

Dynamic analysis on market structure of China's coal industry



Qing Yang, Lei Zhang*, Xin Wang

School of Management, China University of Mining and Technology, Xuzhou 221116, PR China

ARTICLE INFO

Keywords:

Coal industry
Market structure
Market concentration
Factors
Dynamic analysis

ABSTRACT

According to industrial organization theory, market structure is a crucial factor to market performance. Based on the VAR model and the data from 1994 to 2014, we revealed the dynamic response route of the market structure to these factors and the change process of contribution rate of these factors to the market structure. It shows that market structure is inertial adjustment; technology advance and industry policy have continuous effects on improvement of market concentration ratio; market size and production scale have sustained negative effects on market concentration ratio; fixed capital has barrier effect, which is mainly the entry barrier effect at the beginning, and then the exit barrier effect continues to play a leading role. Therefore, the government has no need to introduce special policies to encourage merger or expansion on the capacity as enterprises would do it spontaneously; it is necessary to make market access system stricter, to improve exit compensation mechanism and to promote technological innovation; all these policies need dynamic adjustment based on the stages of economic cycle.

1. Introduction

As China's basic energy, coal plays an important role in China's economic development and national energy security. Throughout the history of China's coal industry, the market structure of low concentration has been a major obstruction for the development of the coal industry. As the state had actively developed small coal mines from the early 1980s to the middle of 1990s, state key coal mines, local state coal mines, and small coal mines of all types were accounted for 36.6%, 16.3% and 47.1% of the total output and concentration ratio of the top eight companies was only 11% (Fig. 1), belonging to decentralized competitive market structure in 1997. Since then, China coal industry has become the "small, scattered, chaotic" market structure. Since the late 1990s, low concentration brings about increasingly serious negative effects, including frequent accidents, low technology, disordered production and surplus production driven by a large number of small mines especially illegal ones. With the outbreak of the Asian financial crisis in 1997, China's coal industry was seriously threatened with massive overcapacity and a loss of 400 and 1800 million yuan respectively in 1998 and 1999. With the booming coal demand from 2002 to 2012, coal enterprises had made increased profit gradually. However, the low concentration and decentralized operation led to unordered competition, dramatically increasing coal production and enormous waste of resources, which damage the basis of the long-term development in the coal industry (Wang, 2012). At present, as China's coal market has turn into a rapidly descending channel, the excessive

competition in this market structure has generated price-cutting among coal enterprises, which in turn results in a sharp decline in coal prices and profit with the negative profit growth rate from 2012 to 2015, especially -65% in 2015. In conclusion, the market structure of low concentration has a negative effect on market performance, including lower technology and safety level and excessive competition, which in return caused dramatically increasing production in economic boom and price-cutting among coal enterprises in economic recession.

Furthermore, as the core topic in industry organization theory, there are abundant researches on the relationship between market structure and market performance. Since the hypothesis, the former depends the latter, was put forward in 1959 (Bain, 1959), the positive relationship of concentration ratio, a common indicator of market structure and market performance is verified in banking, insurance, manufacturing and so on (Rhoades, 1982; Frame and Kamerschem, 1997; Maudos, 1996; Bajtelsmit and Bouzouita, 1998; Jacquemin et al., 1980; Conyon, 1995; Gerard et al., 1999), but instability causal, non-monotone linear or negative relationship is found in a few researches (Zaralis, 1991; Yoon, 2004; Bloch, 1994). As for China's coal industry, current researches have a consensus on the benefit of higher concentration ratio to market performance. Chen and Zhou (2010) conclude this positive relationship and the profits from efficiency rather than market power by CDW. Li et al. (2007) finds that higher concentration ratio has significant and positive effect to improve the performance of profit and safety. Chen (2013) further measures the optimal concentration ratio with CR_8 of 53% based on the

* Corresponding author.

E-mail address: mailing126@126.com (L. Zhang).

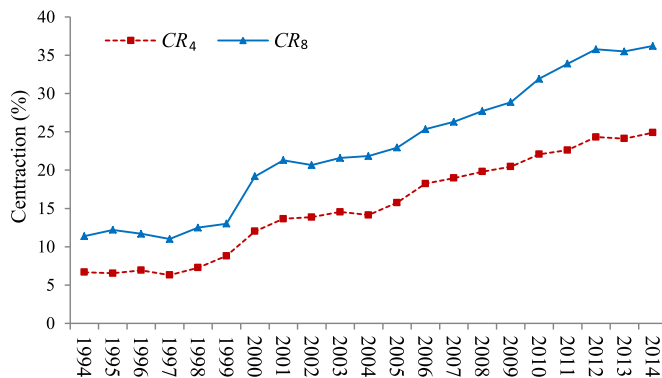


Fig. 1. China's coal market concentration ratio in 1994–2014.

Source: calculation of data from China coal industry yearbook (1982–2013) and China coal industry website (<http://www.coalchina.org.cn/>).

goal to meet national economic development and enterprise profit maximization, implying there is a long way to rise for China's coal market concentration due to under 40% now. These results show higher concentration is beneficial to better market performance at present and for some time in the future.

Therefore, the state issued a series of policies aimed at the promotion of market concentration and the optimization of the market structure, but the market structure of low concentration never changes. The state forced to close mines and depress output, especially small mines in 1998, and focused on large coal bases development since 2003. These policies have promoted market concentration ratio (Fig. 1), but the competitive market structure of China's coal industry still never changes. Therefore, the excessive competition caused by the market structure of low concentration is still a major barrier for the development of China's coal industry. The reasons are that existing policies mainly focus on the cultivation of large- and medium-sized coal enterprises and the close of small coal mines, but the factors of market structure is complicated, which also includes market size, barriers to entry, production scale, technical innovation level, etc. (Wang and Li, 2012; Chen, 2013). As a consequence, it is the key of the transformation from competitive to monopolistic market structure to reveal the key factors of the market structure in China's coal industry.

As for China's coal market structure, its factors studied include barriers to entry (Li and Shen, 2013; Liu and Zhou, 1998), market size (Li and He, 2000; Wang and Li, 2012), lagging concentration (Wang and Li, 2012), geographical factors (Li and He, 2000), industrial policy (Chen, 2010), etc. Methods adopted are qualitative and quantitative analysis method, such as multivariate regression and gray correlation among which the most common is multiple regression. These methods belong to the static equilibrium analysis, by which it is difficult to reveal influencing strength, functional path and dynamic contribution to the improvement of market structure at different years from each factors although it is easy to get the long-term equilibrium relationship between market structure and its factors. Thus, this limits the reference value for policy which may be implemented more uncertainly and blindly. Specifically, as policy effect changes with time, governments may enhance the efforts of implementation blindly when the policy has not yet worked fully, resulting in a drastic fluctuation in coal economy and market structure in the later year. More dangerously, the policy tends to have a more drastic fluctuation when the policy has a negative effect on the optimization of market structure in short term and a positive effect in the long term.

Furthermore, there may be endogenous and non-stationary in the model of multiple regressions, which destroys the basic hypothesis of classical linear regression model with inconsistent estimation and then affects the credibility of policy advice based on the researches (Chen, 2010). Therefore, it is an urgent need to introduce a dynamic and systematic model to study China's coal market structure to provide reference on the dynamic effects of policy.

The contribution in this article is that dynamic adjustment of market structure driven by its factors and the change of the contribution rate of its factors are revealed by impulse response function and variance decomposition and the deficiency in the multiple regression equation model effectively can be make up for by introducing VAR model (Pervukhina et al., 2014). Those results can be a support for not only the practical and feasible policy design on market structure but the dynamic adjustment of policy in strength in later stages. Therefore, the result is beneficial to the adaptation and the feedback of policies for external environmental changes and the decrease of tentative or choppy reforms, which promotes the upgrade of market structure and the growth of China's coal industry with steady steps.

2. Methodology and data

2.1. VAR model

Vector autoregressive (VAR) was adopted for following reasons. (1) The traditional structural equation describes the relationship between variables based on economic theory. However, current industrial organization theory is not enough to provide a rigorous support for the dynamic relationship between market structure and its factors, and endogenous problem may make the estimation more complex due to the probable mutual causal relationship between market structure and its factors. As a nonstructural equation model, VAR can solve the above problems by the construction of simultaneous equations including the market structure and its factors in current period and lag periods (Pervukhina et al., 2014). (2) Using VAR model, we can analyze the dynamic effect of market structure from its factors shocked by policy with impulse response function and the contribution of its factors to the change of market structure in later periods with variance decomposition.

The mathematical expression of general VAR (P) model is as follows:

$$y_t = \phi_1 y_{t-1} + \dots + \phi_p y_{t-p} + Hx_t + \varepsilon_t, \quad t = 1, 2, \dots, T \quad (1)$$

Where y_t is a $n \times 1$ vector of endogenous variables, p is the lag order, $k \times k$ matrix, ϕ_1, \dots, ϕ_p , and $k \times d$ matrix H are coefficient matrixes to be estimated.

We will identify a specific VAR model and test its stability after choosing reasonable variables of influencing factors, testing stationarity of each sequence and co-integration relationship and determining the lag order below.

Based on the existing results and the characteristics of China's coal industry, there are proxy variable of market structure and possible factors as follows.

- (1) Market structure, measured by an indicator of market concentration ratio, CR_8 . It can be calculated by dividing the raw coal production of the top eight enterprises by the total coal production in China. The reasons why raw coal production is used are as follows. ① The coal production of coal enterprises determines their market share and market power and can truly reflect their market position and competitiveness. Furthermore, with universal diversification of coal enterprises, coal production can distinguish coal section from total scope of business. ② As an popular and standard indicator in the world, CR_8 is convenient not only to measure market structure by current classification method, but compare with those of other countries (Bain, 1959).
- (2) Minimum efficient scale. If the average costs down with expansion of scale, companies will continue to increase production, until the situation where average cost in long-term reaches or closes to the minimum. This scale level is also known as the minimum efficient scale, which realizes economy of scale. On the proxy variable, the average scale of enterprises is adopted instead of minimum efficient scale (Comanor and Wilson, 1967; Greer, 1971; Guth,

- 1971; Porter, 1974; Sawyer, 1971; Lyons, 1980). Some studies find that economy of scale has significantly positive influence on market concentration (Weiss, 1963; Strickland and Weiss, 1976; Hart and Clarke, 1980). However, a research shows that minimum efficient scale has no significant effect in China's manufacturing (Guo and Li, 2014). This result is explained from the following aspects. With dispersed market structure and low market-oriented behavior in China's manufacturing, there is a good deal of irrational entry of enterprises whose scales are under minimum efficient one and the rate of exit is much higher than those of entry at the same period. That is similar to the situation of China's coal market, so it is not included in this research.
- (3) Market size, measured by the change rate of raw coal demand in China. Market size refers to the number of a product or service absorbed by markets in a certain period without the strategy of suppliers or the product price. At a certain minimum efficient scale, an industry with greater demand accommodates more enterprises, resulting in lower concentration ratio. Market size mostly have a significantly negative influence on the concentration ratio (Pashigian, 1969; Hart and Clarke, 1980; Chou, 1986; Ratnayake, 1999; Bhattacharya, 2002), while the studies of Greer (1971), Ornstein et al. (1973), and Kambhampati (1998) show that it has no significantly effect. In the practice during "golden decade" (2002–2012), a lot of small enterprises enter the market with rising demand in China's coal industry. Therefore, it is assumed market size has a negative influence on concentration ratio.
 - (4) Production scale, measured by the change rate on raw coal capacity. Generally speaking, in the industry with rapid expansion of scale, big enterprises are difficult to make full use of all opportunities of expansion, and attract more small enterprises to enter with lower concentration, which has been confirmed by Gratton and Kemp (1977), and Mueller and Hamm (1974). For China's coal market, when the expansion of production scale mainly comes from existing firms, concentration ratio will increase and vice versa, so the influence of production scale on concentration ratio is assumed to be positive or negative.
 - (5) Fixed capital, measured by the fixed capital of national coal enterprise. The more capital the industry requires, the higher barriers to exit it would have. Ratnayake (1999), and Bhattacharya (2002) verifies the positive relationship between per capita capital and market concentration. Yet, The degree of barriers to exit is determined not by all assets, but by sunk costs, a part of fixed assets and fixed assets is adopt in this article due to unavailable sunk costs. In addition, the specificity of fixed capital in coal market to some extent may form large sunk costs, leading to higher exit barrier and lower market concentration. Thus, the total effect depends on the intensity of entry and exit barriers effect.
 - (6) Technology, measured by physical labor efficiency of producer in state key coal mines. As a barrier to entry, the higher requirement at technical level increases the difficulty of entry of enterprises and causes higher concentration ratio. The result of Beattie et al. (2003) shows that technology has a significant effect on market concentration in British audit industry. Peretto (1996) thinks that the improvement of corporate technology can effectively enhance concentration ratio. As for the practice in China's coal industry, large enterprises have higher technology of production than the small one, so it is assumed technology has a positive influence on concentration ratio.
 - (7) The first-lagged market structure. There are inconsistent results in the direction of its influence on the current one. For instance, a research of French's manufacturing shows it has a negative impact on the current one (Jenny and Weber, 1978). However, Levy (1985) thinks it has a positive effect on the current one by analyzing the concentration ratio in the United States from 1963 to 1972. VAR model in this article can reveal the influence of market structure in a certain period on one in the later by impulse

response analysis, so the factors chosen don't have to consider it again.

- (8) Industry policy, which has a significant effect on industry development (Krueger and Tuncer, 1982; Blonigen and Wilso, 2010; Han and Hong, 2014). Obviously, its industry policy also has an important influence on market structure throughout the history of China's coal industry. The concentration ratio had a slightly decline from 1980 to 1997 with the policy of "developing large, medium, and small mines together", and then had a rapid rising from 6.87% in 1997 to 24.89% in 2014 as the state has focused on annexation and reorganization as well as solving the problem of small mines since 1998 (Fig. 1). The industrial policy is quantified based on Libecap (1978), and then a positive or negative value is given to the policy for higher or lower concentration ratio respectively. Thus, industrial policy is assumed to have a positive influence on concentration ratio.

In conclusion, market structure is measured by CR_8 , and its factors includes market size, production scale, fixed capital, technology and industry policy denoted by Q_d , CAP , K , $EFFI$, POL respectively in this market structure model.

2.2. Data

The time span is 21 years from 1994 to 2014 as market structure is an issue in market economy which in coal market has become since 1994. The data of raw coal production in China's top eight enterprises and the total one to calculate CR_8 was from China's Coal Industry Yearbook (1982–2013) and China coal industry website (<http://www.coalchina.org.cn/>). Data on physical labor efficiency of producer in state key coal mines and production scale was obtained from China Coal Industry Yearbook (1982–2013) and the defaults of 2013 and 2014 are supplemented by interpolation. The information of coal consumption and fixed capital were from China Statistical Yearbook (1994–2015). The date of industry policies are from China industry policy website (<http://zc.wefore.com/>). All variables in the model were transformed into logarithmic form to avoid possible heteroscedasticity and multicollinearity.

3. Results and discussion

3.1. Result

3.1.1. Unit root test

In order to test the stationary of sequences, three kinds of unit root tests, ADF, DFGLS and PP, are conducted. Sequences at level are non-stationary series, and those at 1st difference are stationary with significance at 5% or 1% levels in Table 1. Thus, all sequences are integrated of order 1 which can be tested by co-integration.

3.1.2. Johansen co-integration test

The difference is a simple way to solve non-stationary sequences, but the economic meaning of model could be changed after difference. To solve this problem, Engle and Granger proposed the theory and method of co-integration, that is, the linear combination among non-stationary sequences may be a stationary sequence, which is called a co-integration equation. We adopt Johansen co-integration test, a multivariate co-integration method rather than EG test in which a linear model is designed but most of the relationships among economic variables are nonlinear in fact. According to the result of trace and max-eigenvalue test, there are long-term co-integration relationships among market structure, production scale, technology, fixed capital, market size and industry policy at the 0.05 level.

Table 1
Unit root test.^a

Variables	ADF test	DFGLS test	PP test	Conclusion
ln CR _s	-0.76	-0.60	-0.76	Non-stationary
Δ ln CR _s	-4.12***	-4.03***	-4.12***	Stationary
ln K	-0.53	-0.61	-0.31	Non-stationary
Δ ln K	-3.62**	-2.70***	-3.62**	Stationary
ln CAP	-2.52	-2.22	0.14	Non-stationary
Δ ln CAP	-8.55**	-8.13***	-8.97***	Stationary
ln Q _d	-2.05	-2.13	-2.05	Non-stationary
Δ ln Q _d	-4.03***	-4.14***	-4.03***	Stationary
ln EFFI	-1.28	0.30	-1.96	Non-stationary
Δ ln EFFI	-4.47***	-4.25***	-4.65***	Stationary
ln POL	-7.28***	-1.42	-2.50	Non-stationary
Δ ln POL	-5.40***	-4.58***	-4.50***	Stationary

^a “***” and “**” denote significance at 5% and 1% levels respectively; The consistent result of two of them was chosen when three results of the test were diverse.

3.1.3. VAR specifications

- (1) The optimal lag order. The greater number of lag order can reflect more comprehensive dynamic characteristics of the model but may lose more degrees of freedom damaging the effectiveness of parameters. The VAR (1) is established because the best lag order is 1 based on five kinds of criterions in Table 2.
- (2) Robustness test. To ensure the preferred model is well-specified, it is necessary to conduct the stability test of the VAR model. The VAR is stable and can conduct impulse response analysis as inverse roots of AR characteristic polynomial are with the unit circle in Fig. 2.

3.1.4. Generalized impulse response functions

We resort to generalized impulse response functions to reveal dynamic adjustment of market structure in direction and extent in the face of various shocks from its factors in the short and long term. In Fig. 3, the extent of impact of all factors on market structure peaks in the first three years, later becomes weaker gradually and tends to stable in the end. The impact from the shock of market structure itself continues for the shortest time and appears to a convergence to steady state in the 4th year, while the impact from the shock of other factors tends to stabilization in the 6th–8th year.

A positive shock of market structure has a positive effect on itself, which weakens gradually with time and tends to zero after the 4th year. This shows that the viscous effect of the adjustment of market structure decreases gradually and exists for 4 years.

The concentration ratio suffers a negative effect from a positive shock of production scale. There are a slight fluctuation in the first 3 years, later lower impact and a steady state in the 6th with approximate zero steady value.

The concentration ratio shows a positive inverted “U-shaped” response to the positive shock of technology. The largest impact reaches in the fourth year after the shock and there is a steady state in the 8th years with slight negative effect. This illustrates the technology of coal enterprises has become an important factor for the promotion of corporate power and the expansion of market share and further promote higher concentration ratio gradually and then the industry pattern led by large enterprises.

Table 2
Lag selection criteria.^a

Lag order	LogL	LR	FRP	AIC	SC	HQ
0	-60.62	NA	4.48*10 ⁻⁵	7.01	7.31	7.06
1	47.76	136.90*	2.73*10 ^{-8*}	-0.61*	1.48*	-0.25*

^a “*” indicates lag order selected by the criteria.

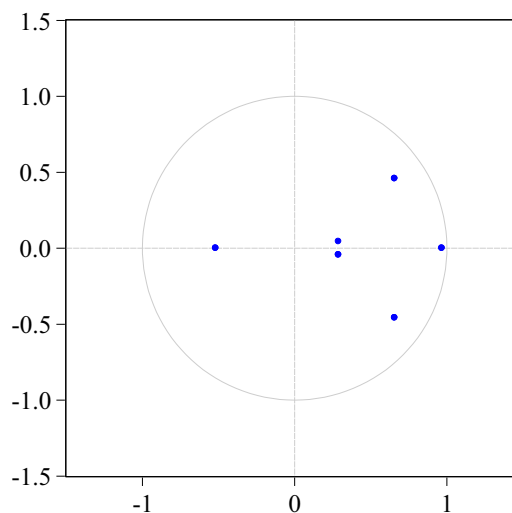


Fig. 2. Inverse roots of AR characteristic polynomial.

Concentration ratio has a negative impact in the first year, then has a callback to the negative effect and tends to steady state rapidly after a positive shock of fixed capital. The negative effect has the longer duration than the positive one in the process, which shows the effect of the barrier to entry is stronger than one of exit in the first year and the latter has played a leading role since the second year.

Concentration ratio shows a negative response to a positive shock of market size in the short and long run. Specially, the power of impact peaks in the third year, later begins with reduction and tends to steady state after the 6th year.

Industry policy has a positive “U” impact on concentration ratio. This impact peaks in the third year, then reduces gradually and tends to steady state in the 8th year, which indicates the significant influence of industry policy on concentration ratio and 7-year deadline of policy effect.

3.1.5. Variance decomposition

The relative importance of the different driving forces of market structure in China's coal industry in short and long run can be obtained by analyzing the proportion of the forecast error variance from each factor in ten years as shown in Table 3. The market structure itself gives the greatest contribution in the both long and short run. Industry policy and technology follow it. The former has a higher proportion than the latter in short run with 5 0.22% and 7.97% proportion in the second year respectively and has a lower one than the latter since the 4th year with 18.59% and 31.22% in the long run. And the proportions of other three factors are under 10% in the short and long run among which that of market size is the lowest. As for trends, production scale, fixed capital and market size have rising, inverted “U” and falling trends respectively.

3.2. Discussion

The adjustment of market structure is of inertia and receives the greatest influence from itself in the both long and short run. Based on the rising concentration ratio of China's coal industrial and this result, we can predict China's coal enterprises will promote concentration ratio spontaneously without external shocks. It shows that coal enterprises have wills and actions to absorb and reorganize small enterprise and expand production scale for more market share and profit. It inspires the government has no need to introduce special policy to encourage merger or expansion of the capacity because enterprises themselves would spontaneously adopt measures to do it, and drive the China's coal industry shift to the oligopolistic market structure.

Technology is the most significant contributor to promote concentration ratio in the short run and long run, apart from the lagged market structure. The positive relationship between concentration ratio and technology in China's coal industry is consistent with that in other countries (Levy, 1985). This shows that China's coal enterprises can obtain the advantage of competition to occupy a larger market share, which enhances concentration ratio by technical innovation and independent intellectual property when other factors are unchanged. As is shown in Fig. 4, the technological advance is of inertia, suggesting that break original balance can be broken by innovation of a few enterprises and other enterprises are induced to maintain a new balance, which makes technical progress follow the path of "balance - unbalance - balance" and promote the virtuous cycle of market structure. In recent years, the decreasing coal price compels the incumbent firms to pay more attention to technology innovation for higher labor efficiency and lower cost. In addition, the higher standard of energy conservation and emissions reduction also appears to improve the technology of clean coal. According to the results of this study, it can be expected that the improvement in technology will be beneficial to the gradual promotion of concentration ratio.

Production scale has a sustained negative effect to concentration ratio. During "Golden Decade" in China's coal industry, the expansion of production scale is more from the entry of small enterprises than expansion of incumbent enterprises, which restrains the promotion of concentration. It implies that low economic and technical barriers to entry and no obvious scale economy in China's coal industry. In recent years, as production scale shrink with the negative shock of demand and policy, the concentration ratio experiences the twofold impact, the weakening inhibition effect of previous eight years and the current pulling effect, and the latter will be strong gradually in the total utility. The pull effect is from two sides below: (1) In the shrinking production scale, the small-sized coal mines have lower barrier of exit with lower fixed capital; (2) Large coal enterprises have more obvious advantages on the payment of downstream enterprises and bank loans than small-sized enterprises which makes small-sized enterprises more likely to exit the market with the breakage of capital chain. It can be predicted the current shrink of production scale will promote the concentration ratio in China's coal industry and drive it to transform for oligopolistic market structure.

Fixed capital has a barrier effect with the larger effect of barriers to entry in the beginning and greater effect of barriers to exit in the long run. The latter comes from two aspects. On the one hand, the specificity of fixed capital in China's coal industry may be formed great sunk costs increasing barriers to exit. On the other hand, the exit of coal mines will hinder the economic development, and lead to a lot of unemployment to some extent without sound compensation mechanism as the production of coal is the main source of economic growth and solving employment in China's some regions. Generally speaking, the barrier to entry is still lower, although the specificity of fixed capital also forms the barriers to entry. For instance, the minimum registered capital standard is low although the registered capital of several coal enterprises amounts up to 10 billion. Coal enterprises in Shandong, for example, are required to have the registered capital of no less than 8 million yuan. Therefore, the effect of barriers to entry from fixed capital is completely offset by the barrier to exit.

Market size has lasting negative effect on concentration ratio, which is consistent with previous results (Wang, 2012; Li and Shen, 2013). Compared with the expansion of incumbent firms, the growth of market demand attracts more capacity from new small enterprises, which reduces the concentration ratio. This shows low barriers to entry in China's coal industry including the relatively low admittance criterion of technology, security and capital and little economy of scale, and the shrinking market size will make more small coal enterprises exit from the market because of the larger barrier to exit in big enterprises, which promotes market concentration ratio. It can be expected that shrinking coal demand since 2012 will drive higher

concentration ratio in the next couple of years and then promote the optimization of the market structure.

Industry policy is the most significant factor of market structure except for lagging market structure in the short run. It indicates that the introduction of related policy is a more effective way to improve market structure than others in the short term. Moreover, the policy effect is of hysteresis and deadline to some extent. It starts to play a role in the second year and becomes obvious in 3th–5th. It manifests the government should make a full consideration of an rising trend for the first four years and an downward trend after the 4th years instead of only current year when assessing or foresting policy effect. According to 7-year deadline of policy effect, the effect is very weak without new related policy introduced in the 8th year.

4. Conclusions and policy implications

Based on the VAR model and time series data from 1994 to 2014, we reveal the dynamic path of the market structure driven by its main factors. The Result shows that market structure is inertial adjustment and enterprises would spontaneously adopt measures to do it, and drive the China's coal industry shift to the oligopolistic market structure; technological advance and industry policy have continuous improvement to concentration ratio; market size and production scale have significant and sustained negative effects on concentration ratio; fixed capital is of the barrier effect, which is mainly the effect of a barrier to entry in the beginning, and then the effect of the exit barrier play a leading role.

According to this result, there are some policy implications to optimize the market structure in China's coal industry:

- (1) The stricter market admittance criterion should be set up. According to the negative relationship between concentration ratio and market size (Fig. 3), the expansion of market size can bring about the entry of a large number of small-sized enterprises, which implies the entry barrier is relatively low. And compared with the admittance criterion of technology in developed countries, such as the United States and Australia, those in China is still low, although including the criterion of production technology, equipment and recovery rate of the resource. Therefore, in order to weaken the inhibitory effect of market size on concentration ratio in economic boom, the government should set up stricter market admittance criterion, especially technology admittance criterion, the most important factor in the long run except for lagging market structure (see Table 3). The stricter admittance criterion of technology is not only beneficial to limit the entry of small coal mines by the increase of barriers to entry, but promote the continuous optimization of market structure by virtuous cycle of technology according to the inertia of technology adjustment (see Fig. 4), which thus benefits to form the industry dominated by large enterprises with advanced technology. According to the result of this article, the effects of those policies of admittance criterion will have a weak effect on the optimization of market structure in the second year, the largest effect in the fourth or fifth and then an effect with a downward trend.
- (2) The exit compensation mechanism should be improved. As is shown in Fig. 3, less production scale and fixed capital can enhance concentration ratio mainly, and more fixed capital plays a dominant role in the reduction of concentration ratio by its exit barrier effect. Besides, one of the reasons of high exit barrier is imperfect market exit compensation mechanism based on the discussion section in this article, and eliminating unadvanced and excess capacity is an important task during the 13th Five-Year-Plan (2016–2020). Thus, it is necessary to perfect exit compensation mechanism for the smooth exit of unadvanced and excess capacity which in return enhances concentration ratio driven by lower exit barrier, as well as less fixed capital and production scale. The state

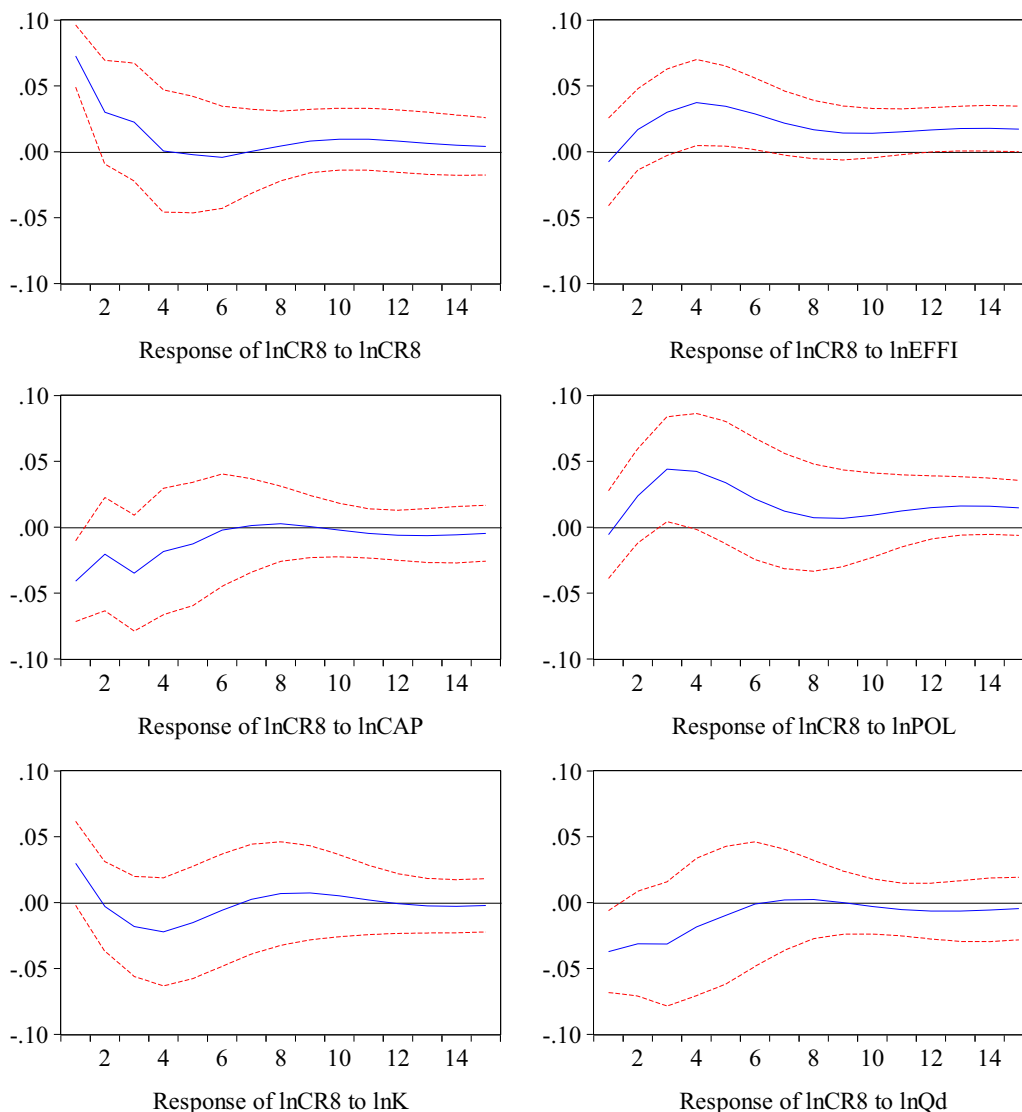


Fig. 3. Response of market structure to its factors.

Table 3
Variance decomposition of factors of market structure in China's coal industry.

Period	S.E.	ln CR ₈	ln EFFI	ln CAP	ln K	ln Q _d	ln POL
1	0.07	100.00	0.00	0.00	0.00	0.00	0.00
2	0.09	79.23	5.22	0.04	4.99	2.56	7.97
3	0.11	58.05	12.74	4.51	7.77	2.09	14.84
4	0.12	45.77	19.75	5.51	8.89	1.98	18.11
5	0.13	40.20	24.51	5.74	8.68	1.74	19.13
6	0.13	37.83	27.57	5.40	8.31	1.64	19.24
7	0.14	36.59	29.29	5.35	8.04	1.66	19.07
8	0.14	35.81	30.20	5.60	7.85	1.70	18.83
9	0.14	35.37	30.74	5.84	7.69	1.71	18.65
10	0.14	35.05	31.22	5.89	7.56	1.70	18.59

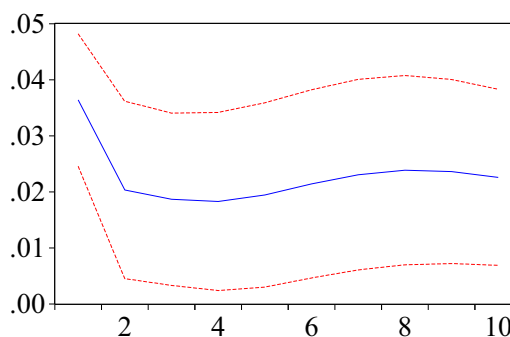


Fig. 4. Response of technology to itself.

should set special exit subsidy fund for skill train of re-employment, basic living expenses, economic compensation to those are near to statutory retirement age and willing to retire, as well as the payment of basic endowment and medical insurance premium by a special institution. In addition, the state should build quantitative criteria of compensation and supervise its implementation. It has positive effect on the smooth exit of coal mines with unadvance technology and poor management, which in return promote higher

concentration ratio and sustainable development of coal industry.
(3) The incentive mechanism of technology innovation should be promoted. Technology is the most significant contributor to the optimization of market structure in long run except for the lagging market structure in Table 3. At present, the technological innovation has become increasingly large-scale and high risk which can't be independently undertaken only by enterprises, so overall technology of China's coal mines is relatively backward, especially

the technology of clean coal of being late starters. Therefore the measures of tax incentives for independent innovation can effectively promote technology innovation, the use of high-tech equipment and the formation of virtuous cycle, "innovation - profit incentives - innovation further", and then pull the continuous ascension of the concentration ratio. Based on the results in this article, the policy effectiveness of the technical advance to the adjustment of market structure is limited in the second year, reaches the maximum in the fourth or fifth year and then continues to weaken. The sustaining implementation of the policy, together with the inertial effect of technology and market structure adjustment will promote the virtuous cycle of technical promotion and the continuous optimization of market structure in China's coal industry.

- (4) The policy strength should be dynamically adjusted based on the stages of the economic cycle. According to the negative relationship between market size and concentration ratio in Fig. 3, market can spontaneously reduce and enhance concentration ratio in economic boom and recession respectively. As the supplement of market regulation, the policy strength should be dynamically adjusted based on the stages of the economic cycle for steady promotion of market structure. Specially, in the economic recession, the gliding demand and production can promote concentration ratio and those effects exist mainly in the first six years while the boom of the coal industry will lead to a decline of concentration ratio based on our results. In consequence, more moderate policy for promotion of concentration ratio should be carried out in the depression and recovery to avoid the shock of adjustment of market structure and coal economy; In economic prosperity, as well as the first six years after recession, more robust policy should be implemented to offset the spontaneous effect of decreasing concentration ratio caused by coal market and promote the continuous optimization of market structure and the stable growth in China's coal industry.

Acknowledgements

This work was supported by the Natural Science Foundation of China (No. 71373261).

References

- Bain, J.S., 1959. *Industrial Organization*. Harvard Univ. Press, Cambridge.
- Bajtelmsmit, V.L., Bouzouita, R., 1998. Market structure and performance in private passenger automobile insurance. *Appl. Financ. Econ.* 65, 503–514.
- Beattie, V., Goodacre, A., Fearnley, S., 2003. And then there were four: a study of UK audit market concentration—causes, consequences and the scope for market adjustment. *J. Financ. Regul. Compliance* 11, 250–265.
- Bhattacharya, M., 2002. Industrial concentration and competition in Malaysian manufacturing. *Appl. Econ.* 34, 2127–2134.
- Bloch, H., 1994. Sample-selection procedures for estimating the relationship between concentration and profitability from cross-industry data. *Rev. Ind. Organ.* 9, 71–84.
- Blonigen, B.A., Wilso, W., 2010. Foreign subsidization and excess capacity. *J. Int. Econ.* 80, 200–211.
- Chen, Q., 2010. *Advanced Econometric and Applications of Stata fourth ed.*. High. Educ. Press, Beijing.
- Chen, X.Y., 2013. *Empirical Research on Chinese Coal Industry Concentration*. Nanjing University of Aeronautics and Astronautics, Nanjing.
- Chen, X.Y., Zhou, D., 2010. An empirical study of market concentration of China's coal industry. *Contemp. Financ. Econ.* 303, 80–89.
- Chou, T.C., 1986. Concentration, profitability and trade in a simultaneous equation analysis: the case of Taiwan. *J. Ind. Econ.* 34, 429–443.
- Comanor, W.S., Wilson, T.A., 1967. Advertising market structure and performance. *Rev. Econ. Stat.* 49, 423–440.
- Conyon, M.J., 1995. Industry profit margins and concentration: evidence from UK manufacturing. *Int. Rev. Appl. Econ.* 9, 275–290.
- Frame, W.S., Kamerschem, D.R., 1997. The profit-structure relationship in legally protected banking market using efficiency measures. *Rev. Ind. Organ.* 12, 9–22.
- Gerard, G., Kamerschen, D., Delorme, C., 1999. Market structure and price–cost margins in Philippine manufacturing industries. *Appl. Econ.* 31, 857–864.
- Gratton, C., Kemp, J.R., 1977. Some new evidence on changes in U.K. industrial market concentration 1963–1968. *Scott. J. Polit. Econ.* 24, 177–181.
- Greer, D.F., 1971. Advertising and market concentration. *South. Econ. J.* 38, 18–22.
- Guo, S.L., Li, Q.H., 2014. A study on the dynamic changes in the market clustering of China's manufacturing industry and the influencing factors. *Economist* 3, 25–36.
- Guth, L.A., 1971. Advertising and market structure. *J. Ind. Econ.* 19, 179–198.
- Han, Q., Hong, Y.M., 2014. National industrial policy, asset price and investor behavior. *Econ. Res. J.* 12, 143–158.
- Hart, P., Clarke, R., 1980. *Concentration in British Industry*. Cambridge Univ. Press, Cambridge, 1935–1975.
- Jacquemin, A., Ghellinck, E.D., Huvener, C., 1980. Concentration and profitability in a small open economy. *J. Ind. Econ.* 29, 131–144.
- Jenny, F., Weber, A.P., 1978. The determinants of concentration trends in the French manufacturing sector. *J. Ind. Econ.* 26, 193–207.
- Kambhampati, S., 1998. Market structure dynamics in Indian industry. *Bull. Econ. Res.* 50, 133–153.
- Krueger, A.O., Tuncer, B., 1982. An empirical test of the infant industry argument. *Am. Econ. Rev.* 72, 1142–1152.
- Levy, D., 1985. Specifying the dynamics of industry concentration. *J. Ind. Econ.* 34, 55–68.
- Li, P.L., Shen, Y., 2013. Research on the influential factors of the western coal industrial concentration based on grey correlation. *Stat. Inf. Forum* 5, 56–62.
- Li, Y.M., et al., 2007. Positive analysis on concentration and performance of China coal industry. *J. Beijing Jiaotong Univ. (Soc. Sci.)* 6, 11–14.
- Li, Y.X., He, J.H., 2000. Coal market structure, behavior and effect. *Manag. World* 5, 196–197.
- Libecap, G.D., 1978. Economic variables and the development of the law: the case of western mineral rights. *J. Econ. Hist.* 38, 338–362.
- Liu, W., Zhou, M., 1998. The adjustment of market structure from the barriers of entry and exit in coal industry. *Coal Econ. Res.* 9, 13–15.
- Lyons, B.R., 1980. A new measure of minimum efficient plant size in U. K. manufacturing industries. *Economica* 47, 19–34.
- Maudos, J., 1996. Market structure and performance in Spanish banking using a direct measure of efficiency. *Appl. Financ. Econ.* 8, 191–200.
- Mueller, W.F., Hamm, L.G., 1974. Trends in industrial market concentration, 1947–1970. *Rev. Econ. Stat.* 56, 511–520.
- Ornstein, S.I., Weston, J.F., Intriligator, M.D., Shrieves, R.E., 1973. Determinants of market structure. *South. Econ. J.* 39, 612–625.
- Pashigian, B.P., 1969. The effect of market size on concentration. *Int. Econ. Rev.* 10, 291–314.
- Peretto, P.F., 1996. Sunk costs, market structure and growth. *Int. Econ. Rev.* 37, 895–923.
- Pervukhina, E., Emmenegger, J.F., Golikova, V., Osipov, K., 2014. An optimization technique based on a vector autoregression model with state space representation: application to Ukrainian cargo transport data. *Optimization* 63, 93–108.
- Porter, M.E., 1974. Consumer-behavior, retailer power and market performance in consumer-goods industries. *Rev. Econ. Stat.* 56, 419–436.
- Ratnayake, R., 1999. Industry concentration and competition: New Zealand experience. *Int. J. Ind. Organ.* 34, 429–443.
- Rhoades, S., 1982. Redistribution effects of output due to monopoly in banking. *J. Monet. Econ.* 9, 375–387.
- Sawyer, M.C., 1971. Concentration in British, manufacturing industry. *Oxf. Econ. Pap.* 23, 352–383.
- Strickland, A.D., Weiss, L.W., 1976. Advertising, competition, and price–cost margins. *J. Polit. Econ.* 84, 1109–1121.
- Wang, B.W., 2012. *The Researches on China's Coal Industry Centration and Policy*. Beijing Jiaotong University, Beijing.
- Wang, B.W., Li, W.X., 2012. China's coal industry concentration and its influencing factors. *Product. Res.* 5, 168–169.
- Weiss, L.W., 1963. Factors in changing concentration. *Rev. Econ. Stat.* 45, 70–77.
- Yoon, S., 2004. A note on the market structure and performance in Korean manufacturing industries. *J. Policy Model.* 26, 733–746.
- Zaralis, G., 1991. Profitability, concentration and trade flows: issues of non-linearity and exogeneity. *Rev. Ind. Organ.* 3, 215–229.