[*MARKETS FOR SUSTAINSABLE GROWTH IN CHINA: EFFECTIVENESS AND EFFICIENCT OF REGIONAL CARBON TRADING*]

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Overview

With rapid development of industrial society, large-scale use of fossil energy has caused severe pollution, influenced the Earth's ecological systems, increased global temperatures, and contributed to frequent severe weather. China accounts for the largest share of the world's total greenhouse gas emissions. The scale and growth of industrial activities and energy consumption in China explain the high level of emissions. In September 2020, China announced ambitious goals for sustainable energy and carbon neutrality by 2060, and to curb peak carbon emissions by 2030. In the past, China has mostly relied on administrative tools to reduce carbon emissions. Achieving "carbon neutrality" through administrative means is effective but also costly and inefficient. The National Development and Reform Commission of China was aware of this dilemma, and this was reflected in the plan to launch the regional and national emission trading schemes. Beijing, Shanghai, Guangdong, Shenzhen, and Hubei are pioneering regional carbon trading in China. However, there are differences in natural resources and climatic features among these five jurisdictions, as well as significant differences in economic development, energy market structure, and residents' willingness to offset carbon emissions. By the virtue of the price mechanism and legal construction divergence, the regional markets represent disequilibrium states. Notably, disjoint regional markets have caused market inefficiency, increasing the difficulty of linking to the national market.

Therefore, it would be of some importance to analyse the dynamic fluctuations (in terms of lead-lag relationships) of the emerging regional carbon markets in China — and essential to examine which regional ETS pilot's market design most suits China's socio-economic needs. It is essential to measure and assess regional ETS data from the previous pilot phase intending to contribute to the national market design. China is a large, populous, and diverse country and the performance of its carbon and energy markets has regional, national, and global effects.

Methods

The co-integration among the CO_2 emissions products of different regional environmental exchanges describes how markets, each of which might be non-stationary, but may nonetheless be linked. The multivariate vector auto-regression (VAR) model is a system regression model with multiple dependent variables, and each variable in the VAR system is endogenous. The VAR model is a reformulation of the covariance of my data, with two covariances discussed in the model: i) the covariance between the variables at time t ; ii) their covariance between time t and time $t - h$. This model allows me to analyse both the short-run and long-run dependencies of these variables. Engle and Granger (1987) pointed out that most of the macro economic variables may be non-stationary through time. It is expected that non-stationary price variables could be bound together and converge to some stationary processes by long-run equilibrium relationships.

Johansen (1988), Johansen and Juselius (1990), and Juselius, K. (2006) used likelihood ratio tests based on a VAR estimation and provided a vector equilibrium correction (VEC) model. This method is estimated by the full information maximum likelihood as suggested in Johansen (1988). The VEC model gives a reformulation of VAR model in terms of differences, lagged differences, and levels of the process, which naturally classified the relationship into short-run and long-run effects. The error correction formulation for VAR (p) is described as:

$$\Delta x_t = \Gamma_1^{(m)} \Delta x_{t-1} + \Gamma_2 x_{t-2} + \cdots + \Gamma_{p-1} x_{t-p+1} + \Pi x_{t-m} + \varepsilon_t \qquad (1)$$

where m is an integer between 1 and p, defining the lag placement of the ECM term. The rank of matrix Π (r) is the error correction term and it determines the long-run relationship. Either $\Pi = 0$, or it must have reduced the rank: $\Pi = \alpha\beta'$, where α denotes the estimation on the speed of adjustment to the equilibrium, and β denotes the cointegration vectors. Both α and β are $n \times r$ matrices, r is the rank of Π and the number of co-integrating relations, in order to make Equation (1) a stationary process. With the co-integration $\Pi x_{t-m} = \alpha\beta^T x_{t-m}$, the linear combinations $\beta^T x_{t-m}$ should be stationary and could be interpreted as deviations from long-run equilibrium; the matrix α is the adjustment speed coefficients. Thus, the cointegrated VAR (p) model is given by:

$$\Delta x_t = \Gamma_1^{(m)} \Delta x_{t-1} + \Gamma_2 x_{t-2} + \cdots + \Gamma_{p-1} x_{t-p+1} + \alpha\beta' x_{t-m} + \varepsilon_t \quad (2)$$

where $\beta' x_{t-m}$ is the error correction term that shows the long-run relationships between five variables.

Interventions and market reforms frequently show up in energy markets, especially for early stage carbon markets, as they are market-driven tools based on policies. This paper uses transitory dummies to account for transitory shocks in the markets, and then the reformulated model is expressed as Equation (3):

$$\Delta x_t = \Gamma_1^{(m)} \Delta x_{t-1} + \Gamma_2 x_{t-2} + \cdots + \Gamma_{p-1} x_{t-p+1} + \alpha\beta' x_{t-m} + \Phi_{tr} D_{tr,t} + \varepsilon_t \quad (3)$$

The VAR (p) model can be given different parametrizations without imposing any binding restrictions on the model parameters and multicollinearity effects would present in those time-series data. There are tests available to test one at a time whether a specific variable does not belong to the co-integrating vector. Thus, the long-run exclusion tests are conducted in this paper. If the restrictions are accepted, the variable can be omitted from the long-run relations, and the VAR model can be reformulated without losing information. The test of the same restriction on all beta is given in Johansen (1996), Section 7.2.

Results

This paper focuses on the fragmentation of these markets' compliance instruments, examines the market architecture and maturity of the regional ETS groups, and quantitatively analyses the integration level of China's carbon markets. The dynamic linkage effects between emission allowances prices are investigated using Johansen's cointegration test, the inclusion of some transitory shock dummies is considered in the model to capture the impact of policy changes in regional ETSs.

The empirical results exhibit that there is one cointegrating vector in my monthly price data, which reveals that emission prices of regional ETS pilots in China have equilibrium relationships in long term.
Beijing ETS and Shenzhen ETS prices show positive relationships to Guangdong ETS while Shanghai and Hubei show negative to Guangdong ETS. The long-run emission price elasticity for Beijing, Shanghai, Shenzhen, and Hubei is respectively at 0.746, -0.490, 0.085, and -0.835. The price elasticity for Shenzhen emission allowances is relatively lower. However, after long-run exclusion tests, Beijing and Shenzhen and Hubei's allowances prices can be omitted in the long-run relation in our sample period. Shanghai and Guangdong's allowances prices are significantly in the long-run relation, with each percentage-point increase in the Shanghai emission allowances price will cause the decrease of 0.49% in the Guangdong price. In the short run, Beijing's, Hubei's, and Guangdong's emission allowances prices remain unaffected by any short-term causality effect from other regional ETS pilots. Both Shanghai and Shenzhen seem to be led by changes in lagged Beijing emission allowances prices. The lagged emission allowances prices in the Beijing and Hubei ETS pilots have significant impact on their current emission allowances prices.

Conclusions

In conclusion, the general low level of co-integration in China's ETS pilots within the sample period may be due to the different economic development levels, energy structures, and degrees of government supervision in each pilot as well as different choices of sector coverage and market threshold in regional ETS. As the national ETS is at a key stage of construction, greater attention should be paid to exploring reasons for differences among the regional pilot carbon markets, to improve market mechanisms.

This paper describes the market architecture of China's pilot carbon markets and carries out an empirical analysis of market co-integration. Not only does this procedure provide a platform for performing detailed static analysis, it also takes advantage of the dynamic time-varying correlation among the five major ETSs, so that the results will be closer to reality. In addition, because this study focuses on the early stages of China's regional ETSs, it could motivate and show the path to future carbon markets in developing countries, such as Columbia, Mexico, and Kazakhstan, and the wider research community. Through the novel approaches in the paper, I hope to make meaningful contributions to the existing literature. Nevertheless, statistical models have strong data assumptions, fixed structure, and low accuracy. The powerful artificial intelligence models that capture the nonlinear, complicated relationship among regulation rules and the factors regarding ETS can be considered in future research.
Moreover, the broader literature has been generally silent on environmental justice (EJ) evaluation of carbon pricing. Under the ETS, the factories that spew toxins into the air could buy more emission allowances to pollute; factories could also be relocated to unregulated areas. This raises considerations regarding the large poverty groups and the racial minorities living close to pollution facilities, where they receive increasing environmental burdens. Thus, there has been growing concern from EJ aspects, which has overtaken efficiency evaluations in some sense. In future research I would like to apply different-in-difference research to identify how ETSs differentially affect carbon emissions between controlled and uncontrolled facilities.