

# Effects of Futures Varieties Opening Up on Currency Internationalization: Evidence from China\*

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## Abstract

The internationalization of the futures market has a certain impact on the internationalization of the RMB, and the opening up of futures varieties to the outside world is the most important link in the internationalization of the futures market, and it is necessary to quantitatively study the quantitative impact of the opening up of futures varieties on the internationalization of the RMB. Based on the monthly data from 2018 to 2022, this paper adopts the quantitative research method of cointegration-related theoretical model for the domestic international commodity futures (crude oil, iron ore, PTA) variables (futures price, turnover, position volume) on the variables of RMB internationalization (RMB international payment global market share, cross-border trade RMB business settlement amount, foreign exchange reserves, RMB real effective exchange rate index, RMB financial transactions), and studies the overall impact of international commodity futures on RMB internationalization. The study shows that the three indicators of the international commodity futures variable have different degrees of influence on the RMB internationalization index, of which the influence of price and open interest is significantly greater than the turnover. In the long run, the international futures price and open interest have a positive impact on the internationalization of the RMB, the turnover has a negative impact, and the impact of crude oil futures prices and open interest is stronger than that of iron ore and PTA. In the short term, the international commodity futures indicators have a certain impact on the internationalization of the RMB, crude oil and iron ore have a greater impact than the PTA, there are differences in the international development of different commodity markets, and the fitting

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effect of the model crude oil is better than other varieties. It is recommended to promote balanced development of the futures market internationalization through a variety of measures, continuously improve the international pricing power and influence of futures varieties, increase the open interest of futures, moderately reduce the turnover, and effectively promote the further development of RMB internationalization.

### Keywords

International Commodity Futures, Internationalization of RMB, Granger Causation Test, Cointegration Test, ECM

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## 1. Introduction

After more than thirty years of development, Chinese futures market is becoming more and more mature, the function of the futures market has been further exerted, the futures market has become an important part of the China economy, especially in recent years, the international situation has changed, the international development of the futures market has been further promoted, and the risk management function of the futures market in economic operation has been fully reflected.

In order to further expand the influence of the domestic futures market and international pricing capabilities, the pace of opening up of Chinese futures market in recent years has gradually accelerated, since the launch of international crude oil futures on March 28, 2018, by the beginning of 2022, the internationalization commodity futures varieties has reached 9 (varieties are as follows: Crude oil, Low sulfur fuel oil, No. 20 glue, International copper, Crude oil options, Palm oil, Iron ore, Palm oil options, Purified Terephthalic Acid (PTA)), and the three types of commodity futures, commodity options and stock index options have been opened to qualified foreign investors (QFII and RQFII). The internationalization of futures varieties has effectively promoted the international pricing influence of Chinese commodity futures, from the perspective of the three major Chinese futures commodity exchanges: in Shanghai, the crude oil transshipment export business using Shanghai crude oil futures price pricing has developed to South Korea, Singapore and other places, further highlighting the price influence of Shanghai crude oil futures prices in Northeast Asia; In Dalian, iron ore futures have been participated by hundreds of overseas customers in dozens of countries and regions, and iron ore futures have developed into the world's largest trading volume and the only iron ore derivative with single physical delivery; In Zhengzhou, PTA, as the first chemical variety introduced to overseas traders in China's futures market, has become a price vane for the global polyester industry.

Chinese futures market is open to the outside world, and the internationalization of futures varieties is in the right time in today's sudden global situation,

especially in the face of Russian-Ukrainian military conflicts, the intensification of the China-USA game, the gradual decline of dollar credit, and the rapid development of RMB internationalization. Therefore, in the new round of international competition, the internationalization of the renminbi (RMB) is expected to further promote the further improvement of China's comprehensive national strength. In the process of the internationalization of the RMB, the futures market, as an important part of China's capital market, is particularly urgent to effectively use the internationalization of the futures market and further promote the internationalization of the RMB. Therefore, studying the impact of the internationalization of futures varieties on the internationalization of RMB is of great theoretical and practical significance for further promoting the internationalization of RMB. Theoretically, a research framework on the relationship between futures internationalization and RMB internationalization was established; In practice, in the process of promoting the internationalization of the RMB, by effectively promoting the internationalization of futures varieties, and then promoting the internationalization of the futures market, through the internationalization of the futures market, so as to further promote the internationalization of the RMB.

## 2. Literature

Due to the relatively short time for the internationalization of Chinese futures varieties, from the perspective of the existing literature, there are relatively few literatures studying the relationship between the internationalization of domestic futures varieties and the internationalization of the RMB, and the basic research is analyzed from a qualitative point of view, and the relationship and interaction between the internationalization of futures varieties and the internationalization of the RMB are discussed from a qualitative perspective. For example, [Li and He \(2018\)](#) analyzed the relationship between commodities and the internationalization of the US dollar, and proposed to promote the internationalization of the RMB through commodity trading. [Ba and Wang \(2019\)](#) proposed that commodities should become a key part of the layout of the new stage of RMB internationalization through the analysis of the expansion path of the RMB's international monetary function, the expansion path of the spatial scope and the stability of the exchange rate. [Pan and Wu \(2021\)](#) believe that commodity trade, futures markets and currency internationalization support and promote each other. Since 2009, China's domestic futures market has been opened to the outside world and the international use of RMB in the field of commodity trade has steadily expanded, but an effective positive interactive relationship has not yet been formed with the process of RMB internationalization.

In addition, in the literature on the relationship between commodity futures and RMB internationalization, some of them focus on the relationship between specific international varieties and RMB internationalization, mainly through

qualitative research methods. For example, [Chang and Yan \(2018\)](#) believe that the launch of China's crude oil futures will be a new starting point for the internationalization of the RMB. Through RMB settlement, the RMB has become a reserve currency necessary for all countries in the world and a benchmark currency for international financial markets. [Zhong \(2018\)](#) believes that the launch of China's crude oil futures will be conducive to maintaining China's energy security, reducing the risk of single petrodollar pricing, and also helping to promote the internationalization of the RMB. [Liu \(2018\)](#) believes that the development and improvement of China's crude oil futures market is conducive to breaking the monopoly of the oil market, building a multi-level financial market system, attracting more international funds to participate in China's capital market and the international circulation of the RMB, and promoting the internationalization of the RMB. [Mei \(2018\)](#) believes that the energy issue is related to national security and stability, the game between China and the United States in the field of energy is inevitable, China's acquisition of oil pricing power will impact the petrodollar system, and China must also promote RMB-denominated imports of energy to improve the internationalization of RMB. [Zheng and Liu \(2018\)](#) believe that the RMB becoming an internationally denominated currency and a cross-border trade settlement currency is a key step in the internationalization of the RMB. In the process of internationalization of iron ore futures, iron ore futures are denominated and settled in RMB, which not only helps to promote the RMB to become the denominated currency of international trade in commodities and the currency of international investment and financing, but also helps the RMB to become a cross-border trade settlement currency. At the same time, the internationalization of iron ore futures has opened up a return channel for offshore RMB, improved the international circulation mechanism of RMB, and effectively promoted the internationalization of RMB. [Du \(2019\)](#) analyzes the opportunities and challenges of RMB pricing in the crude oil futures market based on the development status of Crude Oil Futures in China. It is believed that accelerating the improvement of the investment structure of INE crude oil futures, accelerating the process of RMB internationalization and strengthening energy cooperation with oil-producing countries are important ways to realize the pricing power of RMB over crude oil futures. [Zhang and Gao \(2019\)](#) believe that RMB -denominated international crude oil trading will help enhance the scale of foreign investors holding RMB as a means of payment for transactions. In order to further promote the internationalization of the RMB under the new model of "denominated currency + financial opening-up", the RMB pricing of crude oil futures and the RMB repatriation mechanism of oil are organically combined with the implementation of the "Belt and Road" initiative, and various financial risks related to it are controlled.

From a quantitative point of view, there are very few research literatures, only two studies focusing on the relationship and impact of specific futures varieties

of crude oil futures and RMB internationalization: Zou (2019) analyzed the correlation between RMB crude oil futures and RMB internationalization based on the grey correlation analysis model and the grey GM(1,3) model, and predicted the relevant indicators of RMB internationalization; Based on monthly data, Gao and Gao (2022) selected micro indicators of the domestic crude oil futures market and RMB internationalization indicators, and quantitatively studied the overall impact of crude oil futures on RMB internationalization by using Granger causality, cointegration test and error correction model, and obtained many valuable conclusions.

In summary, the existing literature to study the relationship and impact between the internationalization of futures varieties and the internationalization of the RMB is mainly qualitative research, and the quantitative research is only focused on the research of a single variety of crude oil futures, which is still blank from multi-variety research perspective of studying the internationalization of the futures market and the internationalization of the RMB. Therefore, in order to further study the function and influence of the international varieties of the Chinese futures market, and to study the relationship and influence between the international varieties of the domestic futures market and the internationalization of the RMB from a quantitative point of view, this paper adopts the theory and model of cointegration related that has been relatively mature in recent years, specifically studies the degree of influence of the international varieties of the domestic futures market on the internationalization of the RMB, draws relevant and meaningful conclusions, and provides a valuable reference for policy makers and regulators.

### **3. The Selection of Variables and the Processing of Data**

#### **1) Selection of variable indicators**

After years of development of Chinese futures market, the progress of internationalization is slow, from 2018, the internationalization speed of the futures market began to accelerate, as of May 2022, the three domestic exchanges have launched futures varieties that foreign capital can participate in trading, from the Shanghai Futures Exchange, the Shanghai International Energy Trading Center, which is controlled by it, has launched four international futures varieties of crude oil, low-sulfur fuel oil, No. 20 rubber, and international copper. From the perspective of Dalian Commodity Futures Exchange, two futures varieties of iron ore and palm oil have been launched successively. From the perspective of Zhengzhou Commodity Futures Exchange, PTA futures varieties have been launched. The three major futures exchanges have launched a total of seven international commodity futures varieties.

From the perspective of several domestic futures exchanges, crude oil, iron ore and PTA are the three major domestic futures exchanges Shanghai Futures Exchange, Dalian Commodity Futures Exchange and Zhengzhou Commodity Futures Exchange basically launched the first international futures varieties in

2018, and the launch time of the three major futures varieties is earlier than that of other international futures varieties, and the operation is relatively stable. Therefore, we have selected crude oil, iron ore and PTA futures, which are the first of the three major domestic futures exchanges, as the representatives of domestic international futures varieties. The crude oil futures indicator selects the crude oil futures launched by the Shanghai International Energy Trading Center of the domestic Shanghai Futures Exchange as the research variables, and selects the crude oil futures price, turnover and open interest as the crude oil futures indicators; The iron ore futures index selected the iron ore futures introduced by the domestic Dalian Commodity Futures Exchange in May 2018 as the research variable, and the iron ore futures price, turnover and open interest as the iron ore futures indicators. The PTA futures indicator selects the PTA futures introduced by the domestic Zhengzhou Commodity Futures Exchange in November 2018 as the research variable, and the price, turnover and open interest of the PTA futures as the PTA futures indicators.

Based on the research literature of [Gao and Gao \(2022\)](#), we have improved the selection of RMB internationalization indicators, broadened the scope of RMB internationalization indicators, and selected RMB internationalization indicators more comprehensively from five variables: RMB international payment, cross-border trade RMB settlement, RMB global foreign exchange reserves, RMB exchange rate, and RMB financial transactions. Among them, the indicators of RMB international payment select the global share of RMB international payment; Cross-border trade RMB settlement indicators select the RMB settlement amount of cross-border trade; RMB Global Foreign Exchange Reserves Indicator Selects foreign exchange reserve; The RMB exchange rate selects the RMB real effective exchange rate index; In terms of RMB financial transactions, the indicators select the RMB overseas direct investment, the total amount of domestic assets purchased by foreign investors (including treasury bonds, institutional bonds, corporate bonds, and corporate stocks), the foreign exchange market turnover (including spot, forward, swap, and options), and the total amount of domestic RMB financial assets held by overseas institutions and individuals (including stocks, bonds, and deposits). For the results of the selection of each variable, see [Table 1](#).

## 2) Processing and description of data

Since crude oil futures, iron ore futures and PTA futures were launched and introduced to foreign investors in March, May and November 2018 respectively, all the above data selections are based on this as the starting point. Since the relevant data indicators of RMB internationalization only have monthly, quarterly and annual data, and the futures-related data have daily, weekly, monthly, quarterly and annual data, from the perspective of data availability, this paper selects monthly data, and the selected time periods are 48 monthly data between 2018.3-2022.2, 46 monthly data between 2018.5-2022.2, and 40 monthly data between 2018.11-2022.2.

**Table 1.** Variables and indicators.

Item	Variables	Indicators
International futures varieties	Crude oil futures	futures price
		turnover
		open interest
	Iron ore futures	futures price
		turnover
		open interest
	PTA futures	futures price
		turnover
		open interest
RMB internationalization	RMB international payment	global share of RMB international payment
	Cross-border trade RMB settlement	RMB settlement amount of cross-border trade
	RMB global foreign exchange reserves	foreign exchange reserve
	RMB exchange rate	RMB real effective exchange rate index
	RMB financial transaction	RMB overseas direct investment, total amount of domestic assets purchased by foreign investors
		foreign exchange market turnover total amount of domestic RMB financial assets held by overseas institutions and individuals

Note: The variable data in the table is derived from Wind information and the author's processing.

In the above indicators, the total amount of domestic assets purchased by foreign investors is obtained by adding up the actual data of foreign investors purchasing domestic treasury bonds, institutional bonds, corporate bonds, and company stocks; The turnover of the foreign exchange market is obtained by adding up the actual data of the foreign exchange market spot, forward, swap and options market transaction volume; The total amount of domestic RMB financial assets held by overseas institutions and individuals is obtained by adding up the actual data of domestic RMB stocks, bonds and deposits held by overseas institutions and individuals.

Among them, the individual missing data in the original data are filled by the method of three moving averages. The above data are treated logarithmically

except for percentage data. Source: Wind Information Data.

The following makes the descriptive statistics and correlation coefficients for each variable indicator (see Appendix **Tables A1-A6**). Appendix **Tables A1-A3**, respectively, shows the descriptive statistics of crude oil futures, iron ore futures and PTA futures variables (futures price, turnover, open interest) and RMB internationalization variables, and it can be seen from the results that the distribution of each variable data mostly satisfies the normal distribution; Appendix **Table A4** shows the correlation coefficient between crude oil futures variables (futures price, turnover, open interest) and various variables of RMB internationalization, and it can be seen from the results that most of the variables of crude oil futures price and turnover and RMB internationalization variables have a negative correlation relationship with different strengths and weaknesses, and the open interest has a positive correlation relationship with different strengths and weaknesses; Appendix **Table A5** shows the correlation coefficient between iron ore futures variables (futures price, turnover, open interest) and various variables of RMB internationalization, and it can be seen from the results that there is a positive correlation between iron ore futures prices and various variables of RMB internationalization, and the turnover and open interest and various variables of RMB internationalization has different strengths and weaknesses negative correlation; Appendix **Table A6** shows the correlation coefficient between PTA futures variables (futures price, turnover, open interest) and various variables of RMB internationalization, and it can be seen from the results that there is a negative correlation between PTA futures prices and various variables of RMB internationalization, and the positive correlation between the turnover and open interest and most of its variables is different.

## 4. Empirical Model Estimates

### 1) Unit-root Test

We perform stationarity tests on the selected data, stationarity tests are commonly used in unit root test methods, and there are many unit root test methods, generally DF, ADF test and Philips nonparametric test (PP test). This paper uses the most commonly used Residuals-based ADF test of **Engle & Granger (1987)**. Under the premise of ensuring that the residual terms are not correlated in the test, we use the AIC criterion and the SC criterion to determine that the lag order when both values are the minimum is the optimal lag order. The specific test results are seen Appendix **Table A7**.

From the above unit root test results, it can be seen that in the original sequence of each variable index, except for LNI1, which is non-stationary at the 5% and 10% significance levels, the other variable indicators are non-stationary at the 1%, 5%, and 10% significance levels. Except for the first-order differential sequence of each variable index sequence at the 5% and 10% significance levels, the first-order differential sequence is stable, and the other variable index sequences are stationary at the 1%, 5%, and 10% significance levels.

In summary, through the unit root test results, we can see that the variables of the international futures we selected and the variables of the RMB internationalization are all first-order single-integer sequences.

## 2) Granger causality test results

We do Granger causality test between the variables of the selected domestic international futures and the variables of the RMB internationalization, because the causality test is more sensitive to the lag order, in the actual test, according to the AIC, SC criterion, when the value of the two is the smallest is the best lag order. The specific test results are seen Appendix **Tables A8-A10** (The variables in the article are as follows: IP indicates Global market share of RMB international payment, LNIS indicates RMB business settlement amount of cross-border trade log and LNFR indicates the logarithm of foreign exchange reserve, LNER indicates the logarithm of RMB real effective exchange rate index, LNRI indicates the logarithm of t RMB overseas direct investment, LNFB indicates Total amount of domestic assets purchased by foreign investors, LNFA indicates the total logarithm of Total domestic RMB financial assets held by overseas institutions and individuals, and LNFV represents the logarithm of foreign exchange market turnover, LNP1 represents the logarithm of domestic crude oil futures prices, LN V1 represents the logarithm of domestic crude oil futures turnover, and LNI1 represents the logarithm of domestic crude oil futures open interest, LNP2 represents the logarithm of domestic iron ore futures prices, LN V2 represents the logarithm of domestic iron ore futures turnover, and LNI2 represents the logarithm of domestic iron ore futures open interest, LNP3 represents the logarithm of domestic PTA futures prices, LN V3 represents the logarithm of domestic PTA futures turnover, and LNI3 represents the logarithm of domestic PTA futures open interest, the following is similar).

From the above-mentioned Appendix **Table A8** causal relationship test results between the crude oil futures variables and the variables of RMB internationalization, it can be seen that at the 10% significance level, the crude oil futures price (LNP1) has a significant guiding effect on foreign exchange reserves (LNFR) and Total domestic RMB financial assets held by overseas institutions and individuals (LNFA) in the RMB financial trading indicators; At the 10% significance level, crude oil futures open interest (LNI1) have a strong guiding effect on foreign exchange reserves (LNFR) and RMB overseas direct investment (LNRI) and Total domestic RMB financial assets held by overseas institutions and individuals (LNFA), and foreign exchange market turnover (LNFV); crude oil futures turnover has no significant guiding effect on the variable indicators of RMB internationalization. On the contrary, at the significance level of 10%, the Global market share of RMB international payment (IP), RMB business settlement amount of cross-border trade (LNIS), RMB overseas direct investment (LNRI) and foreign exchange market turnover (LNFV) in RMB financial transactions have a significant guiding effect on crude oil futures prices (LNP1); At the significance level of 10%, the foreign exchange market turnover (LNFV) has a significant guiding effect on the crude oil futures turnover (LNV1).

From the above-mentioned Appendix **Table A9** causal relationship test results between iron ore futures variables and various variables of RMB internationalization, it can be seen that at the 10% significance level, iron ore futures prices (LNP2) have a significant guiding effect on RMB business settlement amount of cross-border trade (LNIS), RMB overseas direct investment (LNRI) and Total amount of domestic assets purchased by foreign investors (LNFB) in RMB financial trading indicator. At the 10% significance level, iron ore futures open interest (LNI2) have a significant guiding effect on RMB real effective exchange rate index (LNER) and foreign exchange market turnover (LNFV). At the 10% significance level, iron ore Futures turnover (LN V2) has a significant guiding effect on the Global market share of RMB international payment (IP). On the contrary, at the significance level of 10%, RMB business settlement amount of cross-border trade (LNIS) and the RMB overseas direct investment (LNRI), and the Total amount of domestic assets purchased by foreign investors (LNFB) in the RMB financial transaction index have a significant guiding effect on the iron ore futures open interest; At the significance level of 10%, the RMB overseas direct investment (LNRI), the Total amount of domestic assets purchased by foreign investors (LNFB), and foreign exchange market turnover (LNFV) in the RMB internationalization indicator have a strong guiding effect on the iron ore futures turnover.

From the above-mentioned Appendix **Table A10** causal relationship test results between PTA futures variables and various variables of RMB internationalization, it can be seen that at the 10% significance level, the PTA futures price (LNP3) has a significant guiding effect on foreign exchange reserves (LNFR) and the Total domestic RMB financial assets held by overseas institutions and individuals(LNFA) in RMB financial trading indicators; At the 10% significance level, PTA futures open interest (LNI3) have a significant guiding effect on RMB business settlement amount of cross-border trade (LNIS), foreign exchange reserves (LNFR) and foreign exchange market turnover (LNFV) in RMB financial trading indicators; At the 10% significance level, the PTA futures turnover has no significant guiding effect on the various variables of RMB internationalization. On the contrary, at the significance level of 10%, the Global market share of RMB international payment (IP), RMB business settlement amount of cross-border trade (LNIS) and RMB overseas direct investment (LNRI) and foreign exchange market turnover (LNFV) in the RMB financial transaction indicator have a significant guiding effect on PTA futures prices (LNP3); At the 10% significance level, the RMB business settlement amount of cross-border trade (LNIS) and the RMB real effective exchange rate index(LNER) in the RMB internationalization index have a significant guiding effect on the PTA futures open interest (LNI3); At the 10% significance level, the various variables of RMB internationalization do not have a significant guiding effect on the PTA futures turnover (LNV3).

### **3) Cointegration relationship test between international commodity futures variables and RMB internationalization variables**

We use Johansen's (1988) Great Likelihood Estimation (MLE) test, respectively, to cointegration test IP, LNIS, LNFR, LNER, LNRI, LNFB, LNFA, LNFV and international commodity futures (crude oil, iron ore, PTA) variables (futures price, turnover, open interest), select the optimal lag order by testing, and finally select the cointegration equation corresponding to the root of the respective maximized features, Specific results are shown in Appendix **Tables A11-A13**.

It can be concluded from the above Appendix **Table A11** cointegration equation: in the long run, when the domestic crude oil futures price rises by 1 percentage point, the Global market share of RMB international payment (IP), RMB business settlement amount of cross-border trade (LNIS), foreign exchange reserves (LNFR), RMB real effective exchange rate index (LNER), RMB overseas direct investment (LNRI), Total amount of domestic assets purchased by foreign investors (LNFB), The total amount of domestic RMB financial assets held by overseas institutions and individuals (LNFA) and the foreign exchange market turnover (LNFV) (hereinafter referred to as "RMB internationalization indicators") rose by 1.405, 1.625, 0.073, 0.150, 1.446, 1.447, 0.221, 0.602 percentage points; When the domestic crude oil futures turnover rose by 1 percentage point, the various RMB internationalization indicators fell by 0.024, 0.021, 0.028, 0.041, 0.335, 0.788, 0.180 percentage points, of which the foreign exchange market turnover (LNFV) rose by 0.137 percentage points; When the domestic crude oil futures position increased by 1 percentage point, the RMB internationalization indicators rose by 0.738, 1.205, 0.021, 0.063, 0.486, 0.588, 0.210 and 0.414 percentage points respectively.

Therefore, from the perspective of long-term cointegration relationship, the impact of domestic crude oil futures prices and domestic crude oil futures open interest on RMB internationalization indicators is consistent, while the impact of domestic crude oil futures turnover on RMB internationalization indicators is basically opposite to the impact of crude oil futures prices and crude oil futures open interest. In general, the price and open interest of domestic crude oil futures have a positive long-term impact on the internationalization of the RMB, and the turnover has a negative long-term impact.

From the above Appendix **Table A12** cointegration equation, it can be concluded that in the long run, when the domestic iron ore futures price rises by 1 percentage point, the indicators of RMB internationalization rise by 0.648, 1.466, 0.017, 0.391, 1.459, 0.474, 0.075, 0.296 percentage points, respectively; When the domestic iron ore futures turnover rose by 1 percentage point, the Global market share of RMB international payment (IP), RMB business settlement amount of cross-border trade (LNIS), RMB real effective exchange rate index (LNER), RMB overseas direct investment (LNRI), and the foreign exchange market turnover (LNFV) fell by 1.624, 0.626, 0.059, 0.186 and 0.446 percentage points respectively, and foreign exchange reserves (LNFR), Total amount of domestic assets purchased by foreign investors (LNFB), The total amount of domestic RMB financial assets held by overseas institutions and individuals (LNFA) rose by 0.032,

0.762 and 0.110 percentage points; When the domestic iron ore futures open interest rose by 1 percentage point, the Global market share of RMB international payment (IP), RMB business settlement amount of cross-border trade (LNIS), RMB real effective exchange rate index (LNER), RMB overseas direct investment (LNRI), and the foreign exchange market turnover (LNFV) rose by 1.672, 1.016, 0.228, 0.104, 0.354 percentage points respectively, foreign exchange reserves (LNFR), Total amount of domestic assets purchased by foreign investors (LNFB), The total amount of domestic RMB financial assets held by overseas institutions and individuals (LNFA) fell by 0.065, 1.220 and 0.239 percentage points.

Therefore, from the perspective of long-term cointegration relationship, the impact of domestic iron ore futures prices and open interest on RMB internationalization indicators is basically the same, while the impact of domestic iron ore futures turnover on RMB internationalization indicators is mostly opposite to the impact of iron ore futures prices and iron ore futures open interest. In general, the domestic iron ore futures price and open interest have a positive long-term impact on the internationalization of the RMB, and most of the turnover has a negative long-term impact.

From the above Appendix **Table A12** cointegration equation, it can be concluded that in the long run, when the domestic PTA futures price rises by 1 percentage point, the indicators of RMB internationalization rise by 0.776, 1.281, 0.282, 0.868, 0.062, 0.338, 0.559, 1.253 percentage points, respectively; When the domestic PTA futures turnover rose by 1 percentage point, the RMB internationalization indicators fell by 0.104, 0.567, 0.111, 0.379, 0.081, 0.308, 0.274 and 0.420 percentage points respectively; In the long run, when the domestic PTA futures open interest rose by 1 percentage point, the RMB internationalization indicators rose by 0.158, 0.925, 0.064, 0.130, 0.816, 0.418, 0.123, 0.543 percentage points respectively.

Therefore, from the perspective of long-term cointegration relationship, the impact of domestic PTA futures prices and open interest on RMB internationalization indicators is consistent, while the impact of domestic PTA futures turnover on RMB internationalization indicators is the opposite of the impact of PTA futures prices and open interest. In general, the price and open interest of domestic PTA futures have a positive long-term impact on the internationalization of the RMB, and the turnover has a negative long-term impact.

#### **4) Error Correction Model (ECM) results**

According to **Engle & Granger (1987)** expression theorem, cointegration systems have three equivalent forms of expression: vector autoregressive (VAR), moving average (MA), and error correction model (ECM), of which ECM can most directly describe the synthesis of short-term fluctuations and long-term equilibrium, and is the most commonly used. **Engle & Granger (1987)** proved that a cointegration sequence must be represented as an error-corrected representation. Therefore, when the variable sequence is cointegration, an error cor-

rection model should be established.

Based on the analysis of the long-term equilibrium equation between the domestic international commodity futures (crude oil, iron ore, PTA) variables (futures price, turnover, open interest) and the variables of RMB internationalization established above, we establish a dynamic error correction model, in which the selection of the lag order in the model is selected according to the AIC and SC criteria to select the best lag order, and finally obtain the dynamic error correction model of the international commodity futures variable and the RMB internationalization variable as shown in the Appendix **Tables A14-A16**.

From the above Appendix **Table A14** error correction model of the crude oil futures variables (futures price, turnover, open interest) and various variables of RMB internationalization, it can be seen from the short-term dynamics: the first-order difference of the Global market share of RMB international payment (D(IP)) is affected by its own and the logarithmic difference of crude oil futures variables by 1 to 7 orders, and the cumulative impact is  $-1.800$ ,  $-5.030$ ,  $2.047$ ,  $3.537$  units, and the impact of the error correction term is  $-0.777$  units; The first-order difference of the RMB business settlement amount of cross-border trade (D (LNIS)) is affected by the first-order difference of its own and crude oil futures variables logarithmic first-order difference of 1 to 7 order, with cumulative effects of  $-1.986$ ,  $-0.935$ ,  $-0.006$  and  $-1.462$  units, respectively, and the impact of error correction terms being  $-0.600$  units; The first-order difference of the logarithm of foreign exchange reserves (D (LNFR)) is affected by its own and the logarithmic first-order difference of crude oil futures variables by 1 to 7 order, with cumulative effects of  $-0.301$ ,  $-0.044$ ,  $-0.006$ ,  $0.013$  units, respectively, and the impact of error correction terms is  $0.138$  units; The first-order difference of the logarithm of the RMB real effective exchange rate index (D (LNER)) is affected by its own and the first-order difference of the logarithmic of crude oil futures variables by 1 to 6 orders, with cumulative effects of  $3.306$ ,  $-0.424$ ,  $0.006$  and  $-0.281$  units, respectively, and the impact of the error correction term is  $-1.181$  units; The first-order difference of the logarithmic of RMB overseas direct investment (D(LNRI)) is affected by its own and the logarithmic first-order difference of crude oil futures variables by 1 to 7 orders, with cumulative effects of  $-3.840$ ,  $-4.063$ ,  $-1.185$  and  $1.520$  units, respectively, and the impact of error correction terms is  $0.591$  units; The first-order difference of the Total amount of domestic assets purchased by foreign investors (D (LNFB)) is affected by the first-order difference of its own and crude oil futures variables by 1 to 6 order, with cumulative effects of  $-0.22$ ,  $-2.312$ ,  $2.445$ ,  $-2.300$  units, respectively, and the impact of error correction terms being  $-1.021$  units; The first-order difference of the logarithm of Total domestic RMB financial assets held by overseas institutions and individuals (D (LNFA)) is affected by the first-order difference between themselves and the logarithmic difference of crude oil futures variables by 1 to 4 order, with cumulative effects of  $0.129$ ,  $-0.342$ ,  $0.088$  and  $-0.142$  units, respectively, and the impact of error correction

terms being  $-0.074$  units; The first-order difference of the logarithm of the foreign exchange market turnover (D (LNFV)) is affected by its own and the first-order difference of the logarithmic of crude oil futures variables by 1 to 7 order, with cumulative effects of  $-1.148$ ,  $1.719$ ,  $-0.235$  and  $1.121$  units, respectively, and the impact of the error correction term is  $-0.034$  units.

Therefore, from the above-mentioned short-term dynamic error correction model of the various variable indicators of domestic crude oil futures and RMB internationalization, it can be seen that the logarithmic first-order difference of the global market share of RMB international payment, the amount of RMB overseas direct investment, the Total amount of domestic assets purchased by foreign investors, and the foreign exchange market turnover in the RMB internationalization index is relatively small from the perspective of short-term dynamics, which is greatly affected by the logarithmic first-order difference of domestic crude oil futures variables, and the logarithmic first-order difference of other RMB internationalization indicators is relatively small.

The trend chart of the first-order difference actual value and model fitting value of each indicator of RMB internationalization is based on the dynamic error correction model of domestic crude oil futures variables and RMB internationalization variables, respectively, and it can be seen from the trend chart that the fitting effect of each model is good (See Appendix **Figure A1**).

From the above Appendix **Table A15** error correction model of the iron ore futures variables (futures price, turnover, position volume) and various variables of RMB internationalization, it can be seen from the short-term dynamics: the first-order difference of the global market share of RMB international payment (D(IP)) is affected by its own and the logarithmic first-order difference of iron ore futures variables lags from 1 to 6 order, and the cumulative effect is  $-8.043$ ,  $-0.478$ ,  $-2.611$ ,  $3.388$  units, and the impact of the error correction term is  $0.937$  units; The first-order difference of the logarithm of RMB business settlement amount of cross-border trade (D (LNIS)) is affected by its own and iron ore futures variables logarithmic first-order difference lag of 1 to 5 order, with cumulative effects of  $-2.143$ ,  $-1.459$ ,  $1.346$  and  $-1.513$  units, respectively, and the impact of error correction terms being  $-0.384$  units; The first-order difference of the logarithm of foreign exchange reserves (D (LNFR)) is affected by its own and the first-order difference of the iron ore futures variable logarithmic lag of 1st to 5th order, with cumulative effects of  $-1.389$ ,  $-0.055$ ,  $-0.046$ , and  $0.124$  units, respectively, and the influence of error correction terms being  $-0.523$  units; The first-order difference (D (LNER)) of the RMB real effective exchange rate index logarithmic is affected by its own and iron ore futures variables logarithmic first-order difference lag of 1 to 5 order, with cumulative effects of  $-0.355$ ,  $0.038$ ,  $-0.053$  and  $0.068$  units, respectively, and the impact of the error correction term is  $0.060$  units; The logarithmic first-order difference of RMB overseas direct investment (D (LNRI)) is affected by its own and iron ore futures variables logarithmic first-order difference lag of 1 to 6 orders, with cumulative effects of

–1.294, –4.825, 1.129 and –1.011 units, respectively, and the impact of error correction terms being –0.846 units; The first-order difference of the logarithm of Total amount of domestic assets purchased by foreign investors (D (LNFB)) is affected by the first-order difference of its own and iron ore futures variables by a logarithmic difference of 1 to 6 order, with cumulative effects of –5.558, 5.527, 1.188 and –1.600 units, respectively, and the impact of error correction terms being 0.761 units; The first-order difference of the logarithm of Total domestic RMB financial assets held by overseas institutions and individuals (D (LNFA)) is affected by the first-order difference of the logarithmic difference of its own and iron ore futures variables by 1 to 6 orders, and the cumulative impact is 2.795, –0.871, –0.812, –2.735 units, respectively, and the impact of the error correction term is –1.479 units; The first-order difference of the logarithm of the foreign exchange market turnover (D (LNFV)) is affected by its own and the iron ore futures variable logarithmic first-order difference lag of 1 to 4 order, with cumulative effects of 0.550, –0.404, –0.235, and 0.766 units, respectively, and the impact of the error correction term is –0.641 units.

Therefore, from the above-mentioned short-term dynamic error correction model of the various variable indicators of domestic iron ore futures and RMB internationalization, it can be seen that only the logarithmic first-order difference of Global market share of RMB international payment, RMB business settlement amount of cross-border trade, RMB overseas direct investment amount, and Total amount of domestic assets purchased by foreign investors in the RMB internationalization index is greatly affected by the logarithmic first-order difference of domestic crude oil futures variables. The logarithmic first-order difference of other RMB internationalization indicators is relatively small affected.

The trend chart of the first-order difference between the first-order difference of each variable of RMB internationalization and the trend chart of the model fitting value made according to the dynamic error correction model between the domestic iron ore futures and the various variable indicators of RMB internationalization, can be seen from the trend chart that the fitting effect of each model is better (See Appendix **Figure A2**).

From the above Appendix **Table A16** error correction model of the PTA futures variables (futures price, turnover, open interest) and various variables of RMB internationalization, it can be seen from the short-term dynamics: the first-order difference of the global market share of RMB international payment (D(IP)) is affected by its own and the logarithmic difference of PTA futures variables from 1 to 3 order, and the cumulative impact is 1.711, 0.032, 0.476, –0.276 units, and the impact of the error correction term is –1.824 units; The first-order difference of the logarithm RMB business settlement amount of cross-border trade (D (LNIS)) is affected by the first-order difference of its own and PTA futures variables logarithmic first-order difference of 1 to 2 order, with cumulative effects of –1.205, –1.138, 0.228 and 0.071 units, respectively, and the impact of error correction terms being –0.464 units; The first-order difference of

the logarithm of foreign exchange reserves (D (LNFR)) is affected by its own and PTA futures variables logarithmic first-order differential lag of 1 to 5 order, with cumulative effects of  $-2.482$ ,  $0.039$ ,  $0.046$ ,  $0.016$  units, respectively, and the impact of error correction terms being  $-0.026$  units; The first-order difference (D (LNER)) of the logarithm of the RMB real effective exchange rate index (D (LNER)) is affected by its own and PTA futures variables logarithmic first-order difference lag of 1 to 5 order, with cumulative effects of  $-0.207$ ,  $-0.008$ ,  $0.070$ , and  $-0.022$  units, respectively, and the impact of error correction terms being  $-0.057$  units; The first-order difference of the logarithm of RMB overseas direct investment (D(LNRI)) is affected by its own and PTA futures variables logarithmic first-order difference lag of 1 to 4 order, with cumulative effects of  $-1.481$ ,  $1.590$ ,  $0.512$  and  $-0.287$  units, respectively, and the impact of error correction terms being  $0.148$  units; The first-order difference of the logarithm of the Total amount of domestic assets purchased by foreign investors (D (LNFB)) is affected by the first-order difference lag of its own and PTA futures variables logarithmic first-order differences of 1 to 3 order, with cumulative effects of  $1.649$ ,  $-1.300$ ,  $0.918$ , and  $-1.31$  units, respectively, and the impact of error correction terms being  $-1.822$  units; The first-order difference of the logarithm of Total domestic RMB financial assets held by overseas institutions and individuals (D (LNFA)) is affected by the first-order difference between themselves and PTA futures variables by a logarithmic difference of 1 to 4 order, with cumulative effects of  $0.262$ ,  $-0.198$ ,  $0.017$  and  $0.004$  units, respectively, and the impact of error correction terms being  $0.001$  units; The first-order difference of the logarithm of the foreign exchange market turnover (D (LNFV)) is affected by its own and PTA futures variables logarithmic first-order difference lag of 1 to 3 order, with cumulative effects of  $-1.349$ ,  $-0.057$ ,  $0.276$ ,  $-0.064$  units, respectively, and the impact of error correction terms is  $-0.162$  units.

Therefore, from the above-mentioned short-term dynamic error correction model of each variable index of domestic PTA futures and RMB internationalization, it can be seen that only the logarithmic first-order difference of the Total amount of domestic assets purchased by foreign investors in the RMB internationalization indicator is greatly affected by the logarithmic first-order difference of domestic PTA futures variables, and the logarithmic first-order difference of other RMB internationalization indicators is relatively small.

The following trend chart of the first-order difference of the variables of RMB internationalization made according to the dynamic error correction model between the domestic PTA futures variable and the indicators of the RMB internationalization variables, respectively, can be seen from the trend chart that the fitting effect of each model is still good (See Appendix [Figure A3](#)).

## 5. Conclusion

Based on the monthly data from 2018 to 2022, this article aiming the micro variables (futures price, turnover, open interest) of Chinese international com-

modity futures (crude oil, iron ore, PTA) market at the various variables of RMB internationalization (Global market share of RMB international payment, RMB business settlement amount of cross-border trade, foreign exchange reserves, RMB real effective exchange rate index, RMB overseas direct investment, Total amount of domestic assets purchased by foreign investors, Total domestic RMB financial assets held by overseas institutions and individuals, Foreign exchange market turnover) adopts the quantitative research method of cointegration related theoretical model to study the overall impact of international commodity futures on the internationalization of the RMB.

The results of the Causal Test show that the futures prices in the international commodity futures variables have a strong guiding effect on some of the five variables of RMB internationalization, among which the prices of crude oil and PTA futures have a significant guiding effect on the Total domestic RMB financial assets held by overseas institutions and individuals in RMB financial trading variables and the foreign exchange reserves ; Iron ore futures prices have a significant guiding effect on the RMB business settlement amount of cross-border trade, the RMB overseas direct investment and the total amount of Total amount of domestic assets purchased by foreign investors in RMB financial transaction indicators. Compared with the futures price, the futures open interest in the international commodity futures variable has a strong guiding effect on more variables in the five variables of RMB internationalization, among which the crude oil futures open interest has a strong guiding effect on foreign exchange reserves and the RMB overseas direct investment, the Total domestic RMB financial assets held by overseas institutions and individuals, and the foreign exchange market turnover in RMB financial transaction variables; The iron ore futures open interest has a significant guiding effect on the RMB real effective exchange rate index and the foreign exchange market turnover in the RMB financial transaction variables; PTA futures open interest have a significant guiding effect on the RMB business settlement amount of cross-border trade, foreign exchange reserves and RMB financial transaction variable indicators of RMB overseas direct investment, and the foreign exchange market turnover; The futures turnover in the international commodity futures variable has less impact on the RMB internationalization variable than the futures price and open interest, among which, in addition to the iron ore futures turnover has a significant guiding effect on the global market share of RMB international payment, the turnover of crude oil and PTA futures has no significant guiding effect on the various variable indicators of RMB internationalization.

From the perspective of the impact of the three micro indicators of the international commodity futures market on the internationalization of the RMB, the three indicators have different significant effects on the five variables of the RMB internationalization, indicating that the introduction of the internationalization of domestic commodity futures has promoted the process of RMB internationalization. Due to the short launch time of domestic international commodity fu-

tures, there is still a certain gap between its international pricing power and influence and related international commodity futures, which requires domestic international commodity futures to further enhance its international influence and promote the further improvement of RMB internationalization.

The Cointegration Test shows that the impact of crude oil and PTA futures prices and open interest on various indicators of RMB internationalization is consistent, while the impact of the turnover of the two on the indicators of RMB internationalization is opposite, while the impact of iron ore futures prices and open interest on various indicators of RMB internationalization is mostly consistent, and the impact of turnover on various indicators of RMB internationalization is also mostly opposite.

In general, the price and open interest of crude oil and PTA futures in international commodity futures have a positive long-term impact on the internationalization of RMB, and the turnover has a negative long-term impact; The price of iron ore futures has a positive long-term impact on various indicators of RMB internationalization, and the open interest shows most of the positive impact, and the turnover shows most of the negative impact; From the perspective of impact intensity, the impact of crude oil futures prices and open interest on various indicators of RMB internationalization is stronger than that of iron ore and PTA, and the impact of the turnover of the three is weaker, which is due to the fact that crude oil futures are the first international varieties launched for international investors in China, while iron ore and PTA are open to international investors on the basis of the original futures varieties, and there are differences in the scale of international investor participation. Therefore, enhancing the international pricing ability of international commodity futures prices, increasing the holding volume of international futures varieties, and appropriately reducing the turnover will help further promote the international development of the RMB.

The established Error Correction Model shows that the short-term dynamic impact of the three variable indicators of international commodity futures (futures price, turnover, and open interest) on the variables of RMB internationalization is different, among which the first-order difference of crude oil futures variables has a greater impact on the log-first-order difference of the global market share of RMB international payment, the RMB overseas direct investment, the Total amount of domestic assets purchased by foreign investors, and foreign exchange market turnover in the RMB internationalization index. The logarithmic first-order difference on other RMB internationalization indicators has less effect; The first-order difference of iron ore futures variables has a greater impact on the logarithmic first-order difference of Global market share of RMB international payment, RMB business settlement amount of cross-border trade, RMB overseas direct investment, and Total amount of domestic assets purchased by foreign investors, and has a smaller impact on other log-first-order difference of RMB internationalization indicators; The first-order difference of

the PTA futures variable only has a greater impact on the log-first-order difference of the Total amount of domestic assets purchased by foreign investors in the RMB internationalization index, and has a smaller impact on the log-first-order difference of other RMB internationalization indicators.

The use of international commodity futures variables to simulate the various indicators of RMB internationalization shows that the use of crude oil futures variables is better than the simulation effect of iron ore and PTA futures variables, therefore, the impact of international commodity futures on the internationalization of RMB has a large difference, in general, international commodity futures have a certain impact on RMB internationalization, crude oil and iron ore than PTA the impact is larger, there are differences in the international development of different commodity futures markets.

In summary, the internationalization of Chinese futures market varieties has played a certain role in the development of RMB internationalization. In order to further promote the impact of the internationalization of the futures market on the internationalization of the RMB, Chinese futures market needs continuous improvement in the process of internationalization, and continuously improve the international pricing power and influence of domestic futures. First of all, from the perspective of policies and regulations, the Futures Derivatives Law (hereinafter referred to as the Futures Law) was voted and passed by the 34th session of the Standing Committee of the 13th National People's Congress on April 20 this year, and came into force on August 1. The futures market ushers in its own laws, the futures market will be more orderly under the regulation of the law in the future market construction, the internationalization of the futures market has a solid institutional foundation, which is conducive to attracting international institutional investors to enter the domestic futures market, and will continue to expand the international influence of the domestic futures market; Secondly, from the perspective of supervision, on the basis of giving full play to the five-in-one market supervision, strengthening the supervision of the market within the scope of the futures law, and preventing malicious speculation and manipulation of the market is conducive to the steady operation of the internationalization of the futures market and the process of RMB internationalization; Third, from the perspective of futures exchanges, continue to expand the scope of specific open varieties, deepen the price influence of open varieties, and strive to promote breakthroughs in regional pricing influence of key varieties such as crude oil, PTA, and iron ore; Expand the diversified open model, steadily promote the layout of maritime Delivery Warehouse, and gradually realize the "introduction of the transaction and the delivery going out". Deeply promote institutional opening-up, constantly improve the market operation rules of international futures varieties, the development of international varieties launched by several domestic futures exchanges is uneven, it is suggested that in the process of promoting the internationalization of futures varieties, we should learn from each other's strengths, continuously improve the variety rule system,

and promote the balanced development of the internationalization of different varieties; Introduce more overseas traders to participate in Chinese futures market, optimize the position structure of international futures varieties, and facilitate the healthy operation of international futures varieties, thereby promoting the international development of RMB; Forth, from the perspective of the construction of the futures derivatives market, the futures law further regulates the development of the futures and derivatives markets, and under the framework of the futures law, establishes a market system of spot and forward, on-site and over-the-counter integration, continuously expands the application scenarios of international futures varieties, and promotes the continuous improvement of the pricing influence of domestic international futures varieties. Actively promoting the internationalization of the domestic futures market is conducive to the healthy development of Chinese capital market, which can better promote the development of the internationalization of the RMB and will also have a positive impact on the steady operation of the national economy.

The research of this paper has certain limitations, due to the relatively short launch time of other international varieties, the data sample is relatively small, the research of this paper is based on a representative study of 3 international futures varieties, which does not include all existing international varieties, with the continuous increase of international varieties, after running for a period of time, the scope of research varieties can be expanded in the future, and it may be more meaningful to study the impact of international varieties on the internationalization of the RMB from the whole. In addition, from the perspective of research methods, more quantitative model research methods can be explored in the future to study the impact of futures internationalization on RMB internationalization.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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## Appendix

**Table A1.** Descriptive statistics of crude oil futures variables and RMB internationalization variables.

	IP	LNIS	LNFR	LNFR	LNRI	LNFB
Mean	2.006	8.5889	10.355	4.826	7.983	10.804
Median	1.945	8.588	10.347	4.825	7.946	10.768
Maximum	3.200	9.0489	10.389	4.884	8.855	11.502
Minimum	1.620	8.167	10.327	4.786	7.067	9.646
Std. Dev.	0.294	0.187	0.019	0.028	0.381	0.402
Skewness	1.695	0.231	0.425	0.304	0.332	-0.377
Kurtosis	7.335	2.905	1.795	2.203	2.795	2.860
Jarque-Bera	60.569	0.445	4.347	2.010	0.965	1.176
Probability	0.00	0.800	0.114	0.366	0.617	0.555
Sum	96.280	412.259	497.032	231.652	383.198	518.619
Sum Sq. Dev.	4.061	1.639	0.015	0.036	6.834	7.591
Observations	48	48	48	48	48	48

	LNFA	LNFV	LNP1	LN V1	LN I1
Mean	10.998	12.071	6.016	15.906	11.053
Median	10.926	12.075	6.095	15.921	11.046
Maximum	11.487	12.393	6.432	17.038	12.089
Minimum	10.526	11.713	5.410	14.701	9.012
Std. Dev.	0.321	0.161	0.241	0.543	0.563
Skewness	0.138	-0.197	-0.886	-0.118	-0.878
Kurtosis	1.525	2.402	2.855	2.457	5.523
Jarque-Bera	4.501	1.026	6.315	0.700	18.901
Probability	0.105	0.599	0.043	0.704	0.000
Sum	527.881	579.405	288.755	763.487	530.587
Sum Sq. Dev.	4.832	1.211	2.741	13.879	14.924
Observations	48	48	48	48	48

Note: IP indicates Global market share of RMB international payment, LNIS indicates RMB business settlement amount of cross-border trade log and LNFR indicates the logarithm of foreign exchange reserve, LNER indicates the logarithm of RMB real effective exchange rate index, LNRI indicates the logarithm of t RMB overseas direct investment, LNFB indicates Total amount of domestic assets purchased by foreign investors, LNFA indicates the total logarithm of Total domestic RMB financial assets held by overseas institutions and individuals, and LNFV represents the logarithm of foreign exchange market turnover, LNP1 represents the logarithm of domestic crude oil futures prices, LN V1 represents the logarithm of domestic crude oil futures turnover, and LN I1 represents the logarithm of domestic crude oil futures open interest, the following is similar.

**Table A2.** Descriptive statistics of iron ore futures variables and RMB internationalization variables.

	IP	LNIS	LNFR	LNFR	LNRI	LNFB
Mean	2.022	8.603	10.355	4.826	7.994	10.819
Median	1.950	8.591	10.346	4.826	7.946	10.771
Maximum	3.200	9.049	10.389	4.884	8.855	11.502
Minimum	1.650	8.167	10.326	4.786	7.068	9.646
Std. Dev.	0.290	0.177	0.018	0.028	0.380	0.401
Skewness	1.771	0.329	0.401	0.289	0.340	-0.442
Kurtosis	7.581	3.042	1.718	2.109	2.804	2.973
Jarque-Bera	64.277	0.833	4.387	2.159	0.960	1.502
Probability	0.000	0.659	0.112	0.340	0.619	0.472
Sum	93.000	395.736	476.326	222.003	367.727	497.684
Sum Sq. Dev.	3.7812	1.413	0.0150	0.036	6.498	7.248
Observations	46	46	46	46	46	46

	LNFA	LNFV	LNP2	LNV2	LNI2
Mean	11.018	12.0792	6.560	15.933	13.931
Median	10.941	12.083	6.504	15.931	13.845
Maximum	11.482	12.393	7.060	17.009	14.667
Minimum	10.594	11.713	6.120	15.210	13.298
Std. Dev.	0.312	0.1589	0.2612	0.4401	0.382
Skewness	0.111	-0.285	0.236	0.483	0.414
Kurtosis	1.496	2.559	2.230	2.560	2.182
Jarque-Bera	4.430	0.996	1.561	2.162	2.593
Probability	0.110	0.610	0.458	0.340	0.273
Sum	506.824	555.644	301.759	732.906	640.827
Sum Sq. Dev.	4.372	1.132	3.082	8.7402	6.573
Observations	46	46	46	46	46

Note: LNP2 represents the logarithm of domestic iron ore futures prices, LN V2 represents the logarithm of domestic iron ore futures turnover, and LNI2 represents the logarithm of domestic iron ore futures open interest, the following is similar.

**Table A3.** Descriptive statistics of PTA futures variables and RMB internationalization variables.

	IP	LNIS	LNFR	LNFR	LNRI	LNFB
Mean	2.039	8.631	10.357	4.830	8.040	10.863

## Continued

Median	1.9500	8.597	10.349	4.831	7.977	10.873
Maximum	3.200	9.049	10.389	4.884	8.855	11.502
Minimum	1.650	8.167	10.329	4.786	7.068	9.646
Std. Dev.	0.303	0.172	0.018	0.028	0.383	0.412
Skewness	1.668	0.138	0.234	0.192	0.145	-0.717
Kurtosis	6.923	3.398	1.522	2.091	2.824	3.273
Jarque-Bera	44.212	0.391	4.005	1.622	0.192	3.552
Probability	0.000	0.822	0.135	0.444	0.908	0.169
Sum	81.540	345.254	414.279	193.187	321.601	434.502
Sum Sq. Dev.	3.5791	1.1581	0.0133	0.0305	5.734	6.605
Observations	40	40	40	40	40	40

	LNFA	LNFV	LNP3	LNV3	LN13
Mean	11.077	12.091	8.457	15.275	14.580
Median	11.080	12.105	8.494	15.348	14.591
Maximum	11.482	12.393	8.797	16.685	15.042
Minimum	10.594	11.713	8.114	13.971	13.769
Std. Dev.	0.290	0.166	0.199	0.599	0.275
Skewness	-0.072	-0.461	-0.318	-0.162	-0.533
Kurtosis	1.547	2.523	2.055	2.936	3.260
Jarque-Bera	3.554	1.795	2.162	0.182	2.008
Probability	0.169	0.407	0.339	0.913	0.366
Sum	443.010	483.626	338.280	611.010	583.202
Sum Sq. Dev.	3.283	1.079	1.545	13.997	2.950
Observations	40	40	40	40	40

Note: LNP3 represents the logarithm of domestic PTA futures prices, LN V3 represents the logarithm of domestic PTA futures turnover, and LN13 represents the logarithm of domestic PTA futures open interest, the following is similar.

**Table A4.** Correlation coefficients between crude oil futures variables and various variables of RMB internationalization.

Variable	IP	LNIS	LNFR	LNFR	LNRI	LNFB	LNFA	LNFV	LNP1	LNV1	LN11
IP	1										
LNIS	0.594	1									
LNFR	0.529	0.710	1								
LNFR	0.481	0.538	0.793	1							

**Continued**

LNRI	0.538	0.880	0.754	0.677	1							
LNFB	0.483	0.738	0.694	0.637	0.724	1						
LNFA	0.507	0.817	0.883	0.794	0.786	0.796	1					
LNFBV	0.482	0.700	0.430	0.246	0.662	0.373	0.425	1				
LNP1	0.291	-0.061	0.092	0.023	-0.010	-0.119	-0.131	-0.016	1			
LNV1	0.1421	-0.119	-0.298	-0.220	-0.216	-0.297	-0.270	0.161	0.405	1		
LNI1	0.123	0.431	0.150	0.194	0.240	0.351	0.494	0.2754	-0.650	0.018	1	

**Table A5.** Correlation coefficients between iron ore futures variables and various variable indicators of RMB internationalization.

Variable	IP	LNIS	LNFR	LNFR	LNFR	LNRI	LNFB	LNFA	LNFBV	LNP2	LNV2	LNI2
IP	1											
LNIS	0.556	1										
LNFR	0.542	0.754	1									
LNFR	0.495	0.573	0.794	1								
LNRI	0.536	0.910	0.765	0.694	1							
LNFB	0.465	0.737	0.702	0.651	0.712	1						
LNFA	0.465	0.796	0.920	0.829	0.801	0.798	1					
LNFBV	0.447	0.675	0.437	0.251	0.657	0.342	0.378	1				
LNP2	0.280	0.519	0.676	0.464	0.491	0.505	0.750	0.250	1			
LNV2	-0.233	-0.228	-0.319	-0.359	-0.366	-0.368	-0.333	-0.284	-0.086	1		
LNI2	-0.158	-0.266	-0.410	-0.428	-0.350	-0.495	-0.507	-0.240	-0.351	0.762	1	

**Table A6.** Correlation coefficients between PTA futures variables and various variable indicators of RMB internationalization.

Variable	IP	LNIS	LNFR	LNFR	LNFR	LNRI	LNFB	LNFA	LNFBV	LNP3	LNV3	LNI3
IP	1											
LNIS	0.546	1										
LNFR	0.522	0.730	1									
LNFR	0.513	0.537	0.788	1								
LNRI	0.531	0.915	0.741	0.656	1							
LNFB	0.442	0.713	0.685	0.653	0.700	1						
LNFA	0.459	0.747	0.943	0.843	0.791	0.794	1					
LNFBV	0.439	0.675	0.422	0.231	0.660	0.304	0.337	1				
LNP3	0.272	-0.195	-0.064	-0.101	-0.156	-0.335	-0.287	0.040	1			
LNV3	0.248	0.043	0.175	0.054	0.062	-0.080	-0.017	0.192	0.633	1		
LNI3	0.136	0.415	0.458	0.226	0.331	0.307	0.424	0.250	-0.152	0.422	1	



**Table A8.** Results of the causal relationship between crude oil futures variables and various variables of RMB internationalization.

Null Hypothesis	Sample	F-Statistic	Prob.
LNP1 does not Granger Cause IP	47	0.53547	0.4682
IP does not Granger Cause LNP1		4.07201	0.0497
LNV1 does not Granger Cause IP	47	0.15199	0.6985
IP does not Granger Cause LNV1		1.44834	0.2352
LNI1 does not Granger Cause IP	47	0.01190	0.9136
IP does not Granger Cause LNI1		0.81344	0.3720
LNP1 does not Granger Cause LNIS	47	0.49067	0.4873
LNIS does not Granger Cause LNP1		2.86593	0.0975
LNV1 does not Granger Cause LNIS	47	0.47927	0.4924
LNIS does not Granger Cause LNV1		1.91024	0.1739
LNI1 does not Granger Cause LNIS	47	2.51044	0.1203
LNIS does not Granger Cause LNI1		1.40726	0.2419
LNP1 does not Granger Cause LNFR	46	2.62058	0.0849
LNFR does not Granger Cause LNP1		0.96664	0.3889
LNV1 does not Granger Cause LNFR	46	0.48720	0.6179
LNFR does not Granger Cause LNV1		9.64020	0.0004
LNI1 does not Granger Cause LNFR	46	3.82246	0.0300
LNFR does not Granger Cause LNI1		2.13783	0.1309
LNP1 does not Granger Cause LNER	47	0.00941	0.9231
LNER does not Granger Cause LNP1		2.24108	0.1415
LNV1 does not Granger Cause LNER	47	2.04524	0.1597
LNER does not Granger Cause LNV1		0.07015	0.7924
LNI1 does not Granger Cause LNER	47	0.09216	0.7629
LNER does not Granger Cause LNI1		1.14902	0.2896
LNP1 does not Granger Cause LNRI	47	0.16677	0.6850
LNRI does not Granger Cause LNP1		3.93703	0.0535
LNV1 does not Granger Cause LNRI	47	0.65688	0.4220
LNRI does not Granger Cause LNV1		2.10073	0.1543
LNI1 does not Granger Cause LNRI	47	4.10789	0.0488
LNRI does not Granger Cause LNI1		0.45700	0.5026
LNP1 does not Granger Cause LNFB	47	0.11094	0.7407
LNFB does not Granger Cause LNP1		0.38101	0.5402

**Continued**

LNV1 does not Granger Cause LNFB	47	0.77600	0.3832
LNFB does not Granger Cause LNV1		0.48333	0.4906
LNI1 does not Granger Cause LNFB	47	1.43521	0.2373
LNFB does not Granger Cause LNI1		0.12048	0.7302
LNP1 does not Granger Cause LNFA	47	13.0875	0.0008
LNFA does not Granger Cause LNP1		1.32808	0.2554
LNV1 does not Granger Cause LNFA	47	0.27164	0.6048
LNFA does not Granger Cause LNV1		1.64655	0.2061
LNI1 does not Granger Cause LNFA	47	4.71400	0.0354
LNFA does not Granger Cause LNI1		0.01182	0.9139
LNP1 does not Granger Cause LNFV	47	0.06266	0.8035
LNFV does not Granger Cause LNP1		3.00384	0.0901
LNV1 does not Granger Cause LNFV	47	0.37907	0.5413
LNFV does not Granger Cause LNV1		0.10482	0.7477
LNI1 does not Granger Cause LNFV	47	4.27124	0.0447
LNFV does not Granger Cause LNI1		2.49646	0.1213

**Table A9.** Results of causal relationship test between iron ore futures variables and various variables of RMB internationalization.

Null Hypothesis	Sample	F-Statistic	Prob.
LNP2 does not Granger Cause IP	45	0.78181	0.3816
IP does not Granger Cause LNP2		0.22648	0.6366
LNV2 does not Granger Cause IP	45	3.71416	0.0607
IP does not Granger Cause LNV2		0.47229	0.4957
LNI2 does not Granger Cause IP	45	0.99785	0.3236
IP does not Granger Cause LNI2		0.54578	0.4642
LNP2 does not Granger Cause LNIS	45	3.39137	0.0726
LNIS does not Granger Cause LNP2		0.08398	0.7734
LNV2 does not Granger Cause LNIS	45	0.03389	0.8548
LNIS does not Granger Cause LNV2		2.04352	0.1603
LNI2 does not Granger Cause LNIS	45	0.00241	0.9611
LNIS does not Granger Cause LNI2		2.95848	0.0928
LNP2 does not Granger Cause LNFR	45	2.45776	0.1244
LNFR does not Granger Cause LNP2		0.04151	0.8395

## Continued

LNV2 does not Granger Cause LNFR	45	0.00206	0.9640
LNFR does not Granger Cause LNV2		1.15666	0.2883
LNI2 does not Granger Cause LNFR	45	0.00264	0.9592
LNFR does not Granger Cause LNI2		0.89097	0.3506
LNP2 does not Granger Cause LNER	45	1.13639	0.2925
LNER does not Granger Cause LNP2		0.52525	0.4726
LNV2 does not Granger Cause LNER	45	1.24765	0.2704
LNER does not Granger Cause LNV2		1.17024	0.2855
LNI2 does not Granger Cause LNER	45	3.69412	0.0614
LNER does not Granger Cause LNI2		0.14713	0.7032
LNP2 does not Granger Cause LNRI	42	2.33622	0.0758
LNRI does not Granger Cause LNP2		0.77908	0.5468
LNV2 does not Granger Cause LNRI	42	0.47098	0.7566
LNRI does not Granger Cause LNV2		2.22609	0.0875
LNI2 does not Granger Cause LNRI	42	1.54063	0.2133
LNRI does not Granger Cause LNI2		2.61990	0.0526
LNP2 does not Granger Cause LNFB	45	5.87215	0.0198
LNFB does not Granger Cause LNP2		0.27406	0.6034
LNV2 does not Granger Cause LNFB	45	1.64234	0.2070
LNFB does not Granger Cause LNV2		7.82423	0.0077
LNI2 does not Granger Cause LNFB	45	2.44035	0.1258
LNFB does not Granger Cause LNI2		5.99828	0.0186
LNP2 does not Granger Cause LNFA	45	0.49272	0.4866
LNFA does not Granger Cause LNP2		0.19125	0.6641
LNV2 does not Granger Cause LNFA	45	1.02401	0.3174
LNFA does not Granger Cause LNV2		1.52348	0.2240
LNI2 does not Granger Cause LNFA	45	0.48116	0.4917
LNFA does not Granger Cause LNI2		1.04196	0.3132
LNP2 does not Granger Cause LNFV	42	0.09040	0.9848
LNFV does not Granger Cause LNP2		0.92984	0.4586
LNV2 does not Granger Cause LNFV	42	1.90210	0.1334
LNFV does not Granger Cause LNV2		4.02848	0.0091
LNI2 does not Granger Cause LNFV	42	3.40026	0.0196
LNFV does not Granger Cause LNI2		1.75820	0.1609

**Table A10.** Results of causal relationship test between PTA futures variables and RMB internationalization variables.

Null Hypothesis	Sample	F-Statistic	Prob.
LNP3 does not Granger Cause IP	39	0.04342	0.8361
IP does not Granger Cause LNP3		5.06096	0.0307
LNV3 does not Granger Cause IP	39	1.00872	0.3219
IP does not Granger Cause LNV3		2.19702	0.1470
LNI3 does not Granger Cause IP	39	1.39025	0.2461
IP does not Granger Cause LNI3		0.48477	0.4907
LNP3 does not Granger Cause LNIS	39	1.04790	0.3128
LNIS does not Granger Cause LNP3		4.82705	0.0345
LNV3 does not Granger Cause LNIS	39	0.00204	0.9642
LNIS does not Granger Cause LNV3		0.03554	0.8515
LNI3 does not Granger Cause LNIS	39	4.77249	0.0355
LNIS does not Granger Cause LNI3		3.14858	0.0845
LNP3 does not Granger Cause LNFR	39	2.93434	0.0953
LNFR does not Granger Cause LNP3		1.36644	0.2501
LNV3 does not Granger Cause LNFR	39	0.06931	0.7938
LNFR does not Granger Cause LNV3		0.39366	0.5343
LNI3 does not Granger Cause LNFR	39	3.55165	0.0676
LNFR does not Granger Cause LNI3		0.44603	0.5085
LNP3 does not Granger Cause LNER	36	0.71691	0.5878
LNER does not Granger Cause LNP3		1.06368	0.3936
LNV3 does not Granger Cause LNER	36	0.41995	0.7928
LNER does not Granger Cause LNV3		0.67456	0.6154
LNI3 does not Granger Cause LNER	36	1.45322	0.2439
LNER does not Granger Cause LNI3		2.81226	0.0451
LNP3 does not Granger Cause LNRI	39	0.42426	0.5190
LNRI does not Granger Cause LNP3		3.81207	0.0587
LNV3 does not Granger Cause LNRI	39	0.09309	0.7620
LNRI does not Granger Cause LNV3		0.61591	0.4377
LNI3 does not Granger Cause LNRI	39	3.46456	0.0709
LNRI does not Granger Cause LNI3		1.87970	0.1789
LNP3 does not Granger Cause LNFB	39	1.28216	0.2650
LNFB does not Granger Cause LNP3		0.41066	0.5257

## Continued

LNV3 does not Granger Cause LNFB	39	0.05918	0.8092
LNFB does not Granger Cause LNV3		0.16288	0.6889
LNI3 does not Granger Cause LNFB	39	0.64484	0.4272
LNFB does not Granger Cause LNI3		1.04278	0.3140
LNP3 does not Granger Cause LNFA	39	7.74667	0.0085
LNFA does not Granger Cause LNP3		0.87153	0.3568
LNV3 does not Granger Cause LNFA	39	1.75918	0.1931
LNFA does not Granger Cause LNV3		0.00063	0.9801
LNI3 does not Granger Cause LNFA	39	0.51091	0.4794
LNFA does not Granger Cause LNI3		0.36107	0.5517
LNP3 does not Granger Cause LNFV	39	0.15940	0.6921
LNFV does not Granger Cause LNP3		11.3723	0.0018
LNV3 does not Granger Cause LNFV	39	1.40200	0.2441
LNFV does not Granger Cause LNV3		0.55653	0.4605
LNI3 does not Granger Cause LNF	39	4.45039	0.0419
LNFV does not Granger Cause LNI3		2.83893	0.1007

**Table A11.** Long-term cointegration equation between crude oil futures variables and variables of RMB internationalization.

variable	LNP1	LNV1	LNI1	TREND	c	Trend and constant selection	Lag order interval selection
IP	1.405 (0.078)	-0.024 (0.019)	0.738 (0.046)		14.260	constant	1 to 7
LNIS	1.626 (0.229)	-0.021 (0.067)	1.205 (0.156)		14.247	constant	1 to 7
LNFR	0.073 (0.005)	-0.028 (0.002)	0.021 (0.004)		10.131	constant	1 to 7
LNFR	0.150 (0.031)	-0.041 (0.009)	0.063 (0.015)		1.917	constant	1 to 6
LNRI	1.446 (0.111)	-0.335 (0.037)	0.486 (0.055)	0.015 (0.002)	1.153	Linear trend and constant	1 to 6
LNFB	1.447 (0.246)	-0.788 (0.070)	0.588 (0.136)		8.136	constant	1 to 4
LNFA	0.221 (0.176)	-0.180 (0.050)	0.210 (0.078)	0.015 (0.002)	9.828	Linear trend and Constant	1 to 4
LNFV	0.602 (0.061)	0.137 (0.015)	0.414 (0.043)		1.666	Constant	1 to 7

Note: The numbers in parentheses are the standard deviation, the following is same.

**Table A12.** Long-term cointegration equation between iron ore futures variables and RMB internationalization variables.

Variable	LNP2	LN2	LNI2	TREND	c	Trend and constant selection	Lag order interval selection
IP	0.648 (0.100)	-1.624 (0.133)	1.672 (0.159)		0.398	constant	1 to 6
LNIS	1.466 (0.201)	-0.626 (0.216)	1.016 (0.253)		5.218	constant	1 to 5
LNFR	0.017 (0.019)	0.032 (0.012)	-0.065 (0.014)	0.001 (0.001)	10.634	Linear trend and Constant	1 to 5
LNFR	0.391 (0.032)	-0.059 (0.063)	0.228 (0.024)				1 to 5
LNRI	1.459 (0.124)	-0.186 (0.228)	0.104 (0.226)				1 to 5
LNFB	0.474 (0.097)	0.762 (0.102)	-1.220 (0.265)		12.545	constant	1 to 6
LNFA	0.075 (0.025)	0.110 (0.013)	-0.239 (0.015)	0.022	11.543	Quadratic trend and constant	1 to 6
LNFB	0.296 (0.129)	-0.446 (0.104)	0.354 (0.126)		12.318	constant	2 to 5

**Table A13.** Long-term cointegration equations between PTA futures variables and RMB internationalization variables.

Variable	LNP3	LN3	LNI3	TREND	c	Trend and constant selection	Lag order interval selection
IP	0.776 (0.180)	-0.104 (0.080)	0.158 (0.109)	0.011 (0.001)	5.578	Linear trend and Constant	1 to 3
LNIS	1.281 (0.361)	-0.567 (0.154)	0.925 (0.037)	-0.016 (0.003)	7.491	Linear trend and Constant	1 to 2
LNFR	0.282 (0.063)	-0.111 (0.030)	0.064 (0.037)		8.733	Constant	1 to 5
LNFR	0.868 (0.239)	-0.379 (0.113)	0.130 (0.151)		1.392	Constant	1 to 5
LNRI	0.062 (0.421)	-0.081 (0.196)	0.816 (0.268)	0.050 (0.003)	4.612	Linear trend and Constant	1 to 4
LNFB	0.338 (0.224)	-0.308 (0.010)	0.418 (0.143)	0.030 (0.002)	5.727	Linear trend and Constant	1 to 3
LNFA	0.559 (0.343)	-0.274 (0.142)	0.123 (0.197)	0.012 (0.002)	8.415	Linear trend and Constant	1 to 4
LNFB	1.253 (0.158)	-0.420 (0.082)	0.543 (0.064)				1 to 3

**Table A14.** Short-term Error correction model between domestic crude oil futures variables and RMB internationalization variables.

ECM	Y1	Y2	Y3	Y4
EC	-0.777 (1.193)	-0.600 (0.219)	0.138 (0.436)	-1.181 (0.263)
Y1 (-1)	-0.412 (1.143)	Y2 (-1) -0.468 (0.252)	Y3 (-1) -0.214 (0.521)	Y4 (-1) 0.629 (0.241)
Y1 (-2)	-0.343 (1.142)	Y2 (-2) -0.555 (0.310)	Y3 (-2) -0.630 (0.601)	Y4 (-2) 0.600 (0.266)
Y1 (-3)	-0.388 (1.051)	Y2 (-3) -0.461 (0.331)	Y3 (-3) 0.010 (0.447)	Y4 (-3) 0.955 (0.278)
Y1 (-4)	-0.223 (0.906)	Y2 (-4) -0.146 (0.323)	Y3 (-4) -0.613 (0.435)	Y4 (-4) 0.687 (0.254)
Y1 (-5)	-0.269 (0.717)	Y2 (-5) -0.220 (0.344)	Y3 (-5) 0.490 (0.355)	Y4 (-5) 0.407 (0.211)
Y1 (-6)	0.032 (0.551)	Y2 (-6) 0.014 (0.305)	Y3 (-6) -0.250 (0.335)	Y4 (-6) 0.028 (0.225)
Y1 (-7)	0.197 (0.343)	Y2 (-7) -0.150 (0.259)	Y3 (-7) 0.906 (0.398)	
X11 (-1)	-1.702 (1.419)	-1.048 (0.473)	-0.001 (0.021)	-0.135 (0.036)
X11 (-2)	-0.680 (1.173)	-0.095 (0.457)	0.016 (0.027)	-0.115 (0.038)
X11 (-3)	0.108 (0.869)	-0.212 (0.448)	-0.048 (0.024)	-0.059 (0.026)
X11 (-4)	-1.049 (0.860)	-0.156 (0.411)	0.033 (0.025)	-0.079 (0.029)
X11 (-5)	-0.806 (0.753)	-0.116 (0.386)	-0.035 (0.023)	-0.025 (0.022)
X11 (-6)	-1.600 (0.719)	0.135 (0.314)	0.023 (0.017)	-0.011 (0.019)
X11 (-7)	0.699 (0.732)	0.577 (0.293)	-0.032 (0.017)	
X12 (-1)	0.073 (0.144)	-0.037 (0.069)	-0.002 (0.015)	0.048 (0.012)
X12 (-2)	0.346 (0.170)	0.066 (0.076)	-0.001 (0.014)	0.041 (0.011)
X12 (-3)	0.498 (0.198)	0.020 (0.074)	-0.007 (0.012)	0.041 (0.010)
X12 (-4)	0.554 (0.240)	-0.135 (0.071)	-0.002 (0.011)	0.044 (0.009)

## Continued

X12 (-5)	0.399 (0.290)	-0.182 (0.096)	-0.006 (0.010)	0.035 (0.009)
X12 (-6)	0.282 (0.283)	-0.163 (0.099)	-0.002 (0.007)	0.023 (0.009)
X12 (-7)	-0.105 (0.219)	-0.090 (0.090)	0.014 (0.007)	
X13 (-1)	-0.383 (0.669)	-0.455 (0.212)	-0.011 (0.010)	-0.071 (0.016)
X13 (-2)	-0.429 (0.485)	-0.362 (0.173)	0.010 (0.010)	-0.066 (0.016)
X13 (-3)	-0.488 (0.437)	-0.379 (0.166)	-0.002 (0.010)	-0.055 (0.015)
X13 (-4)	-0.844 (0.379)	-0.268 (0.157)	0.008 (0.010)	-0.043 (0.012)
X13 (-5)	-0.733 (0.380)	-0.071 (0.143)	0.006 (0.008)	-0.025 (0.010)
X13 (-6)	-0.632 (0.373)	-0.013 (0.140)	0.015 (0.008)	-0.021 (0.009)
X13 (-7)	-0.028 (0.332)	0.086 (0.111)	-0.013 (0.008)	
C	0.0920 (0.070)	0.040 (0.025)	0.002 (0.002)	0.002 (0.002)
R-squared	0.876	0.852	0.821	0.787
Adj. R-squared	0.512	0.422	0.300	0.433
Sum sq. resids	0.516	0.125	0.001	0.001
S.E. equation	0.227	0.112	0.006	0.007
F-statistic	2.438	1.983	1.577	2.223
Log likelihood	30.257	58.704	178.533	163.320
Akaike AIC	-0.013	-1.435	-7.427	-6.699
Schwarz SC	1.254	-0.169	-6.160	-5.612
Mean dependent	0.013	0.006	0.001	0.002
S.D. dependent	0.327	0.147	0.007	0.010

Note: Y1, Y2, Y3, Y4 represent D (IP), D (LNIS), D (LNFR), D (LNER), EC represents error correction terms, X11, X12, X13 represent D (LNP1), D (LNV1), D (LNI1), C represents constant terms. Where the negative numbers in parentheses represent the lag order of each first-order differential variable, and the values in parentheses represent the standard deviation of each error correction model equation, the following is similar.

ECM	Y5	Y6	Y7	Y8
EC	0.591 (1.483)	-1.021 (0.226)	-0.074 (0.080)	-0.034 (0.665)
Y5 (-1)	-1.691 (1.388)	Y6 (-1) -0.150 (0.172)	Y7 (-1) 0.085 (0.176)	Y8 (-1) -0.828 (0.710)
Y5 (-2)	-1.630 (1.171)	Y6 (-2) -0.083 (0.164)	Y7 (-2) -0.204 (0.193)	Y8 (-2) -0.749 (0.806)
Y5 (-3)	-0.807 (0.874)	Y6 (-3) 0.120 (0.167)	Y7 (-3) 0.024 (0.185)	Y8 (-3) -0.503 (0.788)
Y5 (-4)	-0.131 (0.510)	Y6 (-4) -0.107 (0.137)	Y7 (-4) 0.224 (0.169)	Y8 (-4) 0.286 (0.708)
Y5 (-5)	0.193 (0.319)			Y8 (-5) 0.270 (0.575)
Y5 (-6)	0.226 (0.194)			Y8 (-6) 0.294 (0.376)
				Y8 (-7) 0.082 (0.278)
X1 (-1)	0.484 (1.586)	-0.903 (0.360)	-0.005 (0.049)	-0.231 (0.421)
X1 (-2)	1.673 (1.915)	-1.274 (0.450)	-0.083 (0.051)	0.935 (0.464)
X1 (-3)	0.858 (1.196)	-0.676 (0.417)	-0.068 (0.052)	0.230 (0.602)
X1 (-4)	1.392 (1.340)	0.541 (0.368)	-0.186 (0.051)	0.339 (0.506)
X1 (-5)	-0.401 (0.698)			-0.111 (0.484)
X1 (-6)	0.057 (0.633)			0.114 (0.389)
X1 (-7)				0.443 (0.344)
X2 (-1)	-0.251 (0.549)	0.773 (0.194)	0.010 (0.018)	-0.021 (0.098)
X2 (-2)	-0.122 (0.478)	0.585 (0.178)	0.017 (0.015)	0.180 (0.095)
X2 (-3)	-0.238 (0.436)	0.688 (0.157)	0.042 (0.015)	0.084 (0.100)
X2 (-4)	-0.200 (0.358)	0.399 (0.145)	0.019 (0.015)	-0.124 (0.111)

## Continued

X2 (-5)	-0.238 (0.258)			-0.065 (0.123)
X2 (-6)	-0.136 (0.232)			-0.177 (0.106)
X2 (-7)				-0.112 (0.112)
X3 (-1)	0.654 (0.744)	-0.693 (0.198)	-0.045 (0.023)	0.3422 (0.240)
X3 (-2)	0.612 (0.647)	-0.568 (0.190)	-0.012 (0.022)	0.192 (0.254)
X3 (-3)	0.447 (0.575)	-0.510 (0.183)	-0.061 (0.020)	0.086 (0.291)
X3 (-4)	0.051 (0.387)	-0.529 (0.170)	-0.024 (0.020)	0.223 (0.263)
X3 (-5)	-0.031 (0.251)			0.081 (0.216)
X3 (-6)	-0.213 (0.220)			0.070 (0.165)
X3 (-7)				0.127 (0.126)
C	0.093 (0.066)	0.051 (0.031)	0.020 (0.007)	
R-squared	0.815	0.812	0.657	0.883
Adj. R-squared	0.506	0.685	0.423	0.584
Sum sq. resids	0.755	0.879	0.012	0.176
S.E. equation	0.224	0.187	0.021	0.126
F-statistic	2.640	6.362	2.811	2.953
Log likelihood	23.718	22.634	115.760	51.772
Akaike AIC	0.111	-0.216	-4.547	-1.139
Schwarz SC	1.198	0.522	-3.810	0.086
Mean dependent	0.015	0.017	0.019	-0.002
S.D. dependent	0.319	0.334	0.028	0.196

Note: Y5, Y6, Y7, and Y8 represent D (LNRI), D (LNFB), D (LNFA), D (LNFV), respectively, and the following are similar.

**Table A15.** Short-term error correction model between domestic iron ore futures and RMB internationalization variables.

ECM	Y1	Y2	Y3	Y4
EC	0.937 (0.519)	-0.384 (0.114)	-0.523 (0.124)	0.060 (0.035)
Y1 (-1)	-1.972 (0.765)	Y2 (-1) -0.664 (0.204)	Y3 (-1) -0.390 (0.179)	Y4 (-1) 0.113 (0.262)
Y1 (-2)	-1.868 (0.732)	Y2 (-2) -0.689 (0.232)	Y3 (-2) -0.510 (0.227)	Y4 (-2) 0.124 (0.257)
Y1 (-3)	-1.610 (0.834)	Y2 (-3) -0.297 (0.275)	Y3 (-3) -0.375 (0.206)	Y4 (-3) -0.313 (0.254)
Y1 (-4)	-1.312 (0.758)	Y2 (-4) -0.224 (0.224)	Y3 (-4) -0.109 (0.158)	Y4 (-4) -0.166 (0.187)
Y1 (-5)	-1.085 (0.584)	Y2 (-5) -0.269 (0.205)	Y3 (-5) -0.005 (0.158)	Y4 (-5) -0.113 (0.196)
Y1 (-6)	-0.196 (0.400)			
X21 (-1)	0.213 (0.653)	-0.367 (0.217)	0.007 (0.010)	0.016 (0.020)
X21 (-2)	0.491 (0.700)	-0.397 (0.192)	-0.005 (0.011)	0.021 (0.018)
X21 (-3)	0.248 (0.641)	-0.015 (0.201)	-0.013 (0.012)	-0.029 (0.019)
X21 (-4)	0.250 (0.665)	-0.390 (0.215)	-0.023 (0.012)	0.016 (0.023)
X21 (-5)	-1.402 (0.733)	-0.290 (0.224)	-0.021 (0.014)	0.014 (0.024)
X21 (-6)	-0.278 (1.065)			
X22 (-1)	-1.589 (0.727)	0.202 (0.110)	-0.019 (0.006)	-0.008 (0.008)
X22 (-2)	-0.998 (0.729)	0.348 (0.105)	-0.012 (0.005)	-0.019 (0.009)
X22 (-3)	-0.804 (0.532)	0.282 (0.101)	-0.005 (0.004)	-0.007 (0.008)
X22 (-4)	-0.509 (0.477)	0.345 (0.098)	-0.006 (0.004)	-0.011 (0.008)
X22 (-5)	-0.204 (0.388)	0.169 (0.097)	-0.004 (0.004)	-0.008 (0.008)
X22 (-6)	-0.096 (0.277)			

## Continued

X23 (-1)	1.603 (0.959)	-0.224 (0.165)	0.027 (0.009)	-0.006 (0.014)
X23 (-2)	0.891 (0.772)	-0.279 (0.153)	0.031 (0.008)	0.024 (0.014)
X23 (-3)	0.645 (0.578)	-0.327 (0.138)	0.025 (0.008)	0.009 (0.013)
X23 (-4)	0.278 (0.420)	-0.453 (0.146)	0.026 (0.009)	0.023 (0.013)
X23 (-5)	0.055 (0.372)	-0.230 (0.131)	0.015 (0.007)	0.018 (0.014)
X23 (-6)	-0.084 (0.319)			
C	0.129 (0.069)	0.038 (0.020)	0.003 (0.001)	
R-squared	0.739	0.798	0.722	0.566
Adj. R-squared	0.235	0.563	0.398	0.109
Sum sq. resids	1.051	0.169	0.001	0.002
S.E. equation	0.284	0.097	0.005	0.009
F-statistic	1.468	3.396	2.225	1.238
Log likelihood	15.133	52.547	169.768	144.772
Akaike AIC	0.557	-1.527	-7.388	-6.189
Schwarz SC	1.666	-0.598	-6.460	-5.302
Mean dependent	0.004	0.006	0.001	0.002
S.D. dependent	0.325	0.147	0.007	0.010

Note: X21, X22, and X23 represent D (LNP2), D (LNV2), D (LNI2), respectively, and the following are similar.

ECM	Y5	Y6	Y7	Y8
EC	-0.846 (0.206)	0.761 (0.566)	-1.479 (0.189)	-0.641 (0.204)
Y5 (-1)	-0.274 (0.201)	Y6 (-1) -1.219 (0.498)	Y7 (-1) 0.599 (0.106)	Y8 (-1)
Y5 (-2)	-0.446 (0.213)	Y6 (-2) -1.278 (0.479)	Y7 (-2) 0.456 (0.141)	Y8 (-2) -0.372 (0.175)
Y5 (-3)	-0.184 (0.228)	Y6 (-3) -0.868 (0.358)	Y7 (-3) 0.401 (0.138)	Y8 (-3) 0.270 (0.195)
Y5 (-4)	-0.308 (0.204)	Y6 (-4) -0.997 (0.305)	Y7 (-4) 0.489 (0.112)	Y8 (-4) 0.430 (0.211)

## Continued

Y5 (-5)	-0.082 (0.171)	Y6 (-5)	-0.630 (0.331)	Y7 (-5)	0.392 (0.119)	Y8 (-5)	0.222 (0.199)
Y5 (-6)		Y6 (-6)	-0.566 (0.254)	Y7 (-6)	0.458 (0.113)		
X21 (-1)	-1.164 (0.405)		1.406 (0.823)		-0.136 (0.032)		
X21 (-2)	-1.248 (0.395)		-0.668 (0.685)		-0.161 (0.031)		-0.153 (0.231)
X21 (-3)	-0.230 (0.421)		1.208 (0.817)		-0.178 (0.035)		0.071 (0.244)
X21 (-4)	-1.136 (0.436)		1.546 (0.884)		-0.194 (0.032)		-0.171 (0.250)
X21 (-5)	-1.047 (0.471)		0.062 (0.698)		-0.141 (0.032)		-0.151 (0.260)
X21 (-6)			1.973 (0.946)		-0.061 (0.037)		
X22 (-1)	0.284 (0.153)		0.067 (0.390)		-0.186 (0.024)		
X22 (-2)	0.286 (0.157)		0.483 (0.416)		-0.196 (0.028)		0.227 (0.092)
X22 (-3)	0.121 (0.133)		0.048 (0.297)		-0.138 (0.024)		0.222 (0.118)
X22 (-4)	0.328 (0.140)		-0.019 (0.261)		-0.129 (0.017)		0.335 (0.097)
X22 (-5)	0.113 (0.137)		0.405 (0.252)		-0.107 (0.018)		-0.018 (0.104)
X22 (-6)			0.204 (0.216)		-0.056 (0.014)		
X23 (-1)	-0.112 (0.205)		-0.750 (0.730)		0.349 (0.044)		
X23 (-2)	0.055 (0.201)		-1.135 (0.611)		0.364 (0.048)		-0.147 (0.129)
X23 (-3)	-0.305 (0.190)		-0.470 (0.429)		0.278 (0.041)		-0.161 (0.130)
X23 (-4)	-0.557 (0.214)		-0.199 (0.335)		0.266 (0.033)		-0.225 (0.126)
X23 (-5)	-0.092 (0.204)		-0.378 (0.324)		0.192 (0.035)		-0.088 (0.142)
X23 (-6)			0.197 (0.278)		0.063 (0.026)		
C			0.081 (0.050)		0.056 (0.008)		

## Continued

@TREND (18M03)			-0.003 (0.001)	
R-squared	0.870	0.808	0.948	0.740
Adj. R-squared	0.733	0.440	0.837	0.559
Sum sq. resids	0.531	0.881	0.002	0.389
S.E. equation	0.167	0.260	0.011	0.130
F-statistic	6.345	2.194	8.496	4.093
Log likelihood	29.696	18.576	142.977	35.880
Akaike AIC	-0.435	0.381	-5.948	-0.944
Schwarz SC	0.452	1.490	-4.796	-0.225
Mean dependent	0.016	0.016	0.023	-0.002
S.D. dependent	0.323	0.348	0.028	0.196

**Table A16.** Short-term error correction model of various variable indicators of domestic PTA futures and RMB internationalization.

ECM	Y1	Y2	Y3	Y4
EC	-1.824 (0.693)	-0.464 (0.151)	-0.026 (0.124)	-0.057 (0.044)
Y1 (-1)	0.876 (0.592)	Y2 (-1) -0.657 (0.172)	Y3 (-1) -0.398 (0.304)	Y4 (-1) 0.366 (0.290)
Y1 (-2)	0.5293 (0.475)	Y2 (-2) -0.548 (0.189)	Y3 (-2) -0.7124 (0.318)	Y4 (-2) 0.333 (0.329)
Y1 (-3)	0.306 (0.340)		Y3 (-3) -0.683 (0.425)	Y4 (-3) -0.311 (0.374)
			Y3 (-4) -0.413 (0.398)	Y4 (-4) -0.149 (0.329)
			Y3 (-5) -0.276 (0.406)	Y4 (-5) -0.032 (0.318)
X31 (-1)	0.519 (0.781)	-0.669 (0.274)	0.001 (0.025)	0.003 (0.031)
X31 (-2)	-0.516 (0.681)	-0.469 (0.305)	0.027 (0.027)	-0.007 (0.030)
X31 (-3)	0.032 (0.729)		0.043 (0.030)	0.010 (0.035)
X31 (-4)			-0.015 (0.028)	-0.038 (0.033)
X31 (-5)			-0.017 (0.027)	0.024 (0.032)
X32 (-1)	0.077 (0.147)	0.160 (0.065)	0.003 (0.014)	0.019 (0.015)

**Continued**

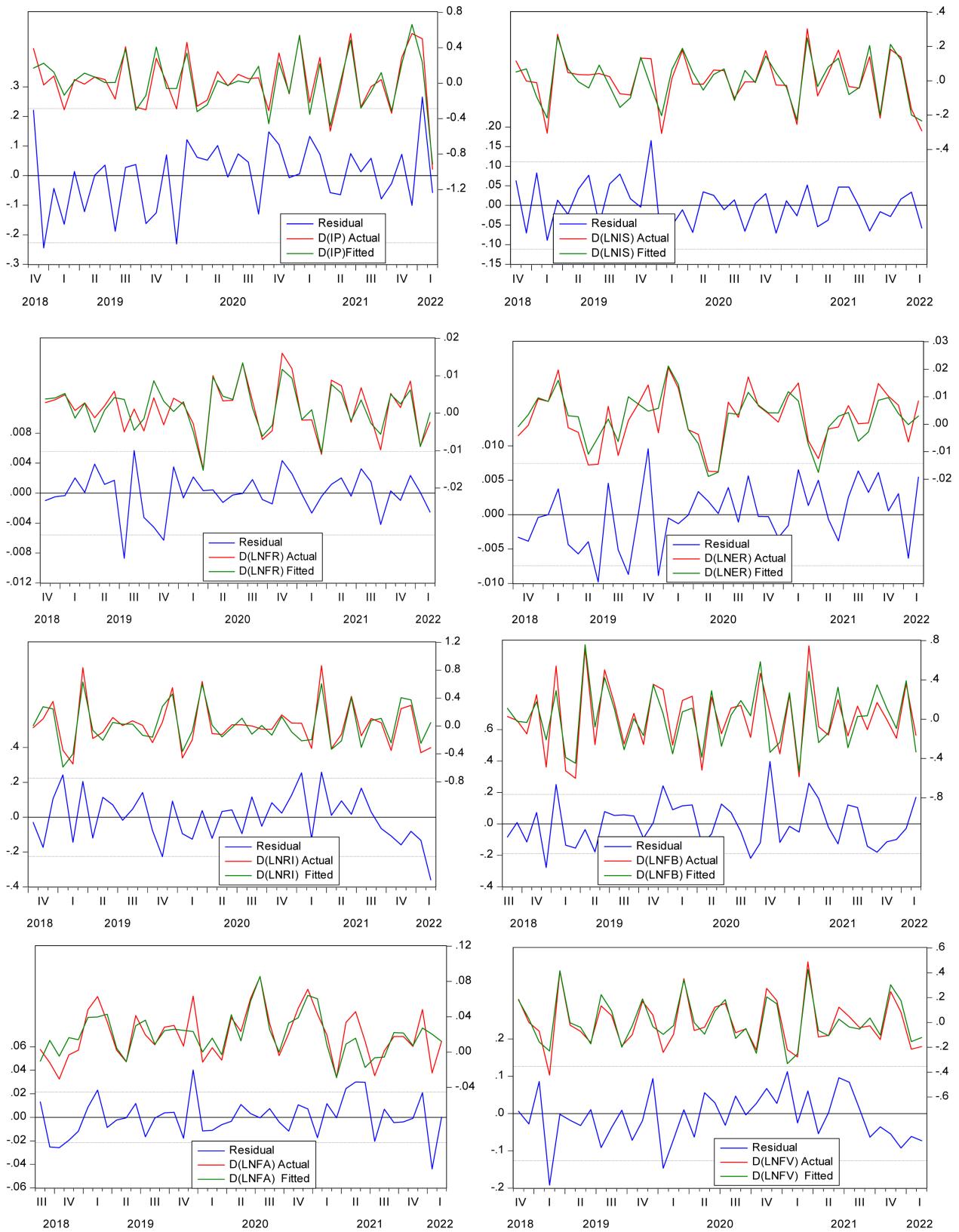
X32 (-2)	0.233 (0.150)	0.068 (0.053)	0.004 (0.015)	0.012 (0.014)
X32 (-3)	0.166 (0.148)		0.002 (0.014)	0.008 (0.015)
X32 (-4)			0.004 (0.011)	0.019 (0.016)
X22 (-5)			0.003 (0.006)	0.012 (0.010)
X33 (-1)	0.119 (0.331)	-0.069 (0.143)	0.010 (0.012)	-0.031 (0.018)
X33 (-2)	-0.143 (0.332)	0.140 (0.131)	0.014 (0.010)	0.001 (0.018)
X33 (-3)	-0.252 (0.376)		0.007 (0.013)	-0.001 (0.022)
X33 (-4)			0.002 (0.015)	-0.005 (0.022)
X33 (-5)			-0.009 (0.011)	-0.017 (0.018)
C	-0.015 (0.055)	0.020 (0.018)	0.005 (0.003)	0.003 (0.002)
R-squared	0.547	0.619	0.561	0.639
Adj. R-squared	0.280	0.492	-0.206	0.009
Sum sq. resids	1.775	0.315	0.001	0.001
S.E. equation	0.284	0.108	0.008	0.010
F-statistic	2.042	4.873	0.732	1.014
Log likelihood	3.090	35.656	134.102	125.500
Akaike AIC	0.606	-1.387	-6.594	-6.088
Schwarz SC	1.222	-0.951	-5.607	-5.101
Mean dependent	0.011	0.003	0.001	0.002
S.D. dependent	0.335	0.152	0.007	0.010

Note: X31, X32, and X33 represent D (LNP3), D (LNV3), and D (LNI3), respectively.

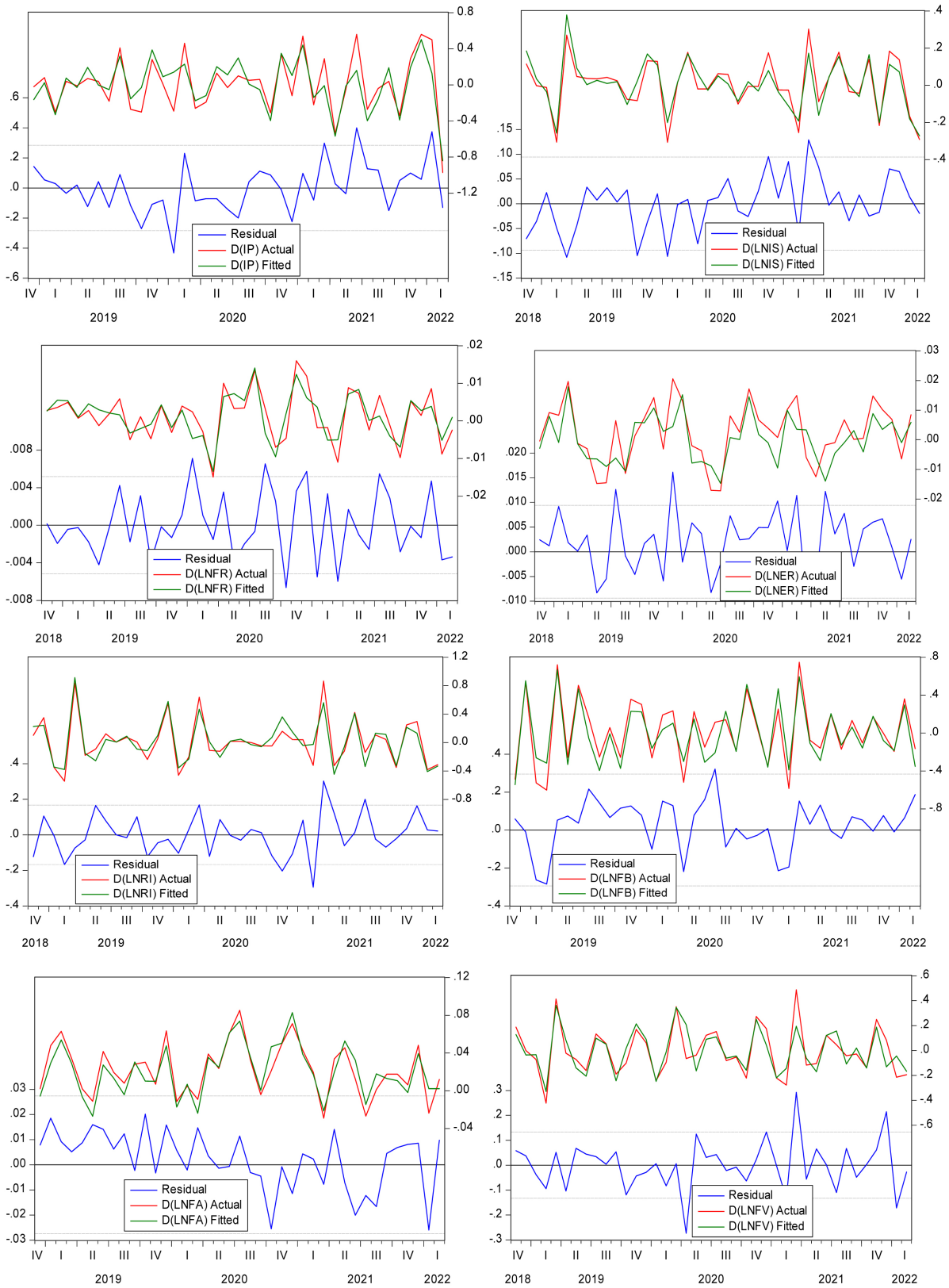
ECM	Y5	Y6	Y7	Y8
EC	0.148 (0.185)	-1.822 (0.280)	0.001 (0.043)	-0.162 (0.222)
Y5 (-1)	-1.089 (0.305)	Y6 (-1) 0.621 (0.212)	Y7 (-1) 0.340 (0.192)	Y8 (-1) -0.489 (0.271)
Y5 (-2)	-0.647 (0.362)	Y6 (-2) 0.530 (0.194)	Y7 (-2) -0.066 (0.190)	Y8 (-2) -0.559 (0.242)

## Continued

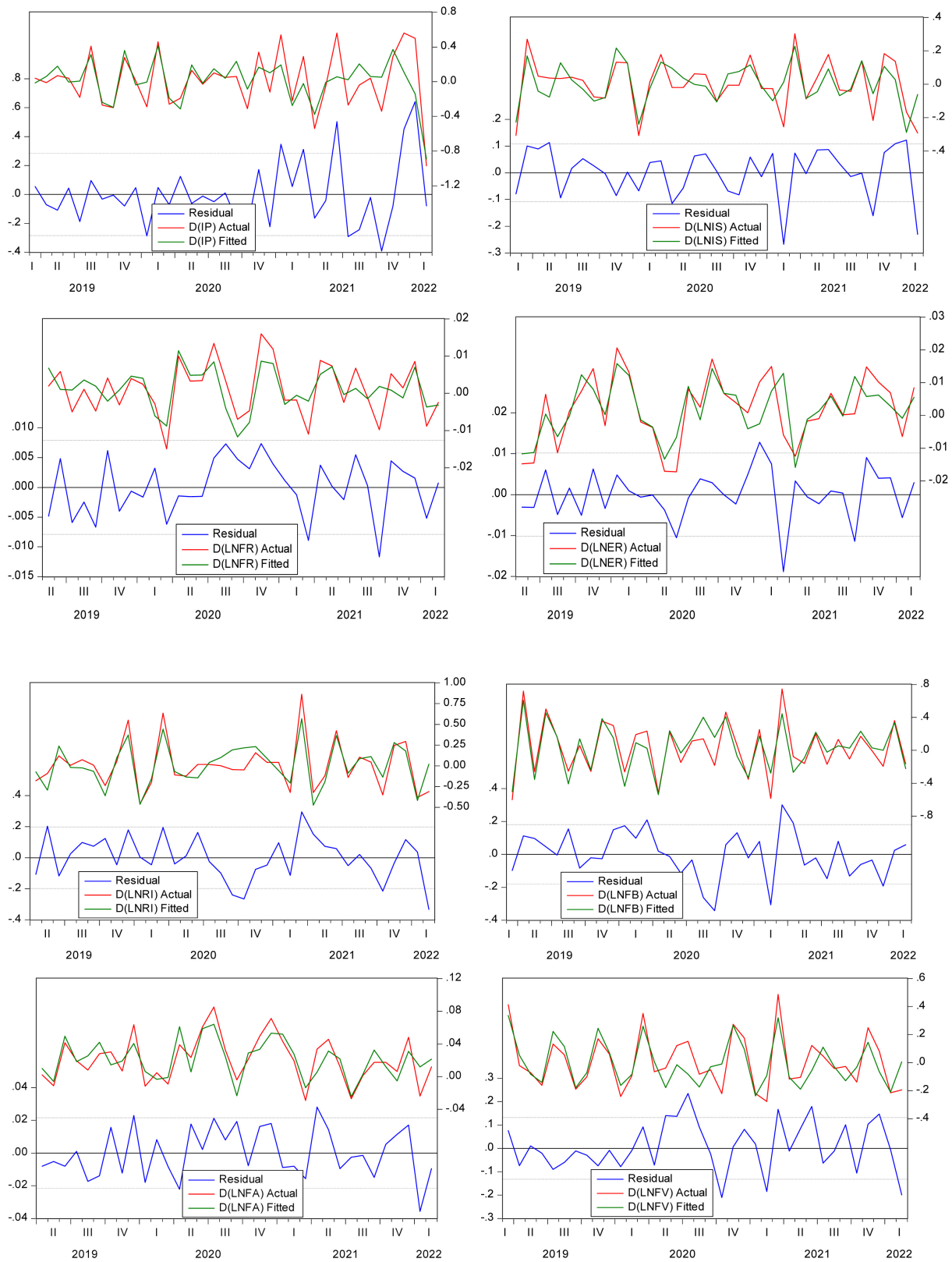
Y5 (-3)	0.135 (0.339)	Y6 (-3)	0.498 (0.148)	Y7 (-3)	-0.307 (0.206)	Y8 (-3)	-0.301 (0.201)
Y5 (-4)	0.120 (0.250)			Y7 (-4)	0.295 (0.187)		
X31 (-1)	0.199 (0.684)		-0.313 (0.528)		-0.087 (0.073)		0.279 (0.357)
X31 (-2)	0.679 (0.665)		-0.878 (0.450)		0.125 (0.077)		-0.003 (0.322)
X31 (-3)	0.912 (0.616)		-0.115 (0.501)		-0.079 (0.066)		-0.333 (0.361)
X31 (-4)	-0.200 (0.695)				-0.157 (0.069)		
X32 (-1)	0.138 (0.122)		0.431 (0.126)		-0.005 (0.015)		0.093 (0.110)
X32 (-2)	0.181 (0.155)		0.290 (0.113)		-0.018 (0.018)		0.093 (0.101)
X32 (-3)	0.123 (0.154)		0.197 (0.106)		0.018 (0.020)		0.090 (0.088)
X32 (-4)	0.070 (0.130)				0.022 (0.013)		
X33 (-1)	0.207 (0.261)		-0.366 (0.244)		-0.007 (0.025)		0.196 (0.155)
X33 (-2)	0.383 (0.264)		-0.535 (0.236)		0.084 (0.026)		-0.033 (0.175)
X33 (-3)	-0.279 (0.376)		-0.409 (0.250)		-0.022 (0.035)		-0.227 (0.196)
X33 (-4)	-0.598 (0.375)				-0.015 (0.031)		
C	0.092 (0.043)		0.016 (0.02)		0.014 (0.010)		
@TREND (18M03)							
R-squared	0.765		0.810		0.697		0.685
Adj. R-squared	0.530		0.698		0.394		0.521
Sum sq. resids	0.667		0.716		0.008		0.403
S.E. equation	0.198		0.180		0.022		0.132
F-statistic	3.251		7.214		2.302		4.170
Log likelihood	19.661		19.428		97.286		29.800
Akaike AIC	-0.095		-0.302		-4.531		-0.934
Schwarz SC	0.705		0.314		-3.731		-0.362
Mean dependent	0.007		0.030		0.021		0.006
S.D. dependent	0.289		0.328		0.028		0.191



**Figure A1.** Actual value and fitted value graph of the error correction model between crude oil futures variables and RMB internationalization variables.



**Figure A2.** Actual value and fitted value graph of error correction model of iron ore futures and RMB internationalization indicators.



**Figure A3.** Actual value and fitted value graph of error correction model of PTA futures variable and RMB internationalization variable index.