

Carbon Price Drivers: An Updated Literature Review

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ABSTRACT

Since the creation of the European Union Emissions Trading Scheme (EU ETS) in 2005, a burgeoning academic literature has emerged to identify the factors that shape the price of carbon, where one European Union Allowance is equal to one ton of CO₂-equivalent emitted in the atmosphere. Thus, there is a need for an updated and thorough literature review on the state-of-the-art on topic that this paper aims to fulfill. Namely, we consider the main econometric studies that have been recently published in the academic literature, which feature the influence of the following determinants to explain the variation of the price of carbon: institutional decisions; energy prices and weather events; macroeconomic and financial market shocks. The paper concludes with some directions for future research in this area.

Keywords: Carbon Price; Banking Borrowing; Energy Prices; Macroeconomy; Financial Markets; Econometrics

1 INTRODUCTION

Ellerman and Buchner (2007), and Convery and Redmond (2007) masterly produced an early literature review on the carbon price development in their respective articles for the first issue of the *Review of Environmental Economics and Policy*. This work was further elaborated by Convery (2009) alone in his reflections on the emerging literature on emissions trading in Europe, and compiled in an edited volume by Ellerman, Convery and De Perthuis (2010). Zhang and Wei (2010) provided further insights, based on evidence from the operating mechanism and economic effects of the newly created EU Emissions Trading Scheme (EU ETS).

Building upon these initial contributions, this paper provides a systematic update on the cutting-edge literature of carbon price drivers from 2007 onwards. It reviews mainly economic

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and econometric studies which have identified inter-relationships between the price of CO₂ on the one hand, and its main fundamentals that allow to explain and forecast its variation overtime on the other hand. By doing so, this paper calls for more research in this promising area, since many puzzles remain to be solved by researchers in empirical work, especially concerning the adjustment of carbon prices to the macroeconomic environment.

At first glance, this paper features that the price of carbon is classically driven by the balance between supply and demand, and by other factors related to market structure and institutional policies. On the supply side, the number of allowances distributed is determined by each Member-State through National Allocation Plans (NAPs), which are then harmonized at the EU-level by the European Commission. On the demand side, the use of CO₂ allowances is a function of expected CO₂ emissions. In turn, the level of emissions depends on a large number of factors, such as unexpected fluctuations in energy demand, energy prices (*e.g.*, oil, gas, coal) and weather conditions (temperatures, rainfall and wind speed). The demand for allowances can be affected by economic growth and financial markets as well, but that latter impact needs to be further assessed in the academic community.

The remainder of the paper is structured as follows. Section 2 explains how institutional decisions affect the price path of carbon. Section 3 introduces the mechanisms at stake between the price of CO₂ and the price of other energy markets. In addition, it provides the main intuition behind the influence of extreme weather and temperatures events. Section 4 develops the links with the macroeconomic and financial markets. Section 5 briefly concludes.

2 INSTITUTIONAL DECISIONS

In this section, we consider two main categories of institutional decisions that are likely to impact the price of carbon: *(i)* the emissions shortfall factor, defined as the difference between verified emissions and allocated allowances within a given compliance year, and *(ii)* the effects of banning banking from phase I to phase II of the scheme.

2.1 The emissions shortfall factor

The best example of the influence of institutional decisions on the price development of carbon may be found during the year 2006. Indeed, during that year Ellerman and Buchner (2008) report that the first report of verified emissions published by the European Commission at the aggregated EU-wide level has had a dramatic impact on the carbon price, which fell by almost fifty percent in a few days. The main reason behind this structural change in the price of carbon may be found in the ratio of allocated allowances to actual emissions: as all installations surrendered their quotas and sent their information to the regulator, it could be assessed for the first time that the carbon market was over-supplied, or “over-allocated”.

As too many allowances were obviously distributed during the first phase going from 2005 to 2007, economic agents have rationally integrated this reliable information in the price signal of CO₂, which has broadly fluctuated ever since in the range of fifteen to twenty euros per ton.

Alberola et al. (2008a) provide a rigorous econometric analysis of such institutional effects, based on the detection of structural changes in the data, which may be dated back to the announcements by the European Commission during the so-called “first compliance event”, which is due to happen on a yearly basis by May 15. Chevallier et al. (2009) extended this analysis to the 2006 compliance event by using option price data.

2.2 Banking restrictions

Another equally important effect of institutional decisions, which is often disregarded by analysts and academics, is the decision by the European Commission to ban the transfer of any banked or borrowed allowances from phase I (2005-2007) to phase II (2008-2012). As a consequence, any allowances in surplus as of December 31, 2007 would be worthless on January 1, 2008. The main reason behind that decision may be found in Alberola and Chevallier (2009), who advocate that the European Commission did not want to transfer market design imperfections from the “warm-up” period of the scheme to the corresponding period of commitment of the Kyoto Protocol.

Therefore, the banking instrument, which allows industrial operators to smooth emissions and to manage their stock of allowances in a flexible inter-temporal way (see Chevallier (2011a) for a theoretical literature review), has been “sacrificed” in October 2006 in an official press release from the European Commission. From that date until the end of phase I, two price signals have been coexisting: CO₂ spot and futures prices valid for phase I which were gearing towards zero (their actual value as of December 2007), and CO₂ futures prices valid for phase II fluctuating in the range of twenty euros (with a perception of increased allowance scarcity during 2008-2012).

Paoletta and Taschini (2008) have shown how to model the properties of CO₂ spot returns during this very specific period of the end of phase I. On this topic, it is also worth highlighting the important theoretical contribution by Daskalakis et al. (2009) under the form of an explicit modeling of the effects of banning banking on pricing CO₂ futures prices during the first phase. Next, we detail the inter-relations between CO₂ and energy market prices.

3 ENERGY PRICES & WEATHER

This section first reviews the links between “traditional” energy markets (oil, gas, coal, electricity) and the latest energy market to date created by environmental regulation, *i.e.* the carbon market. Then, we focus on the fuel-switching behavior in the electricity sector, which has a central role in shaping the price of carbon under current market conditions. Third, we detail the role played by (unanticipated) weather events.

3.1 The influence of oil, gas, and coal prices

Based on economic analysis (essentially demand and supply fundamentals), Christiansen et al. (2005) have identified the following factors as being the price determinants in the EU ETS: policy and regulatory issues; market fundamentals, including the emissions-to-cap ratio, the role of fuel-switching, weather and production levels. Mansanet-Bataller et al. (2007) and Alberola et

al. (2008a) were the first analyses to uncover econometrically the relations between energy markets and the CO₂ price. Based on phase I spot and futures data, the former group of authors establishes that carbon prices in the EU ETS are linked to fossil fuel (*e.g.*, oil, gas, coal) use. By using an extended dataset, the latter group of authors emphasizes that the nature of this relationship between energy and carbon prices varies depending on the period under consideration, and the major influence of institutional events (as detailed above).

Bunn and Fezzi (2009) further quantify the mutual interactions of electricity, gas and carbon prices in the UK. By using a structural, co-integrated vector error-correction model, they derive the dynamic pass-through of carbon prices into electricity prices, and the response of electricity and carbon prices to shocks in the gas price. Finally, it is worth highlighting the work by Hintermann (2010), who derives a structural model of the allowance price under the assumption of efficient markets and examines the extent to which this variation in price can be explained by marginal abatement costs.

3.2 Power producers' fuel-switching behavior

Obviously, the demand for fossil fuels depends on their absolute as well as *relative* prices. From that perspective, the marginal fuel-switching costs from highly carbon-intensive sources of energy (such as coal) to lower carbon-intensive sources for power and heat generation (such as gas) constitute another important determinant of the CO₂ price. As a general rule-of-thumb, carbon abatement in the short-run heavily depends on the behavior of power and heat operators, who are the main actors under the EU ETS (with over fifty percent of emissions capped by the scheme). Moreover, emissions abatement costs from the power sector are assumed to be the lowest compared to other sectors, based on fuel-switching from coal to gas. Among other contributions, we may cite here Delarue and D'haeseleer (2007), Alberola et al. (2008a), and Keppler and Mansanet-Bataller (2010) who have separately studied these causalities between CO₂ and electricity variables (such as clean dark and clean spark spreads, and the *switch* price) during the first phases of the EU ETS.

On this topic, the interested reader may refer as well to Delarue et al. (2010) for a useful topography of abatement by fuel-switching in the European power sector, based on the E-Simulate model.

3.3 The role played by temperatures and extreme weather events

As outlined by Christiansen et al. (2005), Mansanet-Bataller et al. (2007), Alberola et al. (2008) and Hintermann (2010), CO₂ prices are also affected by unexpected climatic variations, including temperatures, rainfalls, and wind. For instance, cold winters (hot summers) increase the need for heating (cooling) by using electricity. When departing from seasonal averages, Alberola et al. (2008a) show that extreme (and essentially unanticipated) temperatures events have a statistically significant effect on carbon price changes. Furthermore, rainfalls, wind speed and hours of sunshine directly affect the share of power generated by carbon-free heat generation from hydropower, wind and solar energy. Taken together, these factors may contribute to explain why the weather is widely acknowledged to play an important role in shaping the price of carbon.

More research is needed in that direction, namely by gathering more extensive datasets at the European level, and by considering explicitly nonlinearities in the data (as temperatures events may have a significant effect on the price of carbon above or below a given threshold for example). In the next section, we introduce the CO₂ price fundamentals linked to the global macroeconomic environment.

4 MACROECONOMIC AND FINANCIAL MARKET SHOCKS

In what follows, we detail the links that have been identified in previous literature between the price of CO₂ on the one hand, and macroeconomic and financial markets on the other hand. Of particular interest for future researchers will be to assess comprehensively the impact of the economic recession on the carbon market.

4.1 Industrial production

Based on the characteristics of the global economic context and changes in industrial production in EU ETS sectors during 2005-2007, Alberola et al. (2008b, 2009) provide the first rigorous econometric exercises aimed at disentangling the potential impacts ranging from production to environmental conditions on carbon prices. This relationship may be understood intuitively: as industrial production increases, associated CO₂ emissions increase, and therefore more CO₂ allowances are needed by operators to cover their emissions. This economic logic results in carbon price increases *ceteris paribus*. The authors show empirically that fluctuations in the level of economic activity are a key determinant of the level of carbon price returns in the combustion, paper and iron sectors (which account for nearly eighty percent of allowances allocated), and in four countries (Germany, Spain, Poland, UK).

More recently, Declercq et al. (2011) investigate the impact of the economic recession on CO₂ emissions in the European power sector during the years 2008 and 2009. Based on a counterfactual scenario for the demand for electricity, the CO₂ price, and fuel prices, their simulations demonstrate that an emissions reduction of about 150 million ton may be expected from the European power sector during the period as a consequence of the recession.

4.2 Macroeconomic and financial markets indicators

Interestingly, several studies uncover some econometric links between the carbon market and several indicators related to macroeconomic and financial markets. Oberndorfer (2009) has first tackled this issue from the angle of the stock markets. The author shows that CO₂ price changes and stock returns of the most important European electricity corporations are positively related. This effect is particularly strong for the period of carbon market shock in early 2006 (as detailed above), and differs with respect to the countries where the electricity corporations analysed are headquartered. Next, the article by Chevallier (2009) has provided a more comprehensive treatment of the relationship between the carbon market on the one hand, and stock and bond markets on the other hand. By estimating various volatility models for the carbon price with

standard macroeconomic risk factors, the authors documents that that carbon futures returns may be weakly forecast on the basis of two variables from the stock and bond markets, *i.e.* equity dividend yields and the “junk bond” premium. Finally, we may cite in this strand of literature the paper by Chevallier (2011b), who assesses the transmission of international shocks to carbon spot and futures carbon prices by using a broad dataset of macroeconomic, financial and commodities indicators. According to the economic theory, the author shows that carbon prices tend to respond negatively to an exogenous recessionary shock in global economic indicators.

Last but not least, note that the article by Mansanet-Bataller et al. (2011) contains an updated study on the main energy markets and macroeconomic fundamentals of CO₂ prices during Phase II, along with an analysis of the Kyoto Protocol’s Certified Emissions Reductions (CERs), which are valid for compliance under the EU ETS and may yield to arbitrage strategies by market participants.

However, more work is needed on this topic, especially to understand the adjustment process of carbon prices to the macroeconomic environment, for instance by focusing on the underlying nonlinearities of the data. As of today’s state-of-the-art literature, economic activity is perhaps the most obvious and least understood driver of CO₂ price changes.

5 CONCLUDING REMARKS

While the world’s international climate policy negotiations have never been so blurred, the European carbon market is functioning since 2005, and has been confirmed to operate by the European Commission at least until 2020. In this context, an updated literature review on the pricing mechanisms for CO₂ seems both necessary and useful. By parsing through the recent academic literature, this paper shows that some fundamentals have been identified and confirmed by many empirical studies to date: policy and regulatory issues; market fundamentals (including the emissions-to-cap ratio, the role of fuel-switching, weather); and macroeconomic activity. While more research needs to be pursued concerning the adjustment of the price of carbon to the global economic recession, these studies may be helpful for policy makers, analysts and industrial operators regulated by the EU ETS. As a deeper knowledge of the complex pricing mechanisms at stake is gained, more accurate price forecasts and policy recommendations can indeed be formulated.

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