production levels.

---

[1] EU (2007). 2020 energy strategy. Technical report, European Union.
[2] Downward, A. (2010). Carbon charges in electricity markets with strategic behavior and transmission. The Energy Journal, 31(4):159.
[3] Bushnell, J. and Chen, Y. (2012). Allocation and leakage in regional cap-and-trade markets for CO_2. Resource and Energy Economics, 34(4):647-668.
[4] Hobbs, B. F. (2001). Linear complementarity models of Nash-Cournot competition in bilateral and poolco power markets. Power Systems, IEEE Transactions on, 16(2):194-202.

Results

	Price of CO_2	€0/ton		€10/ton		€20/ton		€30/ton		€40/ton		€50/ton	
	Year	**ETS**	**non-ETS**	**ETS**	**non-ETS**	**ETS**	**non-ETS**	**ETS**	**non-ETS**	**ETS**	**non-ETS**	**ETS**	**non-ETS**
Emissions [ktCO$_2$]	**Actual 2013**	172,074	35,830										
	Baseline	145,565	35,152	123,977	45,343	112,198	45,148	102,834	44,824	66,130	44,586	62,691	44,514
	Base wet year	139,517	31,194	117,458	43,176	107,985	42,846	100,284	42,479	64,464	42,154	61,442	42,048
	Base dry year	157,768	34,971	130,958	49,006	118,881	48,903	108,986	48,656	69,345	48,470	65,522	48,421
% change compared to baseline	**Baseline**	0%	0%	-15%	29%	-23%	28%	-29%	28%	-55%	27%	-57%	27%
	Base wet year	0%	0%	-16%	38%	-23%	37%	-28%	36%	-54%	35%	-56%	35%
	Base dry year	0%	0%	-17%	40%	-25%	40%	-31%	39%	-56%	39%	-58%	38%
Carbon leakage (CL)	**Baseline**	0.00%		5.64%		5.53%		5.35%		5.22%		5.18%	
	Base wet year	0.00%		7.02%		6.83%		6.61%		6.42%		6.36%	
	Base dry year	0.00%		7.28%		7.23%		7.10%		7.00%		6.98%	

In the table above, we present main results related to emissions and carbon leakage in different scenarios. We have three types of water years, viz., wet, dry, and normal, with six levels of CO_2 permit prices (€0-50/ton). Our analysis decomposes the CO_2 reduction into three categories: demand response, fuel switching, and increase in imports from the non-regulated area. The emissions associated with the increased imports are what determines the level of carbon leakage, which is defined as follows:

$$CL = \frac{e_{New}^{Non-ETS} - e_{Base}^{Non-ETS}}{e_{Base}^{ETS} + e_{Base}^{Non-ETS}} \qquad (1)$$

where *e* is emissions, the superscript indicates the area of SEE-REM, and the subscript the scenario.

Introduction of allowance prices translates into a higher cost of generation for the producers in the ETS area, thereby leading to higher electricity prices. Higher electricity prices in the ETS area suppress power demand and induce increased imports from the non-ETS area. The latter is due to the fact that higher ETS-region electricity prices offer economic incentives for non-ETS producers to increase their exports while, at the same time, driving up domestic prices. For example, a price of €10/ton causes a reduction of emissions by 15% in the ETS area and an increase in emissions of 29% in the non-ETS area, effectively offsetting ETS emissions reduction by 5.64%. Furthermore, a detailed analysis indicates that associated with, for example, an allowance price of €30/ton scenario, prices in Macedonia increase from €21.19/MWh to €23.71/MWh on average throughout the year.

As for the decomposition of CO_2 reduction, the inclusion of allowances prices might also change the merit-order curve, thereby leading to fuel switching. In fact, we notice an increase in low-carbon technology generation in the ETS area (e.g. natural gas) and a reduction of high-carbon technology generation (e.g. coal). Regarding the variation of hydropower production levels, as expected, emissions are higher in the dry year and lower in the wet year. This is particularly noticeable in the non-ETS area where most of the countries have a large proportion of hydropower in their generation mix.

In relation to the interaction between CO_2 allowances prices and levels of hydropower production, we have two main observations. First, total ETS and non-ETS emissions are lower in the wet year and higher in the dry year compared to the baseline, yet carbon leakage in both the wet and the dry year is higher than the baseline. Higher carbon leakage in the dry year is expected due to lower availability of domestic low-polluting sources in the ETS. Higher carbon leakage in the wet year could be due to a lower demand for conventional thermal power in the hydro-rich non-ETS countries. This, in turn, renders more capacity available for export. Second, increasing the price of CO_2 allowances leads to a slight decrease in leakage, which can be explained by demand response to higher domestic electricity prices in the non-ETS area.

Conclusions

Through the analysis of the SEE-REM, we conclude that implementation of ETS might face two main challenges: carbon leakage and an increase in electricity prices in some non-ETS countries. The former suggests that the policy currently in place in the EU might overlook the emissions that might be produced as a result of increased imports by the ETS countries on the periphery of the ETS from countries with less strict CO_2 emissions reduction policies. This can have an effect on the competitiveness of the producers in ETS member countries on the periphery of the ETS and undermine EU targets for CO_2 emissions reduction. The latter suggests that the current policy can have undesirable outcomes for the consumers in the non-ETS countries due to higher domestic electricity prices while non-ETS producers would experience an increase in their profits due to higher power prices as well as exports.