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Macroeconomics, finance, commodities: Interactions with carbon markets in a data-rich model

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ABSTRACT

This article assesses the transmission of international shocks to EUA spot, EUA futures, and CER futures carbon prices using a broad dataset that includes 115 macroeconomic, financial and commodities indicators with daily frequency from April 4, 2008 to January 25, 2010 totalling 463 observations. The framework adopted is a Factor-Augmented Vector Autoregression model with latent factors extracted from the dataset, as proposed by Bernanke et al. (2005). The main results can be summarized as follows. First, based on impulse responses, we show that carbon prices tend to respond negatively (between −0.2 and −1.2 standard deviation) to an exogenous shock that reduces global economic indicators by one standard deviation. Second, we find evidence that the responses are heterogeneous among the different kinds of carbon prices: CER futures prices tend to react much more significantly than EUA spot and futures prices. Third, the factors explain about 50% of the total variance of all variables in the dataset. The largest contribution is accounted for by the factor correlated with commodities markets, which explains about 28% of the total variability.

1. Introduction

Factor methods arise from the need for macroeconomists and central bankers to follow hundreds of time-series variables as proxies for the state of the economy. Thus, it appears necessary to gather as much information as possible from as many variables as possible. This methodology typically yields to models with a large number of variables and associated parameters to estimate. To that end, factor models have been developed to extract the information in datasets with many variables while, at the same time, keeping the model parsimonious (see Stock and Watson, 2006 for a survey). Key contributions include Bernanke et al. (2005) and Stock and Watson (2005), who have combined factor methods with VAR methods, known as Factor-Augmented VARs (FAVARs).

Since then, the growing interest in combining the theoretical insights provided by VARs with factor methods' ability to extract information in large datasets has motivated the development of Factor-Augmented VARs. Recent studies have investigated how macroeconomic indicators respond to monetary policy shocks.[1] In the field of energy markets, Zagaglia (2010) studies the dynamics of oil futures prices in the NYMEX using a large panel dataset that includes global macroeconomic indicators, financial markets indices, quantities and prices of energy products. The author shows that a factor correlated purely to financial developments contributes to the model performance, in addition to factors related to energy quantities and prices.

In analogy to previous studies, this article analyzes the dynamics of macroeconomic factors, and the associated financial and commodities markets, as those variables enter our FAVAR model. In contrast to previous studies, we investigate how these indicators impact *carbon* prices. The current financial crisis linked to sub-primes in the U.S. has indeed been spreading to many economic sectors, including energy markets. Understanding the international transmission of shocks across such markets appears important to inform adequate policy responses and participants' hedging strategies. Analysts have typically attempted at quantifying the transmission of global shocks to carbon prices.[2] It appears that carbon prices have been plummeting from January 2009 onwards, *i.e.* 18 months after the first interest rates cut by the U.S. Federal Reserve in July 2007 which is mostly viewed as being the start of the economic downturn. Our focus consists also in identifying the "commodity markets" channel of the international transmission

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[1] See among other studies in this fastly growing literature Alessi et al. (2009); Altissimo et al. (2009); Ang and Kristensen (2010); Ang et al. (2008); Bai and Ng (2002, 2006, 2007, 2010); Bekaert et al. (2010); Boivin and Giannoni (2007); Boivin and Ng (2006); Boivin et al. (2008, 2010); Forni et al. (2003, 2009); Giannone et al. (2006); Gupta et al. (2010); Ludvigson and Ng (2007, 2009, forthcoming); Moench (2008); Moench and Ng (in press); Mumtaz and Surico (2009).

[2] See for instance the headlines "Crunch time" on September 15, 2008 at http://www.carbon-financeonline.com/, and "Carbon and the credit crunch" on October 13, 2008 at http://www.pointcarbon.com/.

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mechanism, which is assumed to operate through a growing connection between the macroeconomic and financial markets spheres (Tang and Xiong (2009)). To document the transmission of such shocks on carbon markets, along with the time-frame for such shocks to be effectively transmitted into lower levels of carbon prices, constitutes the central goal of this paper. This piece of research appears also relevant to document empirically the effects of the recent "rush to commodities" episode on carbon markets, as market observers have noticed an adjustment of global commodity prices to the economic downturn, but with various levels of lag.

To our best knowledge, this is the first study of the effects of global macroeconomic, financial and commodities markets shocks on carbon prices using a FAVAR model. The only article dealing with the impact of macroeconomic factors on carbon prices is that by Chevallier (2009). The author documents that a weak link exists between macroeconomic factors and carbon prices based on asymmetric GARCH modelling. The author shows 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. Analyzing the effect of the global recession on carbon markets cannot be tackled in a VAR framework, since we can only look at a small number of variables of interest, which would possibly cause puzzling results. Another well-known problem of small-scale VAR-type analysis is the arbitrary acceptance of specific variables as the counterparts of theoretical constructs, which may not be perfectly represented by the selected variables. In contrast, given its econometric structure, the FAVAR model addresses these concerns.[3] Against this background, our article takes the analysis one step further to study the dynamics of carbon prices in a data-rich model of 115 variables (originally from a database of over 1300 time-series).[4] The dataset contains detailed information on macroeconomic, financial and commodities variables. We exploit the information from this large dataset to investigate the sources of change in carbon prices over the period by *(i)* extracting common factors from the large dataset, and *(ii)* modelling the joint dynamics of the factors and carbon prices in a FAVAR. The factors therefore represent the drivers of carbon prices that are "latent", *i.e.* not directly observable from the information set. As shown by Bernanke et al. (2005), the use of sparse information in the forms of factors extracted from large datasets solves the problem of choosing the most representative variables (absent potential measurement errors) in standard Vector Autoregression. In contrast, the FAVAR captures the interactions between carbon price changes and factors of different nature.

The contributions of the article are twofold. First, we quantify the dynamic effects on carbon markets of a shock that reduces global economic indicators by one standard deviation. Second, we assess the extent to which these shocks are being transmitted to carbon prices, in terms of size, significance and temporal profile. The categories of carbon prices under consideration are: *(i)* European Union Allowances (EUA) spot and futures prices valid for compliance under the EU Emissions Trading Scheme (EU ETS), and *(ii)* secondary Certified Emissions Reductions (CER) valid for compliance under the Kyoto Protocol and up to a fixed limit (13.4% on average) within the EU ETS. The main results are as follows. In response to a contractionary economic shock, carbon prices decrease within 9 periods, implying a delayed effect to such global shocks. The impact is maximum on EUA spot prices by −0.3 standard deviation, on EUA futures prices by −0.2 standard deviation, and on CER futures prices by −1.2 standard deviation. Therefore, the drop in CER futures prices is much more significant than for EUA spot and futures prices. Carbon prices react most especially to commodities markets. Indeed, the latent factor correlated with commodities variables contributes to about 28% of the total variation in the dataset, while the latent factor correlated with macroeconomic and financial variables explains above 21% of total variability. Overall, these results appear useful for regulated utilities, brokers and various financial institutions in order to better understand the relationships between carbon and global macroeconomic, financial and commodities markets. This study extends Chevallier (2009) to the inclusion of a more comprehensive set of macroeconomic risk factors. Zagaglia (2010)'s analysis is most similar in spirit to this article, as the author uses a FAVAR to gauge the evolution between macroeconomic factors and oil futures prices. The two analyses differ, however, in the energy market analyzed and in the empirical application conducted.

The article is structured as follows. Section 2 details the methodology. Section 3 describes the data used. Section 4 presents the results. Section 5 concludes.

2. Methodology

Bernanke et al. (2005) pointed out that macroeconomic aggregates might not be perfectly observable, neither to the policy maker, nor to the econometrician. Instead, such indicators should be viewed as noisy measures of the "true" underlying economic concepts. Hence, these concepts should be treated as unobservable in the empirical estimation strategy in order to avoid confounding measurement errors with fundamental economic shocks. Accordingly, they proposed a methodology to extract a few common factors from a large number of macroeconomic time-series and key economic indicators.

In what follows, the model presented is based on the assumption that carbon prices are driven by macroeconomic, financial and commodities shocks. The determinants of macroeconomic, financial and commodities shocks are proxied by unobservable factors that summarize the common information in a large number of time-series. Then, the joint dynamics of observable and unobservable variables are modelled in Bernanke et al. (2005)'s FAVAR model.

Noting y_t an $M\times 1$ vector of time-series variables, and denoting y_{it} a particular variable, the FAVAR builds on the dynamic factor model structure commonly formulated in state-space form (Stock and Watson, 2002b):

$$\begin{aligned} y_{it} &= \lambda_{0i} + \lambda_i f_t + \gamma_i r_t + \epsilon_{it} \\ f_t &= \Phi_1 f_{t-1} + \ldots + \Phi_p f_{t-p} + \epsilon_t^f \end{aligned} \tag{1}$$

for $i=1,\ldots,M$, where f_t is defined as a $q\times 1$ vector of unobserved latent factors (where $q<<M$) which contains information extracted from all the M variables assumed to drive the dynamics of the economy, λ_i is an $1\times q$ matrix of so-called factor loadings, λ_{0i} represents the intercept for every dependent variable, r_t is a $k_r\times 1$ vector of observed variables,[5] ϵ_{it} is i.i.d $N(0,\sigma_i^2)$ and ϵ_t^f is i.i.d $N(0,\sum^f)$.

The FAVAR extends the state equation for the factors to allow for r_t to have a VAR form:

$$\begin{pmatrix} f_t \\ r_t \end{pmatrix} = \tilde{\Phi}_1 \begin{pmatrix} f_{t-1} \\ r_{t-1} \end{pmatrix} + \ldots + \tilde{\Phi}_p \begin{pmatrix} f_{t-p} \\ r_{t-p} \end{pmatrix} + \tilde{\epsilon}_t^f \tag{2}$$

where $\tilde{\epsilon}_t^f$ is i.i.d $N(0,\tilde{\Sigma}^f)$. We interpret the factors as summarizing information contained in a large dataset of macroeconomic, financial and commodities time-series. Altogether, the suggested model is completely characterized by Eqs. (1) and (2). In a nutshell, it is a dynamic factor model that has a FAVAR as the state equation.

In theory, the FAVAR model can be estimated by using the Kalman filter and maximum likelihood methods. This approach however may become computationally infeasible when the number of economic indicators entering the vector y_t is large. Bernanke et al. (2005)

[3] We thank a referee for highlighting this point.

[4] The time-series contained in the full dataset are described in an online appendix, which can be found at doi:10.1016/j.econmod.2010.06.016.

[5] For instance, in Bernanke et al. (2005), r_t is set to be the Fed Funds rate and thus $k_r=1$.