Analysis of the historical pass-through of carbon cost to electricity prices in European power markets

Yuanjing Li*, Fabien Roques**

* Corresponding author. Dr., Researcher, Chaire European Electricity Markets (CEEM), University of Paris Dauphine, 75775 Paris Cedex 16, France (ceem-dauphine.org) & Compass Lexecon. E-mail: yuanjing.msli@gmail.com

** Associate Professor of Economics, Dr., Scientific Advisor, Chaire European Electricity Markets (CEEM), University of Paris Dauphine, 75775 Paris Cedex 16, France (ceem-dauphine.org). E-mail: froques@compasslexecon.com

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ABSTRACT

In this paper, we estimate the carbon pass-through rate in the French and Central Western European power market with a linear econometric model using data of French electricity EU ETS forwards over the period of 2011-2018. We find that the period 2011-18 can be split into seven sub-periods with identified structural breaks and that the estimated carbon pass-through rate varies between 0.53 and 1.23 depending on the period considered. The paper contributes to the understanding of the drivers of the carbon cost pass-through by identifying the key events that are associated with these structural breaks and providing the first and the most up-to-date empirical evidence of this pass through over the period of 2011-2018.

Key words: carbon pass-through, EU ETS, forward price

1. Introduction

The European Union emissions trading system (EU ETS) is the world's first and biggest major carbon market, aiming at a market-based solution to reducing greenhouse gas (GHG) emissions. Implemented in 2005, it imposes emission caps to major EU carbon emitters through allocation of tradable carbon allowance (the cap-and trade principle). In the short run, this market-based ETS facilitate covered industries and power generators to use cleaner fuel sources. For instance, a sufficiently high level of carbon price could trigger a switch from coal generation to gas generation in the power sector, as gas plants become cheaper than coal plants and therefore are dispatched before coal plants in wholesale electricity markets. In the long run, EU ETS plays an essential role in promoting low-carbon investment, by creating an incentive for companies to invest in technologies that cut emissions. However, since the implementation, the EU ETS market has gone through many major changes, leading to significant fluctuations of CO2 prices. The persistent and unpredictability of the EU ETS prices has raised doubts on the efficiency of the EU ETS to induce emission abatement and low-carbon technology investment (Liang et al. ,2013).

The EU ETS was initially organised in two phases: Phase 1 between 2005 and 2007, and Phase 2 between 2008 and 2012. Due to over-allocation of free allowances and economic crisis, a surplus of emission allowances has built up in the carbon market since 2009, leading to a collapse of the carbon market at the end of the Phase 2 with a carbon price below 5€/tCO2, seriously undermining economic incentives to reduce carbon emission and the ability of EU ETS to fulfil environmental targets. The rules in the current Phase 3 between 2013 and 2020 and the forthcoming Phase 4 between 2021 and 2030 differ in important respects from those of first two trading periods, after several waves of reforms of the EU ETS, such as allowing back-loading auctions and market stability reserve (MSR), to address the surplus of allowances and to reinforce efficiency of the mechanism. As a result, EU ETS carbon price has been rising since mid-2017 from 5€/tCO2 to above 20€/tCO2 at the end of 2019. As of today, in mid-2019, the carbon price is about 25€/tCO2. The entry into force of the revised EU ETS Directive in April 2018 with reinforced decline in the annual emission caps and MSR is a signal of strengthening EU ETS for the next decade. The carbon price is expected to continue to increase to accelerate energy transition (IEA, 2018).

1.1 Carbon cost pass-through in electricity markets and its policy implications

One of the fundamental questions that has triggered policy debate on the efficiency of the carbon market to deliver economic incentives and to meet environmental goals is whether power producers have passed through the costs of free allocated carbon allowances to electricity prices and to what extent the increase of electricity prices is attributed to carbon pass-through. The answer to this question has multiple policy implications. First, the ability of cost pass-through in an industry is tightly related to competition policy. In the context of electricity markets, based on economic theory, electricity generators would pass on the opportunity costs of CO2 allowances to consumers even if the allowances are distributed for free (i.e. before 2013). Therefore, whether and to what extent partial or full internalisation of carbon costs is an important measure to assess the extent to which electricity generators exercise market power and obtain additional profits due to EU ETS. Second, the extent of pass-through of carbon costs to electricity prices plays an important role in industry competitiveness facing competition from international trade outside EU and further in carbon leakage. Carbon leakage may occur when uneven carbon costs in different jurisdictions lead to a loss of market share or reduction in profit margin for an energy- or electricity-intensive industry facing higher production cost resulting from carbon regulation compared to its competitors in other jurisdictions. The increase in production costs for an industry due to carbon costs reflected in higher electricity prices is defined as indirect cost, in contrast to direct costs, which are related to direct emissions of the industry. Therefore, assessing the level of pass-through of carbon costs to electricity prices is a fundamental step to determine the impact of EU ETS on industry competitiveness and the risk of carbon leakage for European industries owing to indirect carbon costs. Third, the extent of pass-through of carbon costs to electricity prices is an important factor to determine a necessary and sufficient compensation to prevent carbon leakage in Europe due to indirect carbon costs supported by European industries. According to the Guidelines of the EU Emissions Trading Scheme (EU ETS), established by the European Commission (EC) in 2012, Member States have a choice to implement or not to implement a compensation scheme. The motivations behind implementation of a compensation scheme for indirect costs include minimising the risk of carbon leakage, allowing for low-carbon technology investment, and limiting market distortion in the EU internal market. If a Member State chooses to implement a compensation scheme for indirect cost, then the measure must be compliant with the State Aid guidelines. The compensation level for electricity-intensive industries, affecting the distribution of economic surplus among power producers and consumers, is based on an emission factor (tCO2/MWh) that is an estimate of the pass-through of carbon costs to electricity prices.

1.2 Objectives

The objective of the paper is to quantify the pass-through rate of emission costs to electricity prices in France over a period of 2011-2018, and further in Central-Western European (CWE) countries – France, Germany, Belgium, and the Netherlands. Carbon pass-through in this paper is defined as the proportion of carbon prices (expressed in €/tCO2) passed through into electricity prices in wholesale electricity markets – day-ahead markets (expressed in €/MWh). Carbon pass-through is effectively a proportion of higher costs incurred by end-users in the form of higher electricity prices attributable to carbon prices.

To do so, we follow a three-step approach.

- The first step is to identify structural breaks and divide the overall evolution of electricity and carbon prices into sub-periods based on market fundamentals and policy drivers. The identification of the structural breaks and the division into subperiods allow us to tightly follow the dynamics of EU ETS and electricity markets across different periods.
- The second step is to estimate the carbon pass-through rate in the French market with a simple linear econometric model using data of French electricity baseload forwards and EU ETS forwards over the period of 2011-2018. We find that the period of 2011-18 can be split into seven sub-periods with identified structural breaks and the estimated carbon pass-through rate varies between 0.53 and 1.23 depending on the period considered. The year-ahead pass-through rate in 2018 is estimated to be 0.76, consistent with the current definition of emission factors of the Commission for the compensation of indirect costs of electricity end users, implying that this rate can be kept in the short to medium terms.
- The final step is to extend the above modelling framework in the French market to the CWE region. As CWE electricity markets are well interconnected and France is the largest net exporter of electricity, the dynamics of CWE electricity markets are driven

by common factors, such as fuel prices as well as availability of the French and Belgian nuclear generation capacity.

1.3 Contribution

Our paper has multiple contributions to literature. First, it contributes to the economic understanding of carbon cost pass-through in the French and CWE power markets and provides the first empirical evidence over the period of 2011-2018, during which carbon prices have experienced completely opposite evolutions. The whole period of 2011-2018 includes significant EU ETS price fluctuations and both sharp upward and downward trends. Especially, the sharp increase in EU ETS price from 5€/MWh in mid-2017 to above 20€/tCO2 to date has a significant impact on electricity prices, but little research has been realised on this very recent period. To our knowledge, there is no study so far that has comprehensively examined carbon pass-through for such a long period of time and has explored the recent sharp increase in EU ETS price since mid-2017.

Second, we advance a new suggestion that the relationship between carbon and electricity prices is time-varying, which is captured by different evolutions of market fundamentals and EU policy debates. It is challenging to obtain robust estimates based on fluctuating time series and estimates of time-varying econometric models such as Vector Autoregression (VAR) or Error Correction model (ECM) are often to complex to be interpreted due to the compounded/lagged impacts and therefore difficult to be used in policy debate. To reconcile between robustness and policy implications, we suggest a new approach consisting of identification of structural breaks using Quandt Likelihood Ratio (QLR) statistics (Quandt, 1960) and a simple linear regression. Although the econometric technique used in this paper is simple, it is essential to understand the changes in regimes of policy and market fundamentals behind carbon and electricity markets in order to obtain robust estimates. For example, the steep rise in carbon prices since mid-2017 was mainly driven by the entry into force of the revised EU ETS Directive in April 2018, with reinforced decline in the annual emission cap, and MSR, increasing the stability of the EU ETS scheme. Therefore, it is important to distinguish the driving forces in electricity and EU ETS markets related to market fundamentals and policy factors and changing trends in these driving forces would result in different relationships between electricity prices and carbon prices, and therefore different extent of pass-through of carbon costs to electricity prices.

Third, different from research work relying on price series, we suggest that market specifics in the French market, such as nuclear availability, should be carefully accounted for when estimating carbon cost pass-through, because electricity prices are fundamental-driven and sensitive to contemporaneous shocks to demand and supply. As the dynamics of both electricity market and carbon market has experienced significant changes, especially between 2016 and 2018, the identification of the relationship between electricity price and carbon price needs to be based on EU policy and the evolution of market fundamentals, such as underlying commodity prices which enter the short-run marginal costs of generating plants, based on which electricity generators bid in power markets. Our paper is the first to fulfil this requirement and provides up-to-date evidence. The paper also contributes to the EU policy debates on the competitiveness of power markets as well as the appropriate level of compensation level of indirect costs for electro-intensive end users to avoid carbon leakage.

2. Literature review

Numerous academic papers have studied the impact of carbon price on electricity spot or forward markets. Their work can be broadly split into three categories: theoretical work, empirical work and simulation work. Table 1 presents a summary of the literature review.

Table 1: Summary of literature review

Literature	Approach	Market	Period	Definition	Variables included/considered	Result
Bonacina and Gulli, (2007)	Theoretical			Cost pass-through	Under market power the impact of the ETS equals or exceeds that under the competitive scenario only when there is excess capacity and the share of most polluting plants in the market is low enough. Otherwise, the impact under market power is less than under perfect competition and significantly decreases in the degree of market concentration	
Fabra and Reguant (2014)	Theoretical simulation	Spain	01/2004-06/2007	Hourly spot price	Simulating marginal bid estimated by marginal cost according to the degree of competition	0.8 on average
Sijm et al. (2012)	Theoretical			Cost pass-through	The extent of pass-through depends on the degree of market concentration, competition, the carbon price, and available capacity in the market	
Bonacina and Gulli (2007)	Theoretical			Cost pass-through	Using a dominant firm facing a competitive fringe model, the short-run impact of CO_2 emissions trading on wholesale	

					electricity spot markets significantly depend on the structure of the electricity market
Bariss et al. (2016)	OLS regression	Nordic and Baltic	08/2010-05/2015	Daily spot price omitting 7 months outliers	Regional production/consumption, hydro production (monthly totals), coal and CO2 prices as monthly average of daily closing
Hintermann (2014)	OLS regression	Germany	January 2010 through November 2013	Hourly price (baseload, peak, off-peak)	Cost model with marginal costs and carbon cost; Price model with coal, gas, oil, and CO2 prices
Sijm et al. (2006)	OLS regression	Europe	2005	Daily forward power price and fuel cost spread	CO2 price
Sijm et al. (2008)	OLS regression	Europe	2005-2006	Daily spark and dark spread	CO2 price
Fezzi and Bunn (2009)	Time series regression	UK	04/2005-06/2006	Daily spot price difference	Gas price, carbon price, temperature stages
Cotton and De Mello (2014)	Time series regression	Australia	2004-2010	Weekly price	Emission certificate, RES certificates, Gas and Elec price
Freitas and da Silva (2015)	Time series regression	Spain	01/2008-12/2013	Daily spot price for working days	CO2, natural gas, and coal prices, temperature thresholds, hydro, wind
Keppler and Mansanet-Bataller (2010)	OLS and Time series regression	France	04/2005-10/2007	Future price return for 2007 delivery Daily forward and spot price	OLS: CO2 price return, peak-load clean spark spread return TS: Gas, coal, carbon future price

Jouvet and Solier (2013)	Time series regression	Europe	06/2005-12/2010	Daily sport or forward spread with respect to fuel price	CO2 price
Kara et al. (2006)	Simulation with VTT market model	Nordic	2008-2012	Spot price	Market fundamentals
Poyry (2011)	Simulation with BID model	Norway	2013	CO2 quantity	Market fundamentals
Hawkes (2014)	Simulation with TIMES model	UK	2010-2050	CO2 quantity	Market fundamentals
Chen et al. (2008)	Theoretical with simulation of an oligopoly	North western EU (Belgium, France, Germany and the Netherlands)	2005	Capacity weighted emission rate; Average and Marginal pass-through	Market structure - competition, demand elasticity
Capros et al. (2008)	Primes Model	EU	2020 and 2030	CO2 quantity	Market fundamentals

The first strand of literature has been established with theoretical models to study carbon cost pass-through to electricity prices about competition, demand elasticity, supply function, merit order, etc. Particularly, the extent of pass-through largely depends on the degree of market concentration, competition, the level of carbon price, and available capacity in the market (Sijm et al., 2012). When using a dominant firm facing a competitive fringe model, the short-run impact of CO2 emissions trading on wholesale electricity spot markets also significantly depends on the structure of the electricity market (Bonacina and Gulli, 2007). Bonacina and

Gulli (2007) found that under market power, the impact of the EU ETS equals or exceeds the impact under the competitive scenario only when there is excess capacity and the share of most polluting plants in the market is low enough. Otherwise, the impact under market power is less than under perfect competition and significantly decreases in the degree of market concentration. Based on a theoretical model, Fabra and Reguant (2014) simulated the pass-through rate of carbon price to Spanish spot prices using individual bids data from generating firms and found that the pass-through rate is 0.8 on average. Under perfect competition, electricity prices fully internalise the carbon opportunity costs. Under market power, the extent to which carbon costs are passed through to electricity prices depends on many factors, such as (i) the degree of market concentration, (ii) the plant mix operated by either the dominant firm or the competitive fringe, (iii) the carbon price, and the available capacity in the market, i.e., whether there is excess capacity or not.

The second strand of literature has explored modelling capability using electricity market modelling platforms to simulate the impact of carbon prices. This strand of literature can be both backward looking or forward looking. Chen et al. (2008) related market structure to competition and demand elasticity and simulated a capacity weighted emission rate, and an average and marginal pass-through rate of EU ETS price to electricity price in France and found this rate to be 1.15. Other studies, such as Kara et al. (2006), Poyry (2011), and Hawkes (2014), simulated the quantity of CO2 emission relative to electricity generation and calculated a carbon content rate. These simulation studies leveraging market fundamental models aim at replicating market dispatch or market structure, offering a wide range of estimates for CO2 pass-through coefficient depending on simulation periods and countries.

The third strand of literature includes numerous econometric works. Some of the work uses simple OLS regression to estimate the relationship between electricity prices and carbon prices in several countries. For instant, Sijm et al. (2006) reported positive rates of cost pass-through using OLS regressions on electricity spreads for the year 2005, based on daily future prices, of 60-117 % for Germany, and of 64-81 % for the Netherlands. Sijm et al. (2008) extended this analysis in time and space and found positive but incomplete carbon cost pass-through for Germany, France, the Netherlands and Sweden, and possibly full pass-through for the UK. Using time series econometric models, some papers explored interdependence and cointegration of electricity and carbon markets and estimated this relationship with an Error Correction model (ECM) or granger causality tests. Keppler and Mansanet-Bataller (2010) focused on the causal relationship between electricity and carbon prices in the French market and found causality running from CO2 future prices to electricity future prices. Jouvet and Solier (2013) estimated the daily spot or forward spreads in several European countries with respect to fuel prices and CO2 prices and found numerous non-significant and negative coefficients and a coefficient of 1.7 over peak periods for France in 2006, but this result is very sensitive across countries and years. Fezzi and Bunn (2009) used an error-correction model to estimate the daily spot price difference in the UK based on gas and carbon prices as well as different temperature stages and found that an 1% increase in carbon price would result in a 0.32% increase in electricity prices. Cotton and De Mello (2014) conducted an econometric analysis of Australian emissions markets and weekly electricity prices and confirmed the need of using market fundamentals that determines cleared electricity prices such as the short-run marginal cost and generation data. A more recent study Freitas and da Silva (2015) focused on daily spot price for working days in Spain and found a long-term relationship between carbon price and electricity price between 0.2-0.37. Hintermann (2014) studied the carbon pass-through to electricity price in Germany, using a cost-based model with marginal costs and carbon costs and a price-based model with coal, gas, oil, and CO2 prices, and found a rate of 0.98-1.06 from central estimates. As shown above, most econometric studies do not provide up-to-date empirical results. The most recent study on the carbon pass-through rate is Bariss et al. (2016) that studied daily spot price in Nordic and Baltic countries and found a rate of 0.55 and 0.67, respectively.

Due to the multitude of interaction effects in vector error correction models, the effect of a change in an input price on the electricity price must be computed using impulse-response functions, which tend to be sensitive to the inclusion of additional control variables or lags in the underlying model, and also to have large confidence intervals. Also, these are typically run on data aggregated to weekly or monthly level to reduce the noise and thus obtain reasonable long-term adjustments, which comes with a significant reduction in the degrees of freedom, and at a risk of an aggregation of bias. Empirical literature has shown a wide range of results and that an OLS model that accounts for market fundamentals with adjustment for robust estimators is enough to give robust estimates of the CO2 pass-through coefficient. However, existing empirical studies do not cover the majority of the Phase 3 of the EU ETS and therefore cannot offer the most updated view of the market evolutions, especially considering that EU ETS price has been rising significantly since beginning 2017. Our paper fulfils this need and covers the longest period of estimation to provide the most up-to-date evidence and forecast result.

3. Methodology

3.1 Identification of structural breaks

We identify the changes in regime of fundamental policy and market drivers in carbon and electricity markets in France and in CWE region and follow a test for structural breaks with unknown break points developed by Andrews (1993). For each observation at time τ, the whole sample is divided into two subsamples with a period up to τ, and a period after τ. We test whether estimates based on these two subsamples are significantly different.

Accordingly, we test the null hypothesis $H_0: \beta_1 = \beta_2$:

$$y_t = x_t\beta_1 + \varepsilon_t, t = 1, \dots, \tau \tag{1}$$

$$y_t = x_t\beta_2 + \varepsilon_t, t = \tau + 1, \dots, T \tag{2}$$

A Chow test can be constructed after each regression based on F-statistic $F(\tau)$ in the case where the break points are unknown, structural breaks can be identified through a QLR test statistic, which is the maximum of Chow F-statistics, over a range of $\tau_0 \leq \tau \leq \tau_1$:

$$QLR = \max[F(\tau_0), F(\tau_0 + 1), \dots, F(\tau_1 - 1), F(\tau_1)\ ] \tag{3}$$

3.2 Estimation strategy

We estimate the historical CO2 pass-through rate using daily data over the period of 2011-2018 including year-ahead (Y+1) forward base electricity price as dependent variable, year-ahead EU ETS CO2 forward price, year-ahead PEG forward gas price, as well as ARA forward coal price.

The carbon pass-through rate (t/MWh) estimated by a full set of variables is specified as follows:

$$Price_{ElecForward,i} = Constant_i + \beta_{PriceCO2} \times Price_{CO2,i} + \beta_{PriceGas} \times Price_{Gas,i} + \beta_{Coal} \times Price_{Coal,i} + \gamma_{2016} \times D_{2016} + \gamma_{2017} \times D_{2017} + \varepsilon_i$$

(4)

We identify structural breaks to construct relevant estimation periods and ensure robust and stable relationships between Y+1 electricity price and Y+1 CO2 price. We then use data available up to one year ahead to estimate the market view of carbon, commodity and electricity market dynamics. Since the market view is continuous, each regression period is not necessarily on an annual basis but rather regrouped based on structural breaks following important changes of policy drivers or market fundamentals. Those policy changes include important events such as the EU debate on backloading as well as major EU ETS reforms. As the French generation mix is to a large extent constructed by nuclear capacity and the French market is well connected to neighbouring countries, the availability of nuclear generation capacity in France and Belgium constitutes another important price determinant factor in the French power market.

3.3 Data

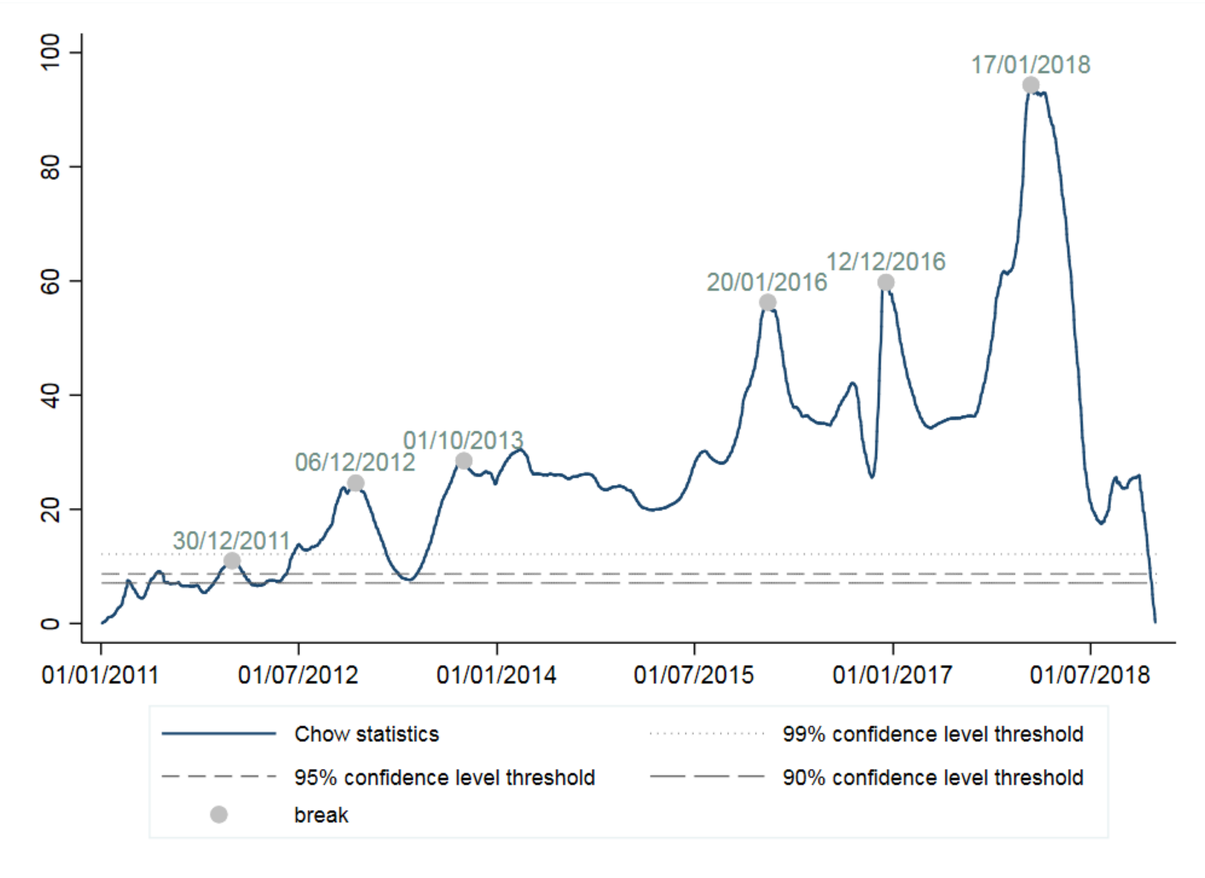
We use daily data over the period of 2011-2018 including year-ahead (Y+1) forward base electricity price as a function of year-ahead EU ETS CO2 forward price, year-ahead PEG forward gas price, as well as ARA forward coal price, sourced from Energymarketprice. We choose forward price data instead of spot price data to estimate the pass-through of carbon costs to electricity prices because forward time series tend to better reflect the long-term equilibrium among electricity, commodity and CO2 markets. In contrast, spot price data often present high volatility and is sensitive to market shocks. As a consequence, estimates of carbon pass-through using spot prices appear to be unstable and counter intuitive in terms of economic sense, as demonstrated by many scholars (Sijm et al., 2008; Sijm et al., 2012, etc.).

4. Results

4.1 Identification of structural breaks

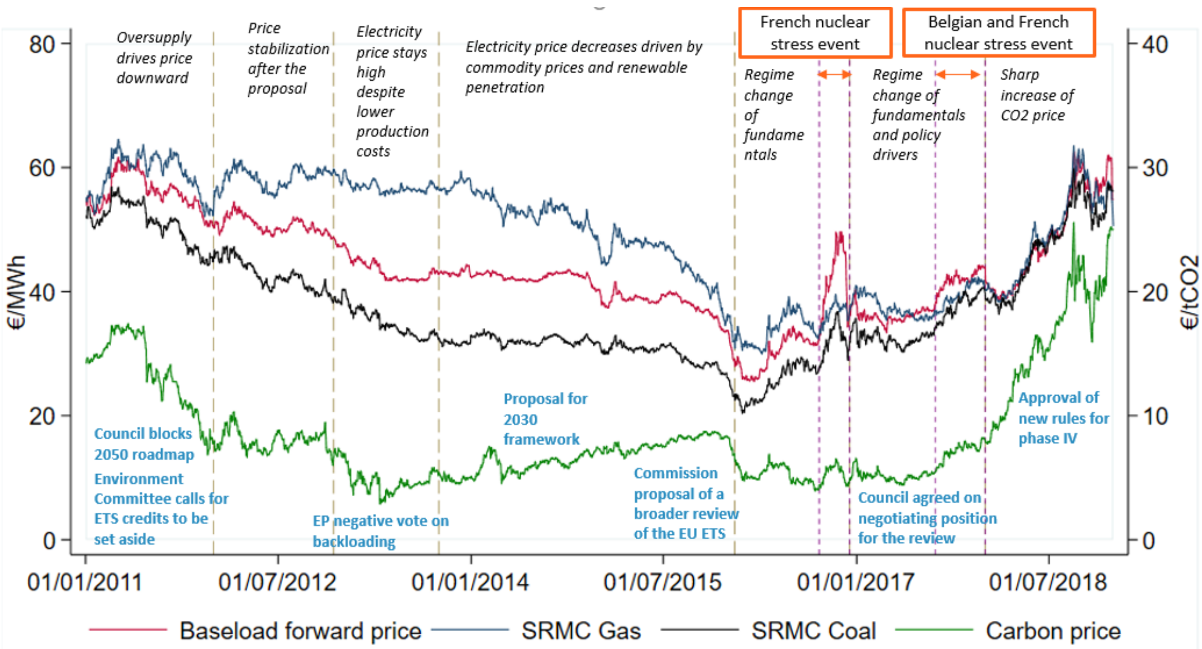
The result of the QLR test by rolling regressions over the period of 2011-2018 is shown in Figure 1. Potential structural breaks are identified with the highest probabilities for each subperiod. As will be discussed below, these structural breaks are fundamentally driven by market and policy drivers in the electricity markets in France and CWE region as well as in the EU ETS market. The test results also indicate a fast-changing relationship between electricity and CO2 prices between 2016-2018, which is tightly related to EU ETS market reforms and fluctuating dynamics of commodity prices.

Figure 1: Quandt Likelihood Ratio (QLR) test for structural breaks



One of the important contributions of this paper is to account for the drivers of the structural breaks as a function of fundamentals, such as changes in terms of policy orientation, commodity markets as well as system stress events. According to the QLR tests, we divide the full sample into seven subsamples to inspect market and policy factors that drive these structural breaks. As shown in Figure 2, the dynamics of the French electricity market and EU ETS market is tightly linked with the tendency of the EU carbon market regulation, evolution of commodity markets – both factors are reflected in the short-run marginal costs (SRMC) of thermal electricity generators, who determine electricity prices to a great extent as marginal generation. In addition, one of the most important specificities of the French electricity price is that it highly depends on the availability of baseload nuclear generation. Stress events of low availability of nuclear generation leads to systematic price peaks.

Figure 2: French baseload forward price against market and policy fundamentals as well as nuclear stress events



The degree of commitment to carbon policy reflected by policy program is a central force driving price formation of the carbon price in EU ETS. Release of supply-side news such as the intent to reduce emission allocation caused substantial price declines between 2011-2012. In contrast, the carbon policy signalled an overall political support for EU ETS such as proposals for EU 2030 framework and proposals for EU ETS reforms triggered an increase in the carbon price. Especially, the recent rapid increase in carbon prices since the beginning of 2017 is a clear result of policy support. Besides policy drivers, the evolution of electricity prices is fundamentally based on commodity prices, as thermal generation costs which reflect both fuel and carbon costs are the major price setters in electricity markets. Therefore, the French electricity prices followed closely the evolution of the short-run marginal costs of thermal plants over the whole period of 2011-2018. Additionally, the French electricity price is sensitive to market shocks particularly the availability of nuclear generation capacity. The winter 2016/2017 and winter 2017/2018 experienced a large amount of price spikes, which evidenced the impact of unavailability of nuclear fleets in France and Belgium that pushed both electricity and carbon markets upwards. Therefore, to study the dynamics of electricity and carbon markets and identify the cost pass-through of carbon cost to electricity price in a robust way, it is essential to account for drivers of policy changes, commodity markets, and stress system events. That is exactly this paper is aiming for.

These identified structural breaks are used as regression periods in the econometric forward model. We keep the full year of 2018 as a period because price trends are consistent. The test results confirm our choice for estimation periods determined by market and policy fundamentals as well as market shocks.

4.2 Estimation results of the French electricity market

The regression results of carbon pass-through using forward EU ETS and electricity baseload prices over the period of 2011-2018 are presented in Table 2.

Table 2: Regression results of the French electricity market

Variables	**01/01/11-29/12/11**	**30/12/11-05/12/12**	**06/12/12-30/09/13**	**01/10/13-19/01/16**	**20/01/16-11/12/16**	**12/12/16-31/12/17**	**01/01/18-31/12/18**
CO2 EU ETS	0.63***	0.53***	1.23***	0.63***	0.87***	0.89***	0.76***
Gas PEG	1.03***	0.67***		0.72***	2.55***		1.40***
Coal ARA		1.20***	1.75***	1.14***		1.51***	
D_2016					8.59***		
D_2017						2.10***	
Constant	20.78***	14.64***	20.42***	10.67***	-13.39***	18.20***	7.46***
Observations	259	244	213	601	233	275	261
Adjusted R2	0.86	0.81	0.93	0.93	0.9	0.95	0.96

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

In the regression, we control the French and Belgian nuclear stress events for the period of September 16, 2016 to December 11, 2016, and from August 12, 2017 to December 31, 2017, during which the French forward prices spike. We keep both gas and coal forward prices in the regression when their coefficients are statistically significant, contributing to the robustness of the pass-through rate, and overall model fit is superior with both variables included. We drop one of the fundamental prices when there is a sign of multicollinearity, that significantly bias estimated coefficient and its variance.

Our results show that most of the estimates of CO2 coefficients are below 1. The estimated pass-through rate stays between 0.53-0.63 until the end of 2012, but peaks at 1.23 between end 2012 and end 2013 due to the collapse of the carbon market in contrast to a relatively stable electricity price level. The estimated pass-through rate increases from end 2016, following a series of announces regarding the EU ETS reform that boost CO2 price. The CO2 pass-through for 2018 is estimated to be 0.76, meaning that an increase of 1€/tCO2 in CO2 price would translate into an increase of 0.76€/MWh in electricity price, which represents a forecast view for 2019.

Therefore, using year-ahead forward data allowed us to obtain a robust estimate of CO2 pass-through rate for different periods. We obtain a CO2 pass-through rate varying between 0.53-1.23 over the period of 2011-2018, varying in the different periods according to structural breaks.

5. Discussions

Since emissions allowances received by generators are for the most part free under the current EU ETS, the passing-through of the opportunity costs of these allowances increases their profits. A carbon pass-through rate of 0.76 indicates that generators effectively internalised most of the opportunity cost and reflected in the electricity market, leading to wind fall profits due to the EU ETS.

Our results serve as an economic basis to stimulate debate in the European parliaments as well as partially coverage concerning the contribution of the EU ETS to power price, raising question whether allocation should be auctioned instead distributed for free.

6. Conclusions

The paper contributes to the economic understanding of carbon cost pass-through in the French market and provides the first empirical evidence over the period of 2011-2018, during which carbon prices have experienced completely opposite evolutions.

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References

International Energy Agency (IEA) (2018). World Energy Outlook.

Laing, T., Sato, M., Grubb, M. and Comberti, C., 2013. Assessing the effectiveness of the EU Emissions Trading System (Vol. 126). London, UK: Grantham Research Institute on Climate Change and the Environment.

Work in progress

To be completed