6. How Does the Reform in Pricing Mechanism Affect the World's Iron Ore Price: A Time-varying Parameter SVAR Model

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Abstract

This paper employs a time-varying parameter structural vector autoregressive (TVP-SVAR) model to examine the dynamic impact of the reform of the pricing mechanism on the world's iron ore price, drawing on the data from January 2005 to December 2021. The empirical results indicate that (1) the volatility of iron ore price has increased dramatically since the introduction of quarterly pricing mechanism based on spot price; (2) the reform of pricing mechanism changes the environment of iron ore market, and the iron-ore trading market has been obviously a shift from a seller's market to a buyer's market; (3) during the quarterly pricing mechanism, the iron ore price responds quickly to the supply and demand situation of the global market, and the strong demand in China replaces the BIG-3 supply as the key factor of the price of iron ore. Furthermore, reducing effect of speculation can be attributed to a more transparent pricing mechanism based on spot price and the advancement of the technological level. Based on the findings, the policy should focus on decreasing the strong demand for iron ore by improving the utilization ratio of scrap steel and by increasing overseas investment.

Keywords: iron ore price; pricing mechanism; TVP-SVAR; time-varying effect; spot price

JEL Classification: D43, L72, Q31

1. Introduction

Iron ore, as the world's largest bulk commodity, plays a key role in industrial production and manufacturing, and the stability of iron ore price is particularly important for national security and social stability, because price volatility can raise the average cost to importers as well as potentially reduce overall socioeconomic welfare (Milstein and Tishler, 2015). With the

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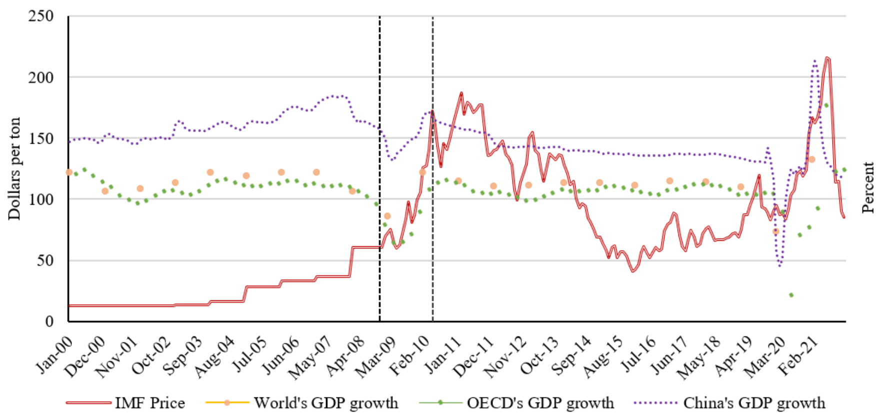
rapid industrialization and urbanization in the developing and emerging countries, the international iron ore price driven by huge demand ranged from a low of \$12.5 per ton in 2000 to a high of \$187.2 per ton in early 2011, which was more than tenfold. This scenario is of great concern, because the elevated price of iron ore likely brings a negative impact to output growth in resource-hungry countries. Figure 1 shows that the economic growth of the world and the OECD slowed down sharply when iron ore price skyrocketed during 2010-2011. It is worth noting that the economic growth in China was slowed down significantly with the high iron ore price during 2010-2011, from 11.8% in January 2010 to 8.3% in December 2011. The adverse impact of the iron ore price on the economic growth has attracted extensive attention to the role of pricing mechanism in restraining price fluctuation.

Figure 1

IMF Price of Iron Ore and the Economic Growth Rates



Notes: The first vertical line presents the introduction of spot price, and the second line presents the date of pricing mechanism change.

Source: WIND database (2022), National Bureau of Statistics (2022).

The international iron ore market has long adopted the annual pricing mechanism, and this pricing system was beneficial not only to the iron ore sellers but also to the buyers, because it has the characteristics of low price and low volatility simultaneously. However, the surging demand for iron ore in China creates a parallel spot market, and the sheer amount of iron ore is traded on spot market (Bhattacharyya and Deepak, 2012). To regain control of iron ore pricing power, the Big-3 abandoned annual pricing in favor of a more flexible quarterly pricing mechanism. The change in pricing mechanism has triggered extensive studies on the relationship between pricing mechanism and international iron ore price, and it is commonly believed that the pricing mechanism has a significant impact on the iron ore market. Nonetheless, no consensus concerning the reform of pricing mechanism on price has been reached. For instance, the European steel industry strongly opposes the introduction of spot price of iron ore, because they argue that spot pricing mechanism surely results in more volatile price of iron ore and downstream industries (Blas, 2010). Gu *et al*. (2019) claim that the annual pricing system is conducive to maintaining price stability of iron ore, while the volatility of the spot iron ore price tends to enlarge. Conversely, Ma (2013) finds that iron ore price has tended to be less volatile after the change of the pricing mechanism. Moreover, Wårell (2014) points out that the reform of the pricing mechanism has no obvious impact on the volatility of iron ore price.

The significant differences in the above conclusions can be attributed to two reasons. On the one hand, many scholars employ static models including the OLS model (Wårell, 2014), the EGARCH model (Ma, 2013), the VECM model (Gu *et al*., 2019), but the dynamic effect of macroeconomy is neglected. As a matter of fact, some recent studies reveal the time-varying nature of international iron ore market (Chen and Yang, 2021; Cross and Nguyen, 2018). Given the wildly fluctuating iron ore price and macroeconomy, it is necessary to employ a TVP-SVAR-SV model to investigate whether the effect of pricing mechanism on iron ore price is time-varying. On the other hand, most of previous studies only focus on a single pricing mechanism or its reform when evaluating its effect on international iron ore market (Wårell, 2018; Gu *et al*., 2019), leading to difficulty in the overall understanding of the effects of pricing mechanism on iron ore market. In fact, international iron ore is determined by many different factors, such as growing demand, restricted supply, China's economy, pricing system, and so on (De Angele, 2011; Pustov *et al*., 2013; Zhu, 2012). In this context, it is critical to illustrate what factor plays a vital role in price fluctuation and whether the key factor has changed after the reform of the pricing mechanism. To summarize, this paper uses the time-varying parameter SVAR model to examine the extent to which key factors influence the iron ore price. Afterwards, the impacts of two pricing mechanisms on international iron ore price are measured by the method of discrete break.

This paper has the following two main contributions. First, economic studies of the relationship between pricing regime and price are mainly focused on the world oil market, but there are few researches regarding the iron ore market. Recently, some studies on the pricing mechanism have examined how the reform of pricing mechanism can affect market power and which direction the pricing mechanism will go (Li and Zou, 2011; Zhu *et al*., 2019). However, it remains unclear how the reform of pricing mechanism affects the world's iron ore price. Therefore, it is essential to fill in the gap associated with the impacts of traditional factors and two pricing mechanisms on the international iron ore price. Second, the TVP-SVAR-SV model is adopted to evaluate the dynamic impacts of the pricing mechanism on international iron ore price, which establishes an extremely dynamic perspective for capturing the influence effects of pricing system.

The rest of this paper is structured as follows: Section 2 presents literature review. Section 3 provides the methodology. Section 4 describes the data and analyzes the empirical results, and further discussion is presented in Section 5. Section 6 reveals the main conclusions.

2. Literature Review

Many scholars have conducted extensive discussions on the factors that have an effect on the world's iron ore price, primarily from the perspectives of market structure and supplier-buyer relation. In fact, there are a host of factors contributing to the price surge of iron ore, such as strained supply, strong demand, market speculation, freight rate and mechanism reform (Astier, 2015; Germeshausen *et al*., 2018; Wårell and Lundmark, 2008; Wårell, 2018). Iron ore is a non-renewable resource, and its price is largely determined by the supply-demand fundamentals in long term (Tilton, 2014). However, speculation and transport costs also play pivotal roles in the soaring price of iron ore. Market speculation can easily push up the world's iron ore price by using financial derivatives, such as iron ore swaps (Bhattacharyya and Deepak, 2012). The rise in iron ore price may not be possible without a high freight rate. A recent paper by Hurst (2015) reveals that iron ore resource has fairly high trade elasticity with respect to transport distance, and transport costs will directly put upward pressure on iron ore price. Additionally, the pricing mechanism has a non-negligible effect on the world's iron ore price. The European steelmakers argue that the quarterly pricing system may not truly reflect fundamentals of supply and demand in the iron ore market (Blas, 2010).

The super-cycle proponents state that the spiraling iron ore price is triggered by demand growth in the booming emerging economies, especially in China (Cuddington and Jerrett, 2008；Heap, 2005). As a matter of fact, China' s imports of iron ore quadrupled between 2005 and 2017, increasing sharply from 275.3 million tons to 1,075.4 million tons. The serious imbalance between supply and demand of the iron ore market is caused by the soaring demand, and market property is transformed gradually into a seller's market (Kirk, 2007). The urbanization and industrialization of China is the major trigger of the spike in world iron ore price, and future developments in iron ore price also depend on China's economic outlook (Hellmer and Ekstrand, 2013; Yu, 2011). Wårell (2014) proves that China's GDP has the highest impact on international iron ore price, both in short and long term. Moreover, Wårell (2018) investigates if the findings of the previous researches still hold when the commodity boom has come to an end in 2014, which is an extension of Wårell (2014), and the finding that China's GDP has a highly significant effect on international iron ore price remains robust. As a consequence, the GDP growth in China is another contributor to price fluctuations. With the flourish development of iron and steel industry, strong growth in underlying demand and tight supply allows the price of iron ore to soar recently (Sukagawa, 2010; Wilson, 2012).

Monopolistic supply is another factor giving rise to a sharp spike in iron ore price (Humphreys, 2010; Ou, 2012; Wårell, 2007). At the beginning of the twenty-first century, the iron ore market has formed the structure of highly monopolization by BIG-3 players after a round of merger and acquisition activity. The high level of supply-side concentration reflects the BIG-3's grip on the world's iron ore industry (Germeshausen *et al*., 2018). Specifically, nearly 80% of global trade and more than 70% of seaborne trade are in the hand of the BIG-3. Furthermore, the BIG-3 can drive up the iron ore price by restricting supply and manipulating the shipping market, obtaining a high price premium (Pustov *et al*., 2013). Germeshausen *et al*. (2018) proves that major producers of iron ore exercise market power to push price up by 20 percent.

Besides, speculative action and freight rates can also have impacts on the world's iron ore price (Wårell, 2018; Zhu, 2012). With the development of financial market, the influence of speculation on iron ore price is not negligible. More specifically, excessive speculation will lead to a widening of the gap between supply and demand, and the imbalance between supply and demand drives up iron ore price. Etienne (2016) demonstrates that there are speculative bubbles in the iron ore market, and the recent sharp spike in iron ore price is driven by excessive speculation. Furthermore, due to the low value-to-weight ratio, freight rates account for a large portion of import price (Gu *et al*., 2019; Robertson and Robitaille, 2017). Consequently, freight rates can put upward pressure on import price of iron ore (Chen *et al*., 2016).

Along with escalating price of iron ore after the change of the pricing mechanism, close attention is gradually paid to the influence of pricing mechanism on iron ore price. The iron ore pricing mechanism, for a long time, was an annually determined fixed pricing mechanism, and its principal effect was to maintain the order of iron ore market and avoid excess volatility in world iron ore price. Nevertheless, as China's demand for iron ore surges, substantial amounts of iron ore are traded at spot price in the Asian market, and international iron ore market finally saw the 2010's shift from the annual pricing system to quarterly contracts based on spot price (Wilson, 2012; Bhattacharyya and Deepak, 2012). With the introduction of the new pricing mechanism, there are growing concerns about price spikes and high volatility. The quarterly pricing mechanism based on spot price is considered as less transparent, which makes hard to maintain price stability (Wårell, 2014). Many scholars confirm that the effect of pricing mechanism on world's iron ore markets cannot be overlooked (Su *et al*., 2017; Zhu *et al*., 2019).

This paper explores the dynamic relations between the world's iron ore price and its main determinants (demand, supply, speculation, China' s economy and pricing mechanism), and the influence mechanism of the change of pricing system on the world's iron ore price is further studied.

3. Methodology

Time-varying parameter structural vector autoregressive (TVP-SVAR) model, first proposed by Primiceri (2005), is generalized from the structural VAR model. Compared with the SVAR model, the TVP-SVAR model can reflect dynamic random information by permitting coefficients and variance-covariance matrix vary with time. Moreover, the time-varying coefficients can capture nonlinear characteristics among the five key variables.

First, a general form of the structural VAR model can be expressed as:

$$Ay_t = C_1 y_{t-1} + C_2 y_{t-2} + \cdots + C_s y_{t-s} + u_t, t = s+1, \cdots, n \quad (1)$$

where: y_t is a $k \times 1$ vector of the observed variables, and A is a $k \times k$ parameter matrix. $C, \cdots, C_s$ are $k \times k$ matrices of coefficients, and u_t is the $k \times 1$ structural shock vector. We assume that $u_t \sim N(0, \Sigma\Sigma)$.

where:

$$\Sigma = \begin{bmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \sigma_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_k \end{bmatrix}$$

Moreover, is required that A is a lower-triangular matrix.

$$A = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1} & \cdots & a_{k,\,k-1} & 1 \end{bmatrix}$$

Furthermore, on the basis of Equation (1), the reduced form SVAR model is proposed as follows:

$$y_t = B_1 y_{t-1} + B_2 y_{t-2} + \cdots + B_s y_{t-s} + A^{-1} \sum \varepsilon_t, \varepsilon_t \sim N(0, I_k) \quad (2)$$

where: $B_i = A^{-1} C_i,\ i = 1, \cdots, s$. Stacking the elements in the rows of B_i to form β in the Equation (2), and the model can be rewritten as:

$$y_t = X_t \beta + A^{-1} \sum \varepsilon_t \quad (3)$$

We define $X_t = I_k \otimes (y'_{t-1}, \ldots, y'_{t-s})$, Where $\otimes$ represents the Kronecker product. In order to get the time-varying model, the parameters in equation (3) ought to change over time. Consequently, the time-varying parameter SVAR model can be expressed as:

$$\mathrm{y_t} = \mathrm{X}_t\beta_t + \mathrm{A}_t^{-1}\textstyle\sum_t \varepsilon_t\,, t = s+1, \cdots, n \qquad (4)$$

where: the parameters β_t, A_t and Σ_t are time-variant.

In this paper, we assume that all variables (Asian demand, the BIG-3 supply, China's economy and speculation) have direct impacts on the world's iron ore price. Specifically, the equation (4) can be written as:

$$\begin{aligned}
InPrice_{i,t} &= a_{10} + \sum_{i=1}^{n}\beta_{11}In\ Demand_{i,t-i} + \sum_{i=1}^{n}\beta_{12}In\ Supply_{i,t-i} + \sum_{i=1}^{n}\beta_{13}In\ China's\ GDP_{i,t-i} \\
&+ \sum_{i=1}^{n}\beta_{14}In\ Speculation_{i,t-i} + \mathrm{A}_t^{-1}\sum\nolimits_t \varepsilon_t \\
In\ Demand_{i,t} &= a_{20} + \sum_{i=1}^{n}\beta_{21}In\ Price_{i,t-i} + \sum_{i=1}^{n}\beta_{22}In\ Supply_{i,t-i} + \sum_{i=1}^{n}\beta_{23}In\ China's\ GDP_{i,t-i} \\
&+ \sum_{i=1}^{n}\beta_{24}In\ Speculation_{i,t-i} + \mathrm{A}_t^{-1}\sum\nolimits_t \varepsilon_t \\
In\ Supply_{i,t} &= a_{30} + \sum_{i=1}^{n}\beta_{31}In\ Price_{i,t-i} + \sum_{i=1}^{n}\beta_{32}In\ Demand_{i,t-i} + \sum_{i=1}^{n}\beta_{33}In\ China's\ GDP_{i,t-i} \\
&+ \sum_{i=1}^{n}\beta_{33}In\ Speculation_{i,t-i} \\
&+ \mathrm{A}_t^{-1}\sum\nolimits_t \varepsilon_t \qquad (5) \\
In\ China's\ GDP_{i,t} &= a_{40} + \sum_{i=1}^{n}\beta_{41}In\ Price_{i,t-i} + \sum_{i=1}^{n}\beta_{42}In\ Demand_{i,t-i} + \sum_{i=1}^{n}\beta_{43}In\ Supply_{i,t-i} \\
&+ \sum_{i=1}^{n}\beta_{44}In\ Speculation_{i,t-i} + \mathrm{A}_t^{-1}\sum\nolimits_t \varepsilon_t \\
In\ Speculation_{i,t} &= a_{50} + \sum_{i=1}^{n}\beta_{51}In\ Price_{i,t-i} + \sum_{i=1}^{n}\beta_{52}In\ Demand_{i,t-i} + \sum_{i=1}^{n}\beta_{53}In\ Supply_{i,t-i} \\
&+ \sum_{i=1}^{n}\beta_{44}In\ China's\ GDP_{i,t-i} + \mathrm{A}_t^{-1}\sum\nolimits_t \varepsilon_t
\end{aligned}$$

The method of Primiceri (2005) and Nakajima (2011) is adopted to model the process of parameters, let a_t be a stacked vector of the lower triangular elements in A_t. The following form can be obtained:

$$a_t = (a_{21}, a_{31}, a_{41}, \cdots, a_{k,k-1})^T, h = (h_{1t}, \cdots, h_{kt})^T \qquad (6)$$

where: $h_{it} = log(\sigma_{it}^2), i = 1\cdots, k$, and $t = s+1, \cdots, n$. The parameters of Equation (4) are in accord with the random walk process:

$$\beta_{t+1} = \beta_t + \mu_{\beta t}$$

$$a_{t+1} + a_t + \mu_{at} \tag{7}$$

$$h_{t+1} = h_t + \mu_{ht}$$

$$\begin{bmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{at} \\ \mu_{ht} \end{bmatrix} \sim N \begin{bmatrix} 0, & \begin{bmatrix} I & 0 & 0 & 0 \\ a_{21} & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{bmatrix} \end{bmatrix} \tag{8}$$

By combining Equations (4), (6), (7) and (8), the typical time-varying structural VAR model is obtained.

The TVP-SVAR model is imposed some basic assumptions. First, the parameters of the model are assumed to follow the random walk process. Second, we set a certain prior of the initial state following normal distribution, $\beta_{s+1} \sim N(\mu_{\beta 0}, \Sigma_{\beta 0})$, $a_{s+1} \sim N(\mu_{\alpha 0}, \Sigma_{\alpha 0})$ and $h_{s+1} \sim N(\mu_{h0}, \Sigma_{h0})$. Third, Σ_β, Σ_a and Σ_h are the diagonal matrices. Last, A_t is a lower triangular matrix whose diagonal elements are one, and Σ_t is assumed to be a diagonal matrix. Thus, the specific forms of A_t and Σ_t are

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1,t} & \cdots & a_{kk-1,t} & 1 \end{bmatrix}, \Sigma_t = \begin{bmatrix} \sigma_{1t} & 0 & \cdots & 0 \\ 0 & \sigma_{2t} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{kt} \end{bmatrix} \tag{9}$$

The TVP-SVAR model is a multivariate time series model, and the parameters and the variance covariance matrix are dynamic changes. The Markov Chain Monte Carlo (MCMC) method is applied to this treatise, and the time-varying parameters are estimated under the framework of a Bayesian inference. There are some advantages to this method. First, the Bayesian inference cannot only decrease sensitivity of the initial value, but also fully utilize the prior information. Second, the MCMC method is able to make statistical inferences for a_t and h_t under the condition that β_t and Σ_t are uncertain. Last but not least, the method of Bayesian analysis is adapted to commendably solve the uncertainty of parameters, and the MCMC sampling is employed to obtain the response function.

4. Empirical Results

4.1. Variable and Statistical Description

This paper uses a five-variable time-varying parameter SVAR model, including iron ore price (x), Asian demand (i), the BIG-3 supply (q), China's GDP (p) and speculation (z). The monthly data covers the period from January 2005 to December 2021, and data availability ultimately determines the start and end dates[3]. Following Wårell (2014) practice, the iron ore price consists of import price and sea freight before November 2008, and we deflate the world's iron ore price with the consumer-price index (CPI). Asia bears the lion share of global iron ore imports, which has already exceeded 80 percent, and the imports of four countries and regions (Korea, Japan, Taiwan and China) account for more than 90 percent of the overall imports in Asia (retrieved from World Steel Association (WSA), Steel Statistical

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[3] *January 2005 is chosen as initiation period mainly because freight rate was not published until 2005, and the ending period is selected because production data of the BIG-3 is last updated to 2021.*

Yearbook, 2018). As a consequence, the imports of four countries and regions are used as a proxy variable for global iron ore demand in this paper. In addition, to ensure the robustness of the study results, this paper uses other variable to measure global iron ore demand. Specifically, the index of global real economic activity (KI) is a measure of global real demand for iron ore (Kilian, 2009), and this index gathered from Kilian's website has been largely used in many studies (Chen and Yang, 2021); hence, the KI is employed to test the robustness of the findings in this paper. Furthermore, the metal price index (MI) is another indicator for the worldwide demand of iron ore, which is collected from International Monetary Fund; the MI standing for global demand has been demonstrated in previous literature (Cross and Nguyen, 2017). As a result, the KI and MI are employed to test the robustness of results in this paper.

The world's iron ore supply is largely in the hands of the BIG-3; hence, the production of BIG-3 is used as a proxy for global supply. The data of BIG-3 supply and China's GDP are quarterly, which are transformed into monthly data by the interpolation method. The exchange volume of iron ore swap (62% Fe content) is used as a proxy variable for market speculation. The data of China's GDP is retrieved from China's National Bureau of Statistics, and the others are collected from the Wind database. Moreover, except for the KI, other variables are expressed in logarithmic form. The Augmented Dickey Fuller (ADF) is always used to test stationarity of time series. The result of the unit root test shows that all variables are first-order difference stationary, I(1) process. The method of multiple imputation is used to deal with missing data[4]. Table 1 lists out descriptive statistics of all variables.

Table 1

Descriptive Statistics of the Five Variables

Variables	Variable symbol	Mean	Max	Min	Std.dev.	Skewness	Kurtosis	ADF test
$DIn(Price)^a$	x	0.002	0.233	-0.332	0.093	-0.304	0.392	-4.172^{***}
$DIn(demand)$	i	0.006	0.319	-0.229	0.076	0.111	2.259	-10.096^{***}
$D(KI)$	ki	-0.350	84.84	-100.2	23.679	-0.435	2.294	-5.435^{***}
$DIn(MI)$	mi	0.005	0.149	-0.220	0.056	-0.114	0.936	-9.750^{***}
$DIn(Supply)$	q	0.004	0.145	-0.139	0.036	-0.407	3.431	-15.924^{***}
$DIn(GDP)$	p	-0.10	1.783	-9.230	0.817	-8.038	87.687	-4.947^{***}
$DIn(Speculation)$	z	0.01	0.173	-0.154	0.046	0.266	1.897	-9.54^{***}

*Notes: [a] D denotes the first difference. *** Statistical significance at the 1% level.*
Source: Wind database (2022), National Bureau of Statistics (2022).

4.2 Evidence on Parameter Evolution

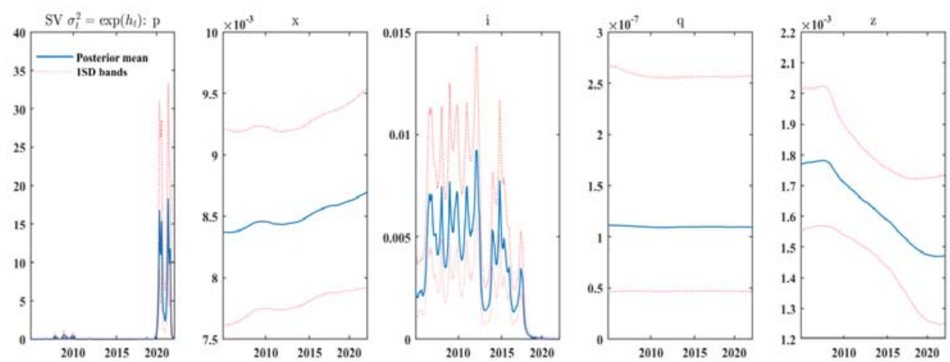
The time-varying parameter SVAR model can capture more accurate behavior and consider time-varying parameters. Figure 2 shows the posterior means of stochastic volatility in the time-varying parameter SVAR model, which reveals the volatility of exogenous shocks. More specifically, stochastic volatility of China's GDP manifests a transient rise around 2009, and it shows a two-humped trend between 2020 and 2021. Moreover, the variation of stochastic volatility for other four factors is gentle, which have always been controlled within 0.01. Asian demand and speculation experience the downward trends, while price shows a tendency for

[4] *The missing data for iron ore production in Japan is from January to October 2009, and interpolation and trend method are applied to fill in missing data.*

gradual increase. Stochastic volatility of global iron ore price rises steadily over the sample period, which remains high and stable. The changing trend of stochastic volatility for China's GDP is relatively consistent with iron ore price, suggesting that China's economic growth may have a significant impact on the world iron ore price. Furthermore, the stochastic volatility of price is high and rising steadily, which means that the iron ore market is increasingly facing significant price volatility. This finding is similar to that of Gu *et al*. (2019), who claim that the volatility of iron ore price will gradually increase after the change of the pricing mechanism.

Figure 2

Posterior Estimates for Stochastic Volatility of Variables

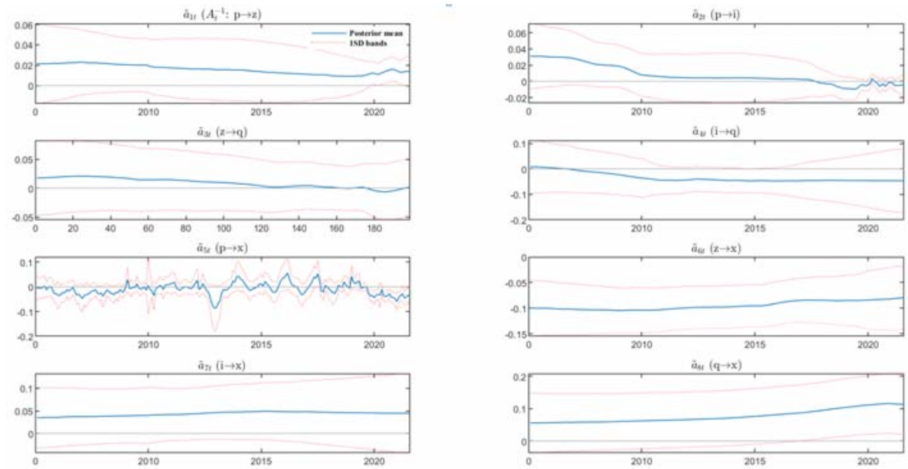


Notes: The solid line denotes the posterior mean, and the dotted lines denote the 95 percent credible intervals.

Figure 3 plots the posterior mean of simultaneous effects between the variables. The simultaneous relation is specified by the matrix A_t in the time-varying parameter SVAR model, and the lower-triangular matrix is allowed to change over time. The simultaneous relations of the iron ore price (x) to the Asian demand (i), supply $(q)$and speculation (z) shocks remain constant. Nevertheless, the simultaneous interactions among other variables fluctuate over time, and the simultaneous relation of the price to China's GDP shock moves up and down violently. The changing simultaneous relations reflect the dynamic relationship between influencing factors and price. However, the previous researches related to iron ore market mostly use the constant models. Therefore, it is very necessary to study the dynamic relationship between the key factors and price by using time-varying parameter model.

Figure 3

Posterior Means of Simultaneous Effects (2005– 2021)



Notes: The solid line denotes the posterior mean, and the dotted lines denote the 95 percent credible intervals.

4.3 Empirical Results of the TVP-SVAR Model

In this paper, the variable set is designed: (p, x, i, q, z), where: p is the China's GDP growth; x is the iron ore price; i is the Asian demand; q is the BIG-3 supply; and z is the speculation. The model of TVP-SVAR can be expressed as: $y_t = X_t\beta_t + A_t^{-1}\sum_t \varepsilon_t$. Consequently, we get the specific expression form of model: $y_t = [p, x, i, q, z]^T$.

Regarding the selection of proper lag orders, the optimal number of lags is 1 based on the Akaike information criterion (AIC), Schwarz Criterion (SC) and Hannan-Quinn Criterion (HQ). The details of VAR lag order selection criteria are presented in Table 3.

Table 3

The Optimal Lag Orders Selection

Lag	LogL	AIC	SC	HQ
0	778.5436	-8.891305	-8.800528	-8.854480
1	873.9242	-9.700278	-9.155613*	-9.618362*
2	900.4459	-9.717769	-8.719217	-9.312695
3	966.6521	-10.19140	-8.738964	-9.602205
4	1009.077	-10.39169	-8.485359	-9.479328
5	1032.491	-10.37346	-8.013248	-9.416014
6	1069.316	-10.50938*	-7.695276	-9.367805
7	1084.674	-10.39855	-7.130559	-9.072851
8	1106.066	-10.35708	-6.635205	-8.847259

*Notes: * indicates lag order selected by the criterion.*

Table 4 and Figure 4 display the estimation results of coefficients in the TVP-SVAR model. In order to get the posterior estimates, we use the MCMC sampling method to draw M= 10,000 samples after the initial 10% samples are discarded. The numerical results in model parameter estimation manifest that all Geweke test's p-values are below critical value, implying that we cannot reject the null hypothesis of convergence to the posterior distribution with significant level 5%. Moreover, the value of inefficiency factor is relatively small, and the highest value of inefficiency factor is only 91.46, meaning that about 109 unrelated samples are generated. The smaller the inefficiency factor, the more efficient is the model.

Table 4

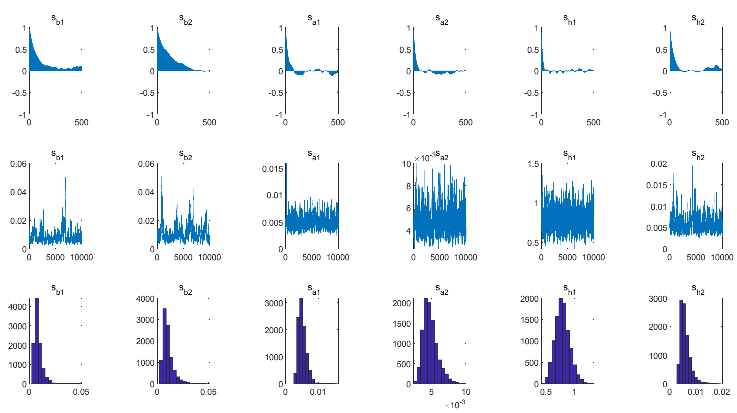
Coefficient Results of TVP-SVAR Model

Parameter	Mean	Stdev.	95 percent interval	Geweke	Inefficiency
$(\Sigma_\beta)_1$	0.0082	0.0037	[0.0038, 0.0182]	0.207	67.42
$(\Sigma_\beta)_2$	0.0088	0.0042	[0.0038, 0.0192]	0.043	91.46
$(\Sigma_\alpha)_1$	0.0052	0.0012	[0.0033, 0.0079]	0.556	41.19
$(\Sigma_\alpha)_2$	0.0049	0.0013	[0.0032, 0.0083]	0.191	50.62
$(\Sigma_h)_1$	0.7924	0.1384	[0.5424, 1.0901]	0.001	23.13
$(\Sigma_h)_2$	0.0057	0.0018	[0.0035, 0.0106]	0.003	39.65

Notes: The estimates of Σ_β and Σ_α are multiplied by 100.

Figure 4

Estimation Results of Parameters



Notes: Autocorrelation coefficient, sample path, and posterior densities of sample.

Figure 4 shows that the autocorrelation coefficients of parameter samples drop gradually, and the fluctuation tends to zero after 500 times of MCMC sampling. The sample paths show stable sampling, indicating that low correlated samples using the effective sampling method have been obtained.

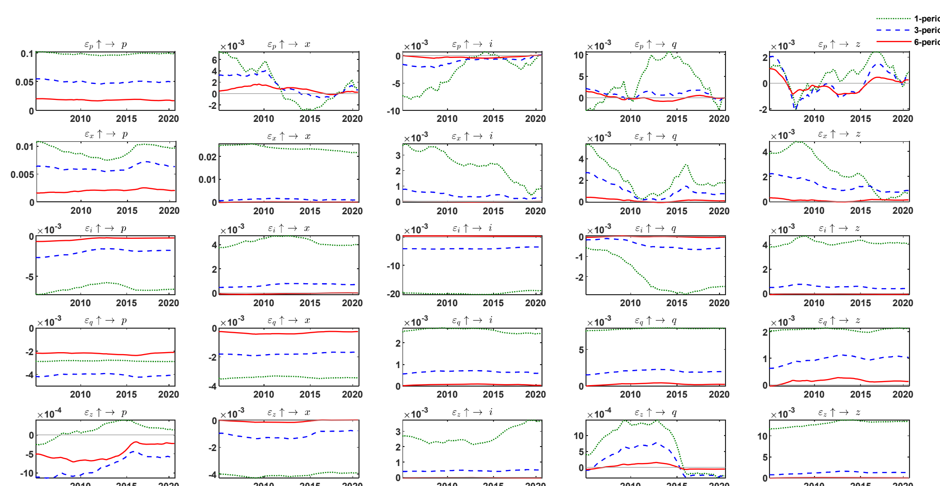
4.4 The Time-varying Response for the TVP-SVAR Model

In Figure 5, the impulses for one-, three- and six-month horizons are used to respectively represent the short-, medium- and long-term effects in this paper.

From the second column in Figure 5, one may see that the impulse responses of iron ore price to a positive China's GDP shock stay positive before 2013, which starts to decrease in the 2010-2019 period. It is noteworthy that the impulse responses present positive values since 2020, and the effect is time-varying. A 1% increase in China's GDP will increase the world's iron ore price by about 0.6% between 2005 to 2010, controlling for other factors. With rapid economic growth in China, the demand for natural resources has increased markedly, resulting in rapid progress of iron ore market (Roache, 2012; Dungey *et al*., 2014). Furthermore, proponents of the super-cycle hypothesis point out that strong demand driven by China's economic development is a leading cause of the iron-ore price surge (Cuddington and Jerrett, 2008; Heap, 2005). That is why China's GDP has an immense effect on global iron ore price. Nevertheless, a drop in China's GDP driven by weak demand has a negative influence on global iron ore price during the period of 2010–2019, and this is mainly due to insufficient demand for steel and real estate during this period. As COVID-19 effects started in the second quarter of 2020, the effect of China's GDP on price has continued to increase.

Figure 5

Time-varying Impulse Responses of TVP-SVAR Model



Notes: Time-varying responses for one-month (dotted line), three-month (dashed line) and six-month (solid line) horizons for the TVP-SVAR model.

The impulse response of global demand is similar to China's GDP, but the effect of demand on iron ore price is more stable. The effect of global demand is maintained between 0.4%

and 0.5% throughout the study period, resolving after six months, which is evidence enough for the importance of demand factor in price fluctuations. According to the traditional demand theory, an increased demand will lead to a price surge, so the increasing demand can cause escalating iron ore price (Hoang and Nguyen, 2018).

Nevertheless, the BIG-3 supply and speculation have negative impacts on the price of iron ore, and the impact degree of global demand on iron ore price is significantly higher than that of supply and speculation. This is because with advancements in technology and the development of derivatives markets, the downstream enterprises can mitigate the negative effects of supply and speculation factors by adjusting their inventory and using portfolios (Wen *et al*., 2019; Chen and Yang, 2021).

4.5 The Time-varying Impulse Response at Different Points in Time

We further analyze the dynamic relationship between various factors and iron ore price when significant historical events occur. Three time points of typical events are picked during the sample period: 2008M12, 2009M5 and 2010M3, which suggests that the outset time of the time-varying impulse responses are 2008M12, 2009M5 and 2010M3. First, the pricing system for iron ore has changed enormously since the introduction of the spot price in December 2008, and global iron ore price associated with spot market are becoming more flexible. As a result, the introduction of spot price may have a direct impact on the world's iron ore price. Second, the Singapore Exchange (GSX) has launched the first iron ore swap contracts in May 2009, and a range of derivatives have been launched since this time. Furthermore, the annual benchmarking pricing system has become a part of the history since March 2010, and Vale is the first to strike deals with Asian steel mills under the new quarterly system linked to the spot market. Consequently, this paper selects these three time points to investigate the impulse responses of price to various factors.

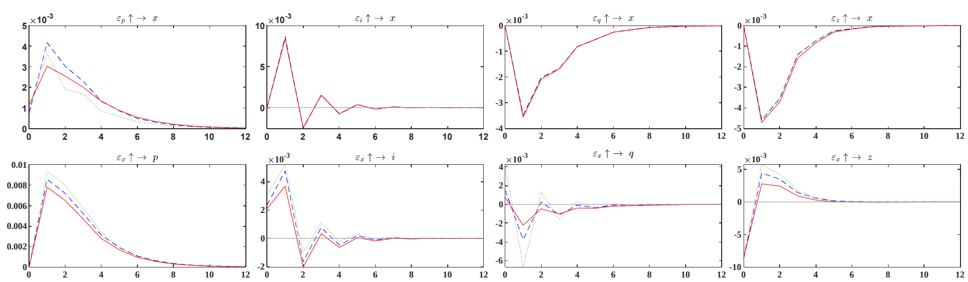
Figure 6 depicts the impulse responses of global iron ore price to China's GDP, supply shock, demand shock and speculation shock at all three time points (in December 2008, in May 2009, in March 2010). The dotted line shows the impact of factors on real price of iron ore over 2008:12-2009:10. The dashed line represents the time-varying impulse response over 2009:05-2010:03, and the solid line is used for the impulse response between March 2010 and January 2011. The first row of Figure 6 displays the response of iron ore price to the positive shock of each factor at three different time points. As one may see, China's GDP growth rates have positive impact on the iron ore price, and the trends are basically same at three time points, while the change degree of the dotted line is the biggest. The result indicates that iron ore price linked with spot market are more sensitive to China's GDP, as spot market is mainly developed in China. Besides, the first row also reports the effects of each factor on iron ore price, and the results show that demand shock has the greatest influence on global price of iron ore. The soaring demand for iron ore pushes the price to a high level (Sukagawa, 2010). Nevertheless, the huge impact of demand shock on price is relatively short-lived, and the results shed light on the shortest but strongest impact of global demand. These results largely confirm the theory of super cycle, which means that the soaring iron ore price is largely driven by strong demand, especially in huge demand for iron ore caused by the rapid industrialization and urbanization in China (Heap, 2005).

The degree and direction of effects of contribution of iron ore price to four factors are described in the second row of Figure 6. Global demand positively responses to price shock at first, indicating that price spike triggers an increase in iron ore demand. To some degree, the result reflects the rigid demand for iron ore in the world. However, the impulse response gradually declines and turns negative thereafter, becoming relatively flatter and close to zero after five months. The decline in global demand for iron ore shows that in order to cope with rising price, steel enterprises might take some measures like reducing imports and adjusting product output, and the iron and steel industry can reduce resource demand by increasing resource efficiency in the long run (He *et al*., 2013). With the increase in international commodity prices, price shifts can translate into inflation, which would cause detrimental effects on the socio-economic development (Chen *et al*., 2020; Chen and Yang, 2021).

Furthermore, the empirical results show that the impulse response of China's GDP to iron ore price is maximal, and one percent price shock leads to an over 0.8 percent increase in China's GDP since the reform of pricing system, indicating that international iron ore market maintains a closer association with China's economic development. This may be due to the fact that a large amount of iron ore is traded in the Asian spot market, and the importance of China in international iron-ore market transactions is continuously increasing. Furthermore, price has a larger impact on the BIG-3 supply than that on speculation, while the effect of price on supply shows a decrease since the introduction of spot price. This is mainly attributed to the fact that the growth rate of demand has tapered after 2010, and the world's iron ore market has turned from a sellers' market to a buyers' market, thus the effect degree on supply decreased gradually. Moreover, the upfront investment for mining industry is huge, so the supply has greater difficulty in adapting to a changing market demand.

Figure 6

Impulse Responses between Price and Influence Factors at Different Points in Time



Notes: The starting points: December 2008 (dotted line), May 2009 (dashed line) and March 2010 (solid line).

5. Discrete Break

After analyzing the whole time period, the method of discrete break is introduced to this section, and the full sample is divided into two periods mapping with the annual and spot price period. There are two major events in iron ore market during the study period. One is the introduction of spot price in 2008/2009, the other is that the annual pricing mechanism moves towards a system of quarterly contracts based on the spot price. The analysis of discrete break may provide more insight into the links between iron ore price and the reform of pricing regime, bolstering confidence in the research results.

5.1 Determination of Sub-sample Period

The spot price was introduced in 2008/2009, and the iron ore price is much more flexible than before. As a result, we set the period of time before December 2008 to be the annual price period, and the period of time after December 2008 is the spot price period.

Specifically, the sub-sample Ⅰ is from January 2005 to November 2008, and the period of sub-sample Ⅱ is chosen from December 2008 to 2021.

5.2 The Point of Pricing Mechanisms

Initially, Japan as the primary target market negotiated with iron ore suppliers about price, and pricing mechanism was based on annual price and lengthy negotiations. The benchmark pricing system was negotiated each year, and the fixed price was not affected by next year's spot price fluctuation. With Chinese iron ore demand surging, China overtook Japan as the world's largest iron ore importer in 2003. However, low concentration of steel industry causes Chinese enterprises lacking voice in pricing negotiations. The main sellers apply more pressure to the demand side during the 2004/2005 negotiations, and Chinese buyers were forced to accept the sky-high price. Subsequently, iron ore price rose by 71.3 percent in April, with the highest increases in the 30-year history of setting of the annual price. Consequently, this paper chooses April 2005 as the point of producer price, and the other point is chosen January 2007 for comparison in sub-sample Ⅰ.

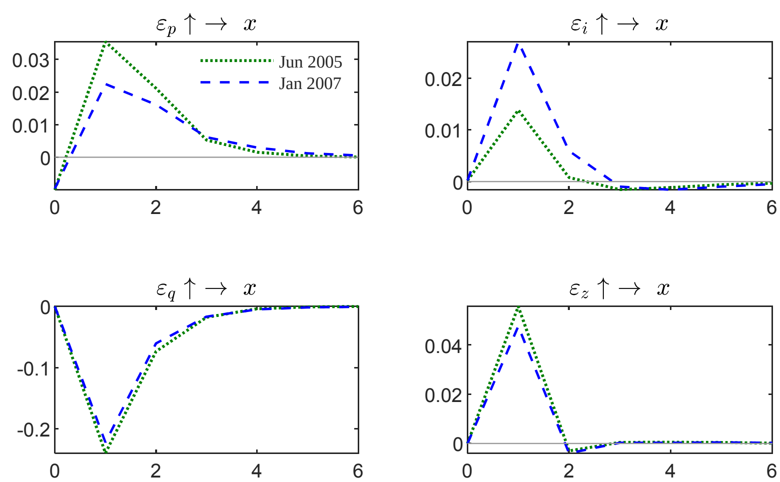
The development and prosperity of iron ore market in China have spawned the spot price, and the sheer amount of iron ore is traded in the spot market. Indian iron ore suppliers prefer to trade in the spot market rather than the traditional market, canceling part of the annual benchmark contract (Sukagawa, 2010). Moreover, the annual pricing mechanism has gradually moved towards a quarterly pricing mechanism based on spot price since March 2010. As a result, the March 2010 is chosen as a representative point for spot price, and the second point (January 2017) is chosen for comparative purpose in sub-sample Ⅱ.

5.3 Empirical Results for the Two Sub-samples

Figure 7 shows the impulse responses of iron ore price to crucial factors over the sub-sample Ⅰ period. The effects of China's GDP and Asian demand on price are positive

Figure 7

The Impulse Response of Sub-sample Ⅰ



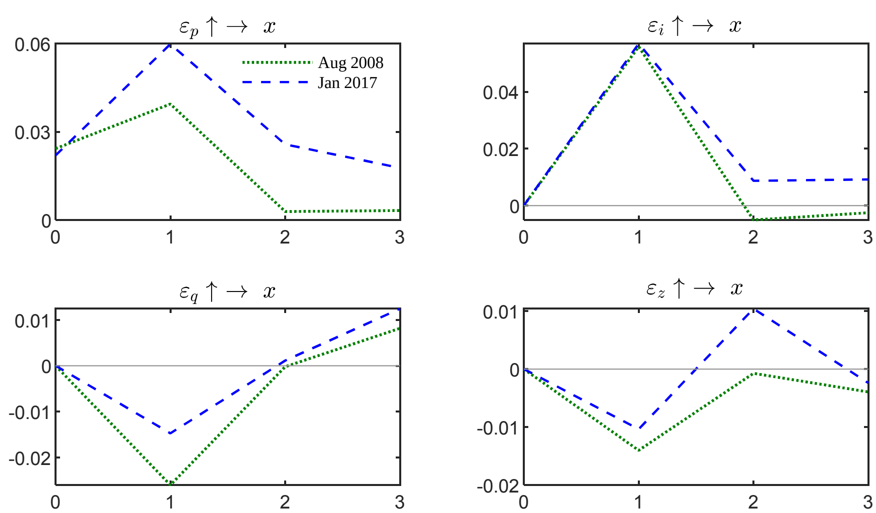
Notes: The point for annual price: June 2005 (dotted line), and the comparative point: January 2007 (dashed line).

On the contrary, the iron ore price responds negatively with one standard deviation (S.D.) innovation in supply increase. Furthermore, during the period of annual price, speculation has a significant positive effect on iron ore price. By further analysis of influence of the extent of various factors on iron ore price, we may see that the BIG-3 supply has the most influence on the world's iron ore price, which means that the BIG-3 has a tight grip on the iron ore market in the annual benchmark system. The empirical result is in line with the views of Radetzki *et al*. (2013), who argue that the iron ore boom can last for over ten years, because of investment lags and long capacity constraints. Speculation is the second most important factor for price surge, and the positive impact of speculation on price may be due to the opaque information of demand and supply in the annual pricing mechanism. Overall, the fluctuation of price is particularly sensitive to supply in sub-sample□.

The impulse responses of sub-sample Ⅱ are generally in line with the results of full sample. The dotted line in Figure 8 represents the reform of pricing mechanism in March 2010, and the quarterly pricing mechanism is based on spot price indices. Specifically, the effects of China's GDP and Asian demand on price are positive in the first two months, while price decreases with one S.D. shock from supply or speculation. The negative response of speculation is very small in sub-sample Ⅱ, and it is not a surprising outcome. The influence of speculation on price is lower during the quarterly pricing mechanism, as this new pricing mechanism is more transparent and more closely follows the current supply and demand behavior. In Figure 8, China's GDP has the largest impact on iron ore price, indicating that China's economy is gradually increasing its impact on the global iron ore market, and the result in this paper supports the conclusion of Wårell (2014; 2018), who detects that GDP growth in China has the most significant impact on iron ore price in either the annual or quarterly pricing regime.

Figure 8

The Impulse Response of Sub-sample Ⅱ



Notes: The point for spot price: March 2010 (dotted line), and the comparative point: January 2017 (dashed line).

6. Further Analysis

6.1 Discussion

The empirical results imply that the reform of pricing mechanism has a remarkable influence on the global iron ore market, and the degree of influence of different factors on price vary a lot with the pricing system change. Specifically, the BIG-3 supply played a crucial role in the world's iron ore price before the introduction of spot market pricing. The annual price is determined by the negotiating power between suppliers and buyers. The concentration of suppliers is high, and more than 80 percent of global supply is in the hands of the BIG-3 producers. However, buyers have little bargaining strength due to low degree of concentration. Therefore, the limited supply is the main determinant of price, and the volatility of iron ore price is relatively low because of the annual pricing feature.

With the rapid growth of spot market, the annual pricing mechanism is replaced by the quarterly benchmarking pricing system based on spot price. Due to the flexibility of quarterly pricing, the global iron ore price triggered higher fluctuations after the change of the pricing system. Meanwhile, China' GDP becomes the decisive factor of the iron ore price under the quarterly pricing system. This is mainly because the price of iron ore is highly sensitive to the supply and demand situation of spot market in the quarterly pricing mechanism, and the demand surge driven by China's economic growth tends to push the iron ore price up. Furthermore, the spot market is mainly developed in China. More concretely, the quarterly price is largely determined by the spot price indices, and the pricing point is CFR Tianjin port in China, so China emerged as the dominant factor influencing the iron ore market after the reform of the pricing system.

This paper explores how does the change of the pricing system affect the world's iron ore market, and this paper further explores the internal mechanism of the reform of pricing system on iron ore price. The empirical results show that the reform of pricing system changes the environment of iron ore market and then has a significant impact on price. Under the annual benchmarking pricing system, the world iron ore price is fixed through negotiations between suppliers and buyers, and the limiting supply of the BIG-3 pushes price up. China factor plays a key role in quarterly price guided by the average spot price after the change of pricing system. Wårell (2014) investigates the direct effect of pricing system on price and finds that China's GDP has the highest influence on price. Our research shows that China has become the vital factor for world iron ore price since the change of the pricing system, thus the view of Wårell is corroborated to some extent.

6.2 Robustness Check

To increase confidence in the robustness of the findings of the present study, other variables are selected to measure global iron ore demand in this section. As mentioned in Section 4, besides the Asian imports, the Kilian index (KI) and the MI can be employed as the proxy variables for the world's demand for iron ore (Chen and Yang, 2021). Consequently, it is highly necessary to use the KI and MI to check the robustness of the empirical findings. Figure 9 presents the results of the impulse responses of iron ore price to China's GDP, MI, supply and speculation shocks, and the results of impulse responses of price to MI and other three types of shocks in Figure 10. The results reveal that although there are some subtle differences between the current and above findings in this paper, no apparent change is found in the magnitude and direction of the impulse response. The results of robustness test are extremely consistent with the reality, which suggests that the findings of this paper are robust.

Figure 9

Impulse Responses of Price to Four Types of Shocks of the Robustness Check

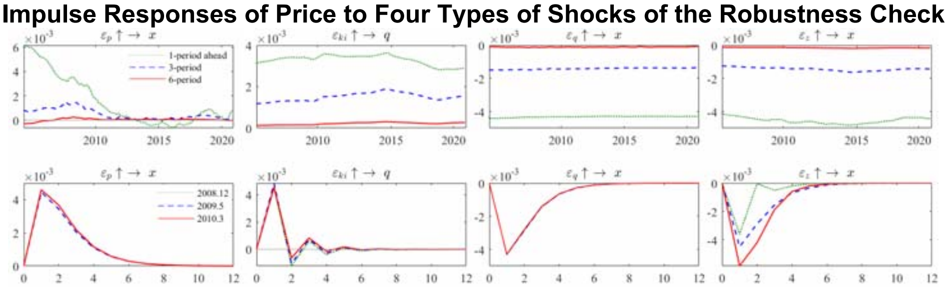
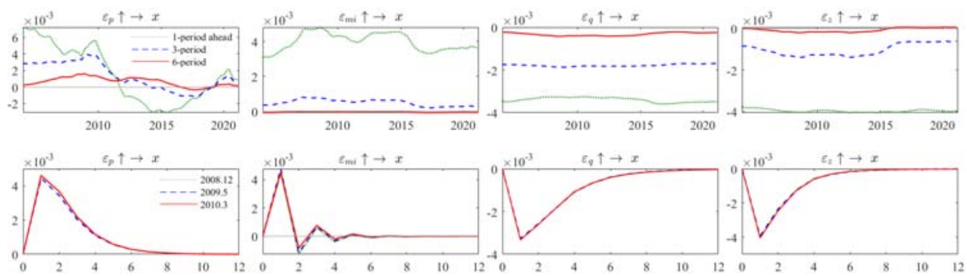


Figure 10

Impulse Responses of Price to Four Types of Shocks of the Robustness Check



7. Conclusion

As an important material for steel production, iron ore is an indispensable resource for the process of urbanization and industrialization of the emerging economies. With the introduction of quarterly pricing mechanism, the iron ore price begins to hike and becomes more volatile. The iron ore price plays a key role in the developing countries and emerging economies, and the analysis of the impact of pricing mechanism on price movements would provide significant insights for policy makers. This paper uses a time-varying structural VAR model to reveal how the reform of pricing mechanism affects world's iron ore price, and the degrees of influence of various factors on price are analyzed under different pricing mechanisms.

The empirical results indicate that the volatility of iron ore price has increased dramatically since the reform of pricing mechanism. Moreover, the BIG-3 supply has the largest impact on iron ore price under the annual pricing mechanism, and this can be attributed to an extremely strong negotiating position. The top three suppliers manipulate iron ore price by controlling supplies and dominating the iron ore market. The reform of pricing mechanism changes the environment of iron ore market, and iron ore market shifts from the seller's market to the buyer's market. China's GDP shock becomes even more significant in explaining the elevated price of iron ore during quarterly pricing, and the mechanism behind the influence of China's GDP is mainly via demand. This result reflects that soaring iron ore price is driven largely by the booming demand for iron ore in China, because the new pricing mechanism is sensitive to supply and demand of iron ore market. During spot market pricing, soaring price is mainly driven by the imbalance of supply and demand in the iron ore market. Strong demand from Asia, particularly from China, leads to tight market and higher iron ore price. Furthermore, the reducing effect of speculation is largely due to the introduction of quarterly pricing mechanism based on spot price, as this pricing regime is more transparent and more closely follows current supply and demand behavior. With the level of technology improved and the evolution of a financial market, the steel companies may attenuate or modify adverse effects of speculation shock through advanced technology, adjusting inventory of iron ore, constructing the portfolio through the derivatives market.

Based on the above empirical findings, this paper produces some policy recommendations: (1) The world iron ore price is more responsive to the demand driven by China's GDP under the quarterly pricing. In order to stabilize price and reduce the adverse effect of price fluctuation, China should decrease the iron ore imports and optimize the trade structure. On the one hand, China should improve the utilization ratio of scrap steel to reduce demand. There is a gap in electric arc furnace (EAF) steel ratio between China and the developed countries such as USA, because of low utilization rate of scrap in China (only about 20%). On the other hand, China can establish strong collaborations with international suppliers to decrease imports of iron ore. (2) Because the new pricing system closely follows the supply and demand relationship, the influence of speculation on price of iron ore tends to decrease. Therefore, speculators can add iron ore to their portfolios aiming to decentralize the investment risk. Moreover, investors can predict price trends of iron ore by analyzing China's economic growth in order to reduce the risk of price volatility.

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