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Study on Chinese foreign exchange reserves

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Abstract

In this paper we attempt to determine whether the Chinese foreign exchange reserves have been too large. We empirically analyzed the foreign exchange reserves first by using the rate analysis method and then using the cost-profit method. Using the rate analysis method we found that the Chinese actual foreign exchange reserves greatly exceeded the 3-month import foreign exchange demands and also that the optimal foreign exchange reserves demands were calculated to be 40% of the total foreign debt balance. Every year the Chinese foreign exchange reserves have exceeded the total amount of import foreign exchange demand as well as exceeding the foreign exchange demands for the foreign debt balance and profit returning foreign exchange demands of foreign investment enterprises. In addition we have found that only from 2000 to 2003 did the Chinese actual foreign exchange reserves exceed the optimal foreign exchange reserves calculated using the Heller model [11] from 1966. In other years they have basically been equal to or less than the optimal value for foreign exchange reserves, which indicates that there are limits to the Heller model.

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1 Introduction

1.1 The background of the article

In an open economy, the foreign exchange reserves are an important index that estimates a country's external economic relationships in terms of exports and capital inflow These reserves are the result of the operation of the macro-economy and can serve as a tool to adjust the macro-economy. The reserves influence many factors in the macro-economy. Observers can get a general view of the condition of a country's macro-economy via the foreign exchange reserves. By regulating the foreign exchange reserves, a country can achieve both internal and external economic balance and establish macroeconomic targets.

The foreign exchange reserves in China have followed a certain developmental process. Before 1992, the national foreign exchange balance plus the National Bank of China foreign exchange balance comprised the Chinese foreign exchange reserves. In 1992, China made an adjustment in the method used to estimate foreign exchange reserves. This adjustment established a new statistical standard, which set the national foreign exchange balance as the major portion of the entire foreign exchange reserves. Prior to 1994, the official exhange rate of Renminbi (RMB) to US dollars wasapproximately 4:1, but was about 8:1 on the open market. In 1994, China unified this dual RMB exchange rate, built up a single, manageable, floating exchange rate based on market demand and supply and thus ensured the stability of the Renminbi for a long time. In December 1996, the RMB became exchangeable with other foreign currencies to allow private businesses and individuals to do business abroad directly. Since that

event, the ability to manage the balance of payments has strengthened, and the amount of the foreign exchange reserves has increased.

The international reserves consist of the gold reserve, the foreign exchange reserves, and Special Drawing Rights (SDR). As far as China is concerned, foreign exchange reserves account for an overwhelming majority of the international reserves. So, models that attempt to describe international reserves are applicable to China's foreign exchange reserves.

Holding foreign exchange reserves is done to assure the international balance of payments, stabilize the domestic currency exchange rate and improve the confidence of investors. But it is also a waste of resources if the nation holds too much money in their foreign exchange reserves. A nation exports certain domestic resources abroad thus increasing the holdings in its foreign exchange reserves. This practice means that a nation gives up using foreign resources in order to increase domestic investment and to promote opportunities for domestic economic growth. Conversely, if its foreign exchange reserves are too small, that country will have difficulty intervening in foreign exchange markets and equalizing the balance of payments, thus cutting down on its ability to deal with the impact of international capital and financial risk. So, research on optimal foreign exchange reserves is important for sustained development.

A reasonable foreign exchange reserve amount should equal

(1) 3-months of import foreign exchange demands; or

(2) The foreign exchange reserve demands calculated at 40% of the total foreign debt balance;

(3) Or the foreign exchange reserves demands calculated at 10% of money plus quasi-money; or

(4) The total of import foreign exchange demands, foreign debt foreign exchange demands and profit returning demands of foreign investment enterprises; or

(5) The optimal foreign exchange reserves calculated using the Heller model [11].

This paper examines whether the Chinese foreign exchange reserve is too large. The management of foreign exchange reserves is also a main concern in the current financial field. Taking these factors into consideration, this paper analyzes some factors closely related to foreign exchange reserves, which will have a positive effect on foreign exchange reserve management.

1.2 A review of the Chinese foreign exchange reserves research literature

1.2.1 Foreign and Chinese scholars have studied foreign reserve demand both theoretically and empirically

Foreign and Chinese scholars have done extensive research on the foreign exchange reserve as shown in the following section.

1.2.1.1. Foreign scholars have studied foreign reserve demand both theoretically and empirically

Scholars outside of China have constructed a large number of foreign exchange reserve function models using ratio analysis, related factors analysis, and cost-benefit analysis.

1.2.1.1.1. *The ratio analysis method*

Ratio analysis is regarded as an empirical method and is an effective and simple way to estimate a reasonable value for international reserves.

1. The ratio of non- gold reserves to imports

Triffin [20] thought that the international reserves of a country should be kept at a certain proportion in relation to its imports. The standard ratio proposed was 40%, with 20% as the lowest limit. Generally, the ratio of international reserves for one year to imports over one year is about 25%; that is, the international reserves can satisfy the import demand for three months.

The limitations to this theory are as follows: (1) International reserves should be

calculated according to different situations in each country. Therefore this method is not universal. (2). Imports are only one of many factors which influence the international reserves. Today, the balance of payments in many countries is primarily determined by capital and financial accounts. (3). This method only considers the function by which the international reserves remedy a deficit in the balance of payments. However, as mentioned above, the international reserve has many other functions.

2. The ratio of foreign exchange reserve to foreign debt balance

The proponents of this method hold that, in theory, the international reserves are a reserve fund to liquidate foreign debt, and thus the ratio reflects this payment ability. The ratio of the foreign exchange reserve to the long-term foreign debt reflects the ability to repay the whole debt for one year using the foreign exchange reserves. Usually, the ratio is between 30%-50%. The ratio of the foreign exchange reserve to the short-term foreign debt corresponds to the capability of paying back spot debt.

1.2.1.1.2. *The factor analysis method*

The factor analysis method is a method for considering and embodying multiple factors in the decision concerning the amount of international reserves. Multifactors, such as imports, foreign debt and direct investment income refund, that influence a country's reserve demand are processed using regression analysis and correlativity analysis, in order to set up the reserve demand function. Scholars from outside of China have formed three famous models for developing countries.

1. The *Flanders model*[2]

In 1971, Flanders constructed a model for studying the demand for reserves in

[2] M.J. Flanders, The Demand for International Reserves, Princeton Studies in International Finance, No. 27. Princeton: International Finance Section, 1971.

developing countries. In order to construct the reserve demand function, he considered that the ratio of international reserves to imports is related to ten parameters because some of the information for the parameters is hard to collect, the model had to be accepted or rejected based on only some of the parameters. His model established a relationship between reserve demand and multi-factors.

2. The *Frenkel model*

Frenkel [8] set up a demand model for reserves. He made a comparison between developed countries and developing countries for the purpose of examining the different structures of the two categories of nations with respect to their international reserves. He concluded that the various factors that influence the demand function are basically the same for both categories of nations and formulated a demand model for developing countries. The result indicated that the flexibility of developing countries with regard to the international reserve demand to trade volume ratio was higher than for developed countries. Also the response to the balance of payments was smaller than for the developed countries.

3. The *Iyoha model*

Iyoha [13] built up a reserve demand model for developing countries. By estimating a coefficient, the model predicted that there is a positive correlation between the reserve demand of developing countries and 1) the expected fluctuation in export income and import income, 2) the interest rate from holding foreign exchange property and 3) the degree of economic openness of a country. The result was satisfying; so it could be used to evaluate a developing country's reserve demand function.

The factor analysis method considers more factors that influence the international reserve demand than the ratio method and gives a more accurate estimate. But, this kind of method also has many limitations. For example, first, when using known data to conduct regression and correlation analyses, the assumption is that the previous data used are all reasonable and that the reserves that a developing country holds meets an appropriate reserve demand. This assumption is very

difficult to support, because the amount of actual reserves that a country holds is a supply amount, not a demand amount. Second, the establishment of the reserve demands function is mainly dependant on experiential data. Its theoretical foundation seems to be very weak. Moreover, because the economy is constantly changing, all of the variables influence each other. Hence for a reserve demand function that includes dozens of interpretative variables; multi-linear relationships would result, which would therefore affect the regression analysis. If a multi-linear relationship is simply avoided the reserve demand function does not include sufficient objective variables, so that the function is not comprehensive enough.

1.2.1.1.3. *The cost-benefit analysis method*

Heller [11] added a cost/benefit method into the demand analysis for international reserves. This method demonstrated that holding the reserves results in an opportunity cost. It means that investment income is lost while holding the reserves. When the marginal cost is equal to the marginal income gained while holding the reserves, the international reserves are at an optimal level. There are two famous models.

1. The *Heller model*.

Heller [11] was the first to use this method to analyze international reserves. Heller [11] set up an international reserves demand model. His model measured the opportunity cost of holding liquid international reserves as the differential between the social rate of return on capital and the return on the liquid international reserves held.

2. The *Agarwal model*.

Overcoming some shortcomings of the Heller [11] model and considering differences in system and structure between developing countries and developed countries, Agarwal built the his model in the Optimal currency reserve in the developing country. The J. Agarwal model established a standard for an optimal

reserve. From one perspective, the optimal reserve should assure investors that enough capital is available when the country faces a balance of payments deficit. In addition, when the cost is equal to the income gained from holding the reserve, the reserve is at its optimal size. Agarwal assumed that the domestic product, which can be produced by inputs from imported goods, measures the opportunity cost of holding the reserve. The benefit of holding the reserves is avoidance of unnecessary adjustment costs when a country experiences an accidental balance of payments deficit.

The Heller [11] model measured the opportunity cost of holding liquid international reserves as the differential between the social rate of return on capital and the return on the liquid international reserves held. Because assessing the social rate of return on capital is difficult, Agarwahl's choice to use the opportunity cost of holding liquid international reserves is subjective. Though the Agarwal model adjusted the H. R. Heller [11] model for developing countries, the Agarwal model did not resolve all the problems in the Heller model. The Agarwal model neglected several problems. For instance, governmental policy could substitute for the reserves as a method for adjusting the balance of payments; the government could choose more than one regulatory policy; developing countries could accumulate finances in the international financial market and liquid capital could influence the demand and balance of payments. Thus, there are some problems with respect to the income of the reserve.

3. Other corrections to the Heller [11] model

Clark [4] expanded the Heller model and made a stochastic model. Hamada and Ueda [10] modified the Heller model with the probability of reserve depletion.

Frenkel and Jovanovic [7] improved the Heller model and made the balance of payments to be variable in the reserve demand equation. Lizondo and Mathieson [17] incorporated the rate of change of the net reserve position into the reserve function using an optimal method.

1.2.1.1.4. *Recent developments in Demand theories for international reserves*

After the 1980's, Chinese academicians joined other researchers from around the world in beginning to study the international reserve model by applying the dynamic adjustment model, and by considering the dissimilarity between the foreign exchange reserve demand and economic variables, as well as the dynamic status of the actual volume of foreign exchange reserve holdings. Bahmani-Oskooee [2] found by using cross-section and cross-time comparative studies of developed countries and less developed countries that developed countries adjust international reserves faster than less developed countries. For both groups of countries, the pace of adjusting international reserves increase after they moved to a floating-exchange rate, compared with the pace under a fixed-exchange rate. Edwards [5] studied the problem of the dynamic adjustment of foreign exchange reserves. His research centered on the international reserve of less developed countries under a fixed-exchange rate institution from 1965-1972, and found that the reason why international reserves of less developed countries' central banks gradually dropped could be ascribed to the inadequacy of the domestic currency demand and the other is that this dynamic model requires that the economic variables satisfy a demand for smoothness. If a unit root exists for economic variables, the possibility exists that the dynamic regressive relationship finally produced according to the unit root variables is a "false regression". Engle and Granger [6] invented co-integration econometric theory, which is a theory from modern econometrics. It proposes a more scientific method for the development of foreign exchange reserves, and a number of academicians have applied it to analyze the foreign exchange reserve problem. Huang [12] conducted in-depth and systematic studies on the Chinese international reserves. He collected relevant economic data from 1980 to 1990, and drew conclusions by establishing an error correction model and co-integration of econometric technology. Bird and Rajan [3] think that crisis countries should seek to replenish and build up their international reserves in the post-crisis period.

1.2.1.2. Chinese scholars' study of the Chinese foreign exchange reserve based on theories and on positive evidence

Liu and Ren [16], making use of the co-integration econometric analytical method, concluded that increases in the degree of openness in the economy, enlargement of the foreign debt, increases in foreign investment, and increased economic development would all contribute to an increase in foreign exchange reserves. On the other hand, improvements in the terms of trade，strengthening of the ability to obtain capital funds from outside of China, and increases in the opportunity costs will all lead to a decrease in the optimal reserve. By making use of this model, they were able to estimate whether the reserves were too large in each period. Xu and Tang [22] analyzed equilibrium and disequilibrium of foreign exchange market and foreign reserve under fixed system and managed floating system in China. Xu [23] deduced that an imbalance in the currency market seriously impacts the variation in the foreign exchange reserves through the co-integration test method. This means that if the supply of either the currency in circulation or money and quasi-money is excessive, the foreign exchange reserves should be adjusted to reduce the supply, whereas if the demand is excessive, the foreign exchange reserves should be adjusted to enlarge the supply. This viewpoint is consistent with the view of the Monetarists with respect to foreign exchange reserves, and it also reflects a macro adjusting and management functioning mechanism for the Chinese foreign exchange reserves. According to Xu [23], the amount of currency in circulation imposes a more notable impact on the foreign exchange reserve in the short-term than does money and quasi-money. In addition, he also found that a long-term equilibrium relationship between the average propensity to import and the demand for foreign exchange reserves does not exist, yet the variation of a short-term average propensity to import exerts comparatively notable negative impacts on foreign exchange reserves. The reason is that under the current foreign exchange supervision system, an increase in imports means that a country would have to sell more foreign exchange, which

would result in a decrease in the volume of foreign exchange reserves that are held.

Wu [21] combined the ratio analysis method and the factor analysis method to study the determinants for reasonable Chinese foreign exchange reserves. He assumed that the Chinese demand foreign exchange reserve consists of four aspects: foreign exchange demanded for imports, foreign exchange demanded for repaying the total foreign debt balance, exchange demanded for profit return from foreign direct investment and foreign exchange reserves demand for the country's intervention in the foreign exchange currency market. He also established a linear equation model. The purpose of his paper was to determine optimal foreign exchange reserves for China, so he did not determine the equation's parameters with time-serial data or test the equation.

Yu [24] found Chinese foreign exchange reserves are higher than optimal foreign exchange reserves.

1.2.2 Reasons for continuous growth of Chinese foreign exchange reserves

Chinese scholars have analyzed the economic reasons that have caused continuous growth in foreign exchange reserves. These are as follows:

1.2.2.1 Every time there is a surplus in capital items the surplus becomes one of the main factors causing continuous growth of foreign exchange reserves

Guan (2001) [9] believes that since 1993 a capital items' surplus has been the main reason for the continuous growth of Chinese foreign exchange reserves. Its main channels are foreign direct investment (FDI) and foreign debt, and large amounts of reserves coming from debt, which means that the source structure of Chinese foreign exchange reserves is unstable.

Ba [1] believes that the condition of capital and financial accounts will become a key factor influencing the balance of payments (BOP) and foreign exchange reserves. Because of restrictions in the present system, the FDI cannot grow very much, and the main reason for capital flow at present is transnational

acquisitions. As far as present transnational acquisitions are concerned, they are mainly in such areas as financial insurance, communication, the chemical industry, the auto industry, etc., which are not available for acquisition in China. However, it is certain that FDI is still one of the main capital inflow sources, and also the main source of surplus in capital and financial accounts. Li [15] believes that FDI is growing rapidly. Since the 1990s, as a result of the promotion of economic globalization, developed countries have rapidly transferred their industries to developing countries. Moreover, open investment areas and fields in China are continuously expanding. The rapid growth of the economy and improvements in the economic structure and investment environment have increased foreign investors' confidence, which has promoted the rapid growth of the FDI in China. Large amounts of FDI inflows into China, but there are no well-established channels for China's own overseas investment. Recently, the growth rate of Chinese outside investment has slowed down considerably.

Ramachandran [19] finds the asymmetric control over capital flows and asymmetric intervention in favour of strengthening export competitiveness in an era of per-sistent capital inflows seem to be responsible for large stockpile of reserves in India.

1.2.2.2 *Each item in the current account causes continuous growth in Chinese foreign exchange reserves*

Guan [9] states that the direct reason for the growth of Chinese foreign exchange reserves is the long-term deposition of the flow of export income. A surplus of current items will actively influence foreign exchange reserves accumulation. A fundamental reason for the growth of Chinese foreign exchange reserves is the result of a surplus in the current account and capital account.

Li [15] states that (1) the competitive advantage of Chinese foreign trade has been enhanced. Finished Chinese industrial products have gradually become increasingly competitive. China is comparatively strongly competitive in

labor-intensive products and low-technology products. At the same time, some technology-intensive products in China have changed from comparatively inferior positions to comparatively superior positions. (2) With the development of foreign business in China, leading companies follow the concept “More export, less import”, in pursuing a trade surplus.

1.2.2.3 *Macro trade policy is the main factor that influences foreign exchange reserves*

Guan [9] stated that the reason why Chinese foreign exchange reserves have increased is due to the China’s specific policy of buying and selling on foreign exchanges.

First, macroscopic economic policy has influenced foreign exchange reserves. In 1994, a single exchange rate was implemented in China, and the devalued Renminbi improved exports.

Secondly, according to the People’s Republic of China foreign exchange management regulations, enterprises did not have the freedom to buy or sell foreign currencies. In addition, Guan [9] also thought that the Chinese National Central Bank held foreign exchange reserves to cover almost all of the domestic foreign currencies. Thus the meaning of foreign exchange reserve in China differed from that in developed countries.

Ba [1] stated that policy factors are the main factors that influence the international payment situation. In 1999, the government increased the number of enterprises exempt from export tax. This significantly increased the financial benefit to these foreign trade enterprises and raised their ability to compete with their rivals, thus increasing the amount of exports.

The subsequent contents of this paper are arranged as follows. Section 2 is an empirical analysis of China’s foreign exchange reserves. Section 2.1 focuses on the ratio analysis method. This method uses the ratios of foreign exchange reserves compared to annual imports, to the short term foreign debt balance; and

to the total foreign debt balance. We analyze the profit-returning foreign exchange demands of foreign investment enterprises year-by-year, the rate of foreign exchange reserves to money and quasi-money supply, and an optimal foreign exchange reserves demand using multiple factors. In Section 2.2 we compute and simulate the optimal foreign exchange reserves using the Heller [11] model based on the cost-profit method. In Section 3 we draw a conclusion.

Adnan Kasman and Duygu Ayhan [14] find that exchange rate Granger cause foreign exchange reserves in the long-run nominal.

Victor Pontines and Ramkishen S. Rajan [18] find that Asian central banks react more strongly to currency appreciations than depreciations and more to nominal effective exchange rates (NEERs) than to bilateral US dollar rates. This rationalizes the relative exchange rate stability and the sustained reserve accumulation in the region.

2 Models and positive analysis

2.1. Positive analysis based on ratio analysis

There are three main sources of foreign exchange reserves: an international trade surplus, a foreign debt balance and a foreign direct investment balance. In addition, with regard to evaluating a reasonable amount of foreign exchange reserves internationally, there are many prevalent ratios and indicators, each of which reflects different aspects of the demand for foreign exchange reserves.

2.1.1. The ratio of foreign exchange reserves to imports

As pointed out by American economist Robert Triffin [20], foreign exchange reserves are proportional to imports. When the two are connected, the demand for reserves increases in accordance with an increase in imports; hence the level of demand for the reserves of a country can be determined by the ratio between its

foreign exchange reserves and imports. Generally the optimal proportion between the two is 40%. When it falls below 30% certain regulatory steps should be taken, and it should not be less than 20%. According to Triffin [20], the ratio between all-year reserves and imports is about 25%. That is, the optimal reserves should meet the demand for imports for 3 months.

Table 1: Ratio of foreign exchange reserves to imports

YEAR	M##	AFR#	AFR/M	OFR1*	AFR/ OFR1
1995	1320.8	735.97	55.72%	330.2	222.89%
1996	1388.3	1050.29	75.65%	347.075	302.61%
1997	1423.7	1398.90	98.26%	355.925	393.03%
1998	1401.7	1449.60	103.42%	350.425	413.67%
1999	1657.0	1546.75	93.35%	414.25	373.39%
2000	2250.9	1655.74	73.56%	562.725	294.24%
2001	2435.5	2121.65	87.11%	608.875	348.45%
2002	2951.7	2864.07	97.03%	737.925	388.12%
2003	4127.6	4032.51	97.70%	1031.9	390.79%
2004	5613.8	6099.32	108.65%	1403.45	434.59%
2005	6601.2	8188.72	124.05%	1650.3	496.20%

: M indicates total imports every year, unit: 0.1 billion USD

: AFR indicates actual foreign exchange reserves every year, unit: 0.1 billion USD

* : OFR1 indicates optimal foreign exchange reserves calculated by 25% of one year's imports sum; the unit: 0.1 billion USD

Data source : (1) database http://www.bjinfobank.com;
(2) database http://www.pbc.gov.cn/diaochatongji/tongjishuju
(3) database http://gcs.mofcom.gov.cn/

Moreover, when the World Bank analyzes the foreign exchange reserves in developing countries, they also use the sum of imports in 3 months results as an optimal amount of foreign exchange reserve. The data are shown in Table 1. From the data in Table 1, since 1995, the ratio of China's foreign exchange reserves to its imports in most years has been higher than 25%, and in some years the ratios show that the reserves are even higher than the imports. The ratio between the actual foreign exchange reserves and the optimal foreign reserves, which is equal to the imports for three months, ranged from about 222% to nearly 500%.

Of course, despite the fact that this ratio is highly adaptive in operation, foreign exchange reserves cannot be measured accurately by taking this theory alone into consideration. In fact, later some researchers provided various amendments and supplements to the theory, suggesting that benefits from exports also influence the demand for reserves, and that reserves are used to offset a balance-of-payments deficit rather than pay for the imports. Therefore the ratio of reserves to the foreign debt balance may also provide a measure for reasonable and optimal reserves. Moreover, the ratio only highlights the reserves demand for international trade, and neglects the influence on reserves from capital and foreign debt.

2.1.2. The ratio of reserves to short-term foreign debt balance

The ratio of reserves to the short-term foreign debt balance is an important ratio measuring a country's capability of refunding debt quickly. Internationally the ratio of reserves to short-term foreign debt balance is generally used to inspect precautionary demand, and it is also an important guarantee for a country, which is financing debt from overseas. The international alert standard is 1, which means 100%. The ratio usually should not fall below 100%, which can guarantee that all the short-term foreign debt can be entirely repaid in a short time. The foreign debt balance can be promptly repaid by holding reserves quantitatively equivalent to the short-term foreign debt balance. Recent research has showned that the ratios in

many countries were rather low before the financial crises in Mexico and Asia broke out. The low ratios caused many foreign debt creditors to lose confidence and eventually led to a financial crisis. From the data in Table 2, we find that since 1995 the AFR/SD ratio in China was much higher than 100% which is favorable for China's borrowing from other countries as well as boosting its foreign creditor's confidence.

Table 2: The ratio of reserves to foreign debt balance every year

YEAR	SD+	D++	AFR#	AFR/SD	AFR/D	OFR2**	AFR/OFR2
1995	119.1	1065.9	735.97	617.94%	69.05%	426.36	172.62%
1996	141.1	1162.8	1050.29	744.36%	90.32%	465.12	225.81%
1997	181.4	1309.6	1398.90	771.17%	106.82%	523.84	267.05%
1998	173.4	1460.4	1449.60	835.99%	99.26%	584.16	248.15%
1999	151.8	1518.3	1546.75	1018.94%	101.87%	607.32	254.68%
2000	130.8	1457.3	1655.74	1265.86%	113.62%	582.92	284.04%
2001	505.8	1701.1	2121.65	419.46%	124.72%	680.44	311.81%
2002	558.0	1713.6	2864.07	513.27%	167.14%	685.44	417.84%
2003	770.4	1936.3	4032.51	523.43%	208.26%	774.52	520.65%
2004	1043.1	2286.0	6099.32	584.73%	266.81%	914.4	667.03%

+：SD indicates short-term foreign debt every year, unit: 0.1 billion USD

++：D indicates the total foreign debt balance every year unit: 0.1 billion USD

#： AFR indicates the actual foreign exchange reserves every year, unit: 0.1 billion USD

**：OFR2 indicates the optimal foreign exchange reserves (calculated by 40% of the total foreign debt balance), unit: 0.1 billion USD

Data source：（1）database http://www.safe.gov.cn/Statistics/

（2）database http://gcs.mofcom.gov.cn/aarticle/Nocategory/

2.1.3. The ratio of foreign exchange reserves to the total foreign debt balance

The ratio of foreign exchange reserves to total foreign debt balance reflects a country's ability to repay its total foreign debt balance with foreign exchange reserves. A reasonable value for this ratio is between 30%-50%, and usually a value of 40% is used to indicate optimal reserves.

From Table 2, the AFR/OFR2 ratio between the actual foreign exchange reserves and optimal foreign reserves ranged from 170% to 670%. This value corresponds to 40% of the total foreign debt balance. If the long-term foreign debt balances consitutes a comparatively greater proportion to the total foreign debt, then the AFR/OFR2 ratio can be smaller and vice versa. Because China's long-term and mid-term foreign debt balance is greater than 50%, the ratio can be smaller. However, since China is a developing country, it is eager to develop its use of foreign investment and foreign debt. The bigger ratio provides favorable conditions for the country to make use of foreign capital and acquire loans from overseas in order to develop the economy. This large ratio also promotes the country's foreign creditors confidence. China's total foreign debt balance is increasing year by year, thus the considerable amount of foreign exchange reserve is another reason for the increase in total foreign debt balance. China possesses a large amount of foreign exchange reserves. However, this fact does not describe the repaying ability of every single company. So this indicator is limited and it can only provide some reference to the repaying ability of the national government.

2.1.4. Foreign exchange reserves demand for profit return

In order to attract foreign capital, all national governments constitute laws to protect a foreign investor's profit and ensure that the principal of the funds can be successfully returned when the operation is over. The amount of return is determined by the level of economic development with respect to a country's capital inflows, as well as the profits and investment policy. Currently in China,

the returned portion of the profit usually is 10%, to 15%[3] of the foreign direct investment balance every year. Hence every year China has to hold certain foreign exchange reserves to handle the returned profit. In Table 3, OFR3 represents the demand for foreign exchange from returned profits calculated as 15% of the foreign direct investment balance in one year (the unit: 0.1 billion USD).

Table 3: Returned profit (OFR3) every year

YEAR	AFR#	FDI##	OFR3***
1995	735.97	375.2	56.28
1996	1050.29	417.3	62.595
1997	1398.90	452.6	67.89
1998	1449.60	454.6	68.19
1999	1546.75	403.2	60.48
2000	1655.74	407.2	61.08
2001	2121.65	468.8	70.32
2002	2864.07	527.4	79.11
2003	4032.51	535.05	80.258
2004	6099.32	610	91.5
2005	8188.72	603	90.45

#: AFR indicates actual foreign exchange reserves every year, unit: 0.1 Billion USD
: FDI indicates the amount of foreign direct investment every year, unit: 0.1 Billion USD
***: OFR3 represents the demand for foreign exchange from returned profits calculated with 15% of the foreign direct investment balance for one year. unit: 0.1 Billion USD

Data source: database http://gcs.mofcom.gov.cn/aarticle/

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2.1.5. The ratio of foreign exchange reserves to Money & Quasi-money

The ratio of foreign exchange reserves to money and quasi-money is used as a financial crisis precaution indicator. Since M2 indicates the liquidity of purchasing foreign assets for domestic institutions and individuals, it implies the potential risk of asset transfer of domestic enterprises and individuals. When the public's confidence in their own country's currency drops, much capital will flow abroad. In order to prevent an excessive decrease in foreign exchange reserves when the capital flows abroad, according to the "currency supply determinism" raised by Johnson and other economists[4], the optimal foreign reserves should be quantitatively equal to M2, i.e. R/M2 is 100%. However, considering that the marginal cost of foreign exchange reserves increases consecutively, the optimal reserve does not need to reach the supply amount of currency. In general, for countries maintaining a pegged exchange rate institution and a fixed exchange rate system, a ratio controlled within 10%-20% is appropriate; while for countries maintaining a floating exchange rate system, a ratio controlled within 5%-10% is satisfactory. Nevertheless, for countries whose economic status is good, whose politics are steady and whose finance environment is solid, the possibility of capital transfer is very small, so the ratio can be correspondingly lower.[5]

In Table 4, the ratios of foreign exchange reserves to money and quasi-money in China are all above 10%. Currently China maintains a semi-pegged-exchange rate system but intends to stop the pegged-exchange rate policy. Therefore the ratio in China falls in a reasonable range, and China has a great capability to repay and thus has a good international reputation.

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[5] Zhao Qingming &Xiao Lan, The study on the China foreign exchange reserve, The Finance on the South, (in Chinese),2005,12

Table 4: The ratio of foreign exchange reserves to Money & Quasi-money（M2）

YEAR	E[Ξ]	AFR[#]	M2[Π]	M2[ΠΠ]	AFR/M2	OFR4[****]	AFR/OFR4
1995	8.3510	735.97	60750.5	7274.637768	10.12%	727.4638	101.17%
1996	8.3142	1050.29	76094.9	9152.401915	11.48%	915.2402	114.76%
1997	8.2898	1398.90	90995.3	10976.77869	12.74%	1097.678	127.44%
1998	8.2791	1449.60	104498.5	12621.96374	11.48%	1262.196	114.85%
1999	8.2783	1546.75	119897.9	14483.39635	10.68%	1448.34	106.79%
2000	8.2784	1655.74	134610.4	16260.4368	10.18%	1626.044	101.83%
2001	8.2770	2121.65	158301.9	19125.51649	11.09%	1912.552	110.93%
2002	8.2770	2864.07	185007.0	22351.93911	12.81%	2235.194	128.14%
2003	8.2770	4032.51	221222.8	26727.41331	15.09%	2672.741	150.88%
2004	8.2765	6099.32	253207.70	30593.57216	19.94%	3059.357	199.37%
2005	8.0759	8188.72	298755.48	36993.45955	22.14%	3699.346	221.36%

Ξ：E indicates exchange rate, RMB/ 1USD

#: AFR indicates actual foreign exchange reserves every year, unit: 0.1 Billion USD

Π：M2 indicates Money & Quasi-money every year, unit: 0.1 Billion RMB

ΠΠ：M2 indicates Money & Quasi-money every year, unit: 0.1 Billion USD

****: OFR4 indicates the demand for foreign exchange calculated based on 10% of the Money & Quasi-money for one year, unit: 0.1 Billion USD

Data source：database http://www.stats.gov.cn/

2.1.6. Multi-factor ratio analysis approach

Internationally there are many prevailing ratios and indicators, each of which reflects demands for foreign exchange reserves from various aspects. However, using them separately may be limited for optimal foreign exchange reserves, so all the ratios and indicators should be taken into account.

The optimal demand for foreign exchange reserves, calculated according to the ratio of foreign exchange reserves to money and quasi-money in China, is almost completely linearly related to the foreign exchange demand for imports, the foreign exchange reserves required for paying off foreign debt, and the foreign

exchange reserves required for returning profits. So when calculating the optimal foreign exchange reserves with the multi-factor ratio analysis approach, the ratio of foreign exchange reserves to money and quasi-money does not need to be taken into account. We consider that the function of money and quasi-money is to maintain the stability of the exchange rate. The function of the foreign exchange demand for imports, foreign exchange reserves demand for paying off foreign debt, and foreign exchange reserves demand for profit returning of foreign-invested enterprises will meet the demand for maintaining the stability of the exchange rate, hence the multi-factor ratio analysis approach analyzes the optimal foreign exchange reserves based on the foreign exchange demand for imports, foreign exchange reserves demand for paying off foreign debt, and foreign exchange reserves demand for returning profit to foreign-invested enterprises. Using all of the above factors, we can formulate a defining model for reasonable and optimal foreign exchange reserves.

$OFR = FR = \alpha 1 \times M + \alpha 2 \times D + \alpha 3 \times FDI$ In the equation

OFR—optimal foreign exchange reserves

FR—basic demand for foreign exchange reserves

M—import total every year;

FDI—the amount of foreign direct investment every year

D—the total foreign debt balance every year;

α1— the ratio of foreign exchange demand for maintaining imports to the annual total of imports;

α2—the ratio of foreign exchange demand for repaying debts to the total foreign debt balance;

α3—the ratio of profits returned to the volume of the foreign enterprise's investment capital;

α1×M —foreign exchange required for imports;

α2×D—foreign exchange required for repaying total foreign debts balance;

α3×FDI—exchange demanded for profits returned to foreign direct investment

From Table 5, we can conclude that considering the three aspects of the foreign exchange required for imports, the foreign exchange reserves needed for paying off foreign debt, and the foreign exchange reserves required for returning profits, the actual foreign exchange reserves exceeded the optimal foreign exchange reserves by 20%-370%. The reason is as follows. First, Chinese leaders encourage exports and make exports a goal. Second, the undervaluation of the RMB causes an increase in exports and capital flowing into China. Third, foreign direct investment has increased, and the quantity of exports is larger for foreign investing companies.

Table 5: foreign exchange reserves calculated by multi-factor ratio analysis

YEAR	OFR1*	OFR2**	OFR2***	OFR$^{\Lambda}$	AFR#	AFR/OFR
1996	347.075	465.12	62.595	874.79	1050.3	120%
1997	355.925	523.84	67.89	947.655	1398.9	148%
1998	350.425	584.16	68.19	1002.775	1449.6	145%
1999	414.25	607.32	60.48	1082.05	1546.8	143%
2000	562.725	582.92	61.08	1206.725	1655.7	137%
2001	608.875	680.44	70.32	1359.635	2121.7	156%
2002	737.925	685.44	79.11	1502.475	2864.1	191%
2003	1031.9	774.52	80.258	1886.678	4032.5	214%
2004	1403.45	914.4	91.5	2409.35	6099.32	253%
2005	1650.3	1000¤	90.45	1740.75	8188.72	470%

* : OFR1 indicates optimal foreign exchange reserves calculated by 25% of one year's imports sum, unit: 0.1 billion USD

** : OFR2 indicates optimal foreign exchange reserves calculated by 40% of the total foreign debt balance, unit: 0.1 billion USD

*** : OFR3 indicates exchange demanded for profits return calculated by FDI balance for one year, unit: 0.1 billion USD

Λ : OFR=OFR1+OFR2+OFR3

: AFR indicates actual foreign exchange reserves every year, unit: 0.1 billion USD

¤: 1000 is estimated by last years

2.2 Empirical studies based on the cost-benefit analysis approach

Heller [11] first analyzed demand for international reserves using a cost-benefit analysis approach. We can calculate the optimal foreign exchange reserves of China using his approach:

$$TCa = B/m \quad (1)$$

$$TCf = r \times R \quad (2)$$

TCa is the total cost of adjustment of the international reserves, and is also the income from international reserves.

△ B is the amount of international payments imbalance.

m is the propensity to import.

TCf is the opportunity cost of holding liquid international reserves.

r is the differential between the social rate of return on capital and the return on the reserves.

R is the quantity of liquid international reserves held.

The marginal income and marginal cost of international reserves , Mca and MCf

$$MCa = 1/m \quad (3)$$

$$MCf = r \quad (4)$$

Heller [11] assumed that an adjustment in policy would not take place until a certain sum of international deficit exceeds the international reserves' adjustment capability. He defined πi as the probability that a country will have to use adjusting as a means of providing for the external balance. Then he obtained：

$$MCf = r = \pi i \times (1/m) = MCa \quad (5)$$

As r and m are known variables, he worked out:

$$\pi i = r \times m \quad (6)$$

Heller [11] suggested the following: The variation in a country's reserves is a random process, yet every time the change of the international reserves is h. He

assumed that a structural international payment imbalance does not exist; that is, a country has achieved a reasonable reserve level. h is the average absolute change in international reserves. Suppose that the odds of surplus and deficit are the same and both are equal to 1/2. If a country faces continuous deficits, the odds of exhausting the reserves so as to avoid a policy adjustment are:

$$\Pr(\mathrm{Ri}) = (0.5)^{i} \quad (\text{when } h = 1) \qquad (7)$$

The probability of running out of reserves and the probability of having to adjust are identical. Combining equations (6) and (7), he obtained:

$$r \times m = \pi i = \Pr(\mathrm{Ri}) = (0.5)^{i} \quad (\text{when } h = 1) \qquad (8)$$

$$i = \frac{\log(r \times m)}{\log 0.5} \qquad (9)$$

when h does not equal 1,

$$\mathrm{Ropt} = h\frac{\log(r \times m)}{\log 0.5} \qquad (10)$$

Ropt indicates optimal foreign exchange reserves

m is the propensity to import

h is the average absolute change in international reserves

m is the proportion of imports relative to the GDP

r is the differential between the social rate of return on capital and the return on the reserves

r=yt-yr

yt: the social rate of return on capital

yr: the return on the reserves

Table 6: Calculations of China's optimal foreign exchange reserves using Heller's (1966) [11] method

YEAR	M##	GDPΣ	GDPΣΣ	m%	AFR#	h*
1996	1388.3	67884.6	8164.899	0.1700	1050.29	213.965
1997	1423.7	74462.6	8982.436	0.1585	1398.90	296.7275
1998	1401.7	78345.2	9463.009	0.1481	1449.60	233.35
1999	1657.0	82067.5	9913.569	0.1671	1546.75	202.695
2000	2250.9	89468.1	10807.41	0.2083	1655.74	151.3625
2001	2435.5	97314.8	11757.26	0.2071	2121.65	180.6875
2002	2951.7	105172.3	12706.57	0.2323	2864.07	353.6175
2003	4127.6	117251.9	14165.99	0.2914	4032.51	621.44
2004	5613.8	136515	16494.29	0.3403	6099.32	1110.895
2005	6601.2	182321	22575.94	0.2924	8188.72	1516.768
YEAR	ytΦ	YrΦΦ	r	Ropt**	AFR/Ropt	
1996	3.05%	2.59%	0.46%	2208.5	47.5%	
1997	3.17%	3.29%	-0.12%	NA	NA	
1998	2.35%	3.50%	-1.15%	NA	NA	
1999	3.42%	2.89%	0.53%	2055.6	75%	
2000	5.56%	2.73%	2.83%	1121.1	148%	
2001	5.35%	0.66%	4.69%	1208.23	176%	
2002	5.62%	0.41%	5.21%	2252.2	127%	
2003	6.25%	-1.03%	7.28%	3454.8	117%	
2004	6.5%	-0.79%	7.29%	5925.1	103%	
2005	10.0%	0.23%	9.77%	7781.0	105%	

##：M indicates annual imports volume, unit: 0.1billion USD

Σ：GDP indicates China's gross domestic product, unit: 0.1 billion RMB

ΣΣ：GDP is indicates China's gross domestic product, unit: 0.1 billion USD

Ж: m indicates the propensity to import

: AFR indicates actual foreign exchange reserves every year, unit: 0.1billion USD

* : h can be calculated using a moving average method, e.g., the value for 1996 equals the average value of the foreign exchange reserves alteration sum (0.1 billion USD) within the former 4 years; that is from 1992 to 1995, the values of h in other years can be deduced in the same way. The prediction for optimal reserves in 1963 in Heller [11] was 1 year, so the value of h was not calculated using the moving average method in [11].

Φ：yt is the social rate of return on capital, which can be substituted by the industrial cost profit rate of all state owned and big non-state owned industrial enterprises in China. As there is no data yet for 2005, the authors picked a typical industry for determining this value and got 10% as the value of yt; readers who need the detailed calculating process can contact the authors.

ΦΦ：yr indicates the return on the reserves; we can use the 1-year-term interest rate of American bond minus the inflation rate in America every year

** : Ropt indicates optimal reserves calculated by cost-benefit analysis approach

NA: indicates that it cannot be worked out by calculation

Data source：

(1) data of American bond 1-year-term interest rate
http://www.federalreserve.gov/releases/h15/data/Annual_Dec_/H15_TCMNOM_Y1.txt
(2) inflation data
http://inflationdata.com/Inflation/Inflation_Rate/HistoricalInflation.aspx
Industrial cost profit rate of all State Owned and sweeping Non-State Owned Industrial Enterprises.
http://202.112.71.17/index/showdoc.asp?filename=200505193144&blockcode=dbjjnj_gyxy

In Table 6 China's optimal foreign exchange reserves is calculated using the Heller [11] method. The social rate of return on capital is calculated using the industrial cost profit rate for all state owned and large non-state owned industrial enterprises. The return on the reserves is the differential between the 1-year interest rate for America's national debt and the inflation rate every year. By examining the data in Table 6 it can be seen that the ratio of China's actual foreign exchange reserves to the optimal foreign exchange reserves for the period from 2000 to 2005 is larger than 1, which indicates that China's actual foreign exchange reserves were excessive in this period by a range varying from about 3% to 76%.

Table 7: Calculation of the social rate of return on capital and the different return on the reserves

YEAR	yt (5)▲	yt (3)▲▲	yrΦΦ	r5▼	r3▼▼	r5▼◆
1996	13.06%	11.59%	2.59%	10.47%	9.00%	10.97%
1997	10.17%	9.18%	3.29%	6.88%	5.89%	7.38%
1998	7.5%	6.69%	3.50%	4.00%	3.19%	4.50%
1999	3.78%	3.51%	2.89%	0.89%	0.62%	1.39%
2000	3.14%	2.89%	2.73%	0.41%	0.16%	0.91%
2001	3.14%	2.89%	0.66%	2.48%	2.23%	2.98%
2002	2.47%	2.21%	0.41%	2.06%	1.80%	2.56%
2003	2.63%	2.32%	-1.03%	3.66%	3.35%	4.16%
2004	3.09%	2.74%	-0.79%	3.88%	3.53%	4.38%
2005	3.73%	3.32%	0.23%	3.50%	3.09%	4.00%
YEAR	r3▼▼◆	r5▼◆◆	r3▼▼◆◆	r5▼◆◆◆	r3▼▼◆◆◆	
1996	9.50%	11.47%	10.00%	11.97%	10.50%	
1997	6.39%	7.88%	6.89%	8.38%	7.39%	
1998	3.69%	5.00%	4.19%	5.50%	4.69%	
1999	1.12%	1.89%	1.62%	2.39%	2.12%	
2000	0.66%	1.41%	1.16%	1.91%	1.66%	
2001	2.73%	3.48%	3.23%	3.98%	3.73%	
2002	2.30%	3.06%	2.80%	3.56%	3.30%	
2003	3.85%	4.66%	4.35%	5.16%	4.85%	
2004	4.03%	4.88%	4.53%	5.38%	5.03%	
2005	3.59%	4.50%	4.09%	5.00%	4.59%	

▲ : yt (5) indicates the 5-year interest rate of China's national debt

▲▲ : yt (3) indicates the 3-year interest rate of China's national debt

ΦΦ : yr indicates the return on the reserves that is the differential between the 1-year interest rate of America's national debt and the inflation rate in America every year

▼ : r5=yt (5)-yr

▼ ▼ : r3=yt(3)-yr

▼ ◆ : r5=yt(5)-(yr -0.5%) , 0.5% indicates the assumed cost of management for foreign exchange reserves

▼ ▼ ◆ : r3=yt(3)-(yr -0.5%), 0.5% indicates the assumed cost of management for foreign exchange reserves

▼ ◆ ◆ : r5=yt (5) -(yr -1%), 1% indicates the assumed cost of management for foreign exchange reserves

▼ ▼ ◆ ◆ : r3=yt (3) -(yr-1%), 1% indicates the assumed cost of management for foreign exchange reserves

▼ ◆ ◆ ◆ : r5=yt (5) - (yr –1.5%), 1.5% indicates the assumed cost of management for foreign exchange reserves

▼ ▼ ◆ ◆ ◆ : r3=yt (3) -(yr-1.5%), 1.5% indicates the assumed cost of management for foreign exchange reserves

NA：Indicates that it cannot be worked out by calculation

It can be seen from Table 7 that China's national debt's interest rate, yt, decreased from 1996 to 1998, but the 1996 figures are obviously larger than those for later years. In 2002 China's national debt interest rate reached its lowest point, and the figure has gone up slightly since then.

It can be seen from Tables 8, 9 and 10 that for a management cost of 0.5%, 1%, or 1.5% and when the 5-year and 3-year Chinese national debt interest rates are taken as the social rate of return on capital, China's actual foreign exchange reserves exceeded the optimal value for foreign exchange reserves from 2000 to 2003, but fell short in other years. The reason for this situation is that among all the variables considered in Heller's [11] model, apart from the changing trend in China's national debt interest rate as stated earlier, the import trend (m) has grown gradually, but when the GDP grew considerably in 2005, m then became small. The average absolute change in international reserves (h) was much larger than that of former years because the foreign exchange reserve grew considerably in 2004 and 2005.

Table 8: When the management cost is 0.5%, the ratio of actual foreign exchange reserves to the optimal foreign exchange reserves

YEAR	m[ж]	AFR[#]	h[*]	Ropt(5)[**]	Ropt(3)[***]	AFR/Ropt(5)	AFR/Ropt(3)
1996	0.1700	1050.29	213.965	1229.177	1273.589	85.45%	82.47%
1997	0.1585	1398.90	296.7275	1904.302	1965.964	73.46%	71.16%
1998	0.1481	1449.60	233.35	1686.954	1753.763	85.93%	82.66%
1999	0.1671	1546.75	202.695	1773.579	1836.736	87.21%	84.21%
2000	0.2083	1655.74	151.3625	1368.799	1438.94	120.96%	115.07%
2001	0.2071	2121.65	180.6875	1326.272	1349.113	159.97%	157.26%
2002	0.2323	2864.07	353.6175	2614.524	2669.162	109.54%	107.30%
2003	0.2914	4032.51	621.44	3956.211	4025.642	101.93%	100.17%
2004	0.3403	6099.32	1110.895	6740.962	6874.437	90.48%	88.72%
2005	0.2924	8188.72	1516.768	9734.376	9971.016	84.12%	82.13%

ж：m is the propensity to import;

#：AFR indicates actual foreign exchange reserves every year, unit: 0.1 billion USD;

*：h is calculated using a moving average method, e.g., the value for 1996 equals the average value of the foreign exchange reserves alteration sum (0.1 billion USD) within the former 4 years, that is from 1992 to 1995; the values of h in other years can be deduced in the same way.
The prediction for optimal reserves in 1963 in Heller [11] is 1 year, so the value of h was not calculated using moving average method in [11].

**：Ropt(5)indicates the optimal foreign reserves in China, when the management cost is 0.5%, the social rate of return on capital is the 5-year interest rate of China's national debt

***：Ropt(3) indicates the optimal foreign reserves in China, when the management cost is 0.5%, the social rate of return on capital is the 3-year interest rate of China's national debt

Table 9: When the management cost is 1%, the ratio of actual foreign exchange reserves to the optimal foreign exchange reserves

YEAR	m[ж]	AFR[#]	h[*]	Ropt(5)[**]	Ropt(3)[***]	AFR/Ropt(5)	AFR/Ropt(3)
1996	0.1700	1050.29	213.965	1215.419	1257.755	86.41%	83.51%
1997	0.1585	1398.90	296.7275	1876.239	1933.713	74.56%	72.34%
1998	0.1481	1449.60	233.35	1651.484	1710.983	87.78%	84.72%
1999	0.1671	1546.75	202.695	1683.724	1728.802	91.86%	89.47%
2000	0.2083	1655.74	151.3625	1273.174	1315.794	130.05%	125.84%
2001	0.2071	2121.65	180.6875	1285.839	1305.272	165.005	162.55%
2002	0.2323	2864.07	353.6175	2523.508	2568.808	113.50%	111.50%
2003	0.2914	4032.51	621.44	3854.453	3916.171	104.62%	102.97%
2004	0.3403	6099.32	1110.895	6567.718	6686.995	92.87%	91.21%
2005	0.2924	8188.72	1516.768	9476.639	9685.686	86.41%	84.54%

ж：m is the propensity to import

#：AFR indicates actual foreign exchange reserves every year, the unit: 0.1 billion USD

*：h is calculated using a moving average method, e.g., the value for 1996 equals the average value of the foreign exchange reserves alteration sum (0.1 billion USD) within the former 4 years, that is from 1992 to 1995; the values of h in other years can be deduced in the same way. The prediction for optimal reserves in 1963 in Heller [11] is 1 year, so the value of h was not calculated using moving average method in [11].

**：Ropt(5)indicates the optimal foreign reserves in China, when the management cost is 1%, the social rate of return on capital is the 5-year interest rate of China's national debt

***：Ropt(3) indicates the optimal foreign reserves in China, when the management cost is 1%, the social rate of return on capital is the 3-year interest rate of China's national debt

Table 10: When the management cost is 1.5%, the ratio of actual foreign exchange reserves to the optimal foreign exchange reserves

YEAR	m[ж]	AFR[#]	h[*]	Ropt(5)[**]	Ropt(3)[***]	AFR/Ropt(5)	AFR/Ropt(3)
1996	0.1700	1050.29	213.965	1202.248	1242.694	87.36%	84.52%
1997	0.1585	1398.90	296.7275	1849.903	1903.723	75.62%	73.48%
1998	0.1481	1449.60	233.35	1619.398	1673.032	89.51%	86.65%
1999	0.1671	1546.75	202.695	1615.086	1650.142	95.77%	93.73%
2000	0.2083	1655.74	151.3625	1206.896	1237.53	137.19%	133.79%
2001	0.2071	2121.65	180.6875	1250.843	1267.754	169.62%	167.36%
2002	0.2323	2864.07	353.6175	2446.297	2484.987	117.08%	115.25%
2003	0.2914	4032.51	621.44	3763.075	3818.624	107.16%	105.60%
2004	0.3403	6099.32	1110.895	6411.387	6519.197	95.13%	93.56%
2005	0.2924	8188.72	1516.768	9246.085	9433.306	88.56%	86.81%

ж : m is the propensity to import

: AFR indicates actual foreign exchange reserves every year, unit: 0.1 billion USD

* : h be calculated using the moving average method, e.g., the value for 1996 equals the average value of the foreign exchange reserves alteration sum (0.1 billion USD) within the former 4 years, that is from 1992 to 1995, the values of h in other years can be deduced in the same way. The prediction for optimal reserves in 1963 in Heller [11] is 1 year, so the value of h was not calculated using the moving average method in [11].

** : Ropt(5)indicates the optimal foreign reserves in China, when the management cost is 1.5%, the social rate of return on capital is the 5-year interest rate of China's national debt

*** : Ropt(3) indicates the optimal foreign reserves in China, when the management cost is 1.5%, the social rate of return on capital is the 3-year interest rate of China's national debt

3 Summary and Concluding Remarks

Using a rate analysis method we found that the following:

1. The ratio of China's foreign exchange reserves to its annual import value has been much higher than the standard ratio (the 3-month import value) since 1995; it even exceeded the annual import value in some years. That is, from 1995 to 2005,

the actual foreign exchange reserves were from 122% to 400% larger than the optimal foreign exchange reserves calculated using 25% of the annual import value as the standard.

2. From 1995 to 2004, the actual foreign exchange reserves were larger than the optimal foreign exchange reserves calculated using the standard of 40% of the foreign debt balance. The excess was from 70% to 570%.

3. The rates for China's foreign exchange reserves and money and quasi-money are larger than 10%. China has presently adopted a pegged exchange rate system, but it is moving toward abolishing this system. Therefore, the Chinese actual foreign exchange reserve is within a reasonable range, which indicates that China has a strong ability to repay foreign debt and an excellent international reputation.

4. From 1995 to 2005, the actual foreign exchange reserves exceeded the optimal reserve level calculated by the sum of import foreign exchange demands, foreign debt demands, and profit returning foreign exchange demands by foreign investment enterprises. The excess was between 20% and 370%. The reasons are as follows: First, China encourages exports viewing them as an index to examine enterprise achievements. Second, the RMB is undervalued, which has caused an increase in exports and an inflow of capital. Third, as the FDI increases; the proportion of foreign enterprise exports is comparatively larger in China.

Using the Heller [11] method to calculate China's optimal foreign exchange Reserve we found that:

1. When the social rate of return on capital is calculated using an industrial cost profit rate for all state owned and large non-state owned industrial enterprises, and the return on the reserves is calculated using the differential between the 1-year interest rate of America's national debt and inflation in America, China's optimal foreign exchange reserves can be calculated yearly. The ratio of China's actual foreign exchange reserves to the optimal foreign exchange reserves from 2000 to 2005 was larger than 1, which indicates that China's actual foreign exchange reserves were excessive in this period by an amount ranging from about 3% to

76%.

2. From 1996 to 2005, assuming that the management cost has increased from 0.5% to 1.5%, and China's national debt interest rate can be taken as the return on the reserves, the ratio of actual foreign exchange reserves to China's optimal foreign exchange reserves has increased correspondingly.

3. From 1996 to 2005, if China's 5-year national debt interest rate is regarded as the social rate of return on capital, the ratio of actual foreign exchange reserves to China's optimal foreign exchange reserves was higher than that calculated using China's 3-year national debt interest rate as the social rate of return on capital.

4. If the management cost is 0.5%, 1%, or 1.5%, and China's 5-year and 3-year national debt interest rates are taken as the social rate of return on capital, China's actual foreign exchange reserves exceeded the optimal foreign exchange reserves from 2000 to 2003, but it was the opposite in other years. The reason for this situation is that out of all the variables considered in Heller's [11] model, except for the changing trend in China's national debt interest rate as stated before, the import trend (m) grew gradually. In order for the GDP to grow by a large amount in 2005, m became small. The average absolute value change in the international reserves (h) was much larger than that in former years because the foreign exchange reserves had grown considerably in 2004 and 2005.

Comparing the rate analysis method with Heller's [11] method, we can see that the ratios of actual foreign exchange reserves to China's optimal foreign exchange reserves calculated using these two methods are quite different, which indicates that it is necessary to study this question using new research methods. Further research will be reported in future papers.

Appendix Table 1: The structure of international reserves in China

YEAR	AFR[#]	GR[Ω]	GP[ΩΩ]	GV[ΩΩΩ]	GV/AFR	SDRs[Ψ]	SDR_S/AFR
1978	1.67	1280	183.75	23.52	14.08383	NA	
1979	8.40	1280	279.06	35.71968	4.252343	NA	
1980	-12.96	1280	600.71	76.89088	-5.93294	NA	
1981	27.08	1267	464.76	58.88509	2.174486	NA	
1982	69.89	1267	314.98	39.90797	0.571011	NA	
1983	89.01	1267	412.84	52.30683	0.587651	NA	
1984	82.20	1267	377.67	47.85079	0.582126	NA	
1985	26.44	1267	316.83	40.14236	1.518244	NA	
1986	20.72	1267	342.57	43.40362	2.094769	NA	
1987	29.23	1267	449.59	56.96305	1.948787	NA	
1988	33.72	1267	451.33	57.18351	1.695834	NA	
1989	55.50	1267	367.6	46.57492	0.839188	NA	
1990	110.93	1267	352.33	44.64021	0.402418	NA	
1991	217.12	1267	366.72	46.46342	0.213999	NA	
1992	194.43	1267	340.8	43.17936	0.222082	NA	
1993	211.99	1267	371.89	47.11846	0.222267	NA	
1994	516.20	1267	385.64	48.86059	0.094654	NA	
1995	735.97	1267	387.56	49.10385	0.06672	5.8	0.007881
1996	1050.29	1267	385.27	48.81371	0.046476	6.18	0.005884
1997	1398.90	1267	340.78	43.17683	0.030865	6.07	0.004339
1998	1449.60	1267	292.27	37.03061	0.025545	6.76	0.004663
1999	1546.75	1267	261.35	33.11305	0.021408	7.41	0.004791
2000	1655.74	1267	285.55	36.17919	0.021851	7.94	0.004795
2001	2121.65	1608	268.35	43.15068	0.020338	8.55	0.00403
2002	2864.07	1929	310.25	59.84723	0.020896	9.92	0.003464
2003	4032.51	1929	356.53	68.77464	0.017055	11.00	0.002728

2004	6099.32	1929	391.99	75.61487	0.012397	12.42	0.002036
2005	8188.72	1929	430.66	83.07431	0.010145	12.58	0.001536

: AFR indicates actual foreign exchange reserves every year, unit: 0.1 billion USD

Ω :GR indicates gold reserves ,the amount of the gold in the December every year , unit: 10,000 Fine Troy Ounce

ΩΩ : GP indicates gold price (the amount of the gold price in June every year) USD/ 1 Fine Troy Ounce

ΩΩΩ : GV GR indicates GOLD RESERVES, unit: 0.1 billion USD

Ψ: SDRs means Special Drawing Rights (SDR), unit: 0.1 billion USD (the unit is converted to USD)

NA indicates that it cannot be worked out by calculation

Data source：

(1) The gold price comes from http://forecasts.org/data/index.htm
(2) The SDRs data comes from http://www.imf.org
(3) The SDRs price comes from
http://www.imf.org/external/np/fin/rates/param_rms_mth.cfm
(4) AFR data comes from http://www.pbc.gov.cn/diaochatongji/tongjishuju

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