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A labor value model for exchange rates in a comprehensive economy

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Abstract:

This paper establishes a labor value model of exchange rate. According to the labor theory of value, the exchange rate is decomposed into the exchange rate of "a country's currency and a unit of product" to obtain the main body of the model, and the capital market adjustment items measured by official foreign exchange reserves are added to obtain the complete model. In the empirical part, the appropriate index was selected, and the cointegration relationship test was carried out, and the ARDL model was established according to the test. The regression coefficient R2 of the model is 98%, and the correlation coefficient between the fitted exchange rate value and the actual exchange rate value is 0.95.

Key words:

Labor value; Exchange rate; Capital market adjustment.

1.A labor value model for exchange rates

1.1 The main body of the model

The labor model of exchange rate proposed in this paper is based on the labor theory of value, which holds that the exchange basis of products and currencies is their intrinsic value, that is, the labor they contain. The more labor it contains, the more it can be exchanged for other products or currency.

Based on this theory, a labor value model of the exchange rate can be established. First of all, the exchange rate of 1 unit of a country's currency to 1 unit of product is:

$$\frac{\text{1 unit of currency}}{\text{1unit of product}} = \frac{\text{The labor within 1 unit of currency}}{\text{The labor within 1 unit of product}} \quad (1)$$

For example, 1 yuan contains 2 labor, and 1 unit of product contains 1 labor in China, then 1 yuan can be exchanged for 2 units of product. The reason why the "amount of labor included" is emphasized is "in a certain country" is that the production efficiency of each country is different, so the amount of labor contained in the same product is not the same in each country[1].

Secondly, the exchange ratio between the currency of country A and the currency of country B of 1 yuan is:

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$$\frac{\text{1 unit of country A currency}}{\text{1 unit of country B currency}} = \frac{\text{1 unit of country A currency to 1 unit of product}}{\text{1 unit of country B currency to 1 unit of product}} \quad (2)$$

For example, 1 yuan can be exchanged for 2 units of products, 1 US dollar can be exchanged for 12 units of products, then 1 US dollar can be exchanged for 6 yuan.

We can notice that the numerator and denominator in equation (2) are exactly the items sought by equation (1), that is, "1 yuan of a country's currency/1 unit of product", then we can replace (2The numerator and denominator of the formula are replaced by equation (1), and equation (2) becomes:

$$\frac{\text{1 unit of country A currency}}{\text{1 unit of country B currency}} = \frac{\text{The labor within 1 unit of country A currency}}{\text{The labor within 1 unit of product in country A}} \div \frac{\text{The labor within 1 unit of country B currency}}{\text{The labor within 1 unit of product in country B}} \quad (3)$$

Among them, "1 unit of country A currency / 1 unit of country B currency" is the exchange rate of country A's currency to country B's currency.

1.2 Adjustments to the capital market

The exchange rate is not only affected by the product market, but also by the supply and demand of funds in the capital market, so the adjustment of the capital market can be added to the above model:

$$\frac{\text{1 unit of country A currency}}{\text{1 unit of country B currency}} = \frac{\text{The labor within 1 unit of country A currency}}{\text{The labor within 1 unit of product in country A}} \div \frac{\text{The labor within 1 unit of country B currency}}{\text{The labor within 1 unit of product in country B}} + \text{capital market adjustment} \quad (4)$$

The adjustment item of the capital market should be a function of the supply and demand of funds in the capital market.

As a result, the labor value model of the exchange rate was established.

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2.Empirical analysis of the model

2.1Calculation of the estimated exchange rate

For equation (4), we can select the following metrics as model variables as shown in Table 1:

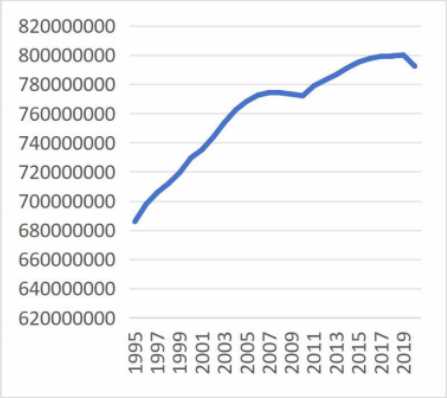
Table 1: Metric design of model variables

Variable	Meaning
A country's total labor force (Labor).	Under the assumption that each worker works a certain number of hours per year, the total working population of a country is a measure of the total number of workers in a country.
Gross Domestic Product (GDP) measured in a country's national currency	There are two influencing factors for the amount of labor contained in a country's currency, one is the total supply of the country's money, and the other is the number of times the country's currency is in circulation each year. According to the monetary quantity equation, these two factors are multiplied to form a country's GDP in its own currency, which measures the total amount of money in circulation in that country[2].
Industrial production index （Products）	A measure of the total quantity of products in a country.

Source: Author of this article

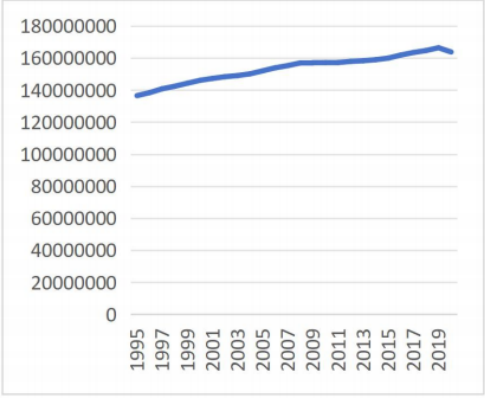
Data is collected for these variables from official sources like the world bank, as is shown in Supplementary figure 1 to Supplementary figure 6:

Supplementary figure 1: The number of people in China's labor force



Source: World Bank

Supplementary figure 2: The number of people in the U.S. labor force



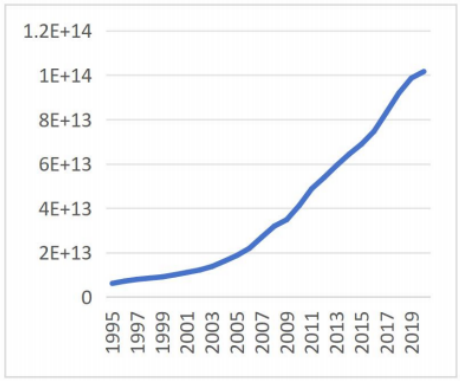
Source: World Bank

Supplementary figure 3: China's local currency GDP at its current price

Supplementary figure 4: U.S. local currency current GDP

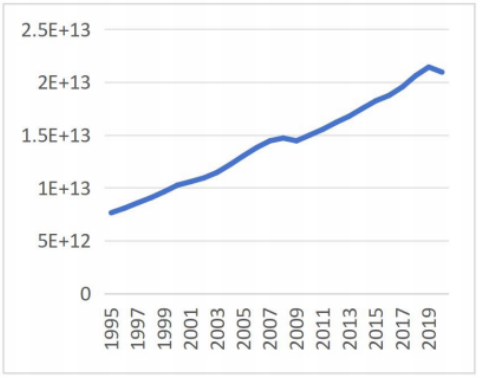
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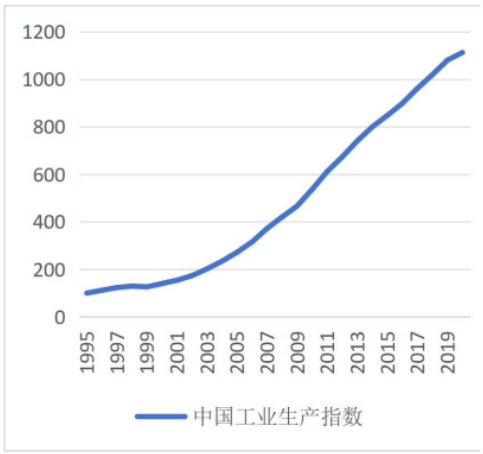
Source: World Bank

Supplementary figure 5: China's Industrial Production Index

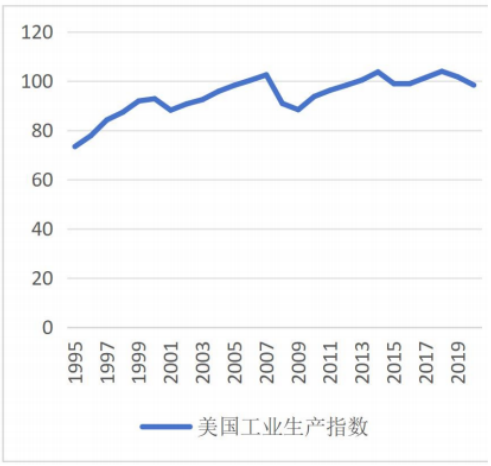


Source: World Bank

Supplementary figure 6: Index of industrial production in the United States



Source: BRICS Joint Statistical Handbook



Source: CEIC

Based on the variables in the table above, the labor value of the exchange rate can be estimated as follows:

$$est = \frac{Labor_c/GDP_c}{Labor_c/Products_c} \div \frac{Labor_u/GDP_u}{Labor_u/Products_u} \quad (5)$$

In Eq. (5), est represents the estimated exchange rate of RMB against the US dollar, with the subscript c representing "China" and the subscript u representing " United States". The value of the estimated exchange rate is shown in Figure 1:

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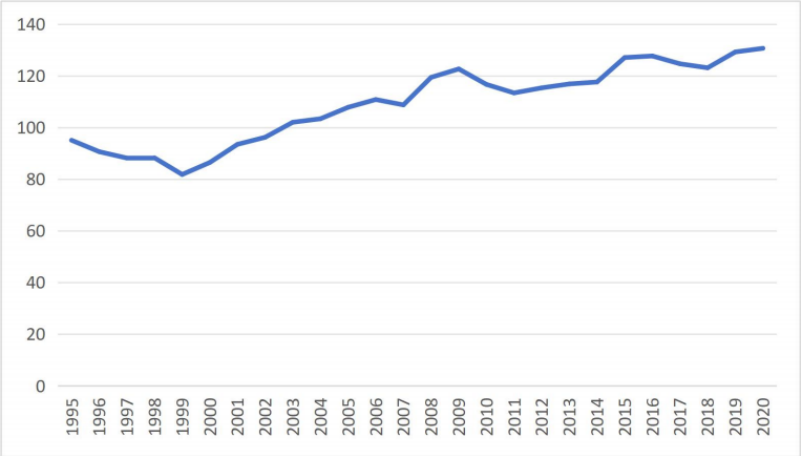
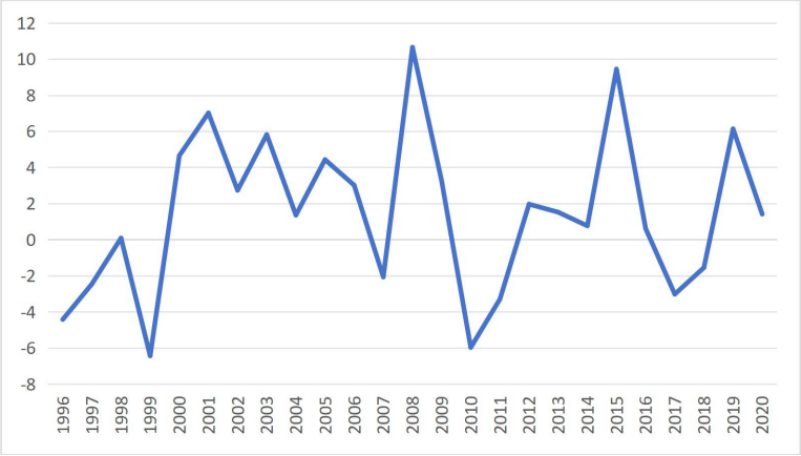


Figure 1: the estimated value of the foreign exchange rate of RMB to US dollar

2.2The ARDL model based on the real rate, estimated rate and capital market adjustment

As is shown in Figure 1, the estimated exchange rate shows a time trend, therefore its first-order difference is calculated to get a non-trend series, which is shown in Supplementary figure 7.



Supplementary figure 7: the first-order difference of the estimated exchange rate

Apart from the estimated exchange rate, the real exchange rate is also needed to construct a model. The real RMB exchange rate against the US dollar is demonstrated in Table 2:

Table 2: Real RMB exchange rate data against the US dollar

year	1995	1996	1997	1998	1999	2000	-
The actual value of the exchange rate of the renminbi against the US dollar	0.1198	0.1203	0.1206	0.1208	0.1208	0.1208	-
year	2001	2002	2003	2004	2005	2006	2007
The actual value of the exchange rate of the renminbi against the US dollar	0.1208	0.1208	0.1208	0.1208	0.1220	0.1254	0.1314
year	2008	2009	2010	2011	2012	2013	-

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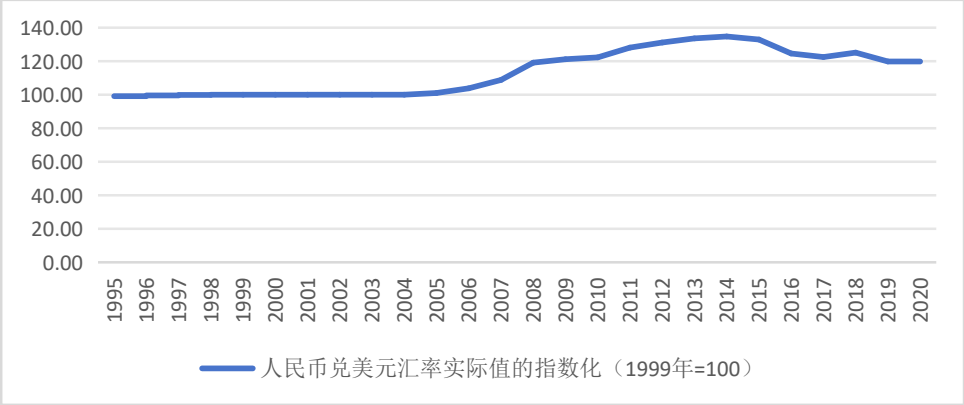
The actual value of the exchange rate of the renminbi against the US dollar	0.1439	0.1464	0.1477	0.1548	0.1584	0.1614	-
year	2014	2015	2016	2017	2018	2019	2020
The actual value of the exchange rate of the renminbi against the US dollar	0.1628	0.1606	0.1505	0.1480	0.1511	0.1448	0.1449

The calculation of the estimated exchange rate involves China's and USA's industrial production index, which is in an indexation form. To keep coherence, the real exchange rate is also indexed as is shown in Supplementary table 1.

Supplementary table 1: The real exchange rate indexation of the RMB against the US dollar

Year	1995	1996	1997	1998	1999	2000	-
Indexation of the real value of the RMB exchange rate against the US dollar (1999=100).	99.13	99.57	99.86	99.99	100.00	100.00	-
Year	2001	2002	2003	2004	2005	2006	2007
Indexation of the real value of the RMB exchange rate against the US dollar (1999=100).	100.01	100.02	100.02	100.02	101.03	103.82	108.82
Year	2008	2009	2010	2011	2012	2013	-
Indexation of the real value of the RMB exchange rate against the US dollar (1999=100).	119.13	121.18	122.27	128.12	131.15	133.61	-
Year	2014	2015	2016	2017	2018	2019	2020
Indexation of the real value of the RMB exchange rate against the US dollar (1999=100).	134.75	132.93	124.59	122.48	125.13	119.83	119.96

And the chart of indexed real exchange rate is given in Supplementary figure 8:



Supplementary figure 8: Indexation chart of the exchange rate data of the renminbi against the US dollar

Similar to the estimated exchange rate, the data of the real exchange rate also has a time trend, so the first-order difference of this real exchange rate data is calculated, as is shown in Supplementary table 2:

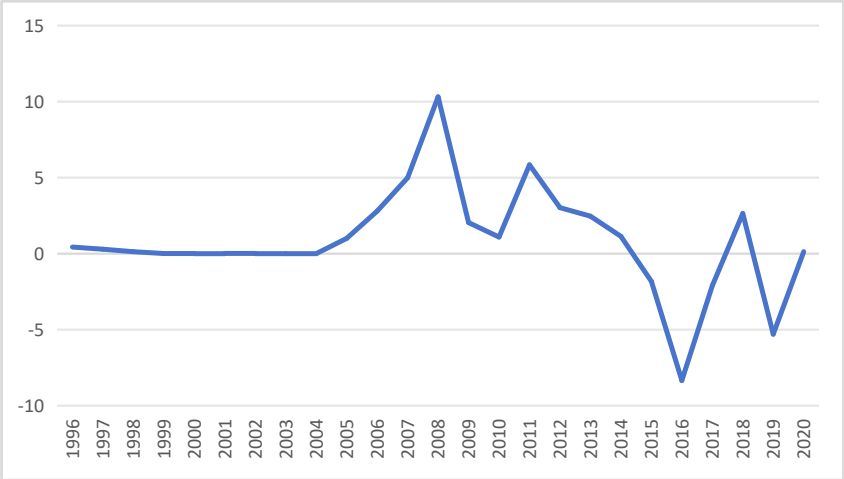
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Supplementary table 2: The first-order difference of the indexation of RMB exchange rate data against the US dollar

Year	1995	1996	1997	1998	1999	2000	-
The indexed first-order difference in the actual value of the RMB exchange rate against the US dollar	-	0.4352	0.2931	0.1291	0.0097	-0.0012	-
Year	2001	2002	2003	2004	2005	2006	2007
The indexed first-order difference in the actual value of the RMB exchange rate against the US dollar	0.0157	0.0012	0.0000	0.0024	1.0070	2.7989	4.9936
Year	2008	2009	2010	2011	2012	2013	-
The indexed first-order difference in the actual value of the RMB exchange rate against the US dollar	10.3169	2.0456	1.0936	5.8436	3.0282	2.4659	-
Year	2014	2015	2016	2017	2018	2019	2020
The indexed first-order difference in the actual value of the RMB exchange rate against the US dollar	1.1396	-1.8198	-8.3426	-2.1070	2.6437	-5.2960	0.1320

As is given by Supplementary figure 9, the first-order difference of the real exchange rate data now shows a converging-back character rather than a time trend.



Supplementary figure 9: First-order difference plot of RMB/USD exchange rate indexation

The estimated exchange rate and real exchange rate data is accomplished. As for the capital market adjustment, it is appropriate to measure it with China's official foreign exchange reserves (Figure 2), for it represents a large portion of US dollar demands. Limited by the accessibility, the data of private US dollar demands is not accessible.

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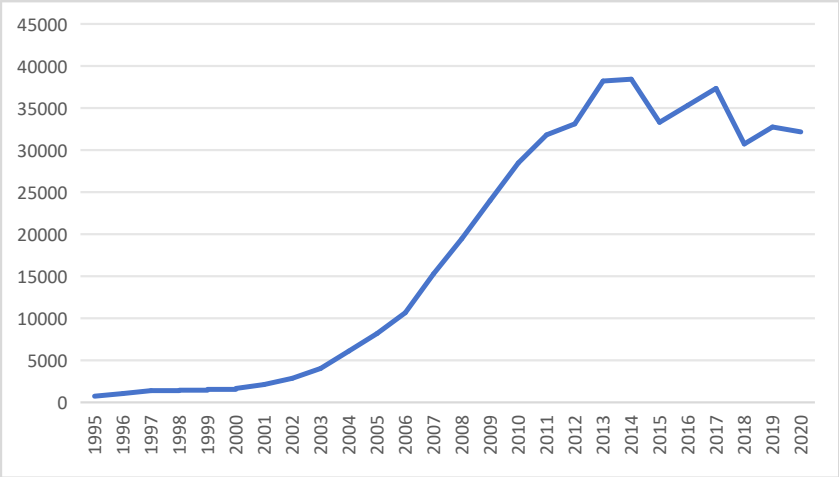
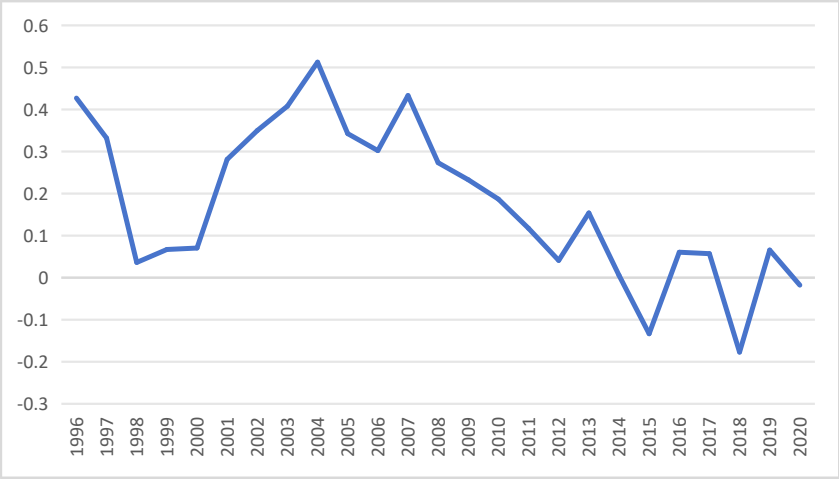


Figure 2: China's official foreign exchange reserves

The data of China's official foreign exchange reserves also has a time trend. Its first-order difference percentage is consequently calculated for detrending (Supplementary figure 10).



Supplementary figure 10: first-order difference percentage of China's official foreign exchange reserves

Using the estimated exchange rate data and capital market adjustments (measured by official foreign exchange reserves), a cointegration model of the RMB/USD exchange rate can be established as follows:

$$\text{Real} = \text{Est} + \gamma \times \text{Reserve} \quad (6)$$

Among them, Real is the actual exchange rate, Est is the estimated exchange rate, and Reserve is the first-order difference of China's official foreign exchange reserves. In the case of a cointegration relationship, an ARDL model can be established based on this relation:

$$\text{Realdif}_t = C + \alpha_1 \times \text{Realdif}_{t-1} + \ldots + \alpha_k \times \text{Realdif}_{t-k} + \beta_1 \times \text{Estdif}_{t-1} + \ldots + \beta_k \times \text{Estdif}_{t-k} + \gamma_1 \times \text{Reservedif}_{t-1} + \ldots + \gamma_k \times \text{Reservedif}_{t-k} + \varepsilon_t \quad (7)$$

Where Realdif is the first order difference of the real exchange rate, Estdif is the first order difference of estimated exchange rate, Reservedif is the percentage of first order difference of China's official foreign exchange reserves, and the error item is subject to a normal distribution:

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$$\varepsilon_t \sim N(\mu, \sigma^2), \quad f(\varepsilon_t) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{(\varepsilon_t - \mu)^2}{2\sigma^2}\right] \qquad (8)$$

2.3Empirical results

The cointegration test of Real, Est, and Reserve variables yields the following results in Figure 3, indicating that the cointegration relationship exists and the ARDL model can be established[3].

Date: 12/27/23 Time: 00:10
Sample (adjusted): 2001 2020
Included observations: 20 after adjustments
Trend assumption: Linear deterministic trend
Series: REAL RESERVE EST
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.991475	105.9272	29.79707	0.0000
At most 1	0.397426	10.63276	15.49471	0.2351
At most 2	0.024781	0.501858	3.841466	0.4787

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 3: Results of the cointegration test

Source: Author of this article

The ARDL model was established for the three variables of Real, Est and Reserve, and the lag order was determined to be 5th order according to the information of the lag length criteria.

The model fitting results are shown in Figure 4:

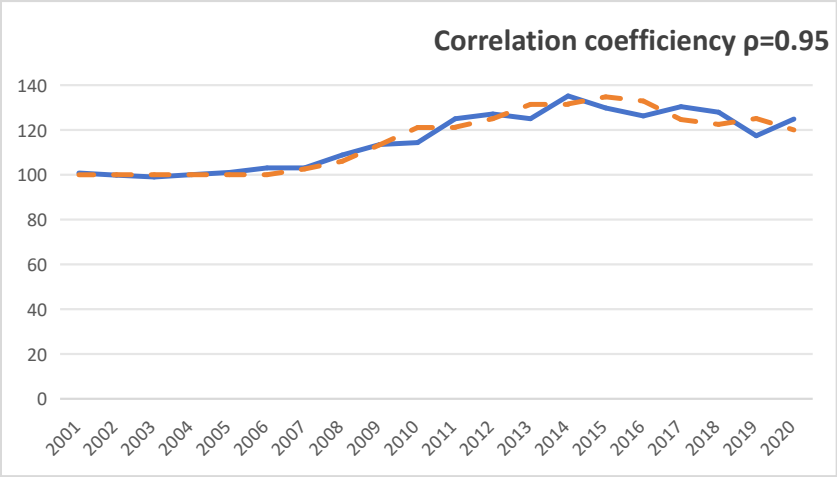


Source: Author of this article

Figure 4: Relationship between the actual exchange rate difference and the fitted exchange rate difference (dotted line)

Based on the fitted exchange rate differences, the fitted exchange rate value is calculated and compared with the actual exchange rate value (Supplementary figure 11).

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Supplementary figure 11: Relationship between real (dotted line) (1990=100) and fitted exchange rates (1990=100)

3.Conclusion

This paper explores the labor value model of the exchange rate. According to the labor theory of value, the exchange rate is decomposed into the ratio of "each unit of currency to each unit of product", so as to obtain the main part of the labor value model. On this basis, the capital market adjustments, measured by official foreign exchange reserves, are added to obtain a complete model. In the empirical part, the appropriate index was selected as the variable, and then the cointegration test was carried out on the variable, and the ARDL model was established accordingly. The regression coefficient of the model is 98%, and the correlation coefficient between the estimated exchange rate value and the actual exchange rate value based on the model is 0.95.

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