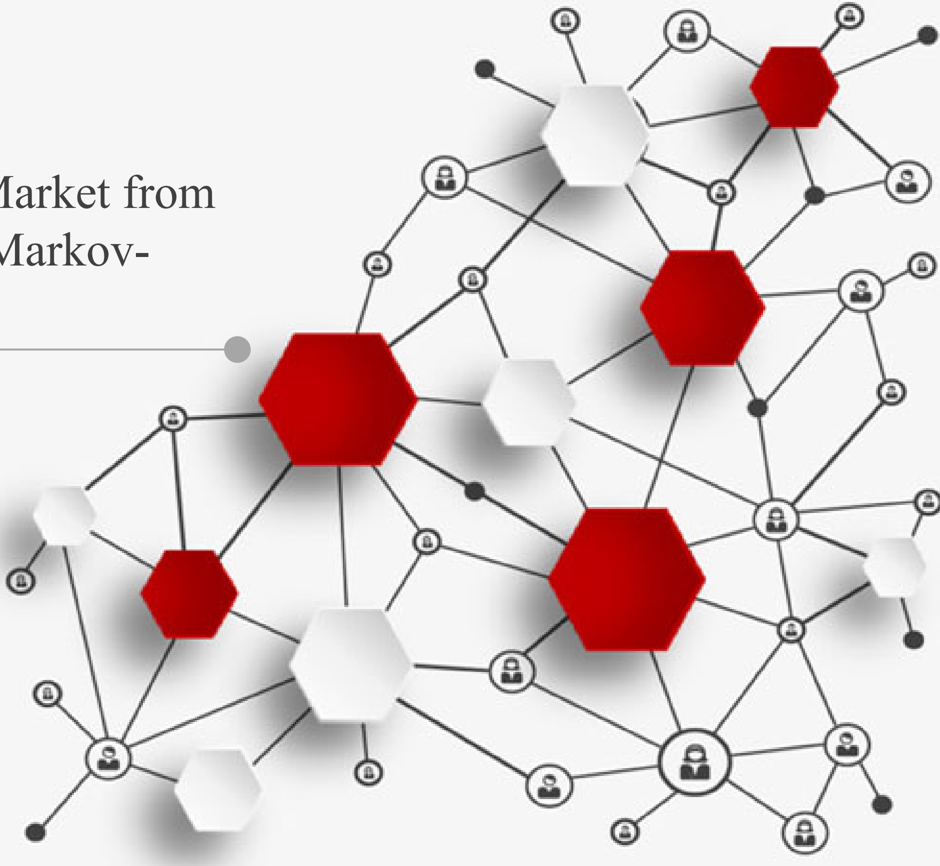
Analysis of Key Factors Influencing Carbon Market from the time-varying perspective evidence with a Markov-switching VAR approach



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[PART ONE]

Introduction

Background

- ✓ **United Nations Framework Convention on climate change**
- ✓ **Kyoto Protocol**
- ✓ **Paris Agreement**
- ✓ **EU carbon emissions trading system**

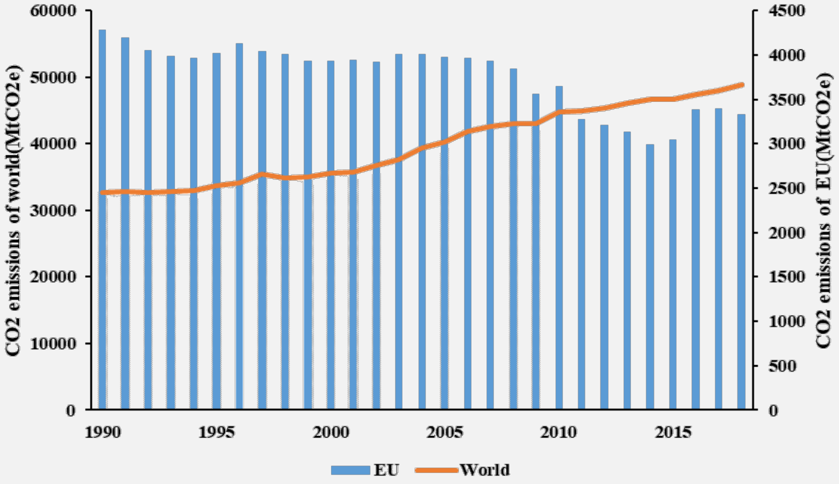

Fig 1-1 The comparation of CO2 emissions

✓ Aggregated demand effect

A fluctuation in energy prices that further affects the change in carbon prices due to the positive shift in the total market demand.

✓ Substitution effect

When the fuel for power generation is changed, the carbon price will fluctuate.

✓ Production restrain effect

When the substitution effect is weak, the high energy price leads to the decline of production and energy consumption, and finally leads to the decline of carbon price.

✓ The industrial production path

the changes to economic growth expectation caused by macroeconomic risk factors can lead to a positive shift in expectation of carbon demand.

✓ The indirect energy price path

Macroeconomic risk factors lead to energy price fluctuations, which can indirectly affect carbon price fluctuations.

Contribution

- ✓ **There are many influencing factors in the energy market and financial market. Which factors are the key determinants?**
- ✓ **What are the time-varying characteristics of different factors and how do they affect the carbon market in different periods?**

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[PART TWO]

Methodology

Methodology

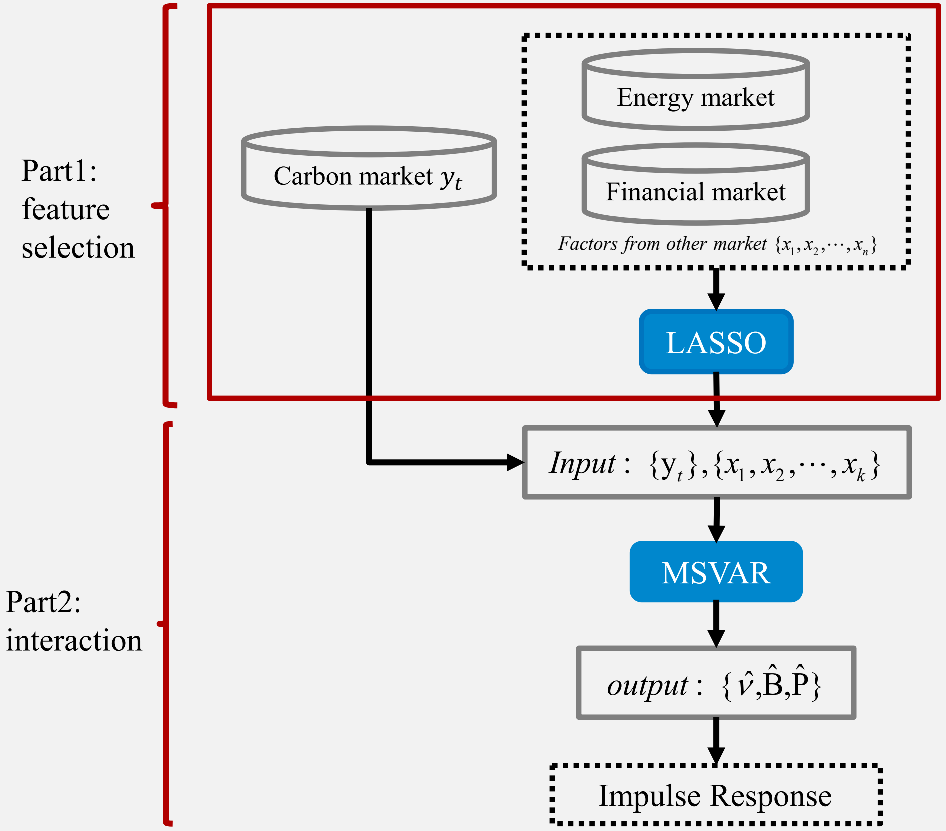

Fig 2-1 Research framework

Methodology

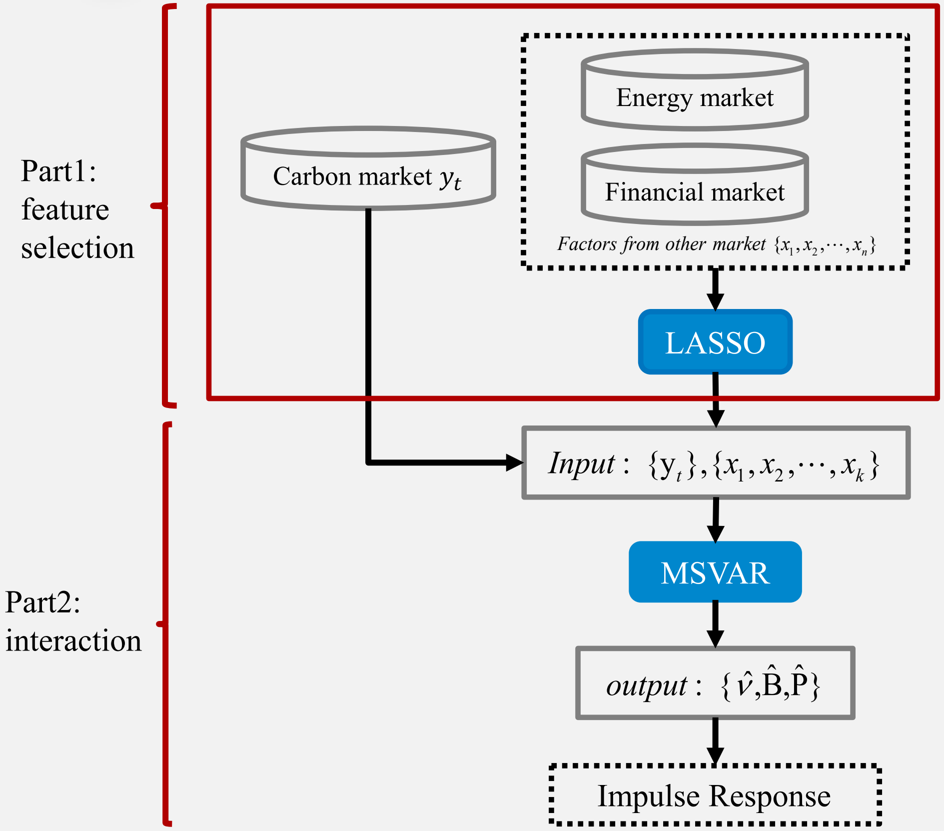

Fig 2-1 Research framework

Least Absolute Shrinkage and Selection Operator

L_1 regularization expression:

$$\hat{\beta}^L = argmin\left\{\sum_{i=1}^{n}\left(y_i - \alpha - \sum_{i=1}^{n}\beta_j x_{ij}\right)^2 + \lambda\sum_j\left|\beta_j\right|\right\}, \lambda > 0$$

Methodology

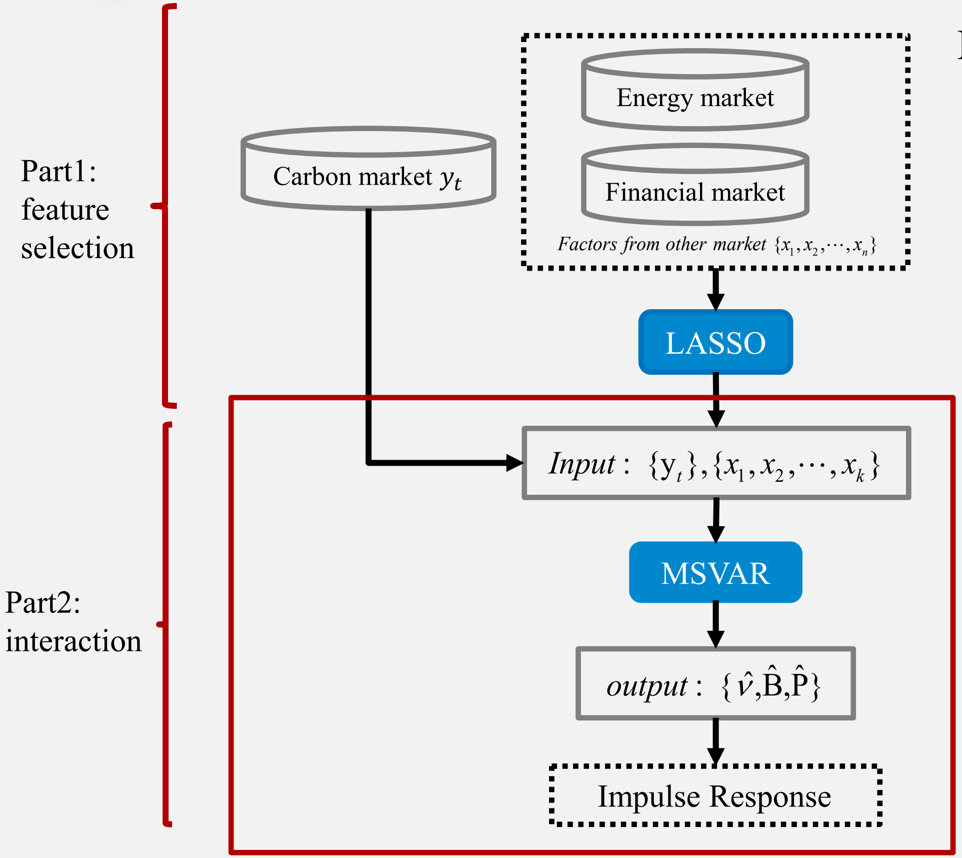

Fig 2-1 Research framework

Markov Switching Vector Autoregressive Model

$$Y_t = \begin{cases} v_1 + B_{11}Y_{t-1} + \cdots + B_{P1}Y_{t-P} + A_1 u_t & if \quad s_t = 1 \\ \vdots & \\ v_m + B_{1m}Y_{t-1} + \cdots + B_{Pm}Y_{t-P} + A_m u_t & if \quad s_t = m \end{cases} \qquad u_t \sim N(0; I_K)$$

$$pr\left(s_{t+1} = j \mid s_t = i\right) = p_{ij} \qquad \sum_{j=1}^{m} p_{ij} = 1$$

$$P = \begin{bmatrix} p_{11} & \cdots & p_{1m} \\ \vdots & \ddots & \vdots \\ p_{m1} & \cdots & p_{mm} \end{bmatrix}$$

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[PART THREE]

Empirical Analysis

Data and description

The European Union (EUA) futures settlement price is selected as the main research object

The sample is the daily data from January 1, 2016 to December 31, 2020

Table 3-1 Time-series data for individual carbon indicators.

Factor	Market	Individual Indicator	Description	Source
Carbon Market Price	Carbon Market	EUA	European Union Allowance future price	European Climate Exchange
Energy Factor	Energy Market	GAS	IPE British Natural Gas Price	The International Petroleum Exchange
		BRENT	Brent Crude Future Price	The International Petroleum Exchange
		COAL	IPE Rotterdam Coal Price	The International Petroleum Exchange
Economic Factor	Bond Market	JUNKBOND	90-day US Treasury bill yield	The Federal Reserve System
		T-BILL	Excess of the yield on corporate bonds rated BAA by Moody's over the yield on AAA-rated bonds	The Federal Reserve System
		ESTB	Euro-area 3-month bond yield	The European Central Bank
		ELTB	Euro-area 10-year bond yield	The European Central Bank
	Stock Market	SP500	S&P 500 Index	Wind Database
		FSTE100	FSTE100 Index	Wind Database
		DAX	DAX Index	Wind Database
		CAC40	CAC40 Index	Wind Database
	Commodity Market	CRB	Commodity Research Bureau Futures Index	Wind Database
	Exchange Market	EUR/RMB	EUR to RMB Exchange Rate	The European Central Bank
		EUR/USD	EUR to USD Exchange Rate	The European Central Bank

LASSO

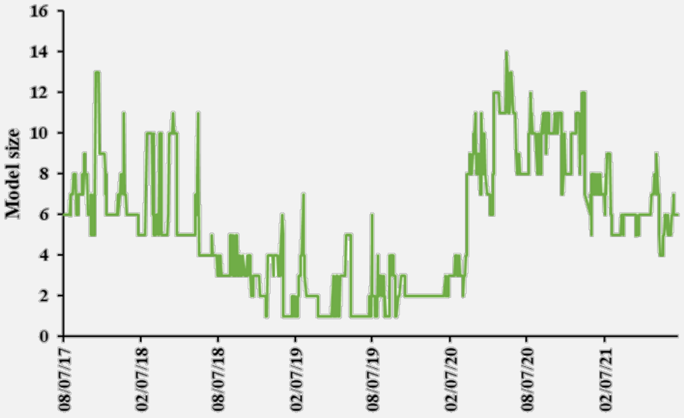


Fig 3-1 The number of selected predictors of the LASSO.

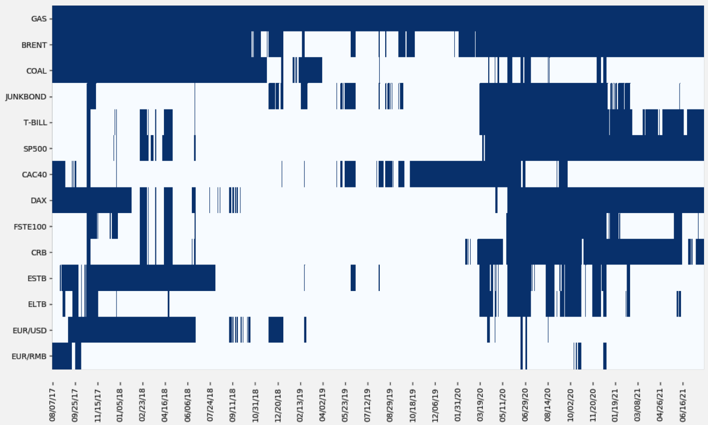


Fig 3-2 Selected predictors of LASSO.

The relevant variables of exchange rate market and bond market are often selected in early stage, and the variables of stock market are selected many times in later stage, the variables of energy market run through the whole period.

Comprehensively considering the situation before and after the COVID-19 pandemic, we take the top five variables GAS (100%), BRENT (75.5%), COAL (41.3%), SP500 (38.5%) and DAX (47.3%) as key determinants.

Parameter Estimation

Table 3-1 MSAH(2)-VAR(1) results.

		EUA_t	GAS_t	$BRENT_t$	$COAL_t$	$SP500_t$	DAX_t
Regimes characteristics							
Duration	Regime1 78.46%						
	Regime2 21.54%						
Volatility	Regime1	0.027	0.028	0.017	0.008	0.006	0.008
	Regime2	0.046	0.057	0.047	0.034	0.021	0.022
Coefficient estimates							
Constant	Regime1	0.002*	-0.000	0.002*	0.000	0.001***	0.001*
		(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
	Regime2	0.002*	-0.000	0.002*	0.000	0.001***	0.001*
		(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
EUA_{t-1}	Regime1	-0.029	-0.018	0.004	-0.015	-0.007	-0.016
		(0.033)	(0.034)	(0.021)	(0.010)	(0.008)	(0.010)
	Regime2	-0.052	-0.059	-0.063	-0.084	0.007	-0.015
		(0.085)	(0.103)	(0.085)	(0.061)	(0.039)	(0.039)
GAS_{t-1}	Regime1	-0.054*	0.074*	-0.021	-0.002	0.004	-0.008
		(0.028)	(0.030)	(0.018)	(0.009)	(0.007)	(0.009)
	Regime2	-0.019	0.089	0.138*	0.259***	0.002	0.009
		(0.067)	(0.086)	(0.069)	(0.051)	(0.031)	(0.032)
$BRENT_{t-1}$	Regime1	-0.149***	-0.002	-0.102***	-0.009	-0.034***	-0.042***
		(0.044)	(0.046)	(0.029)	(0.013)	(0.012)	(0.014)
	Regime2	0.043	-0.044	0.237**	-0.032	0.052	0.095*
		(0.076)	(0.094)	(0.080)	(0.055)	(0.037)	(0.036)
$COAL_{t-1}$	Regime1	-0.052	0.096	0.040	0.064*	0.020	0.027
		(0.070)	(0.072)	(0.042)	(0.026)	(0.016)	(0.021)
	Regime2	-0.097	-0.012	-0.134	-0.125	-0.017	-0.039
		(0.108)	(0.132)	(0.107)	(0.079)	(0.049)	(0.050)
$SP500_{t-1}$	Regime1	0.293*	-0.033	0.097	0.026	-0.043	0.287***
		(0.138)	(0.148)	(0.094)	(0.043)	(0.048)	(0.045)
	Regime2	-0.281	0.040	-0.282	0.024	-0.411***	0.046
		(0.188)	(0.235)	(0.196)	(0.138)	(0.091)	(0.090)
DAX_{t-1}	Regime1	-0.059	-0.164	0.032	0.016	-0.025	-0.139***
		(0.111)	(0.115)	(0.072)	(0.035)	(0.033)	(0.035)
	Regime2	0.173	-0.136	-0.118	0.038	0.063	-0.035
		(0.212)	(0.253)	(0.211)	(0.149)	(0.106)	(0.097)
Std error	Regime1	0.027	0.028	0.017	0.008	0.006	0.008
	Regime2	0.046	0.057	0.047	0.034	0.021	0.022

probabilities	Regime1, t-1	Regime2, t-1
Regime1, t	0.878	0.122
Regime2, t	0.445	0.555

Notes: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels.

These two regimes obviously lead to different estimates of Volatility through standard error: the volatility of regime 2 is significantly higher than that of regime 1.

The estimated coefficient in the low fluctuation period is more significant, and the estimated coefficient is not significant in the high fluctuation state, which may be due to the small amount of data in the high fluctuation state.

MS-VAR

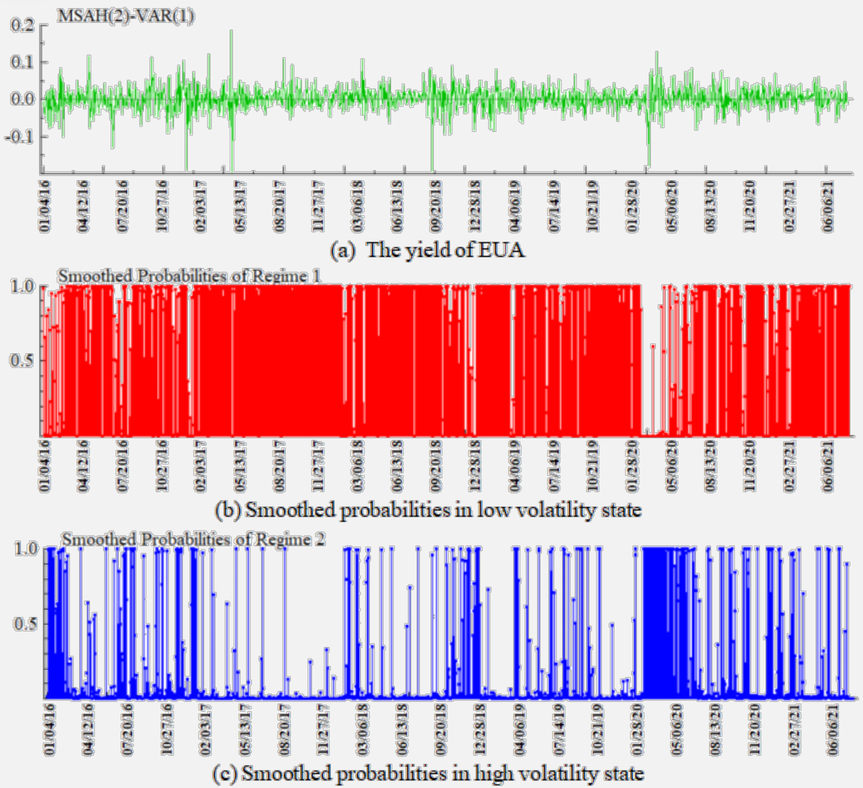
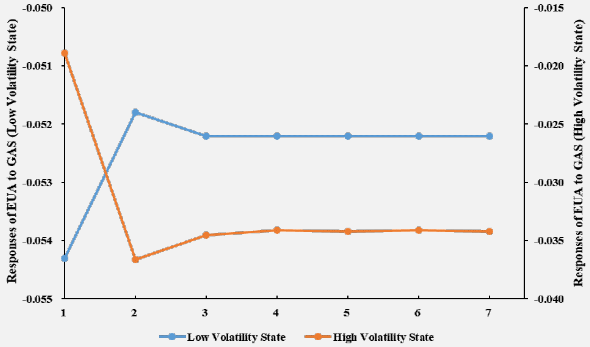


Fig 3-3The yield and smoothed probabilities of EUA.

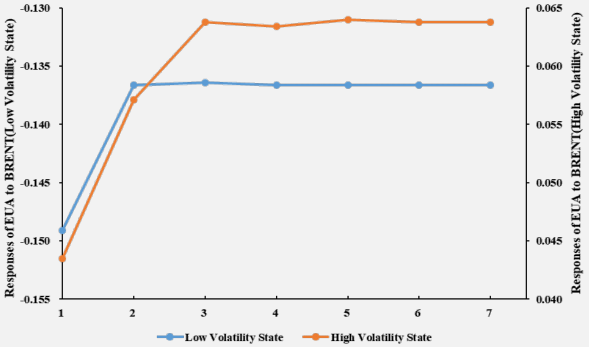
Low volatility state and high volatility state tended to last for an average of 8 and 2 days, respectively, accounting for 78.46% and 21.54% of the samples, respectively.

These findings show that low volatility state has the higher continuous probability, and therefore has strong stability.

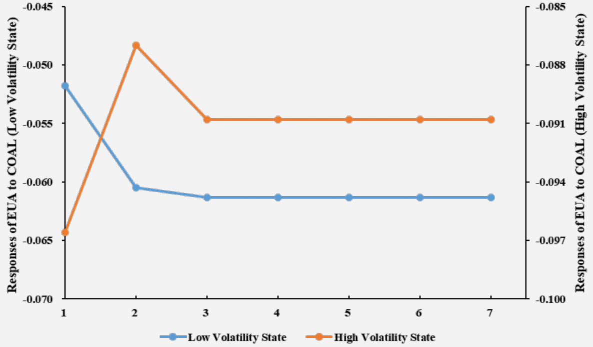
Impulse Response



(a)Cumulative Impulse Responses of EUA to GAS



(b)Cumulative Impulse Responses of EUA to BRENT



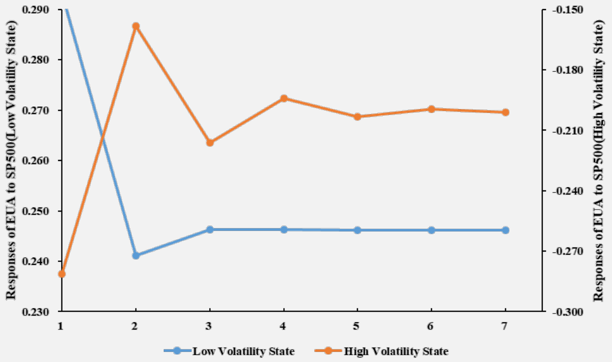
(c)Cumulative Impulse Responses of EUA to COAL

Fig 3-4 Cumulative Impulse Responses of EUA.

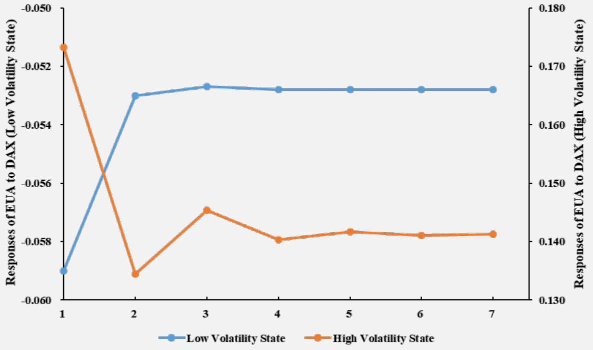
In the energy market, the impact of oil market on carbon market is stronger than that of natural gas market and coal market.

Under the condition of low volatility, we need to pay attention to the positive response of the EU to the impact of energy factors.

Impulse Response



(d)Cumulative Impulse Responses of EUA to SP500



(e)Cumulative Impulse Responses of EUA to DAX

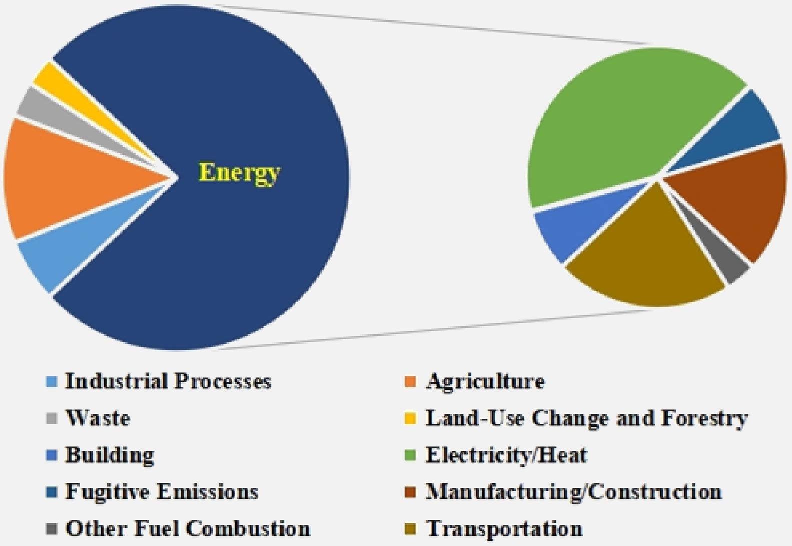
Fig 3-4 Cumulative Impulse Responses of EUA.

In the high fluctuation state, we can notice that the impact of economic factors is relatively strong.

The response of EUA to SP500 index shock is stronger than the impact of energy market factors.

In addition, the response time of EUA to various factors is relatively short, only 3-5 days.

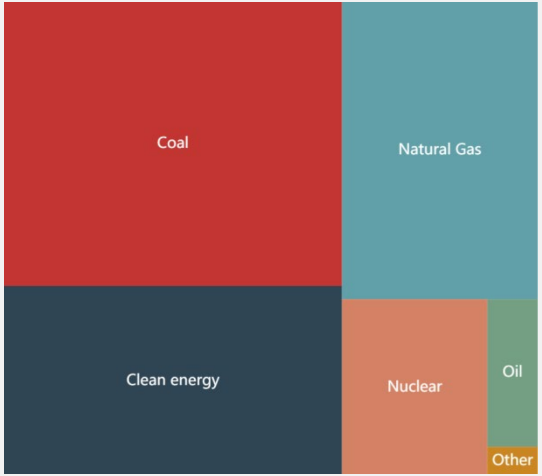
Energy-resource Structure



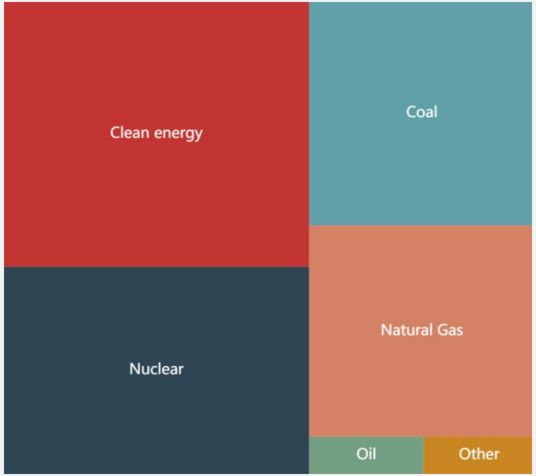
. Fig 3-5 Proportion of GHG emissions in different sectors in 2018.

In 2018, energy consumption accounted for 93% of the total greenhouse gas emissions, of which power generation and heating accounted for 44%.

Energy-resource Structure



(a) power generation sources of World



(b) power generation sources of EU

Fig 3-6 The comparation of power generation sources in 2018.

There are great differences in power generation energy consumption between the world and the EU.

The world's largest power generation energy consumption is coal, while the EU consumes more clean energy. The proportion of clean energy power generation in EU is obviously high.

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[PART FOUR]

Conclusions

Conclusions

- ✓ Energy factors are selected in each period, while economic factors are selected differently in different periods. It shows that energy factors are the long-term influencing factors of carbon market fluctuation, while economic factors have only a short-term impact on carbon market, and economic recession has caused the structural break of carbon price during the COVID-19 pandemic.

- ✓ we use MSVAR model to consider the key factors influencing carbon market from the time-varying perspective. The results show that there are obvious time-varying characteristics and market heterogeneity, in the state of low volatility, we need to pay attention to the positive response of EUA to shocks from energy factors; in the state of high volatility. We can note that the shocks from macroeconomic factors were relatively significant.

- ✓ The government should start with the supply of carbon emission allowance and reduce the discretionary carbon emission allowance. Enterprises need to pay attention to relevant EU policies and make adjustments in advance to avoid the risks caused by rising carbon prices. countries around the world should appropriately adjust the energy structure and transfer to renewable energy to achieve low-carbon emissions.

Thank you!