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Improving Algorithm of Agarwal Model for the Rational Scale of Chinese Foreign Exchange Reserves

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Abstract

It is a kind of vogue to plus constantly the model's items as to meet the possibility in determining the rational scale of foreign exchange reserves. Some demand factors be added to the transformation of the Agarwal model in cost-benefit ideas, its calculation results more, but cannot stand up to the reality of the typical countries, also cannot undergo inspection data, the more special inspection of economic operation of the conforms not actual. This paper eliminates contains repeated in the model modified, and intende to redesign algorithm rules of the model according to economic programs. The rational scale is computed with each passing year since 1997 according to the new algorithm, and improved significantly the international comparability.

Key words: Foreign exchange reserves; Reasonable scale; Agarwal model; Algorithm improved

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INTRODUCTION

Chinese foreign exchange reserves (FER) has increased from $21.2 billion dollars at the beginning of 1994 to 2847.3 billion dollars at the end of 2010, our foreign exchange system being reformed in that year, and Chinese FER has accounted for global 35.6% as to the total economy only of global 9.5%. To overcome the shortage problem of the ability to pay foreign exchange in the past, China would have crossed the rational scale of foreign exchange reserves, causing the domestic liquidity and such as the rising prices secondary hazards. The main problem now is no longer how to increase foreign exchange reserves, but how to control the scale of foreign exchange reserves, how to determine a rational scale has become a hotspot of Chinese foreign exchange management and academic research.

The methods, which are now used for getting the rational scale of our foreign exchange reserves, cannot explain the rapid increase of the actual scale of it. Many people try to narrow the gap between the actual scale and the rational scale by the way of increasing computing projects. Zhu Hao (2011) believes that it is groundless to estimate the rational scale on this idea of the theory, who advocated it that meant bad. According to determine the reasonable scale of foreign exchange reserves, Zhu Hao (2010) suggests on comparative analysis of domestic recent main research that, owing to the cost benefit economic meaning clear, Agarwal model is better than proportion method, demand method and other methods. Even so, the research results of the Agarwal model still cannot get rid of some common defects: the relationship between multiple factors is not overview, sum ability is questionable, and the parameter assignment is arbitrary (Zhu Hao, 2010). This paper attempts to improve the computational formula of Agarwal model in accordance with the original economy meaning, make it has more economic explicable

1. SOME PROBLEMS IN THE STUDY OF AGARWAL MODEL

1.1 Agarwal Model and Its Transformation

Agarwal model is a calculation model, used to estimate the rational scale of foreign exchange reserves according to the cost benefit thought. Considering the characteristics of the developing countries, Agarwal (1971) thinks, the opportunity cost of foreign exchange reserves is domestic investment yields, accordingly constructs Agarwal model as formula (1).

$$R = W(\lg k + \lg q_2 - \lg q_1) / \lg p \tag{1}$$

Where R is the best scale of foreign exchange reserves; W is the balance outstanding of payments; P is the probability for deficit appearing; K is the reciprocal of the output of assets; q_1 is the import content to additional assets; q_2 is the ratio of the import of productive goods and the tatol output.

Owing to the payback reserves and preventive reserves not involved, many people attempt to amend the Agarwal model. Major improvement ideas is the cost benefit method combined with demand method, add he reserve requirement items of the rational scale of foreign exchange reserves such as the debt service payments content requirements, control the foreign exchange market fluctuations, maintain public confidence, etc. So, on the basis of the trade reserve R_1 and the regulatory reserve R_2, it gets the framework model (2) of the rational scale which include the increased debt service reserve R_3 item and the preventive reserves R_4 items as follow.

$$R = R_1 + R_2 + R_3 + R_4 \tag{2}$$

where $R_1 + R_2$ can be determined by the classical Agarwal model, R_3 mainly based on the debt servicing and the backflow of the capital and the profit of foreign direct investment, the need R4 mainly determined by a lot criterions such as maintaining the stable exchange rate, preventing financial risks, promoting the national economic development, and others. The main improved achievements of this kind are as follows:

1. ZHAO Rurui, XIA Houyangxia (2007)'s Agarwal - Wujian model, gotten by the analysis of the WuJian(1998).

$$R = W(\lg k + \lg q_2 - \lg q_1) / \lg p + \alpha_1 \cdot FDI + \alpha_2 \cdot Deb + A \tag{3}$$

2. WEI Xiaoqin, YOU Yuanbao (2004)'s the improved model

$$R = W\left(\lg k - \lg q_1 + \lg q_2\right)/\lg p + \alpha_1 \cdot \mathrm{FDI} + \alpha_2 \cdot \mathrm{Deb} + \mathrm{A} + \mathrm{cT} \tag{4}$$

3. YU Chunhong, MA Lianxia (2006)'s the improved model

$$R = W\left(\lg k - \lg q_1 + \lg q_2\right)/\lg p + \alpha_1 \cdot \mathrm{FDI} + \alpha_2 \cdot \mathrm{Deb} + \left(\mathrm{cT} + \mathrm{dM}\right) \tag{5}$$

4. WANG Qunlin (2008)'s the improved model

$$R = W\left(\lg k - \lg q_1 + \lg q_2\right)/\lg p + \alpha_1 \cdot \mathrm{FDI} + \alpha_2 \cdot \mathrm{Deb} + \mathrm{A} + \left(\mathrm{cT} + \mathrm{dM}\right) \tag{6}$$

where c is the ratio coefficient of stabilizing the currency market exchange rate; T is the trades amount of foreign exchange market; d is the ratio of the personal demand accounts to the gross national income; M - the gross national income ("resident individuals to foreign functions," function log bottomless, maybe mistakes in WANG Qunlin's paper); A - risk and development fund.

1.2 Comparative Analysis for the Typical Research Results

MU Hongmei (2007) calculated the 1985 ~ 2006 Chinese optimal foreign exchange reserves with the classical Agarwal model (1), SONG Juan (2010) calculated the upper and lower limits of the reasonable scale of Chinese foreign exchange reserves from 1982 to 2008 with the amend Agarwal model (6) by WANG Qunlin, and their results see table 1.

Table 1
The Data Table of the Typical Results Calculated by Agarwal Model (Unit: Billion)

years	MU	SONG		years	MU	SONG	
	optimal	lower	upper		optimal	lower	upper
1985	24.1	47.7	58.4	1997	41.2	113.0	174.1
1986	31.5	51.4	62.2	1998	42.3	112.8	177.3
1987	30.2	52.7	64.9	1999	50.7	127.6	194.9
1988	26.6	53.5	68.8	2000	40.4	126.2	200.3
1989	32.1	59.9	82.4	2001	38.8	137.1	224.3
1990	51.2	85.5	102.0	2002	37.5	145.5	245.3
1991	29.8	63.1	81.4	2003	31.4	158.4	279.3
1992	23.6	56.3	77.3	2004	29.0	185.2	336.2
1993	20.1	56.1	83.8	2005	24.7	215.4	399.9
1994	23.3	71.3	105.2	2006	42.7	247.8	469.0
1995	29.1	87.9	132.8	2007	0.0	295.3	575.8
1996	33.4	98.2	150.8	2008	0.0	339.2	681.4

It is great difference of the results calculated between SONG Juan and Mu Hongmei, and this gap widens over time, foe example in 2006, SONG Juan's lower limit is 5.8 times of MU Hongmei's and the upper limit is 11 times. From such a huge gap look, the two model is not of simple inherits relation, but changes in modeling methodology, which requires us to thoroughly analyzed the rationality of two model is built.

1.3 Some Defects of the Calculation Results

MU Hongmei estimates the optimal reserves by the classical Agarwal model; her calculation result is near the actual scale of foreign exchange reserves of most western countries, and of enlightenment. MU Hongmei says that because of the many factors affect foreign exchange reserves and these factors are frequently changed, it is actually quite difficult to establish a suitable scale of foreign exchange reserves. MU Hongmei is not continued to probe in those "difficult" problems. Referring to the circumstance in recent years, MU Hongmei's result perhaps a smaller some (see table 2).

SONG Juan calculates the lower and the upper by the transformation model, which contains more factors, seeming more comprehensive and complete. But SONG Juan's calculation results departure seriously from the actual reserves of the main developed country's (table 2). According the international experience, SONG Juan assigns the model parameters: $\alpha_1 \in [10\%, 15\%]$, $\alpha_2 \in [12\%, 18\%]$, c $\in$ [8%, 18%], d $\in$ [1%, 4%], A $\in$ [5% × R, 10% × R], W = 149 (the annual maximum trade deficit since 1982). Due to the equation (6) for each item in positive, so $R > \alpha_1 \cdot FDI + \alpha_2 \cdot Deb$, $(\alpha_1 \cdot FDI + \alpha_2 \cdot Deb) / R < 1$. But, even assigning the lower limit parameters, $(\alpha_1 \cdot FDI + \alpha_2 \cdot Deb) / R \geq 1$, the data shows in table 2, such as the United States for 22, Germany for 4.4. Contrasting the actual situation of these countries, the correctness of the model (6) is unable to empirical. It will inspire us to redraft Agarwal model, to verify the rationality of improvement ideas constantly adding the contents on-demand.

Table 2
Major National Economic Indicators in 2008 (Unit: Billion)

country	GDP	R	FDI	Deb	The sum
America	14330.0	75.6	316.1	13641.8	1668.6
Germany	3818.0	143.5	24.9	5250.5	632.5
France	2978.0	99.9	100.7	5001.6	610.2
England	2787.0	64.3	96.9	9388.0	1136.2
Italy	2399.0	110.8	17.0	2359.1	284.7
Spain	1683.0	20.8	66.5	2313.6	284.2
Canada	1564.0	43.5	45.0	751.3	94.6
Australia	1069.0	30.6	47.0	763.6	96.3
Holland	909.5	26.6	118.0	2439.8	304.5
Belgium	530.6	16.0	59.7	1346.5	167.5
Sweden	512.9	27.7	43.7	731.6	92.1

Note: The sun is $\alpha_2 \cdot FDI + \alpha_3 \cdot Deb = 10\% \cdot FDI + 12\% \cdot Deb$

Are summed up and see, there are the double counting items in the amend Agarwal model. The modifications of Agarwal model are added its items on the idea of the demand expansion , specifically WANG Qunlin's correction model covers all contents of the other 3 model included, and therefore it could be used as such modified typical. WANG Qunlin's model, R_4 is determined by way of A calculated, cT is also involved in the contents of preventive foreign exchange reserves R_4; Residents foreign demand dM should be included in the contents of trade reserves R_1, and should consequently be included in $R_1 + R_2$, and there may are double counting in the model. In addition, in the debt service $R_3 = \alpha_1 \cdot FDI + \alpha_2 \cdot Deb$, it is not necessary to happen simultaneously both the backflow need $\alpha_1 \cdot FDI$ of the capital and the profit of foreign direct investment foreign and external debt servicing $\alpha_2 \cdot Deb$, so the formula is of questionable. Agarwal – Wu Jian model also needs further study. E.g., the preventive reserves $R_4 = A$, contain only interventions in the currency market demand in the model, but preventive reserves R_4 should contain other needs such as maintaining the stable exchange rate, preventing financial risks and promoting national economic development.

2. IMPROVING THE ALGORITHM OF AGARWAL MODEL

2.1 Improving the Algorithm of Agarwal Model

1st. Calculation R_3. In real economic life, FDI enterprise import and export respectively, and import and remit asynchronously, foreign debt and debt servicing come simultaneously about , new FDI and past capital and profit remittance happen at the same time, new debt can cover the backflow of old debt, the new FDI can make up for past capital and profit remittance, It can ensure meet foreign exchange expenditure demands if only foreign exchange of FDI inflows greater than foreign exchange outflow. Even not on the basis of foreign exchange liquidity balance, it ought also to notice the fact that there not happen at the same time the demands of debt servicing and the backflow of FDI and its profit, but

they are dispersedly remitted in general. Assuming both occurrence time are asynchronous, it can evade payment risks as if the foreign exchange reserves just more than their maximum, and a conservative estimating formula pay back reserves as below:

$$R_3 = \max\{\alpha_1 \cdot FDI, \alpha_2 \cdot Deb\} = (\alpha_1 \cdot FDI) \vee (\alpha_2 \cdot Deb) \quad (7)$$

2nd. Calculation A. Risk and development fund A maybe determined beyond the economic category, but it is with so many unreasonable that demand A is determined by 5% ~ 10% multiplying by the normal demand of foreign exchange reserves, where the normal demand is the sum of other items in various foreign exchange reserves. For example, if the normal amount becomes large, demand A is rising, besides A itself is nothing normal. It is a more reasonable way for A determined in accordance with the nature of preventive reserves from A , estimated the objectivity according to the actual situation. For example, in accordance with the deviation of actual foreign exchange reserves and the regression curve, the amount A maybe determined. Assuming the actual reserves is R_i and the regression amount is $\hat{R}_i$, the amount A can be calculated by the formula (9) with previously 20 years data, going for some value A and then smoothing those linearly.

$$A = \max\left\{\hat{R}_i - R_i, 0 \middle| n-20 \le i \le n\right\} \quad (8)$$

3rd. Determine parameters α_1, α_2. If FDI are profitable in China, FDI will not withdraw from China, and its profit of FDI will again invest in China more; If FDI loses in China, then the surplus of FDI could escape from China, and the fact is no profit repatriation. The average rate of investment profit is 22% for our enterprise with foreign investment, their incurring enterprises is less than 5%, and it doesn't accord with Chinese actual conditions for copy $\alpha_1 \in [10\%, 15\%]$. Looking from statistical perspective, the more appropriate parameter is $\alpha_1 \in [5\%, 8\%]$. Value α_2 is closely related with debt deadline, It perhaps $\alpha_2 \in [12\%, 18\%]$ for short-term debt; For long-term, debt servicing is about 6% to 8% amount owed each year.

4th. Improving algorithm of Model. Preventive foreign currency reserves $R_4 = A$, it can be used to adjust when imbalance in foreign exchange flow, owing to R_2 with regulatory purposes, so both are of the identity in use, and both are not summation relationship but probability sum relations, passingly assuming that coincidence probability is $\omega(0 \le \omega \le 1)$. Debt service reserve R_3 and $R_1 + R_2$ and R_4, they are differ from one another in purpose, and of paratactic complementary relationship, for these reason according to the analysis, Agarwal model should be press algorithm (8) improvement.

$$R = \left[W(\lg k + \lg q_2 - \lg q_1)/\lg p\right] \oplus A + (\alpha_1 \cdot FDI) \vee (\alpha_2 \cdot Deb) \quad (9)$$

where algorithm rules: $a \oplus b = a + b - \omega \cdot (a \wedge b), a \wedge b = \min(a, b)$.

2.2 The Computing Example of Agarwal Model Improved

2.2.1 Parameters and Formula Design

Since 1978, Chinese biggest trade deficit is $14.9bn (in 1985), given the predicted future trade deficit will be no greater than the maximum value, then can make w=14.9 billion dollars. From 1978 to 2008 in China, trade deficit is nine times in 31 years, so the probability of deficit appeared $p = 9 / 31$.

Take interval estimation method, upper and lower limit are separately estimated according to formula (10) e and formula (11).

$$R_{\max} = \left[W(\lg k + \lg q_2 - \lg q_1)/\lg p\right] \oplus A + (0.15 \cdot FDI) \vee (0.18 \cdot Deb) \quad (10)$$

$$R_{\min} = \left[W(\lg k + \lg q_2 - \lg q_1)/\lg p\right] \oplus A + (0.10 \cdot FDI) \vee (0.12 \cdot Deb) \quad (11)$$

where $\omega = 0$ in formula (10) for $\oplus$, $\omega = 1$ in formula (11) for $\oplus$.

2.2.2 Data and the Computational Results

Take Agarwal model improved formulas (9), it needs the data of multivariate statistical as in table 3 for determining reasonable scale of Chinese foreign exchange reserve, see formula(6).

Table 3
The Improved Agarwal Model Variable Numerical Tables (Unit: Billion)

years	GDP	*TIFA*	Δ*TIFA*	Im	*Dets*	*Detl*	*FDI*
1997	952.7	300.9	25.3	28.6	18.1	112.8	221.9
1998	1019.5	343.1	42.2	22.9	17.3	128.7	267.3
1999	1083.3	360.6	17.5	26.8	15.2	136.7	307.6
2000	1198.5	397.6	37.0	46.7	13.1	132.7	348.4
2001	1324.8	449.6	52.0	45.7	50.6	119.5	395.2
2002	1453.8	525.6	76.0	49.3	70.8	115.6	448.0
2003	1641.0	671.3	145.8	72.8	92.2	116.6	501.5
2004	1931.6	851.5	180.2	117.3	123.2	124.3	562.1
2005	2236.6	1083.7	232.2	147.7	156.1	124.9	622.4
2006	2658.4	1379.8	296.1	187.1	183.6	139.4	685.5
2007	3383.8	1805.9	426.1	243.1	153.5	220.1	760.2
2008	4329.2	2488.5	682.6	362.4	163.9	210.8	852.6

To be continued

Continued

years	GDP	*TIFA*	Δ*TIFA*	Im	*Dets*	*Detl*	*FDI*
2009	4912.2	3293.5	805.0	289.8	259.3	169.4	942.6
2010	6034.6	4217.4	924.0	422.2	375.7	173.2	1048.4

Note: 1. Source: data from the China statistical yearbook (2009), increased investment in fixed assets obtained through calculation;
2. Long-term external debt *Detl*, short-term debt *Dets* and FDI are all accumulative amounts.

Using the data in table 3, you can estimates Chinese rational scale of foreign exchange reserves from 1997 to 2010. The specific calculation agreed: import production material replaced by imported primary product, says Im; *TIFA* is the social fixed assets investment Δ*TIFA* is new addition to fixed assets investment standing for new productive accumulation, ; κ is total investment in fixed assets to GDP, says $\kappa = TIFA \div GDP$; q_1 is the proportion of import production material to the productive accumulation, $q_1 = \text{Im} \div \Delta TIFA$; q_2 is the proportion of import production material to GDP, $q_2 = \text{Im} \div GDP$. Will the table 3 data import MATLAB 7.0, calculate the specific quantities of κ, q_1, q_2, and figure out the lower scale and the upper scale of Chinese foreign exchange reserves respectively with formula (10) and formula(11), all see table 4.

Table 4
Chinese Foreign Exchange Reserve Reasonable Scale Table (Unit: Billion)

years	Middle values of $R_1 + R_2$				R_4	R_3		Rational scale		actual
	κ	q_1	q_2	$R_1 + R_2$	A	$\omega = 1$	$\omega = 0$	R_{min}	R_{max}	reserves
1997	0.316	1.133	0.030	57.6	11.7	11.1	17.8	68.7	87.1	139.9
1998	0.337	0.543	0.023	51.2	14.2	13.4	21.4	64.6	86.8	145.0
1999	0.333	1.531	0.025	62.8	16.7	15.4	24.6	78.2	104.1	154.7
2000	0.332	1.263	0.039	55.2	19.3	17.4	27.9	72.6	102.4	165.6
2001	0.339	0.880	0.035	51.9	21.9	19.8	31.6	71.6	105.4	212.2
2002	0.362	0.649	0.034	47.8	24.4	22.4	35.8	70.2	108.0	286.4
2003	0.409	0.499	0.044	40.0	26.9	25.1	40.1	65.1	107.1	403.3
2004	0.441	0.651	0.061	38.4	29.2	28.1	45.0	66.5	112.6	609.9
2005	0.485	0.636	0.066	36.0	45.4	31.1	49.8	76.5	131.2	818.9
2006	0.519	0.632	0.07	34.4	51.5	34.3	54.8	85.8	140.8	1066.3
2007	0.534	0.57	0.072	32.5	56.2	38.0	60.8	94.2	149.5	1528.3
2008	0.575	0.531	0.084	28.9	61.0	42.6	68.2	103.6	158.0	1946.0
2009	0.670	0.360	0.059	26.6	65.7	47.1	75.4	112.8	167.7	2399.2
2010	0.699	0.457	0.070	26.9	72.6	55.5	83.9	128.1	183.4	2847.3

3. RESEARCH CONCLUSION AND INSUFFICIENCY

The results, which are calculated by improved algorithm of Agarwal model, are more close to the actual scale of foreign exchange reserves of main developed countries. From the statistical perspective, this algorithm is markedly strengthened management scientificalness with respect to western countries. The present rational scale is between 120 billion dollars and 180 billion dollars, foreign exchange reserves a, although this scale is still high relative to the actual reserves of most western countries, but it has been relatively closed, and Germany's reserve level has been in this range.

Viewing from the calculation circumstance, $R_1 + R_2$ should decrease as reserves, but decreased preventive reserves of foreign exchange reserves increases with reserves. It is of the theoretic rationality for $R_1 + R_2$ estimated on the basis of cost and benefit thought, but it is not possibility in realistic economic life; And the results of calculation A is of inevitability in realistic economic life, but it is unreasonable in theoretical analysis. That suggests the classic Agarwal model has the defects in fully explaining the reality, and there are theoretical defects in calculating A, they all have the leeway to improve the calculation methods. Model algorithm (10) reflects economic intention on one hand, on the other hand, attempts to counteract the defects of both.

The rational scale is a criterion for foreign exchange reserve management, must not reflect the actual situation of foreign exchange reserves. In other conditions certain circumstances, rational scale is certain. If the actual foreign exchange reserves are small, the rational scale informs the serious shortage of foreign exchange reserves; If the actual reserves is several times of the reasonable reserve, then it reflects the serious excessive foreign exchange reserves. From 1997 to 2002, Chinese foreign exchange reserve is about twice the reasonable reserve, then the ratio increased year by year, approximately 3 times in 2003, and about 15 times in 2010. Chinese foreign exchange reserve excessive is more and more serious problem.

According to economic intention, the algorithm of Agarwal model is amended some; it is a pity that the new model is still imperfect. For example, parameters α_1 and α_2 value shouldn't be copied among papers, and should been deserved according to statistical results, and this paper will but not compensate for this flaw. On the condition that FDI inflows increased over outflow, the preparation of 10% ~ 15% FDI with its profit for remitted, it obviously does not conform to the economic reality, and this is also a turn copy of the parameters. The author thought that rational scale is not to cater to the fact that increased foreign exchange reserves, but to seek to set up a standard for foreign exchange reserves management.

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