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ORIGINAL RESEARCH

The Relationship Between China's Real Estate Market and Industrial Metals Futures Market: Evidence from Non-price Measures of the Real Estate Market

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Abstract

By using non-price indicators of the real estate market, this paper examines the relationship between the real estate market and the industrial metals futures market in China during the 2004–2019 period. Empirical findings from a vector autoregression model (VAR), a causality study, and cointegration analysis suggest that, in the context of China, industrial metals futures have both short-run and long-run associations with the real estate market. The effectiveness of the mechanisms through which the real estate market affects the industrial metals futures market, however, varies across underlying assets and pre-specified indicators. More specifically, the shock of the size of newly started constructions has the greatest accumulated impacts on the copper futures market, increasing the price of copper futures by 2.46% after two years. Additionally, 11.31% of the changes in the price of copper futures can be attributed to fluctuations in the size of newly started constructions, in which the explanatory power has increased horizontally. The results of impulse response functions (IRFs) show that the price of rebar futures is the most sensitive to volatility in sales size in the real estate market, in which the rebar futures price can be expected to increase by 1.65% after two years. The results of the forecast error variance decomposition (FEVD) method suggest that fixed asset investment in the real estate market makes the largest contribution (about 6.28%) to corresponding movements in the rebar futures price.

Keywords Industrial metals futures market · Real estate market · China

JEL Codes C22 · E44 · G13 · G12

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1 Introduction

China has gained dominance in the global economy, becoming the second-largest economy in the world in 2010. Rapid economic development in China has been driven by three engines of growth—namely, domestic investment, domestic consumption, and exports. The real estate market and infrastructural projects are especially responsible for the growth of domestic investment in China. From the industrial chain perspective, industrial metals firms in China, including mining companies, smelters, refineries, and traders, which are positioned at the upstream of industry, are expected to have strong supply–demand relationships with the real estate market, which is the terminal market of industry. As documented by the China Futures Association (CFA) in the *China Futures Industry Annual Report* (2017), in order to reduce the operational risks generated from the volatility of metal prices, a growing number of industrial metals firms in China are becoming involved in the futures market. For instance, industrial metals firms have taken a position opposite to the underlying spot commodity in the futures market, as price fluctuations in the spot market are expected to be offset under the law of one price (i.e., the futures price and the spot price will converge as the maturity of futures contracts approaches). For the timely adjustment of hedging ratios in response to external shocks, it is of great significance to understand the movement patterns of and the relationship between the industrial metals futures market and the real estate market. Specifically, the real estate market, as the terminal market, tends to affect the industrial metals futures market through a mechanism by which price expectation is formed according to the classical supply–demand relation. If the position of investors in the futures market is opposite of the direction of innovation in the terminal market (i.e., the real estate market), corresponding changes in the futures price under extreme conditions (e.g., a unilateral market) could lead to great losses, which spot positions are often unable to offset.

In recent years, the real estate market has become an important engine of economic growth in China. As industrial metals comprise the basic raw materials needed for housing and building construction, the futures market for industrial metals plays a significant role in the Chinese market, not only with respect to price discovery but also in relation to the state of the country's economy. From the perspective of finance, real estate and metals (commodity) futures are financial assets which are widely held in investors' portfolios. A better understanding of the linkages between the real estate market and the metals futures market could therefore be useful to investors to minimize risks across assets. For example, copper futures tend to not only reflect their own fundamentals, such as stock level, basis (i.e., the difference between spot and futures prices), and consumption situation, but also to illustrate the effect of market expectations on the future state of the economy (Guo, 2018). Fluctuations in the real estate market may thus reflect predictions made about economic performance, as described by some business cycle theories (Rebelo, 2005). As economic booms are contemporaneously accompanied by booms in the housing and real estate markets, it is plausible to hedge systematic risk by shortening industrial metals futures or by selling properties. Meanwhile, holding corresponding positions in one market can also enable investors to hedge the risks generated in another market. These hedging operations require a better understanding of the mechanism by which mutual effects across markets are transmitted as well as how the underlying market reacts to external shocks.

Previous literature has primarily focused on four aspects of the commodity futures market, including market efficiency (e.g., Fernandez, 2016; Humphreys, 1987), pricing theory (e.g., Fabozzi et al., 2008; Gorton & Rouwenhorst, 2006; Watkins & McAleer, 2002), and volatility and risk (e.g., Liao et al., 2018; Mo et al., 2018; Zhu et al., 2017), as well as other issues, such as the relationship between margin requirements and market participation (Hardouvelis & Kim, 1995), lead–lag relationships between copper futures markets (Shyy & Butcher, 1994), and the manipulation of the copper futures market on the LME (Gilbert, 1997). Studies on the real estate market mainly focus on the issues of housing price and sustainability development (e.g., Cho, 1996; Chu & Sing, 2004; Guo & Huang, 2010), and the interaction between property and equity markets (e.g., Hui & Chan, 2014; Zhang & Fung, 2006; Zhou & Sornette, 2004). Particularly, the concept of an "economic new normal", whereby economic growth should be generated from structural reform and upgrades in China's economy rather than from focusing on the rate of economic growth, has become a contentious issue (Chan et al., 2016; Ding et al., 2014). A few empirical studies have been conducted on linkages across multiple markets, including commodity and macroeconomic variables (e.g., Bal & Rath, 2015; Gargano & Timmermann, 2014; Hess et al., 2008), commodity and product markets (e.g., Fernandez, 2014; Rallis et al., 2013; Ye et al., 2019), and the real estate and other financial markets (e.g., Lizieri & Satchell, 1997; Okunev et al., 2000; Sim & Chang, 2006). To the best of our knowledge, few studies (e.g., Chan et al., 2011, 2016) have explored the relationship between the real estate market and the industrial metals futures market. In this paper, we aim to empirically investigate this relationship in the context of China by using copper futures and rebar futures[1] as proxies for base metals and ferrous metals, respectively. We extend the extant literature, which primarily uses housing price as a proxy (e.g., Chu & Sing, 2004; Guo & Huang, 2010), and measure the volatility in the real estate market by four indicators according to a typical real estate cycle i.e. investment, start, completion and sale. These indicators are fixed asset investment in the real estate market that describes the overall demand for industrial metals, the size of newly started constructions and the completed size of constructions which reflect the contemporaneous demand of different construction stages, and the sales size of the real estate market used for forecasting future demand. Using the monthly data of the real estate market and the futures market in China during 2004–2019, the main findings were that movements in the industrial

[1] As reported by the International Copper Study Group (ICSG), around one-half of the refined copper produced in the world is consumed in China. It is estimated that in 2018, more than 30% of the copper consumed in China was ultimately used as raw material in housing construction (Huang et al., 2018). This trend also applies to the use of other base metals (e.g., zinc and aluminum) and to ferrous metals, like rebar (Zhuo, 2018).

metals futures market are closely associated with movements in housing indicators, and that the effects of developments in the real estate market on the industrial metals futures market vary across two types of metals futures (i.e., copper and rebar futures). Specifically, copper futures are most sensitive to shocks in the size of newly started constructions, while changes in fixed asset investment in real estate and the sales size of the real estate market tend to have statistically significant impacts on rebar futures. Considering the long-term dynamics between underlying markets, the adjustment of the copper futures price to a level at which equilibrium is attained occurs much quicker than when the same attempt is made for rebar futures.

Our paper contributes to the extant literature in at least two important ways. First, it provides empirical evidence on the relationship between the real economy and the derivatives market, especially the relationship between the real estate market and the industrial metals futures market in rapidly growing, emerging economies, such as China. China's real estate market is not an isolated system but is rather a synthesized network in which the government, financial institutions, firms, and households are closely associated. Fluctuations in the real estate market are likely to have a significant impact on various aspects of economic sectors. By measuring changes in the real estate market using indicators (i.e., fixed asset investment in the real estate market, size of newly started constructions, sales size of the real estate market, and the completed size of constructions) other than housing price,[2] we were able to capture the genuine relationship between the real economic sector and the futures market in China. Second, empirical findings from this paper could help market participants further understand the interaction mechanism of underlying markets, thus enabling them to perform more effectively in portfolio and risk management.

2 Theoretical Foundation and Related Literature

2.1 Theoretical Foundation

In theory, the real estate market and industrial metals futures market are connected through three important channels. First, based on the positions of the real estate market and industrial metals market in the industrial chain, innovations in the real estate market, which is the terminal market, can determine the demand for industrial metals. Industrial metals are the basic raw materials for real estate construction. According to the Shanghai Futures Exchange (SHFE), on average over 30%

[2] The real estate market in China, as the dominant focus of domestic investment, is viewed as an important engine of economic growth. Regulations have been imposed on China's real estate market to ensure housing price stability and mortgage affordability (Glaeser et al., 2017). To curb speculation on residential properties, Chinese authorities have imposed an idle land tax, a land appreciation tax, and a business tax on properties held for less than five years, alongside other regulations on housing supply. In such circumstances, housing prices are likely to lose the explanatory power needed to reflect market expectations based on the supply–demand relation in the real estate market. In addition, with the rigidity of housing prices, it is improbable to relate volatility in the real estate market, which is generated by shocks in the real economy, to changes in other financial variables.

of the supply of copper and about 50% of the supply of rebar in China are used in real estate construction each year. In this situation, the real estate market in China is likely to drive the movements of the industrial metals market, particularly when the supply of industrial metals is fixed. Innovations in the real estate market will affect the demand function of industrial metals market, and subsequently affect the prices of industrial metals. On the contrary, shocks in the industrial metals market are expected to have less impact on the real estate market because the proportion of the costs of industrial metals to the total costs of real estate construction is relatively low compared to the other costs of real estate, such as the cost of land (Glaeser et al., 2017; Liu & Xiong, 2018).[3] In addition, the real estate market in China is strictly regulated by the central and local governments (Glaeser et al., 2017; Guo & Huang, 2010; Liu & Xiong, 2018). For instance, real estate holders are not allowed to sell their properties in two or three years after the first purchase, housing prices are monitored and controlled by the government to be within a pre-specified range.[4] In this sense, China's real estate market has a supply–demand system whereby the effects of innovations in construction materials can be excluded.

Second, based on business cycle theories (Rebelo, 2005), the industrial metals futures market and the real estate market are expected to move synchronously because the two markets commonly reflect the state of economy. The real estate market is strongly and positively linked with the development of the macroeconomy (Raza et al. 2018). Fluctuations in the real estate market tend to move with the changes in the state of economy. More specifically, real estate bubbles are often evident during economic boom periods, while declines in real estate market are frequently seen in the economic recession periods. Since the reform of the commercial housing market in China in 1998, the real estate market, which represents a vital part of aggregate demand in China's economy, contemporaneously reflects the state of the economy and is regarded as an important barometer of the economic condition (Guo & Huang, 2010). The demand for industrial metals is also driven by economic activities and exhibits contemporaneous changes to the state of the economy (Hess et al., 2008). The prices of industrial metals as basic raw materials used in many industries usually reflect the dynamics of supply and demand in the real economy, and industrial metals futures prices normally contain market expectations on the future state of the economy (Guo, 2018).

Third, from the perspective of finance, real estate and commodity futures are financial assets in investors' portfolios, so the industrial metals futures market can be associated with the real estate market through information transmission channel and sentiment contagion channel (see, e.g., Chan et al., 2011). More precisely,

[3] Land is an important input in real estate development, and the price of land, especially commercial land and residential land, in China has increased enormously over the past few decades (see e.g., Glaeser et al., 2017; Liu and Xiong, 2018).

[4] Since the late 2000s, the policy focus in China has shifted to housing market stability (Glaeser et al., 2017). The central and local governments target housing price stability by controlling both the demand and supply activities, for example, restrictions on second and third home purchases and on the resale of homes in less than five years, imposition of real estate taxes that provides an incentive to buy-and-hold, and the government's direction on banks' credit to real estate developers.

innovations in the real estate market, which is an important engine of economic growth in China, normally receive attention from participants in the industrial metals futures market. Investors usually adjust their investment portfolios to respond to shocks in the real estate market. For example, the government's relaxation on housing purchase restrictions in China, which is expected to stimulate the demand for real estate, is likely to positively affect the industrial metals futures market because investors predict the future demand for industrial metals to increase. In this sense, the corresponding prices of industrial metals futures are likely to adjust to the new information of innovations in the real estate market. The real estate market and industrial metals futures market can also be linked through a sentiment contagion channel because the effects of investors responding to shocks in the real economy by adjusting their portfolios[5] can be transmitted across markets.

The real estate market displays a typical cycle, namely investment, start, completion, and sale. Changes in the demand for industrial metals are likely to vary across the stages of the real estate cycle. More precisely, investment in the real estate market reflects the overall demand for industrial metals, the size of newly started constructions and the completed size of constructions show the contemporaneous demand for industrial metals at different stages of construction, while the sales size of the real estate market predicts future demand for industrial metals. The use of industrial metals differs across the construction cycle; for instance, copper is a basic material for producing wires and cables, and rebar is an important input in the structural frames of buildings. Ferrous metals and nonferrous metals have different commodity and financial characteristics. Ferrous metals such as steel and rebar present commodity characteristics (Zhuo, 2018), in which fluctuations in ferrous metals prices mainly reflect the concurrent fundamentals of the supply–demand relation and stock level. Meanwhile, nonferrous metals such as copper exhibit strong financial characteristics (Guo, 2018), in which changes in nonferrous metals prices reflect both fundamentals and the market expectations on the future state of the economy. Based on this theoretical foundation, the real estate market cycle and the characteristics of industrial metals, the responses of industrial metals to shocks in the real estate market are expected to vary across different classes of metals and different stages of the construction cycle in the real estate market.

2.2 Related Literature

Industrial metals futures have become a significant component in investors' portfolios as well as an important instrument for risk management among market participants (e.g., companies, investment banks, hedge funds, and private investment institutions). Unlike typical financial assets, industrial metals futures possess synthetic characteristics of commodity and financial assets (Mo et al., 2018). The prices of

[5] Industrial metals, except precious metals such as gold, are generally considered to be risky assets (Huang et al., 2018) and are more sensitive to investors' sentiment and risk preference (Liao et al., 2018). Meanwhile, real estate constitutes an important component of Chinese households' and firms' investment portfolios (Glaeser et al., 2017; Liu and Xiong, 2018).

industrial metals futures reflect the expectations of investors (Gorton & Rouwenhorst, 2006), as industrial metals and other commodity futures are normally used to insure the future price of underlying commodities. Market participants could earn returns by bearing short-term uncertainty in industrial metals prices. While values of conventional financial assets are forward-looking, those of industrial metals futures depend more on current economic conditions (Gorton & Rouwenhorst, 2006). During a recession period, short-term expectations of economic growth are on the whole pessimistic, and thus the prices of industrial metals are expected in correspondence to the low demand for inputs of resources for production and construction. In this manner, industrial metals futures exhibit corresponding reactions to business cycles.

Previous studies have yielded extensive evidence of close linkages between commodity markets and the macroeconomy, such as GDP growth (e.g., Gargano & Timmermann, 2014; Hess et al., 2008), money aggregates (e.g., Browne & Cronin, 2010; Hammoudeh et al., 2015; He et al., 2018), interest rates (Belke et al., 2014), exchange rates (Bal & Rath, 2015), and inflation (e.g., Fernandez, 2014; Malliaris, 2006). A significant causal mechanism between commodity futures, which are considered to represent an unbiased prediction of future spot prices, and macroeconomic variables was also detected in studies by Acharya et al. (2010) and Zhang et al. (2016). Christie-David et al. (2000) examined the response of gold and silver futures to changes in GDP and found that only gold futures presented sensitivity to changes in GDP. Gargano and Timmermann (2014) determined that the accuracy of forecasting commodity futures mainly relies on the underlying economic state and the prediction horizon. Mo et al. (2018) explored the linkage between the volatility of industrial metals futures and macroeconomic variables using GARCH-type models, revealing the significant effects of the uncertainty of macroeconomic variables on the volatility of commodity futures. In addition, Mo et al. (2018) and colleagues found that using both high- and low-frequency components in modeling, measuring, and forecasting volatility in the commodity market in response to macroeconomic shocks provides more efficient results than applying the traditional models used in earlier studies.

The correlation between the commodity market and the monetary and product markets has also been documented in prior studies. For example, Rallis et al. (2013) showed that fluctuations in commodity prices result in homodromous movements in general product price. With commodities serving as inputs of manufactured goods, the commodity price is expected to contemporaneously affect production costs and subsequently impact general price levels (Bhar & Hamori, 2008). By investigating linear and non-linear Granger causality between US price indices and commodity prices, Fernandez (2014) revealed a linear causality channel from individual commodity to price indices. More recently, Ye et al. (2019) included additional pre-specified determinants from other financial markets in modeling linkages between the commodity futures market and the monetary and product markets. They determined that the causality is much stronger from the commodity futures market to the underlying macroeconomic market (e.g., money market) than reported in previous literature. More importantly, they found that the relationship between commodity futures indices and the predicted value of indicators for other markets tends to be more statistically significant than the relationship between the commodity futures market and concurrent variables of the monetary and product markets.

Some studies have examined interactions between the real estate market and financial markets. For instance, Quan and Titman (1999) explored the linkage between stock returns and innovations in the property market (i.e., property values and rent levels) in the UK. Their results showed that the contemporaneous relationship between real estate price and stock returns tends to be horizontally volatile, and that stock returns are tested to be insignificant. When data across countries are tested for a longer sample interval, significant relations between changes in stock returns and property values can be detected. Okunev et al. (2000), for instance, reported a strong unidirectional and non-linear causal relationship from the stock market to the real estate market in the US. Granger causality, as documented in a study by Sim and Chang (2006), was also found between property price and share price for most regional housing and land markets in South Korea. Nevertheless, no causality channel from an inverse direction was identified. Aye et al. (2013) adopted a non-parametric cointegration test to examine the long-term, bi-directional, causal linkage between the stock and real estate markets in South Africa, with the consequent empirical results being dependent on the selected tests.

Chan et al. (2011) examined asset market linkages with a wider range of datasets and spot prices of commodities, such as oil and precious metals, and the stock index was used for analyzing the joint distribution of asset returns. The existence of two distinct regimes was detected: the tranquil regime, which is characterized by lower volatility and significantly positive stock returns, along with periods of economic expansion; and the crisis regime, typified by periods of economic recession. Ding et al. (2014) investigated the non-linear dependence between the stock and real estate markets in China using quantile regressions. A significant causality between the equity market (i.e., stock returns) and the real estate market (i.e., housing and land returns) was confirmed. They therefore concluded that it would be impossible for investors to hedge risks across these two markets under extremely fluctuating conditions. The findings from this study also suggest that policymakers should be cautious of increasing systemic risks and should take effective actions when extreme returns are observed in underlying markets. Raza et al. (2018) explored the volatility of commodities traded around the world and developed a series of GARCH-type models to measure the efficiency of hedging real estate risks by commodities from a portfolio perspective. Their findings suggest that base commodities and precious metals (i.e., gold) provide the most effective hedge against real estate investments for short- and long-run investment time horizons, respectively. In spite of the increasing number of studies that have explored the relationship between the commodity futures market and the real estate market, empirical studies on the linkages between these two markets in China are still limited.

3 Methodology

In this paper, we adopt a multivariate vector autoregression (VAR) model, a causality test, and cointegration analysis to gauge the impact of the real estate market on the industrial metals futures market in China. Prior studies (e.g., Watkins & McAleer,

2002) about the commodity futures market mostly examined non-ferrous metals, such as copper, zinc, and aluminum. Selecting only base metals as representatives for the metals market could lead to specification bias, which can potentially occur from the assumption that different classes of metals exhibit homogeneity. Such presumptions might not be demonstrated in practice. Non-ferrous metals, especially copper, are likely to exhibit strong financial characteristics similar to those of precious metals (Guo, 2018), while ferrous metals such as steel and rebar are more likely to present commodity characteristics. Therefore, fluctuations in copper prices tend to reflect not only concurrent fundamentals like commodity (e.g., stock level) but also the expectations of market participants about the future macroeconomy (e.g., monetary policy). This could render the findings of empirical studies with different components ambiguous and relatively hard to explain. To avoid such interpretative ambiguity, we used both ferrous metals (i.e., rebar) and non-ferrous metals (i.e., copper) as representatives for the metals futures market in our empirical testing.

Research (e.g., Chan et al., 2016; Ding et al., 2014) on the real estate market usually employs housing prices and the variables derived thereof (e.g., return rate) as indicators for changes in the real estate market. Housing price is ultimately an inappropriate indicator for the study of the real estate market in situations in which strict regulations are imposed on price fluctuations. More particularly, in the case of China, the real estate market is highly governed by both central and local authorities in order to curb speculation. Accordingly, the prices of real estate have remained relatively stable. Housing prices could potentially lose the explanatory power to reflect market expectations based on the supply–demand relation in the real estate market. Considering this fact, in this study, we used indicators other than housing price—namely, fixed asset investment in real estate (*INVESTMENT*), as measured in Chinese yuan; the size of newly started constructions (*NEWLY START*), as measured by areas in square meters; the sales size (*SALES*), as measured by areas in square meters; and the completed construction size (*COMPLETED*), as measured by areas in square meters—to measure innovations in China's real estate market.

3.1 Vector Autoregression (VAR) Model

The dynamic relationships between variables are often expressed via a VAR model, one in which it is plausible to describe the potential dynamics within a multivariate series without considering pre-determined economic fundamentals or the problems associated with simultaneous estimations (Sims, 1972). In its basic form, a VAR model consists of a set of N endogenous variables, $Y_t = (y_{1t}, y_{2t}, \dots, y_{Nt})$, for n = 1, 2, …,N. The VAR (p) process is defined as:

$$\boldsymbol{Y}_t = \boldsymbol{C} + \boldsymbol{\Theta}_1 \boldsymbol{Y}_{t-1} + \dots + \boldsymbol{\Theta}_p \boldsymbol{Y}_{t-p} + \boldsymbol{\varepsilon}_t \quad (1)$$

$$\boldsymbol{Y}_t = \begin{pmatrix} Y_{1t} \\ \vdots \\ Y_{Nt} \end{pmatrix}, \quad \boldsymbol{C} = \begin{pmatrix} C_1 \\ \vdots \\ C_N \end{pmatrix}, \quad \boldsymbol{\Theta}_i = \begin{pmatrix} \theta_{11,i} & \cdots & \theta_{1N,i} \\ \vdots & \ddots & \vdots \\ \theta_{N1,i} & \cdots & \theta_{NN,i} \end{pmatrix}, \quad \boldsymbol{\varepsilon}_t = \begin{pmatrix} \varepsilon_{1t} \\ \vdots \\ \varepsilon_{Nt} \end{pmatrix}$$

To express the dynamic relationships between the futures market and the real estate market, we tested two industrial metals futures (i.e., copper and rebar) with corresponding spot prices[6] and four selected indicators with specific perspectives to measure changes in the real estate market. We constructed four three-variable VAR models (*N*=*3*) for each of the underlying futures, whereby futures price, spot price, and one indicator of the real estate market were involved in a single VAR system. The combinations of variables for the VARs are presented as follows:

Panel of copper:

$$VAR1\begin{pmatrix} \boldsymbol{Y}_1 = copper\,futures\,price \\ \boldsymbol{Y}_2 = copper\,spot\,price \\ \boldsymbol{Y}_3 = INVESTMENT \end{pmatrix}, \quad VAR2\begin{pmatrix} \boldsymbol{Y}_1 = copper\,futures\,price \\ \boldsymbol{Y}_2 = copper\,spot\,price \\ \boldsymbol{Y}_3 = NEWLY-START \end{pmatrix},$$

$$VAR3\begin{pmatrix} \boldsymbol{Y}_1 = copper\,futures\,price \\ \boldsymbol{Y}_2 = copper\,spot\,price \\ \boldsymbol{Y}_3 = SALES \end{pmatrix}, \quad VAR4\begin{pmatrix} \boldsymbol{Y}_1 = copper\,futures\,price \\ \boldsymbol{Y}_2 = copper\,spot\,price \\ \boldsymbol{Y}_3 = COMPLETED \end{pmatrix}.$$

Panel of rebar:

$$VAR1\begin{pmatrix} \boldsymbol{Y}_1 = rebar\,futures\,price \\ \boldsymbol{Y}_2 = rebar\,spot\,price \\ \boldsymbol{Y}_3 = INVESTMENT \end{pmatrix}, \quad VAR2\begin{pmatrix} \boldsymbol{Y}_1 = rebar\,futures\,price \\ \boldsymbol{Y}_2 = rebar\,spot\,price \\ \boldsymbol{Y}_3 = NEWLY-START \end{pmatrix},$$

$$VAR3\begin{pmatrix} \boldsymbol{Y}_1 = rebar\,futures\,price \\ \boldsymbol{Y}_2 = rebar\,spot\,price \\ \boldsymbol{Y}_3 = SALES \end{pmatrix}, \quad VAR4\begin{pmatrix} \boldsymbol{Y}_1 = rebar\,futures\,price \\ \boldsymbol{Y}_2 = rebar\,spot\,price \\ \boldsymbol{Y}_3 = COMPLETED \end{pmatrix}$$

Impulse response functions (IRFs), which can trace the responsiveness of the dependent variables in the VAR to shocks imposed on each of the variables, were used to describe the process. For each variable in the individual equations, a unit shock was applied to the error, and the impacts on the VAR system over time were recorded. For the three-variable VAR model applied in this paper, a total of 3^2 IRFs could be obtained for each VAR system. For this study, only three IRFs were required for analysis, with metals futures acting as the dependent variables. Specifically, we only considered the responses of metals futures (i.e., copper futures and rebar futures) to the shocks imposed by all endogenous variables.

The IRFs are generated by expressing VAR as an infinite vector moving average (VMA) process. Equation (1) was expressed as

[6] If the futures market is dominant in the price discovery process, then the spot price can be expected to have little explanatory power when the futures price is treated as the dependent variable. Otherwise, spot price, which contains all current market information, can be regarded as a control variable for examining the linkage between changes in the futures price and shocks in the real estate market.

$$\boldsymbol{Y}_t = \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t + \sum_{i=1}^{p} \boldsymbol{M}_i \boldsymbol{\varepsilon}_{t-i}, \tag{2}$$

where $\boldsymbol{M}_0 = \boldsymbol{I}$, $\boldsymbol{M}_i = \sum_{j=1}^{\min(p,i)} \boldsymbol{\Theta}_j \boldsymbol{M}_{i-j}$, $i = 1, 2, \ldots$. Impact multipliers $\frac{\Delta y_{ki}}{\Delta \varepsilon_{j0}} = \frac{\partial y_{ki}}{\partial \varepsilon_{j0}}$ refer to the element of (k, j) in matrix $\boldsymbol{M}_i$ (i.e., specified variables of metals futures and the real estate market) which represents the corresponding innovation of k due to one unit of information change in j after period I.

Because components in matrix $\boldsymbol{M}_i$ are often correlated, the IRFs had to be modified by transforming the error variance–covariance matrix of Eq. (2) into a diagonal matrix via the Cholesky factorization method, after which the original IRFs became the orthogonal IRFs. In this case, underlying shocks in the real estate market are less likely to occur in isolation; on the contrary, a contemporaneous correlation between the components of the residual process is likely to exist. A VMA process was derived based on Eq. (2) as

$$\boldsymbol{Y}_t = \boldsymbol{\mu} + \boldsymbol{\Psi}_0 \boldsymbol{u}_t + \sum_{i=1}^{p} \boldsymbol{\Psi}_i \boldsymbol{u}_{t-i} \tag{3}$$

denoting $\boldsymbol{u}_t = B^{-1}\boldsymbol{\varepsilon}_t$, $\boldsymbol{\Psi}_i = \boldsymbol{M}_i P$, $\boldsymbol{\Psi}_0 = B$ and $\sum \boldsymbol{\varepsilon} = BB'$, with B being the lower triangular matrix. The orthogonal IRFs (impact multipliers) were thus rewritten as $\frac{\partial y_{ki}}{\partial u_{j0}}$ for $i = 0, 1, 2, \ldots$, which was employed to measure the variation of k at each period in response to orthogonal changes of information in j. In practice, IRFs are usually multiplied by a standard deviation $\sqrt{d_{jj}}$ to obtain new IRFs by which the information presented in j is especially changed by one standard deviation. Moreover, if prespecified variables are already expressed in the form of a variation by (first) difference (i.e., ΔY_t in logarithm) before constructing a VAR model, then it is implausible to make inferences on IRFs because of the loss of power needed to measure corresponding shocks—accordingly, in this case, it was practical to use the accumulated IRFs, which were calculated as

$$IRF^* = \sum_{j=1}^{T} \Delta Y_{f,t+j} \Big/ \sum_{j=1}^{T} \Delta Y_{x,t+j}, \tag{4}$$

where $\Delta Y_{f,t+j}$ represents changes in the price of industrial metals futures resulting from shocks in the real estate market after j months, and $\Delta Y_{x,t+j}$ corresponds to changes in the real estate indicator. Based on Eq. (4), the accumulated IRFs can be expected to directly reflect the trend of the transmission effects of shocks in the real estate market on the futures market over time.

The forecast error variance decomposition (FEVD) method is based on the orthogonal coefficient matrices of the IRFs, which provides the proportion of movements in the dependent variable that result from their own shocks versus shocks from the other variables. In this study, FEVD was used to analyze how much of the h-step forecast error variance of industrial metals futures prices could be explained by innovations in the spot price and real estate indicators. According to Eq. (3), the forecast error variance for a three-variable VAR can be defined as

$$\boldsymbol{\Sigma}(h) = \boldsymbol{\Psi}_0\boldsymbol{\Psi}_0' + \ldots + \boldsymbol{\Psi}_{h-1}\boldsymbol{\Psi}_{h-1}', \tag{5}$$

$$\boldsymbol{\Sigma}(h) = \begin{bmatrix} var\left(y_{1,T}(h)\right) & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & var\left(y_{3,T}(h)\right) \end{bmatrix},$$

where the diagonal element is the forecast error variance, and further

$$\boldsymbol{\Psi}_k\boldsymbol{\Psi}_k' = \begin{bmatrix} \sum_{j=1}^{3} \Psi_{1j,k}^2 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sum_{j=1}^{3} \Psi_{3j,k}^2 \end{bmatrix},$$

The i-th diagonal element in matrix $\boldsymbol{\Psi}_k\boldsymbol{\Psi}_k'$ is the sum of squares of the elements of the i-th row in matrix $\boldsymbol{\Psi}_k$. Hence

$$\text{var}\left(y_{i,T}(h)\right) = \sum_{j=1}^{3} \Psi_{ij,0}^2 + \ldots + \sum_{j=1}^{3} \Psi_{ij,h-1}^2, \tag{6}$$

and Eq. (6) could be written as

$$\text{var}\left(y_{i,T}(h)\right) = \sum_{k=0}^{h-1} \Psi_{i1,k}^2 + \ldots + \sum_{k=0}^{h-1} \Psi_{i3,k}^2, \tag{7}$$

where $\sum_{k=0}^{h-1} \Psi_{ij,k}^2$ represents the contribution of the new information presented by variable j to forecast error variance which can be defined as the total impact of the three sets of new information for the three-variable VAR system in this study.

FEVD thus yielded

$$FEVD = \frac{\sum_{k=1}^{h-1} \Psi_{ij,k}^2}{\text{var}\left(y_{i,T}(h)\right)}, \quad j = 1, 2, 3 \tag{8}$$

From Eq. (8), FEVD could be interpreted as a partial R^2 for forecast error by a pre-determined forecast horizon (i.e., the number of h).

3.2 Causality Analysis

To detect causalities between the industrial metals futures market and the real estate market regardless of corresponding variables, we employed two types of Granger causality tests (Granger, 1969)—namely, a block significance test and a bivariate Granger causality test. As it can be very difficult to determine which sets of variables have significant effects on each dependent variable when many lags are included in VARs, a block significance test was conducted since it can restrict all the lags of a particular variable to zero. In line with our analysis in Sect. 3.1, it was only necessary to consider the case in which the futures price was treated as the dependent variable. Therefore, the specified three-variable VAR(p) process in this study was as follows:

$$y_{f,t} = \alpha + \sum_{i=1}^{p} \beta_{1i} y_{f,t-i} + \sum_{i=1}^{p} \beta_{2i} y_{s,t-i} + \sum_{i=1}^{p} \beta_{3i} y_{x,t-i} + \varepsilon_t, \tag{9}$$

where $y_{f,t}$ is the price of industrial metals futures, $y_{s,t}$ is the spot price of industrial metals, and $y_{x,t}$ represents the indicator of real estate. As each individual set of restrictions involves parameters drawn from only one equation, the joint hypotheses could easily be tested with the F-test. The restricted residual sum of squares (RRSS) (i.e., $\Sigma\varepsilon_t^2$) could be obtained by running an ordinary least squares (OLS) regression on Eq. (9), while the unrestricted residual sum of squares (URSS) could be calculated by regressing

$$y_{f,t} = \alpha + \sum_{i=1}^{p} \beta_{1i} y_{f,t-i} + u_{1t}, \tag{10a}$$

$$y_{f,t} = \alpha + \sum_{i=1}^{p} \beta_{1i} y_{f,t-i} + \sum_{i=1}^{p} \beta_{2i} y_{s,t-i} + u_{2t}, \tag{10b}$$

$$y_{f,t} = \alpha + \sum_{i=1}^{p} \beta_{1i} y_{f,t-i} + \sum_{i=1}^{p} \beta_{2i} y_{x,t-i} + u_{3t}, \tag{10c}$$

In Eq. (10a), $y_{s,t}$ and $y_{x,t}$ are both blocked from the VAR system; whereas in Eq. (10b), $y_{x,t}$ is excluded, while $y_{s,t}$ is excluded in Eq. (10c). The F-test was constructed as

$$F{-}statistic = \frac{(RRSS - URSS)/p}{URSS/(T - 2p - 1)} \tag{11}$$

where p is the lag order, and T is the number of observations. If all the F-*statistics* are significantly greater than their critical value, it can be concluded that the shocks in spot price and the indicator of real estate not only together but also separately Granger cause the changes in futures prices. Otherwise, each individual case from which the spot price and real estate variables are excluded from the VAR system should be checked.

The bivariate Granger causality test was derived from the two pre-specified variables that we chose to test in this paper (i.e., metals futures and the real estate indicator). The specifications were as follows:

$$f_t = C + \sum_{i=1}^{p} \beta_i f_{t-i} + \sum_{j=1}^{q} \gamma_i x_{t-j} + u_{1t}, \tag{12a}$$

$$f_t = C + \sum_{i=1}^{p} \beta_i f_{t-i} + u_{2t}, \tag{12b}$$

where f_t is the metals futures price, and x_t is the measurement of the real estate market. In this case, the hypotheses are $H_0 : \gamma_i = 0$ versus $H_1 : \gamma_i \neq 0$. If the null hypothesis were to be rejected by a significant F-statistic, then it could be concluded that changes in the corresponding variables of the real estate market are responsible for Granger cause changes to innovations in the price of industrial metals futures.

3.3 Cointegration Analysis

In order to investigate the long-term relationship between the industrial metals futures market and the real estate market, we constructed cointegration frameworks (Engle & Granger, 1987). A cointegrating relationship can be treated as a long-run phenomenon from which underlying variables might deviate in the short run, but their association can be expected to return in the long run. Another important reason for conducting cointegration analysis is the non-stationary nature presented by underlying variables, which would lead to spurious regressions under the OLS method, and the corresponding results of VARs, about which it would be implausible to make inferences. In this case, using stationary data after they have been differenced by first or higher orders is widely accepted, but cointegration analysis is in some ways more practical for avoiding spurious regressions without risking the loss of any long-run information contained in the data.

In this paper, Johansen's (1988) technique was adopted to test for a cointegrating system based on the three-variable VAR process. First, Eq. (1) was derived as

$$\Delta \boldsymbol{Y}_t = \boldsymbol{\Pi} \boldsymbol{Y}_{t-p} + \boldsymbol{\Gamma}_1 \Delta \boldsymbol{Y}_{t-1} + \ldots + \boldsymbol{\Gamma}_{p-1} \Delta \boldsymbol{Y}_{t-(p-1)} + \boldsymbol{\varepsilon}_t, \tag{13}$$

where $\boldsymbol{\Pi} = \left(\sum_{i=1}^{p} \beta_i\right) - \boldsymbol{I}_3$, and $\boldsymbol{\Gamma}_i = \left(\sum_{j=1}^{i} \beta_j\right) - \boldsymbol{I}_3$. In Eq. (13), corresponding variables in the original three-variable VAR system were first differenced, with RHS containing $p-1$ lags of dependent variables, and each variable was attached with a $\boldsymbol{\Gamma}$ coefficient matrix. In line with VARs, the optimal lag order of p could be determined by the Akaike information criterion (AIC).

Then, the rank of matrix $\boldsymbol{\Pi}$ was calculated by assessing the number of its nonzero eigenvalues, which was denoted as λ_i and $i = 1, 2, 3$ for the three-variable VAR. In this case, if the rank of $\boldsymbol{\Pi}$ was not significantly different from zero (i.e., $\lambda_i \approx 0 \forall i$), then the variables in the VAR system would not be cointegrated. Therefore, two Johansen test statistics were formulated as follows:

$$\lambda_{\text{trace}}(r) = -T \sum_{i=r+1}^{3} \ln\left(1 - \hat{\lambda}_i\right), \tag{14a}$$

$$\lambda_{\max}(r, r+1) = -T\ln\left(1 - \hat{\lambda}_{r+1}\right), \tag{14b}$$

where r is the number of cointegrating vectors of the null hypothesis, and $\hat{\lambda}_i$ is the estimated value of the i-th order eigenvalue from matrix $\mathbf{\Pi}$. λ_{trace} is called a trace test, i.e., a joint test with the corresponding null hypothesis, $H_0 : No.\, of\; CVs \leq r$; $\lambda_{\max}$, is another indicator that each eigenvalue is separately tested with the null hypothesis, $H_0 : No.\, of\; CVs = r$. Each eigenvalue was expected to bear an association with a different cointegrating vector, CV, which would then become an eigenvector, and a significantly non-zero eigenvalue would imply a significant cointegrating vector. Notably, for the three-variable VAR model in this paper, the value of r was continually increased in the underlying hypotheses until the null hypothesis was no longer rejected (i.e., $r=3$). Once the cointegrating vectors were collected based on Johansen's (1988) approach, the corresponding cointegrating relationships could be expressed by a vector error correction model (VECM). We only considered the case in which the price of industrial metals futures was treated as the dependent variable, with the error correction model (ECM) consequently defined as follows:

$$\Delta y_{f,t} = C + \sum_{k=0}^{d} \beta_{1k} \Delta y_{f,t-k} + \sum_{i=0}^{p} \beta_{2i} \Delta y_{s,t-i} + \sum_{j=0}^{q} \beta_{3j} \Delta y_{x,t-j} + \gamma ECT_{t-1} + \varepsilon_t, \tag{15}$$

$$ECT = y_{f,t} - \left(\alpha_1 + \varphi_1 y_{s,t} + \varphi_2 y_{x,t}\right), \tag{16}$$

where ECT_{t-1} is the ECT of the last period, and γ governs the speed of adjustment at which markets obtain equilibrium. The first four components of the RHS in Eq. (15) demonstrate the short-term dynamics, while in the long run, $\Delta y_{f,t} = \Delta y_{s,t} = \Delta y_{x,t} = 0$. Thus, the RHS of Eq. (16) describes the long-term linkage between the futures market and the real estate market.

4 Variables and Data

4.1 Variables and Variable Definition

Applying higher-frequency data can capture fluctuations more accurately in the futures prices of underlying metals, which are driven by volatilities in the real estate market (Guo & Huang, 2010). Therefore, instead of using annual or quarterly data as typically employed by previous studies, we used monthly data to avoid moderate size distortions and the loss of explanatory power. We selected copper and rebar as representatives of non-ferrous and ferrous metals futures, respectively. We used the four indicators most frequently adopted in fundamental analyses to measure innovation in the real estate market. Data for the corresponding variables were collected from the China Wind Infor. Ltd. database.

Copper futures price (*COPPER*) and rebar futures price (*REBAR*) were the monthly averaged intraday closed price of copper futures and rebar futures traded on the Shanghai Futures Exchange (SHFE), respectively. We used the dominant futures contracts for both metals, also monthly continuous, with the largest trading volume. As the most active contracts with the highest liquidity compared to other listed contracts, dominant futures contracts are likely to accurately and precisely reflect market expectations and market sentiments, and thus corresponding price volatility can be expected to more effectively measure how the metals futures market reacts to external shocks. Copper spot price was defined as the monthly adjusted spot (cash) price quoted by an online information agency, the Changjiang Non-ferrous Metal Network. The averaged transaction price of refined copper is always viewed as a benchmark for market participants in China, and as such this benchmark was used for empirical testing in this study. Rebar spot price was defined as the monthly adjusted, weighted-average spot price of various types of rebar traded in domestic commodity markets. The size of the sectional area of the underlying rebar ranges from 16 to 25 mm, which represent the main inputs in construction and, importantly, allow for prompt delivery as stipulated in rebar futures contracts.

Data for fixed asset investment in the real estate market (*INVESTMENT*) are accumulated monthly by the National Bureau of Statistics (NBS) of China. These data represent the total amount of capital invested (Chinese yuan) in the real estate market in each reporting period. Fixed asset investment is a crucial indicator of the real estate market, one that not only reflects the macroeconomic situation—for example, substantial investment in the real estate market often suggests an economic boom or even an overheated economy—but also indicates supply fluctuations in the real estate market (i.e., more investment means a greater housing supply). The size of newly started constructions (*NEWLY START*) yields monthly accumulated data which represent the summation of the size of newly started housing constructions in China as measured in square meters in each reporting period. This indicator more directly shows the potential supply of real estate in a specified future period. Its volatility could also represent visible changes in the real estate market. The sales size of the real estate market (*SALES*) constitutes the monthly accumulated sales volume of the real estate market as measured in square meters. This indicator measures the overall size of real estate that has already been sold in each reporting period, and it also reflects actual demand for housing in China's real estate market. The completed size of constructions (*COMPLETED*) includes monthly accumulated data that summarize all areas of real estate, as measured in square meters, that have completed construction in each reporting period. Changes in this indicator reflect fluctuations in explicit supply in the real estate market. Fundamental analysts often categorize fixed asset investment in the real estate market and the size of newly started constructions as leading indicators; the completed size of constructions, on the other hand, is considered to be a synchronized indicator; lastly, the sales size of the real estate market is classified as a lagging indicator. Data for all real estate indicators were obtained from the NBS of China.

Data regarding the copper futures and spot prices were taken from January 2004 to March 2019, here considering the market liquidity of copper futures contracts (listed on the SHFE since 1992) and the availability of data in the real estate market. Because the rebar futures market was established in 2009, data concerning rebar

Table 1 Summary statistics of sample data

Statistic	Futures		Spot			Real Estate Market		
	Copper	Rebar	Copper	Rebar	Invest-ment	Newly-Start	Sales	Completed
Mean	10.7828	8.1392	10.7866	8.1769	8.3995	9.3925	9.0177	8.6612
Median	10.8386	8.2187	10.8380	8.2400	8.6234	9.5613	9.0896	8.5773
Maximum	11.2348	8.5418	11.2397	8.5206	9.5547	10.1178	10.0454	10.4131
Minimum	10.0682	7.4438	10.0688	7.5552	6.7637	8.2732	7.5650	7.3959
Std. Dev	0.2655	0.2766	0.2616	0.2373	0.7727	0.4703	0.5900	0.6866
Skewness	– 0.6617	– 0.9207	– 0.6411	– 0.9250	– 0.4872	– 0.7560	– 0.5852	0.7489
Kurtosis	2.7060	2.9467	2.6901	3.0540	1.9051	2.4227	2.7368	3.3083
N	183	121	183	121	183	183	183	183

Data are expressed in logarithm

futures and spot prices were taken from March 2009 to March 2019. The real estate market variables were retrieved from the same sample period as that used for obtaining data on copper and rebar prices. As the real estate market data collected by the NBS are in a monthly accumulated format (i.e., the data for each month are calculated as the data collected in the current reporting period plus the data collected in the preceding reporting period), we calculated the monthly data for each real estate indicator by subtracting the data of the last reporting month from the data of the current reporting month.

4.2 Data Description

Table 1 presents descriptive statistics of the variables used in this paper. Notably, the standard deviations of industrial metals prices, which ranged between 0.24 and 0.28, were significantly smaller than those generated for the indicators in the real estate market, which ranged between 0.47 and 0.77, thereby implying that the metals market is less volatile than the real estate market. Copper and rebar prices seem to share similar fluctuation levels, whereas volatilities in the real estate market evidently seem to vary on a large scale across the four variables.

As can be seen from the graphs in Fig. 1, the futures prices and spot prices of copper and rebar follow parallel paths, suggesting that the price discovery process generates a parallel tendency between futures prices and spot prices as predicted by relevant theories (i.e., the cost of carry theory and the unbiased predictor hypothesis of futures prices). During the sample period, copper prices suffered a dramatic decline as a consequence of the 2008 global financial crisis; meanwhile, in mid-2015, rebar prices bottomed out due to a crisis in the Chinese capital market. The Chinese stock market crisis also pulled copper prices downward in the second bear period. The prices of both metals rebounded thereafter, following an increasing trend despite some fluctuations. The prices of copper and rebar are not moving around a certain equilibrium point, but present specific distinguished trends affected

Fig. 1 Futures and spot prices of copper and rebar

by external economic factors. From the graphs in Fig. 1, it can be deduced that the futures and spot prices of copper and rebar are not stationary.

As evident from the plots in Fig. 2, all four indicators in the real estate market, especially the completed size of constructions, show characteristics typical of macro time series—seasonality and trend. In our sample data, an extreme point regularly appeared in a certain month (season) of each year, and the mean point increased throughout the sample period. This suggests that the sample data contain not just a random component but trend and seasonal components as well, which in turn implies that the sample data likely constitute a non-stationary series. The seasonality component could be explained by the nature of real estate constructions, which are tightly related to seasons. More specifically, construction corporations tend to commence projects when the weather is suitable for workers and facilities, and they thus avoid construction in the summer or rainy seasons. Past statistics from Huang et al. (2018) indicate that the average completion period for housing construction in China is about two to three years. This consequently generates the so-called completion cycle (i.e., most real estate projects are meant to be completed in certain months of each year) that follows the newly started cycle. Meanwhile, the newly started cycle is accompanied by the investment cycle (i.e., the period in which capital is invested in the real estate market in each year) for a similar reason. Increasing trends of the mean point of real estate indicators are significantly related to economic growth in China. More precisely, investment in real estate constitutes an important part of aggregate demand, and thus the expansion (or even bubble) of the real estate market has stimulated growth in the Chinese economy since 2008 (Guo & Huang, 2010).

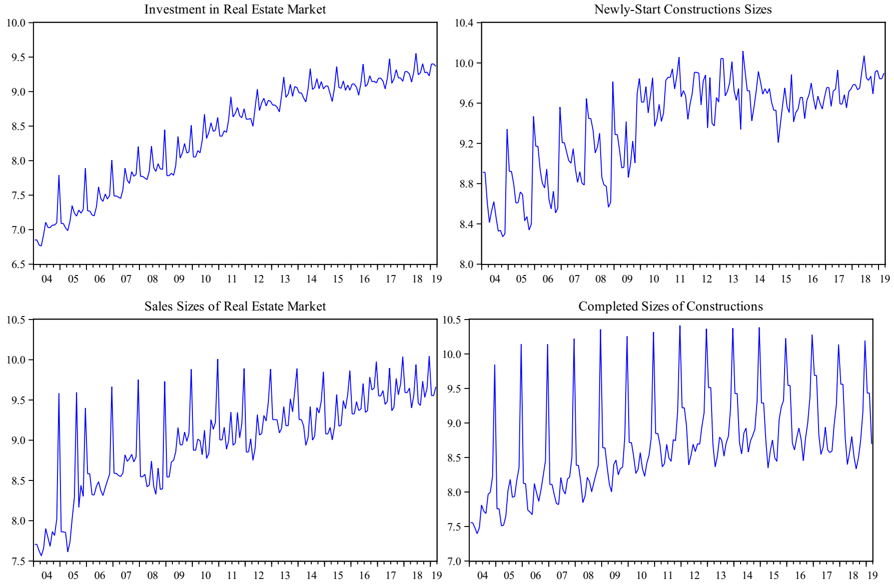

Fig. 2 Indicators of real estate market

5 Empirical Findings

The results of an augmented Dickey-Fuller (ADF) unit root test[7] indicate that none of the underlying variables of the industrial metals futures market or the real estate market are stationary in levels and all of them become significantly stationary in first difference. Hence, corresponding first-order differenced variables were used in constructing VARs. We calculated the optimal lag length for the three-variable VAR based on information criterion. In this paper, as in earlier studies (e.g., Sims, 1972), we adopt the number obtained by the AIC as the lag order for corresponding VARs.

The results of the IRFs of industrial metals futures are shown in Table 2. The accumulated responses of futures prices to their own innovations are greater than those of the other variables, suggesting that futures prices are likely to be the most sensitive to internal changes. The responses to the four underlying real estate indicators were all positive throughout the sample period, implying that positive shocks in the real estate market can be expected to raise the futures prices of metals. However, the transmission mechanism is incomplete and presents a certain time lag. Specifically, a one-unit change in fixed asset investment in the real estate market would increase the price of copper futures by 1.13% after six months, only to then decrease to 0.87% two years later. Meanwhile, a one-unit change in fixed asset investment in the real estate market would increase the price of rebar futures by 0.51% after two

[7] For brevity, we did not report the results of the ADF test. These results can, however, be provided upon request.

Table 2 Impulse response[a] for VARs of industrial metals futures

	Months after Shock	Accumulated response of industrial metals futures to innovations in											
		Futures				Spot				Investment	Newly-Start	Sales	Completed
		VAR1	VAR2	VAR3	VAR4	VAR1	VAR2	VAR3	VAR4	VAR1	VAR2	VAR3	VAR4
Copper	1	0.0639	0.0604	0.0620	0.0627	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	6	0.0949	0.0932	0.0965	0.0978	− 0.0034	− 0.0026	0.0004	− 0.0018	0.0113	0.0406	0.0190	0.0095
	12	0.0970	0.0737	0.0717	0.0745	− 0.0055	− 0.0035	0.0052	0.0028	0.0097	0.0219	0.0097	0.0060
	18	0.0978	0.0741	0.0769	0.0801	− 0.0056	− 0.0025	0.0018	0.0009	0.0091	0.0256	0.0097	0.0054
	24	0.0979	0.0775	0.0790	0.0812	− 0.0058	− 0.0030	0.0030	0.0014	0.0087	0.0246	0.0099	0.0048
Rebar	1	0.0621	0.0578	0.0564	0.0573	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	6	0.0707	0.0755	0.0740	0.0735	0.0083	0.0059	− 0.0012	− 0.0061	0.0045	0.0014	0.0133	0.0084
	12	0.0696	0.0737	0.0909	0.0916	0.0086	0.0132	0.0011	− 0.0054	0.0043	0.0100	0.0145	0.0099
	18	0.0693	0.0745	0.1012	0.1007	0.0089	0.0087	− 0.0021	− 0.0087	0.0050	0.0064	0.0161	0.0113
	24	0.0694	0.0739	0.1026	0.1020	0.0089	0.0104	− 0.0009	− 0.0078	0.0051	0.0068	0.0165	0.0098

[a]Accumulated response to Cholesky one standard deviation

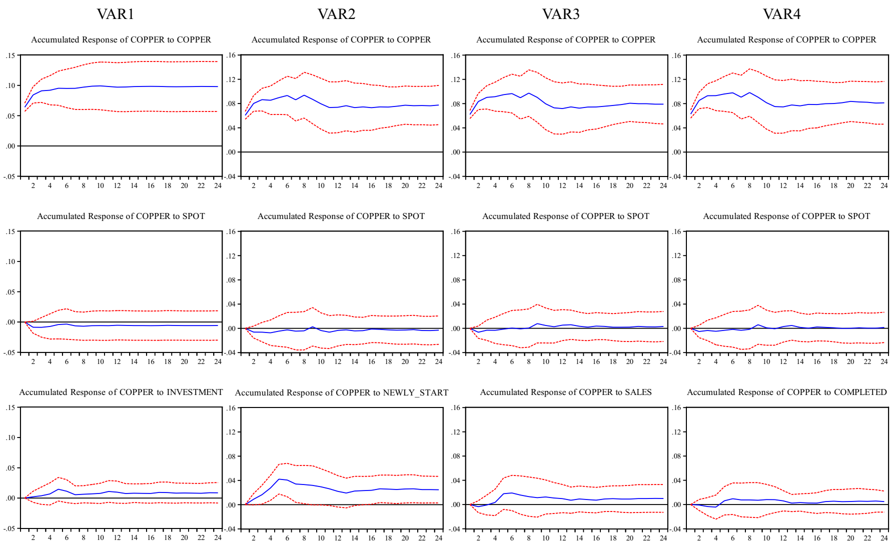

Fig. 3 Accumulated response of copper futures to shocks

years. Similarly, a single positive shock in the size of newly started constructions could be expected to increase the price of copper futures by 4.06% in six months, with the accumulated response remaining at the 2.5% level thereafter. Further, the accumulated response to a single positive shock in the size of a newly started construction for rebar futures would become 0.64% after 18 months. Rebar futures tend to be more sensitive to innovations in the sales size of the real estate market than in other indicators, as the accumulated impact of a one-unit change in the sales size would raise the price of rebar futures by 1.65% in two years, compared to 0.98% for a response to changes in the completed size of constructions and less than 1% for a response to changes in fixed asset investment and the size of newly started constructions for the same period. The shocks in the completed size of constructions only resulted in an increase of 0.48% in copper futures after two years, with the effects geometrically declining over time. In contrast to the impacts on rebar futures, changes in the sales size of the real estate market led to less than a 1% increase in the price of copper futures in two years.

Figures 3 and 4 plot the accumulated IRFs of industrial metals futures. As evidenced from the graphs, internal shocks are dominant in changes to futures prices and also spearhead the price discovery process. Spot price has small, time-invariant impacts on futures prices, especially for copper futures, for which the accumulated response to spot price remains at the zero level. The effects of shocks in real estate indicators on copper futures peak after about five months, then horizontally decay before stabilizing thereafter. The size of newly started constructions has a greater impact on copper futures prices than the other real estate measurements. Rebar futures seem to demonstrate a less accumulated response to innovations in the real estate market. This may imply that the price discovery function of rebar futures is less effective than that of copper futures. Shocks in the spot market possess a larger

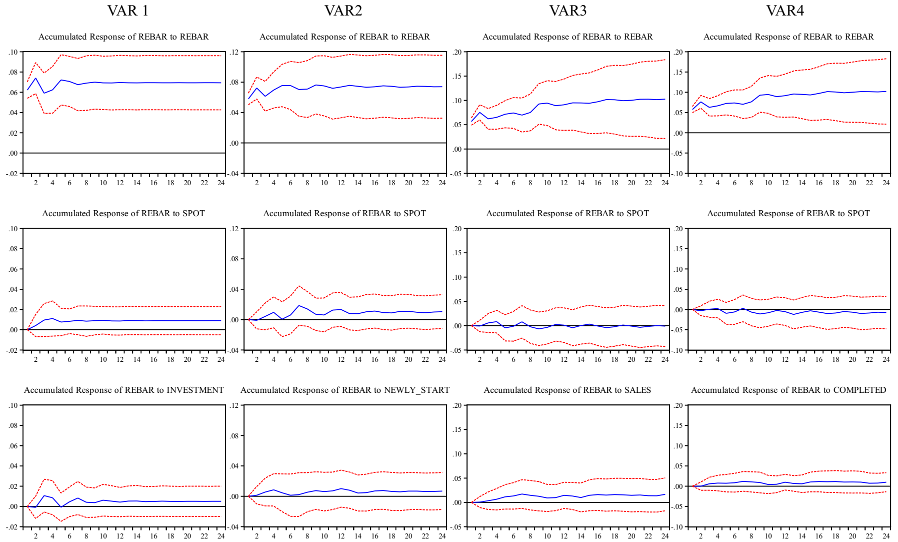

Fig. 4 Accumulated response of rebar futures to shocks

explanatory power for changes in the rebar futures market. The impacts of external innovations (i.e., shocks in the real estate market) on the price of rebar futures could lessen, as investors tend to focus more on the dynamics of the spot market than on changes in the real estate market. In addition, the weaker responsiveness of the rebar futures price to the real estate market might reflect the commodity characteristics of rebar futures, which seem to be stronger than those of the copper futures.

Table 3 presents the results of the FEVD of underlying metals futures. Empirical findings from the FEVD are generally in line with those of the IRFs.[8] In the beginning, external markets contribute nothing to explaining changes in the metals futures market. Innovations of futures prices are completely attributed to the futures prices themselves. Afterward, changes in metals futures prices are still predominantly the result of internal innovations. This empirical finding is consistent with a typical price discovery process, one which expects the futures market to be dominant in the price discovery process. Specifically, 10.17% of the changes in copper futures prices are caused by shocks from newly started constructions after six months. The contribution of such shocks increases to 11.31% after two years. The other three indicators of the real estate market explain less than 6% of the changes in the copper futures market. Innovations in the rebar spot market could explain more than 10% of the changes in the rebar futures market in VAR2, VAR3, and VAR4 specifications, while the explanatory power of innovations in the real estate market for rebar futures prices is less than 3%. This finding provides additional support to our earlier findings that commodity characteristics

[8] Generally, the FEVD can be derived from the IRFs, but the results of the two approaches are not completely consistent as they describe the different properties of the VAR estimates.

Table 3 Forecast error variance decomposition for VAR of industrial metals futures

	Months ahead	Percentage change of industrial metals futures explained by movements in											
		Futures				Spot				Investment	Newly-Start	Sales	Completed
		VAR1	VAR2	VAR3	VAR4	VAR1	VAR2	VAR3	VAR4	VAR1	VAR2	VAR3	VAR4
Copper	1	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.00
	6	96.2806	88.7242	93.4209	96.4118	1.8862	1.1028	1.2610	0.8166	1.8332	10.1729	5.3181	2.7717
	12	95.1354	86.0724	91.8691	94.4793	2.0709	3.0334	2.7123	2.7945	2.7937	10.8942	5.4186	2.7262
	18	94.9697	85.5088	91.3633	93.7342	2.0751	3.2158	2.9471	3.1438	2.9553	11.2754	5.6896	3.1219
	24	94.9314	85.4100	91.3167	93.6422	2.0766	3.2757	2.9854	3.2056	2.9920	11.3144	5.6979	3.1522
Rebar	1	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	93.2176	94.4054	93.3522	94.6797	1.3130	8.2509	5.5278	4.3856	5.4694	1.3309	1.1200	0.9347
	12	92.4005	88.1013	87.7169	88.9762	1.3467	10.0647	10.0534	8.8124	6.2528	1.8341	2.2298	2.2114
	18	92.3625	86.8283	85.5766	86.4733	1.3535	10.8146	11.5113	10.7608	6.2840	2.3571	2.9121	2.7797
	24	92.3616	86.6664	84.8883	85.7030	1.3536	10.9445	11.9995	11.2848	6.2848	2.3891	3.1122	3.0123

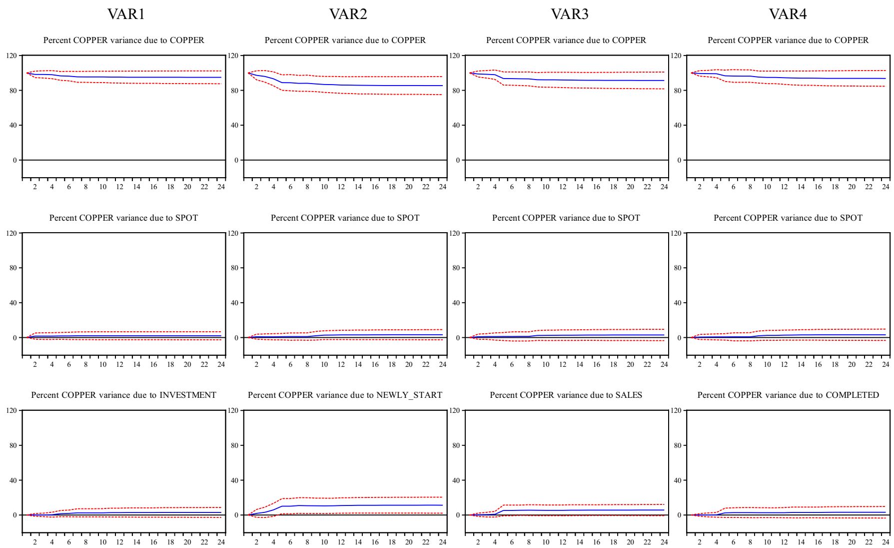

Fig. 5 Forecast error variance decomposition of copper futures

dominate rebar futures. While IRF results indicate that changes in rebar futures prices are mostly caused by shocks from the sales size of the real estate market, the results of the FEVD suggest that shocks from fixed asset investment in the real estate market can explain 6.28% of the changes in rebar futures prices. Most fundamental researchers treat fixed asset investment in the real estate market as a benchmark for predicting the future performance of rebar futures. In summary, copper futures exhibit relatively strong relationships with the real estate market in that they are affected to a large extent by real estate market fluctuations. Meanwhile, rebar futures are also sensitive to shocks from investments in the real estate market, albeit to a relatively weaker degree.

The impacts of innovations generated by the real estate market can be observed in Figs. 5 and 6. Fluctuations in the price of copper futures are mainly due to shocks caused by newly started constructions, while the volatility of fixed asset investment in the real estate market can explain most of the shocks in the price of rebar futures. The effects of changes in the spot market on the price of rebar futures initially increase and then remain stable as time moves on. On the contrary, the spot market has no explanatory power for copper futures, implying a weakly efficient market structure whereby the price discovery process can be expected to be led by the futures market via a unidirectional information transmission mechanism in the copper futures market. Copper futures, which possess greater financial characteristics, tend to be more sensitive to innovations in the real estate market.

The results of a Granger causality test based on the VAR model are reported in Table 4. For copper futures, the *F*-statistic is only significant in VAR2, where newly started constructions are employed as a real estate market measurement, suggesting that changes in the size of newly started constructions can be expected to Granger cause changes in the price of copper futures. This finding supports the empirical

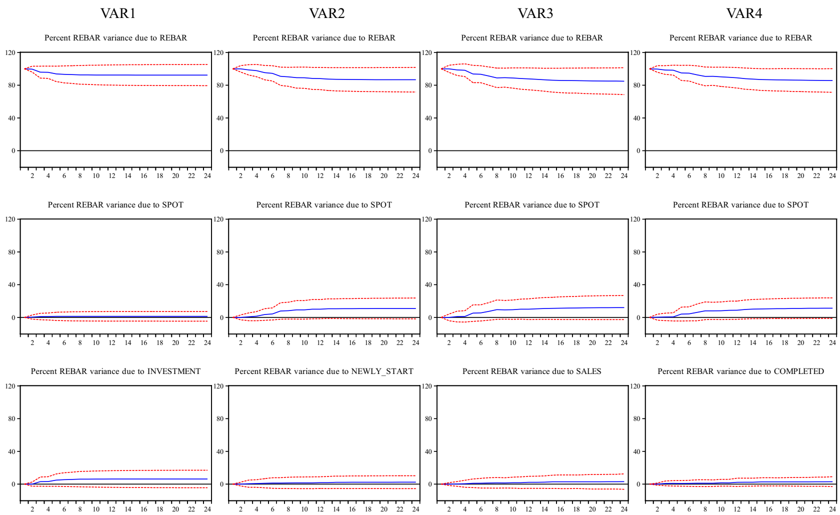

Fig. 6 Forecast error variance decomposition of rebar futures

Table 4 VAR granger causality/block exogeneity wald tests

	VAR1		VAR2		VAR3		VAR4	
Copper	Excluded	χ^2	Excluded	χ^2	Excluded	χ^2	Excluded	χ^2
	Spot	3.7011	Spot	7.3988	Spot	10.9731	Spot	7.5082
	Investment	4.5301	Newly-Start	18.1914**	Sales	9.8685	Completed	6.2294
	All	10.5096	All	30.2641***	All	21.3402	All	17.4383
Rebar	Excluded	χ^2	Excluded	χ^2	Excluded	χ^2	Excluded	χ^2
	Spot	1.7572	Spot	9.4125	Spot	9.5022	Spot	9.3370
	Investment	6.9677*	Newly-Start	1.6852	Sales	5.8752	Completed	3.0096
	All	8.4089	All	11.0108	All	14.6863	All	11.5487

*, **, and *** denote statistical significance at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively

findings generated by the IRF and FEVD approaches, which demonstrated that variations in the size of newly started constructions have the largest impact on and explanatory power for innovations in the copper futures market. Granger causality was only detected in VAR1 for the price of rebar futures when fixed asset investment in the real estate market was used for constructing a three-variable VAR process. This empirical finding confirms the conclusion of the FEVD approach that shocks from fixed asset investment in the real estate market explain changes in the price of rebar futures, and yet this finding is contrary to that of the corresponding IRF, which indicated that shocks from the sales size of the real estate market had the greatest effects on the rebar futures market. A bivariate Granger causality test[9] suggested that Granger causality from the size of newly started constructions was involved in the price of copper futures, providing additional support for our findings. However, another bivariate Granger causality test indicated that the sales size of the real estate market does not Granger cause rebar futures, inferring that the information transmission mechanism from the real estate market to the rebar futures market is not efficient.

The corresponding coefficients of the components constituting the underlying combination of VARs as well as the coefficients of cointegrating vectors[10] for each panel are reported in Table 5. There exist long-term relationships between the industrial metals futures market and the real estate market, with statistically significant coefficients of real estate market indicators in cointegrating equations, which describe the long-run dynamic equilibria. The signs of coefficients for real estate market measurements were all negative in the copper futures panel, but they were conversely all positive in the rebar futures panel, implying that innovations in the real estate market could suppress the price of copper futures and enhance the price of rebar futures in the long run. Because of spot-futures arbitrage, variations in the spot market are negatively correlated with the underlying futures market in the long run. Lastly, the absolute values of the coefficients of the cointegrating vectors, which govern the speed of adjustments made to obtain equilibrium, were, in the copper panel, significantly larger than those in the rebar panel. This may imply that the proportion of the last period's equilibrium error, which was corrected, was greater in the copper futures market than in the rebar futures market. For example, considering the VAR1 model, the coefficient of the cointegrating vector of copper futures was 1.4343, which means that once the initial equilibrium deviated, the price of copper futures was expected to achieve an equilibrium level by 143.43% within one month, or by 100% within 0.7 months; meanwhile, the coefficient of the cointegrating vector of rebar futures was 0.0281, suggesting that the price of rebar futures would achieve equilibrium by 2.81% in one month or by 100% in about 36 months.

The plots of cointegrating relationships between the industrial metals futures market and the real estate market are displayed in Figs. 7 and 8. It can be observed that during the global financial crisis, the dynamics of the copper futures price and the real estate indicators severely fluctuated and greatly deviated from the equilibrium level. The relations, which tend to present similar patterns for each panel of VARs, became less volatile after the global recession, and they remained relatively stable,

[9] The bivariate Granger causality test rejected the null hypothesis for the size of newly started constructions, and thus the size of newly started constructions Granger cause changes to the price of copper futures ($\chi^2 = 2.8691$, $p < 0.001$). The bivariate Granger causality test did not reject the null hypothesis for the other relationships between real estate market indicators and metals futures. For brevity, we did not report the full results; they can, however, be provided upon request.

[10] In this study, we used Johansen's methods for cointegration testing based on a trace test and a maximum eigenvalue test. Given an eigenvalue, the corresponding hypothesis would be rejected in turns until the underlying test statistic was insignificant. As intercepts could be included either in the cointegrating vectors themselves or as additional terms in a VAR process, as in this study, this would be equivalent to including a pre-deterministic trend parameter in the latter case. Each panel of VARs had at least one cointegrating vector whereby industrial metals futures were treated as a dependent variable and a trend was included that could have affected the number of cointegrating vectors.

Table 5 Vector error correction estimates

		Cointegration vector[a]				Coefficient
Copper	VAR1	Futures	C	Spot	Investment	
		1.0000	0.2064	− 1.0144***	− 0.0056***	1.4343
				(0.0022)	(0.0007)	(1.7831)
	VAR2	Futures	C	Spot	Newly-Start	
		1.0000	0.2015	− 1.0086***	− 0.0111***	− 0.8371
				(0.0024)	(0.0013)	(1.5517)
	VAR3	Futures	C	Spot	Sales	
		1.0000	0.2092	− 1.0113***	− 0.0092***	− 1.1616
				(0.0023)	(0.0011)	(1.7197)
	VAR4	Futures	C	Spot	Completed	
		1.0000	0.2297	− 1.0124***	− 0.0106***	− 0.2218
				(0.0028)	(0.0013)	(0.7894)
Rebar	VAR1	Futures	C	Spot	Investment	
		1.0000	1.1105	− 1.1493***	0.0168***	0.0281
				(0.0186)	(0.0126)	(0.3754)
	VAR2	Futures	C	Spot	Newly-Start	
		1.0000	0.8273	− 1.1754***	0.0668***	− 0.0483
				(0.0143)	(0.0165)	(0.2523)
	VAR3	Futures	C	Spot	Sales	
		1.0000	1.1019	− 1.1609***	0.0272***	0.4161
				(0.0127)	(0.0149)	(0.4195)
	VAR4	Futures	C	Spot	Completed	
		1.0000	− 1.1494	− 1.0861***	0.2115***	− 0.1232
				(0.0276)	(0.0392)	(0.1961)

*, **, and *** denote statistical significance at $p<0.1$, $p<0.05$, and $p<0.01$, respectively

Coefficients of futures prices are normalized into unit for convenience

[a]Cointegrating vector in this case is expressed as $Futures = \alpha C + \beta Spot + \gamma Indicator$

alongside the business cycle, thereafter, taking only several months for the futures price to obtain equilibrium. The long-term relationships between the rebar futures market and the real estate market do not generally present a pattern as clear as that for copper futures. The volatilities of cointegrating relations for rebar futures and the real estate market are greater than those for copper futures. Except VAR4, in which the completed size of constructions was used as a real estate market measurement, the other three VARs exhibited identical trends with respect to cointegrating relations between rebar futures and the real estate market. The VAR4 panel displayed evidently larger fluctuations with the greatest coefficient of real estate measurement from the corresponding figures, as shown in Table 5. It also took more time for rebar futures to achieve equilibrium following their divergence.

In summary, the results of the IRFs and FEVD derived from a three-variable VAR process demonstrated that the effects of innovations in the real estate market on

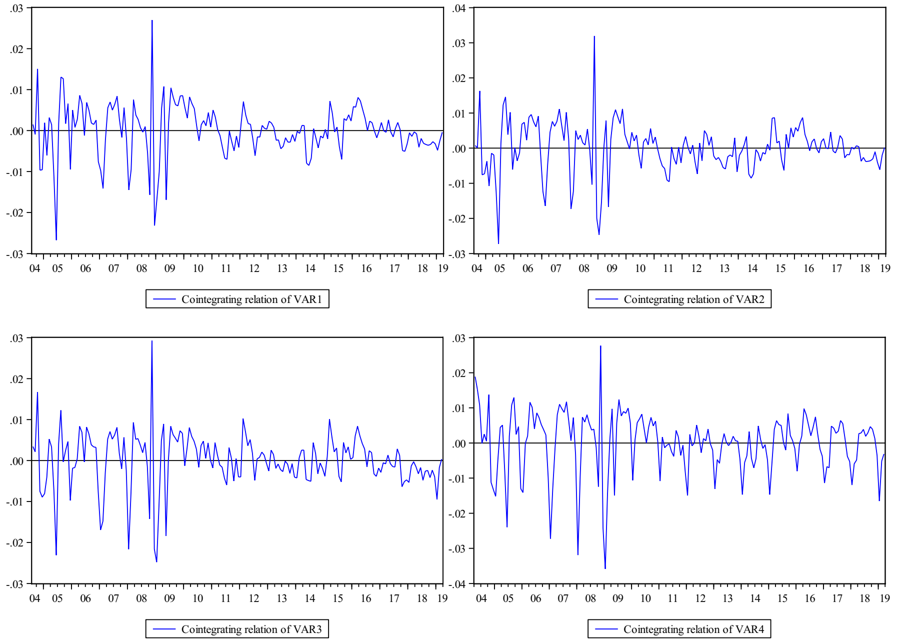

Fig. 7 Cointegrating relationships for copper futures

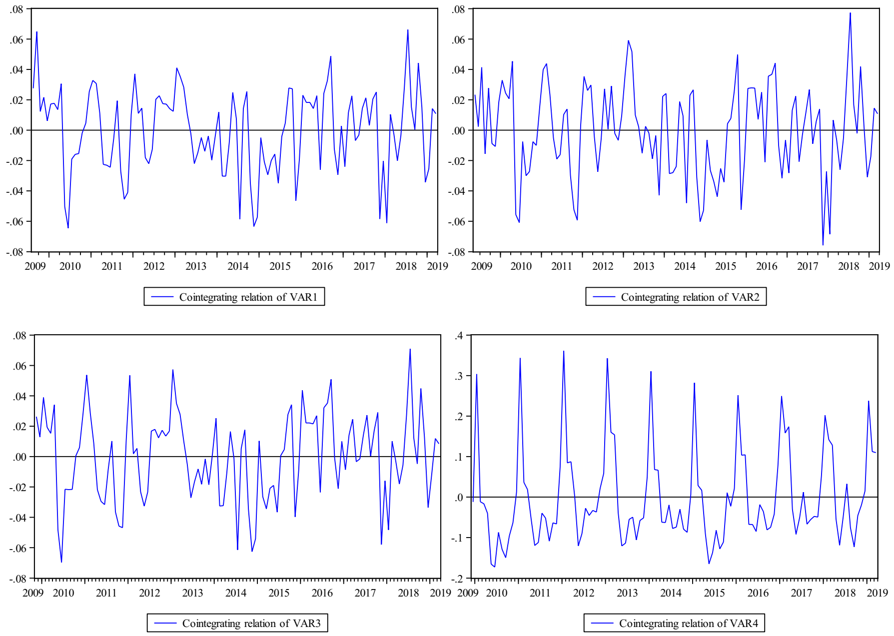

Fig. 8 Cointegrating relationships for rebar futures

industrial metals futures vary across real estate market indicators and differ across futures markets. Consistent with theoretical predictions, the price of copper futures tends to have a stronger response to shocks in the real estate market, as copper futures possess greater financial characteristics than rebar futures. Copper futures seem to be more sensitive to fluctuations in the size of newly started constructions, while innovations in the sales size of the real estate market have the greatest effect on the price of rebar futures. The results of FEVD, however, indicate that shocks in fixed asset investment in the real estate market predominantly explain changes in the price of rebar futures.

The results of Block Endogeneity Wald tests support the notion that fixed asset investment in the real estate market Granger cause innovations in the rebar futures market, while the size of newly started constructions can predict shocks in the copper futures market. The unidirectional information transmission channel from the size of newly started constructions to the copper futures market was further supported by a bivariate Granger causality test. However, we found that changes in fixed asset investment in the real estate market did not Granger cause changes in the price of rebar futures. For rebar futures, the spot market seems to play a crucial role in the price discovery process, whereas the real estate market exerts less influence on the price of rebar futures.

The existence of long-term relationships between the industrial metals futures market and the real estate market was detected in cointegration analysis. The metals futures market and the real estate market are believed to be cointegrated of $I(1)$ with all corresponding variables possessing one unit root. The features of cointegrations are different across markets. More precisely, the copper futures market can be expected to return to its initial equilibrium much quicker than can the rebar futures market. Besides, innovations in the real estate market seem to have negative impacts on the price of copper futures, whereas positive shocks in the real estate market could lead to an increase in the price of rebar futures in the long run. The negative impact of the real estate market on the copper futures market can be attributed to financial homogeneity in copper futures and real estate; that is, the two markets tend to co-move in response to macroeconomic innovations, and thus investors are likely to short-sell copper futures for hedging systematic risks when holding real estate in their portfolios. The results of the cointegration vector indicate that the copper futures market is negatively correlated with the real estate market.

6 Robustness Test

6.1 Structural Stability of VAR

Robustness tests are performed to check the structural stability of VARs as well as the stability of cointegrating relations of key variables. In this study, the CUSUM test based on recursive estimation was employed to test the structural stability of the three-variable VAR model. The corresponding statistic of CUSUM was derived from a normalized version of the cumulative sums of the residuals and under the null hypothesis of perfect parameter stability. The CUSUM-statistic is zero, which consists with assumption of zero expected value of error term. In practice, a set of ± 2 standard error bands are used and plotted around the zero level. Any statistic lying outside the range is regarded as evidence of instability. Empirical results of CUSUM tests for each combination of VARs of the copper panel and the rebar panel indicated that none of the pre-specified VAR models exhibited instability.[11] The CUSUM statistics all resided inside the range of two standard deviations. We therefore concluded that there was no structural breakpoint in the corresponding three-variable VAR process used in this study.

6.2 Engle-Granger Two-Step Method

To check the robustness of our findings about the existence of long-term relationships between the industrial metals futures market and the real estate market, we used an Engle-Granger two-step method, which consists of a single equation technique for detecting cointegrating relations. As all underlying variables were tested to be $I(1)$, it was possible to estimate the cointegrating regression by OLS. The specification was constructed as

$$y_{f,t} = \alpha + \beta_1 y_{s,t} + \beta_2 y_{x,t} + \varepsilon_t, \tag{17}$$

were $y_{f,t}$ is the metals futures price, $y_{s,t}$ is the metals spot price, and $y_{x,t}$ is the real estate indicator. Equation (17) could be estimated by OLS, and the corresponding ECT could thus be obtained by

$$ECT_t = \hat{\varepsilon}_t = y_{f,t} - \hat{\alpha} - \hat{\beta}_1 y_{s,t} - \hat{\beta}_2 y_{x,t}, \tag{18}$$

where $\hat{\alpha}$, $\hat{\beta}_1$ and $\hat{\beta}_1$ are fitted values of coefficients. If the estimate of the residual (i.e., the e) is tested to be $I(0)$ (i.e., stationary), the corresponding variables are said to be cointegrated of $I(1)$, where the linear combination of non-stationary variables with one unit root is stationary.

Estimates of the Engle-Granger two-step method are reported in Table 6, and the ADF test was applied for detecting the unit root. Apparently, the null hypothesis that a unit root exists in the ECT was rejected for all specifications in the copper panel and the rebar panel. Consistent with the results of Johansen's approach based on VARs, the results of the Engle-Granger two-step method also suggest that the industrial metals futures market and the real estate market can be expected to converge in the long run, achieving equilibrium under cointegrating relations.

[11] For brevity, we did not report the results of the CUSUM tests. These results, however, can be provided upon request.

Table 6 Engle-granger two-step cointegration estimates

		Copper				Rebar	
		Coefficient	ADF test			Coefficient	ADF test
I	Constant	– 0.1657***	– 10.3332***	I	Constant	– 0.9425***	– 7.049***2
		(0.0206)				(0.1255)	
	Spot	1.0120***			Spot	1.1427***	
		(0.0020)				(0.0113)	
	Investment	0.0039***			Investment	– 0.0295***	
		(0.0007)				(0.0068)	
II	Constant	– 0.1776***	– 9.9373***	II	Constant	– 1.0805***	– 6.9639***
		(0.0213)				(0.1287)	
	Spot	1.0110***			Spot	1.1653***	
		(0.0021)				(0.0113)	
	Newly-Start	0.0059***			Newly-		
Start	– 0.0320	***					
		(0.0012)				(0.0114)	
III	Constant	– 0.1721***	– 10.1368***	III	Constant	– 1.1928***	– 6.5494***
		(0.0209)				(0.1308)	
	Spot	1.0115***			Spot	1.1562***	
		(0.0020)				(0.0115)	
	Sales	0.0049***			Sales	– 0.0131	
		(0.0009)				(0.0083)	
IV	Constant	– 0.1746***	– 9.3531***	IV	Constant	– 1.2761***	– 6.3692***
		(0.0221)				(0.0115)	
	Spot	1.0137***			Spot	1.1572***	
		(0.0020)				(0.0115)	
	Completed	0.0027***			Completed	– 0.0052	
		(0.0008)				(0.0049)	

*, **, and *** denote statistical significance at $p<0.1$, $p<0.05$, and $p<0.01$, respectively

7 Conclusion

Although earlier studies (e.g., Mo et al., 2018; Ye et al., 2019) have demonstrated the linkages across financial markets, only a few studies have investigated the associations between the commodity futures market and the real estate market. China has taken the position of the world's second-largest economy. Its financial markets, including its derivatives markets, have rapidly developed in recent decades. Nonetheless, studies about the linkage between commodity futures and the real estate market in China are still rare. To address this gap in the literature by providing empirical evidence that can help market participants better understand the characteristics of metals futures for the purpose of portfolio and risk management, it is important to examine the relationship between China's real estate market, which is an important engine of economic growth in China, and the industrial metals futures market from both theoretical and empirical perspectives.

We extend prior studies in two important ways. First, we used copper futures and rebar futures as representatives of base metals and ferrous metals, respectively. While copper futures have more financial characteristics and are expected to move in parallel with the real estate market, rebar futures exhibit the nature of commodity and are expected to show less association with a movement in the real estate market. Second, instead of using housing price as a corresponding variable, as in the extant literature, we employed a set of real estate market indicators, namely fixed asset investment in the real estate market, the size of newly started constructions, the sales size of constructions, and the completed size of constructions, to measure the fundamentals and changes in China's real estate market. As price rigidity exists in the Chinese real estate market, a broader set of indicators can capture a genuine relationship between the commodity futures market and the real estate market. Our study can be extended to other countries where price rigidity exists in the real estate market.

In this study, we employed a three-variable VAR model to investigate the mutual effects of underlying markets, the Granger causality test to detect the information transmission channel between markets, and a cointegration framework based on a VAR model to examine the dynamic equilibrium and long-term relationship between the real estate market and the industrial metals futures market. Our key findings are as follows: First, the effects of innovations in the real estate market on the industrial metals futures market rely on pre-specified housing indicators and vary across metals futures. More precisely, the copper futures price is likely to positively adjust in response to a unit change in the real estate market. The shock of the size of newly started constructions has the greatest accumulated impacts on the copper futures market, increasing the copper futures price by 2.46% in two years. For a 24-month leading period, 11.31% of the changes in the copper futures price can be attributed to fluctuations in the size of newly started constructions, while the explanatory power of such constructions can be seen to horizontally increase. Based on the results of IRFs, the rebar futures price was found to be most sensitive to a volatility in the sales size of constructions in the real estate market, with the price of rebar futures expected to increase by 1.65% after two years. The results of the FEVD procedure indicated that fixed asset investment in the real estate market makes the largest contributions (6.28%) to the corresponding movement of the rebar futures price. One plausible explanation for the different responses of the copper futures market and the rebar futures market to the innovations in real estate indicators is the differences in the consumption periods of industrial metals in the construction cycle. More specifically, copper is primarily used to produce wires and cables, while rebar is generally used for fundamental structural framing. In this sense, the demands for copper and rebar are expected to respond differently to the variations in the real estate indicators that describe the different stages of the real estate cycle, that is, investment stage (fixed asset investment in the real estate market and the size of newly started constructions), construction stage (the size of newly started constructions and the sales size of the real estate market), and completion and sale stage (the completed size of constructions). In addition, nonferrous metals such as copper usually present a financial characteristic more than a commodity characteristic (Huang et al., 2018), while ferrous metals such as rebar normally show the nature of a commodity (Zhuo, 2018). With commodity characteristics, the rebar futures market tends to exhibit more connections with changes in the past demand in the real estate market, as measured by sales size, and with changes in the predicted demand in the real estate market, as measured by fixed asset investments. With fewer commodity characteristics, copper is likely to be more sensitive to changes in the contemporaneous demand, as measured by the size of newly started constructions.

Second, information changes with respect to the size of newly started constructions were found to Granger cause fluctuations in the copper futures market based on the VAR models, whereas such a mechanism was not detected between the sales size of the real estate market and the rebar futures market. The results of a bivariate Granger causality test supported the findings from the FEVD method, that is, innovations in fixed asset investment in the real estate market can predict changes in the price of rebar futures. Third, the industrial metals futures market and the real estate market, with all combinations of the three-variable VARs for the copper panel and the rebar panel, were found to be cointegrated in the first order. Shocks in the real estate market tend to have slightly negative effects on the copper futures market in the long run. This can be explained by hedging positions in the copper futures market. As movement in the copper futures price is highly correlated with changes in the macroeconomy, investors whose portfolios contain real estate tend to offset the systematic risks by short-selling copper futures. In contrast, with a greater commodity nature, the rebar futures market and the real estate market exhibit significantly positive associations. Lastly, when the long-term dynamic equilibrium between underlying markets is broken by shocks, the adjustment speed of the copper futures price is much quicker than that of the rebar futures price. Specifically, it takes less than one month for the copper futures market to return to equilibrium, while it takes more than two months to complete the adjustment process in the rebar futures market.

Our study provides empirical evidence on the linkages between the commodity futures market and the real estate market in China. These findings are useful to investors and corporations for their portfolios and for risk management. For example, as copper futures were found to be more sensitive to innovations in the real estate market, as compared to ferrous metals futures, it is better for investors to use copper futures to hedge macroeconomic risks if certain positions of real estate stocks or other risky assets are involved in investment portfolios. For corporations, such as mining companies and smelters, when participating in the futures market for offsetting fluctuations in the spot price, it is important to dynamically adjust the hedging ratio according to changes in real estate indicators, especially in cases in which the futures positions are opposite to the trend of volatility in the real estate market. As the effects of innovations in the real estate market on the industrial metals futures market vary across real estate market indicators and differ across metals futures, our findings suggest that copper-related participants should focus more on changes in the size of newly started constructions, while rebar-related participants should refer to fixed asset investment in the real estate market and the sales size of the real estate market as key indicators for their investment decisions.

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