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THE IMPACT OF NONLINEARITIES FOR CARBON MARKETS ANALYSES

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ABSTRACT. This paper examines empirically whether nonlinearities play a significant role in the modeling of the carbon price. We highlight the limits of previous carbon markets analyses based essentially on a *linear* econometric framework. Instead, we propose to revisit the main results on carbon pricing and the inter-relationships with energy markets and CERs based on *nonlinear* techniques (threshold vector autoregressive and Markov regime-switching models). While we are able to confirm most of the findings present in the literature, we show interestingly that these results seem to vary (and may even fade) depending on the regimes considered. Thereby, we illustrate the importance of including threshold effects in future studies of the relationships between CO_2 and energy prices, which have been neglected so far.

JEL Classification: C32; C51; Q40; Q54.
Keywords: Carbon Prices; Energy Prices; Nonlinearity; TVAR; MSVAR.

RÉSUMÉ. Cet article examine empiriquement la question de savoir si les nonlinéarités jouent un rôle important dans la modélisation du prix du carbone. Nous soulignons les limites des analyses précédentes du marché du carbone basées essentiellement sur un modèle économétrique *linéaire*. Au contraire, nous proposons de revisiter les principaux résultats sur la détermination du prix du carbone, et les interactions avec les marchés des énergies et des CERs, à partir de techniques économétriques *nonlinéaires* (modèle vectoriel autorégressif à seuil et modèle à changement de régime markovien). Nous confirmons la plupart des résultats de la littérature précédente. Cependant, nous montrons que ces résultats peuvent varier (et même se dissiper) selon les régimes considérés. Nous illustrons ainsi l'importance d'inclure des effets de seuil dans les futures études des relations entre les prix du CO_2 et les prix des énergies, qui ont été négligés jusqu'à présent.

Classification *JEL :* C32 ; C51 ; Q40 ; Q54.
Mots-clefs : Prix du carbone ; prix des énergies ; nonlinéarité ; TVAR ; MSVAR.

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1. Introduction

Carbon pricing has been at the center of many recent developments in the literature (see among others the contributions by Mansanet-Bataller *et al.* (2007), Alberola *et al.* (2008a), Hintermann (2010), Bredin and Muckley (2011), Pinho and Madaleno (2011), Creti *et al.* (2012), as well as Chevallier (2012a) for a review). On the supply side, the amount of CO_2 allowances distributed each year under the European Union Emissions Trading Scheme (EU ETS) is known in advance by all market participants during 2005-2012. On the demand side, carbon prices are impacted by four main drivers related to (*i*) institutional decisions, (*ii*) energy prices, (*iii*) weather events, and (*iv*) macroeconomic factors. As companies pollute (*i.e.* they emit tons of CO_2 in the atmosphere), they face essentially two choices: they need either to pay for the associated pollution (by surrendering allowances from their own registry), or to purchase/sell allowances on the market depending on the excess/lack of pollution compared to their annual endowment. The amount of allowances that a given company needs to balance its actual CO_2 emissions depends on the type of fuel burned[2]. Companies need also to pay attention to the relative variation of energy prices: in case of a rise in the price of oil for instance, the price of many manufactured products (using oil as an input to production, or to produce energy) will similarly increase. That is why the price of carbon, and the demand for CO_2 allowances, is linked to the variation of energy prices[3]. Moreover, it is a virtually unquestioned assumption that the fluctuations in the level of economic activity are a key determinant of the level of carbon prices: as industrial production increases, associated CO_2 emissions increase, and therefore more CO_2 allowances are needed by operators to cover their emissions (on this topic, see more particularly Alberola *et al.* (2008b,2009)).

However, these results were obtained in a *linear* econometric framework (*i.e. linear* regressions for Mansanet-Bataller *et al.* (2007), Alberola *et al.* (2008a) and Hintermann (2010); *linear* cointegration for Bredin and Muckley (2011), Pinho and Madaleno (2011) and Creti *et al.* (2012)). By contrast, this paper proposes several *nonlinear* models to analyse the characteristics of European Union Allowances (EUAs). It is generally recognized that financial time series are characterized by the occurrence of shocks. Because of the existence of these shocks, a linear model of the underlying returns may provide a misleading specification of market movements. If the dynamic propagation of shocks differs from the "usual" behaviour of the time series, then a model that relies on a linear propagation mechanism will necessarily be incorrect (Bradley and Jansen (2004)). Other potential justifications for nonlinearities include the interactions between agents on the carbon and energy markets, whereby different groups of agents can have heterogeneous anticipations about the future price levels, and hence lead to discontinuous pricing strategies (see the model by Corsi (2009)). In response

2. Coal for instance is far more CO_2 intensive than natural gas.

3. In addition, we need to keep in mind that power producers are key players on the carbon market, as they receive globally around 50% of allocation each year. Therefore, their fuel-switching behaviour (producing one unit of electricity based on coal-fired or gas-fired power plants, and switching between inputs as their relative prices vary) constitutes another central factor to explain the variation of the carbon price. More power production will be achieved by more fuel use (associated with CO_2 emissions), and *in fine* there will be a need for more CO_2 allowances (with a positive effect on the CO_2 price). See Chevallier (2011a) for a review.