THE DETERMINANTS OF CARBON PRICE: A DISPATCH-BASED APPROACH

Eduardo Marques[a] (eduardo.marques@dauphine.eu), Arthur Thomas[a] (arthur.thomas@dauphine.psl.eu), Olivier Massol[b](olivier.massol@centralesupelec.fr)

[a] Department of Economics (LEDa), Paris Dauphine University - PSL, Paris, France
[b] Université Paris-Saclay, Graduate School of Economics and Management, Sustainable Economy Research Group

Overview

The European Union Emissions Trading System (EU ETS) is the world's first large-scale CO2 emissions trading system. This market has been organized into four phases: Phase I (2005-2007), Phase II (2008-2012), Phase III (2013-2020), and Phase IV, which is currently ongoing. Phases I and II of the EU ETS have been extensively studied (see (Hintermann, 2010),(Creti, Jouvet, & Mignon, 2012),(Aatola, Ollikainen, & Toppinen, 2013),(Lutz, Pigorsch, & Rotfuß, 2013),(Koch, 2014),(Fell, Hintermann, & Vollebergh, 2015),(Zhu et al., 2019)), with empirical analyses highlighting the interactions between allowance prices, electricity prices, and energy prices.

However, there is a need to question the validity of these earlier analyses in light of the significant transformations occurring in the electricity sector, which remains the most critical sector regulated under the EU ETS. The rapid growth of renewable energy sources has changed the role of thermal power generation from fossil fuels. Thermal generation is no longer the baseload but instead serves as a backup source to compensate for the intermittency of renewables. Consequently, these changes impact the demand for emission allowances.

The objective of this study is to empirically study the determinants of the formation of these emission allowance prices. To do this, we propose adapting the original model introduced by (Thomas, Massol, & Sévi, 2022), which allow us to endogenously capture the non-linearities created by the dispatching of thermal power plants.

Methods

The unique characteristics of carbon allowances require modeling approaches specifically tailored to the carbon market. These approaches must account for: (1) the anticipated nonlinearity in the relationship between carbon prices and fundamental variables, as highlighted by (Boersen & Scholtens, 2014), (2) potential endogeneity among the variables, and (3) the time series properties, including the presence of unit roots. To address these challenges we use an extension of the ARDL model (Auto-Regressive Distributed Lag). Specifically, we employ the ARDL model as developed by (Pesaran, Shin, & Smith, 1999) and (Pesaran, Shin, & Smith, 2001). Unlike other cointegration methods, such as those proposed by (Engle & Granger, 1987) or (Johansen & Juselius, 1990), this approach allows for the interpretation of both short and long-run effects on the dependent variable, regardless of whether the variables have the same order of integration. This model partially addresses issues related to unit roots by accommodating variables of order zero (I(0)), order one (I(1)), or a combination of both.

We aim to model the EU ETS carbon price as a function of energy prices, a primary determinant of carbon pricing. Following previous literature, we use a European index to proxy the broader economic environment. For energy prices, we incorporate the spark and dark ratios, defined as the price of electricity relative to the price of gas and coal, respectively, along with the Brent crude oil price.To compute these ratios, we utilize the EEX German day-ahead peakload electricity price from Bloomberg, the day-ahead gas price and coal futures price from Argus, and the Brent futures price from the Argus platform. Our analysis covers the ongoing Phase IV of the EU ETS, at a daily resolution and applies to German electricity market.

Depending on the observed levels of the relative prices of gas and coal, the choice between natural gas or coal for power production likely varies, directly impacting the demand for carbon permits. Specifically, when the relative price of gas is high, the revenue from gas-fueled generation becomes less attractive compared to coal-fueled generation. This may incentivize a shift from gas to coal-based generation, indicating a stronger positive relationship between the dark ratio and the carbon permits price. Conversely, if gas prices are relatively low, the opposite may occur, with the spark spread driving the carbon price. To account for these non-linearities, we employ partial sum decompositions, as recommended by (Shin, Yu, & Greenwood-Nimmo, 2014). We decompose the spark and dark ratios based on the relative gas/coal price, which we optimize endogenously using the Akaike

Information Criterion (AIC) to determine the threshold ratio that strikes the best balance between accuracy and overfitting.

Results

By implementing the proposed methodology, a specific relative price ratio of 2.15, tailored to the German context, is identified. In the long run, when the price of gas relative to coal is high, our model reveals a substantial rise in carbon prices driven by the dark ratio, while the spark ratio becomes insignificant. This indicates that power producers are shifting from gas to coal-based generation, thereby increasing the demand for carbon permits. Conversely, when gas prices are relatively lower, the model demonstrates a corresponding decrease in carbon prices, driven by the spark ratio, highlighting the substitution effect where gas becomes the preferred fuel for power generation. In this scenario, although the dark ratio is less significant, it remains a positive contributor to carbon allowance prices.

In the short run, only the spark ratio negatively impacts carbon prices when gas prices are low, which may be attributed to the greater flexibility of gas-powered plants in adjusting their production. This flexibility allows for quicker adaptation to market conditions, influencing carbon pricing dynamics.

References

Aatola, P., Ollikainen, M., & Toppinen, A. (2013). Impact of the carbon price on the integrating european electricity market. *Energy Policy*, *61*, 1236–1251.

Boersen, A., & Scholtens, B. (2014). The relationship between european electricity markets and emission allowance futures prices in phase ii of the eu (european union) emission trading scheme. *Energy*, *74*, 585–594.

Creti, A., Jouvet, P.-A., & Mignon, V. (2012). Carbon price drivers: Phase i versus phase ii equilibrium? *Energy Economics*, *34*(1), 327–334.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251–276.

Fell, H., Hintermann, B., & Vollebergh, H. (2015). Carbon content of electricity futures in phase ii of the eu ets. *The energy journal*, *36*(4), 61–84.

Hintermann, B. (2010). Allowance price drivers in the first phase of the eu ets. *Journal of Environmental Economics and Management*, *59*(1), 43–56.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with appucations to the demand for money. *Oxford Bulletin of Economics and statistics*, *52*(2), 169–210.

Koch, N. (2014). Dynamic linkages among carbon, energy and financial markets: a smooth transition approach. *Applied Economics*, *46*(7), 715–729.

Lutz, B. J., Pigorsch, U., & Rotfuß, W. (2013). Nonlinearity in cap-and-trade systems: The eua price and its fundamentals. *Energy Economics*, *40*, 222–232.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289–326.

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American statistical Association*, *94*(446), 621–634.

Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ardl framework. *Festschrift in honor of Peter Schmidt: Econometric methods and applications*, 281–314.

Thomas, A., Massol, O., & Sévi, B. (2022). How are day-ahead prices informative for predicting the next day's consumption of natural gas? evidence from france. *The Energy Journal*, *43*(5), 1–26.

Zhu, B., Ye, S., Han, D., Wang, P., He, K., Wei, Y.-M., & Xie, R. (2019). A multiscale analysis for carbon price drivers. *Energy Economics*, *78*, 202–216.