

China's Profits and Losses from Currency Intervention, 1994-2011

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China's currency policy has been criticized for its apparent pursuit of mercantile advantage by artificially stimulating exports, which potentially have adverse effects on other economies. While China's currency policy may have positive output effects, there may be additional profits or losses. This paper computes the annual and cumulative accounting profits from currency intervention since 1994 when China began its currency intervention. It is shown that profits initially were positive but China since 2006 has lost a massive amount from the currency market.

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Abstract

China's currency policy has been criticized for its apparent pursuit of mercantile advantage by artificially stimulating exports, which potentially have adverse effects on other economies. While China's currency policy may have positive output effects, there may be additional profits or losses. This paper computes the annual and cumulative accounting profits from currency intervention since 1994 when China began its currency intervention. It is shown that profits initially were positive but China since 2006 has lost a massive amount from the currency market.

1. Introduction

Due to China's mounting currency reserves since the 1990s, its currency policy has been under intense scrutiny. This meteoric rise in China's cumulative trade surplus has provoked much debate concerning China's currency valuation and misalignment. The common view is that "China has intentionally depressed the value of its currency, the renminbi (RMB), to gain unfair advantages in the global market." (Cheung, 2012; McKinnon and Schnabl, 2004) China's currency policy has been criticized because of its possible adverse consequences on other economies.

Most major currencies are free-floating vis-à-vis other currencies, except the renminbi.¹ China's low renminbi policy may stimulate its economy and reduce unemployment. For example, Gylfason and Schmid (1983) showed that devaluation has positive output effects in a study of ten countries. While currency devaluation raises a country's trade surplus temporarily, any foreign currency reserve so accumulated must be

used up eventually, and sold at different exchange rates. Hence, the central bank may suffer losses from such intervention.

Profits and losses from currency intervention by the central bank have not received any attention in the literature. There are two main differences between speculation by private investors and the PBC, China's central bank. First, unlike private speculators, PBC simply prints yuan to buy foreign currencies, and hence does not pay interest. Second, no forward currency market for yuan exists due to its regulated status.² PBC keeps track of the fund to purchase foreign currencies.

The purpose of this paper is to investigate China's profits and losses from currency intervention since 1994 when China began to merge the exchange rates in the swap market and official exchange rates. McKinnon and Schnabl (2009) note that renminbi was inconvertible before 1994. Also, China's trade surplus was negligible in 1994. Thus, we choose 1994 as the base year to compute annual and cumulative profits from currency intervention. Since the central bank may retain any amounts of foreign exchange reserve in any period, we utilize the accounting profit concept from currency intervention in a multi-period framework (Ghosh, 1997). We demonstrate that while profits from currency intervention were positive in the 1990s, China has lost a phenomenal sum since 2007.

2. Effects of Yuan Appreciation on China's Trade Surplus

Assume that China is an open Keynesian economy and trades only with the United States. Due to price rigidity some unemployment exists in its domestic market, and changes in the exchange rate affect its gross domestic product (GDP). Let ε denote the dollar price of yuan and let $x(P, \varepsilon, Y^*)$ denote China's export in dollars, where P is the price level

expressed as yuan per unit of output, and Y^* is GDP of the United States. China's GDP, expressed in yuan, is given by:

$$Y = C + I + G + (x / \varepsilon - q),$$

where Y , C , I , G and q are China's income, domestic consumption, investment, government spending and imports, all expressed in yuan. China's import, $q(P, \varepsilon, Y)$, depends on the price level, exchange rate and its GDP. China is free to choose its dollar peg ε . China's net export S_i is defined as

$$S_i \equiv x(P_i, \varepsilon_i, Y_i^*) - \varepsilon_i q(P_i, \varepsilon_i, Y_i), \quad (1)$$

where $\varepsilon_i = P_i^* / P_i$ is the dollar price of yuan, P^* is the dollar price per unit of output in the United States, and Y_i and Y_i^* are China's GDP measured in yuan and U.S. GDP measured in dollars in period i , respectively. China's trade surplus S is measured in dollars. Since China is an open Keynesian economy, a yuan devaluation immediately affects domestic price, $P_i = P_i^* / \varepsilon_i$. However, yuan depreciation does not affect U.S. GDP, i.e., $Y_i^* = Y^*$. Substituting $\varepsilon_i = P_i^* / P_i$ into (1), we get

$$S_i \equiv x(P_i^* / \varepsilon_i, \varepsilon_i, Y_i^*) - \varepsilon_i q(P_i^* / \varepsilon_i, \varepsilon_i, Y_i) = X(P_i^*, \varepsilon_i, Y^*) - \varepsilon_i Q(P_i^*, \varepsilon_i, Y_i).$$

Since foreign price is fixed, $P_i^* = P^*$, and P^* will be suppressed henceforth. Let $F(r)$ be capital or financial *outflow* in dollars, including direct investment, portfolio investment and short-term capital flow, excluding reserve account activities, where r is the domestic interest rate. A balance of payments surplus is written as

$$S_i = X(\varepsilon_i, Y^*) - \varepsilon_i Q(\varepsilon_i, Y_i) - F_i(r). \quad (2)$$

We first consider the gains from currency intervention in a two-period framework. While a country may have a trade surplus in one period, it subsequently must be used up because balance of payments must be balanced in the long run. Equation (1) implicitly defines the equilibrium exchange rate ε_i^o in each period; it is the exchange rate which insures zero balance of payments surplus, $X(\varepsilon_i, Y^*) - \varepsilon_i Q(\varepsilon_i, Y_i) + F(r) = 0$.

Note that Y_i depends on S_i and ε_i , i.e., $Y_i = Y_i(S_i, \varepsilon_i, Y^*)$. Equation (2) implicitly defines the exchange rate as a function of trade surplus and U.S. GDP. Thus, the exchange rate also may be expressed as a function of balance of payments surplus,

$$\varepsilon_i = g(S_i + F_i, Y^*). \quad (3)$$

A change in foreign income Y^* shifts the trade surplus function. Since Y^* is assumed as fixed, we may write the exchange rate as:

$$\varepsilon_i = f(S_i + F_i), \quad (4)$$

where a trade surplus or deficit is expressed in dollars.

We now explore the effect of a yuan devaluation from the equilibrium rate on the trade balance. Note that a change in the exchange rate affects its imports, which in turn affects China's GDP, and hence we may write $Y_i \equiv Y_i(S_i(\varepsilon_i), \varepsilon_i)$. The reduced form of China's import may be written as $Q(\varepsilon_i) \equiv Q(\varepsilon_i, Y_i(\varepsilon_i))$. Differentiating (2) with respect to ε and suppressing i gives:

$$S_\varepsilon = X_\varepsilon - \varepsilon Q_\varepsilon - Q, \tag{5}$$

where subscripts denote partial derivatives. It can be shown that China's trade surplus in yuan also decreases under the same condition. Given that the Marshall-Lerner condition holds,³ the trade surplus function is negatively sloped, as shown in Figure 1. This implies $S_\varepsilon < 0$ and $f'(S) < 0$.

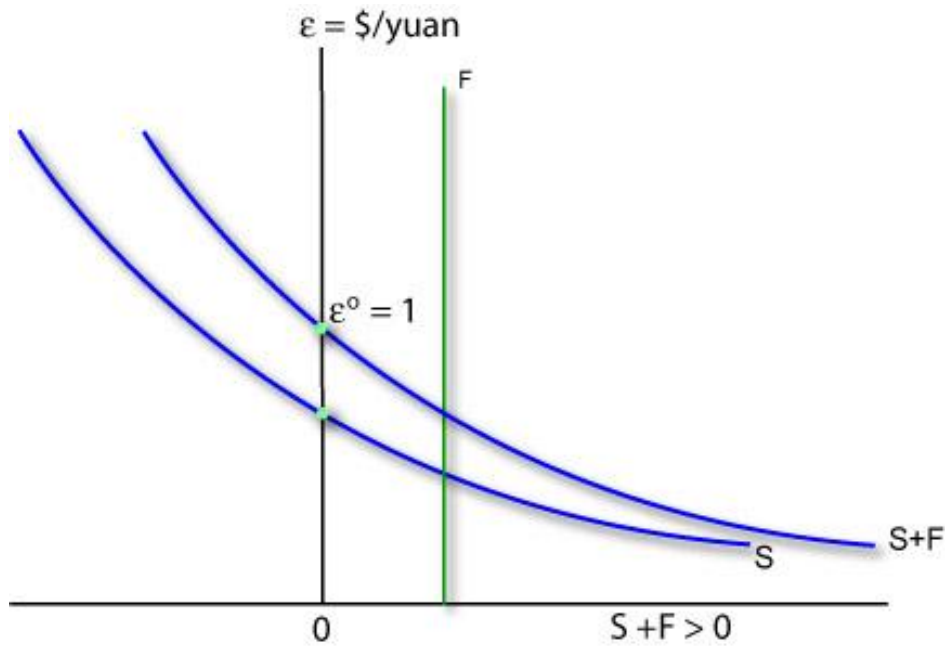


Figure 1: Exchange Rate and Balance of Payments Surplus

In the absence of financial flows, the equilibrium exchange rate is attained where the trade surplus function S intersects the vertical line at $S = 0$. Let $F(r)$ denote net foreign investment by the private sector. If net foreign investment is positive, it shifts the balance of payments curve, $S + F$, to the right, as shown in Figure 1.

3. Annual Profits from Currency Intervention

If China behaves as a price taker in the currency market, an equilibrium exchange rate is that which clears the foreign currency market. If China pegs renminbi at a different rate, a

trade surplus or deficit occurs. For instance, China may choose to devalue yuan below the equilibrium and invest the resulting trade surplus in the United States. Nevertheless, proceeds from foreign investment eventually will be used up in subsequent periods. To consider the benefits of foreign investment by currency intervention in a simple model, first consider a two period model. China is assumed to incur a trade surplus in the first period, which is invested in dollar assets in the United States, and the proceeds are used in the second period.

Let $S_1 = S$ denote China's trade surplus in the first period. The yuan cost of a trade surplus of S dollars is S / ε_1 , where ε_1 is the exchange rate in the first period. Trade surplus of S_1 dollars is invested in US Treasury bills, which grows to $S_1(1+r)$ at the end of the second period, where r is the interest rate on the Treasury bills. Let K and K^* denote China's private investment in the United States and America's investment in China, respectively. We assume that interest rates are equal between the two countries, i.e., $r = r^*$. China's net foreign investment is $F \equiv K - K^*$. The yuan cost of net direct investment is F / ε_1 , which is invested in U.S. Treasury bills. We assume that any foreign investment, whether it is portfolio investment or direct investment, is repatriated in the second period. Thus, the total amount, $(S + F)(1+r)$, is sold in the foreign exchange market in the second period, and the revenue in renminbi is $(S + F)(1+r) / \varepsilon_2$, where $\varepsilon_2 = f(-(S + F)(1+r))$ is the exchange rate in the second period.⁴

The total profit realized from currency intervention is:

$$\pi(S + F) = \frac{(S + F)(1+r)}{\varepsilon_2} - \frac{S + F}{\varepsilon_1} = (S + F) \left(\frac{1+r}{f(-(S + F)(1+r))} - \frac{1}{f(S + F)} \right). \quad (6)$$

In order to consider the benefits from currency intervention for more than two periods, we now relax the assumption that the central bank liquidates its currency reserve in any period. That is, the central bank may sell some of its reserve, or buy even more. If any amount of foreign exchange is retained, it is treated as foreign investment at the current pegged rate. Such action, short of liquidation, may contribute to profits or losses in subsequent periods.

Annual Accounting Profits

Let C_i denote the amount of cumulative foreign currency invested in the U.S. Treasury bills in period i . Assume that the stock of foreign currency reserve at the beginning of period 1 is zero ($C_0 = 0$), and hence $C_1 = S_1$. The yuan cost of purchasing C_1 dollars is C_1 / ε_1 . Foreign investment of C_1 dollars increases to $C_1(1+r_1)$, where r_1 is the interest rate in period i . Thus, the accounting profit in the first period, which is to be known in the second period, is written as:

$$\pi_1(C_1, r_1, \varepsilon_1, \varepsilon_2) = \frac{(S+F)(1+r_1)}{\varepsilon_2} - \frac{S+F}{\varepsilon_1} = \frac{C_1(1+r)}{\varepsilon_2} - \frac{C_1}{\varepsilon_1}. \quad (7)$$

Thus, $\pi_1(S, r_1, \varepsilon_1, \varepsilon_2)$ is the accounting profit in period 1 obtained by assessing the end-of-period currency reserve, $C_1(1+r) = (S+F)(1+r)$, at the unknown exchange rate in the second period, ε_2 . If the central bank liquidates the reserve in the next period, ε_2 can be observed from the trade surplus function. However, the central bank may choose to sell only a part of its reserve or buy even more. We assume that the central bank pegs renminbi each

period, and it does not know at what exchange rate renminbi will be pegged thereafter. Thus, in each period, the subsequent exchange rates will be treated as unknown variables.

In the second period, the cumulative investment in the U.S. Treasury bills is $C_2 = C_1(1+r_1) + S_2 + F_2$, where S_2 and F_2 are the additional purchases of dollar assets and foreign direct investment in period 2, both of which can be negative. Since the central bank holds C_2 in period 2, its yuan cost is C_2 / ε_2 . The cumulative foreign investment C_2 grows to $C_2(1+r_2)$ at the end of the second period, which is to be evaluated at the unknown exchange rate, ε_3 . The market value of the current reserve at the end of period 2 is

$$\frac{C_2(1+r_2)}{\varepsilon_3}.$$

Thus, the accounting profit in the second period is:

$$\pi_2(C_2, r_2, \varepsilon_2, \varepsilon_3) = \frac{C_2(1+r_2)}{\varepsilon_3} - \frac{C_2}{\varepsilon_2}. \quad (8)$$

Similarly, the annual profit in period N is

$$\begin{aligned} \pi_N(C_N, r_N, \varepsilon_N, \varepsilon_{N+1}) &= \frac{(C_{N-1}(1+r_{N-1}) + S_N + F_N)(1+r_N)}{\varepsilon_{N+1}} - \frac{(C_{N-1}(1+r_{N-1}) + S_N + F_N)}{\varepsilon_N} \\ &= C_N \left(\frac{1+r_N}{\varepsilon_{N+1}} - \frac{1}{\varepsilon_N} \right) = C_N \left(\frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}} \right). \end{aligned} \quad (9)$$

It is important to note that if renminbi appreciates too much, the annual profit will be negative. Only if $(1+r)\varepsilon_N > \varepsilon_{N+1}$, the annual profit will be positive. If renminbi appreciates faster than the interest rate, then the annual profit will be negative.

Properties of Annual Accounting Profits

From (9), annual accounting profits depend on ε_N , ε_{N+1} and r_N . Differentiating (9) with respect to r_N yields

$$\frac{\partial \pi_N}{\partial r_N} = C_N \left(\frac{1}{\varepsilon_{N+1}} + \frac{1}{\varepsilon_N^2} \frac{\partial \varepsilon_N}{\partial r_N} \right) \frac{C_N}{\varepsilon_{N+1}} + F'_N \left(\frac{1+r_N}{\varepsilon_{N+1}} - \frac{1}{\varepsilon_N} \right). \quad (10)$$

The first term is positive. The sign of the second term on the RHS is indeterminate. However, if ε_i is a random variable, independently and identically distributed, then $E\varepsilon_{N+1} = \varepsilon_N$ and

hence $\left(\frac{1+r_N}{E\varepsilon_{N+1}} - \frac{1}{\varepsilon_N} \right) > 0$. Since $F'_N > 0$, the second term on the RHS is positive on average.

That is, an increase in the foreign interest rate increases China's annual profits from currency intervention.

Differentiating (9) with respect to ε_N and ε_{N+1} , we get

$$\frac{\partial \pi_N}{\partial \varepsilon_N} = \frac{C_N}{(\varepsilon_N)^2} > 0, \quad (11)$$

$$\frac{\partial \pi_N}{\partial \varepsilon_{N+1}} = -\frac{C_N(1+r_N)}{(\varepsilon_{N+1})^2} < 0. \quad (12)$$

Thus, as yuan appreciates, other things equal, annual profit increases. On the other hand, as the future value of yuan rises, current profit declines, because a given amount of dollar assets fetches a smaller sum in yuan.

The elasticity of annual profit with respect to the future exchange rate is:

$$\begin{aligned}\eta_{\pi\varepsilon_{N+1}} &\equiv \frac{\varepsilon_{N+1}}{\pi_N} \frac{\partial \pi_N}{\partial \varepsilon_{N+1}} = -\frac{\varepsilon_{N+1}}{\pi_N} \frac{C_N(1+r_N)}{(\varepsilon_{N+1})^2} \\ &= -\frac{\varepsilon_{N+1}}{C_N \left(\frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}} \right)} \frac{C_N(1+r_N)}{(\varepsilon_{N+1})^2} = -\frac{\varepsilon_N(1+r_N)}{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}.\end{aligned}\quad (13)$$

Suppose the interest rate were .1 percent (as in 2011) and yuan were undervalued by 10 percent. Then a 1 percent yuan appreciation (from $\varepsilon = .9$ to .91) reduces profits by

$$\eta = -\frac{.9 \times 1.001}{1.001 \times .9 - .91} = 99.$$

Suppose the interest rate is 5 percent and yuan was undervalued by 25 percent. In this situation, a 1 percent yuan appreciation (from $\varepsilon = .9$ to .91) reduces profit by 27 percent.

These examples suggest that profits from currency intervention are very sensitive to exchange rate appreciation, especially when the interest rate is near zero.

Data

China's foreign exchange reserve data were obtained from the State Administration of Foreign Exchange and are shown in Table 1. Column 1 shows foreign exchange reserve for the period 1994-2011.⁵ The 1994-2010 yuan-dollar exchange rate data are from the World Development Indicators database. To calculate the annual and cumulative profits in 2011, exchange rates as of July 1, 2011 and February 13, 2012 were used as proxy for the unknown average exchange rate in 2011 and 2012. Interest rates on U.S. Treasury bills change daily, and the currency reserve data are only annual figures. Thus, a sort of annual average interest

rates is needed to compute potential profits from currency intervention. Six-month interest rates on U.S. Treasury bills were used as the annual interest rates.⁶

Annual Accounting Profits without Financial Flow

Table 1 shows annual profits in yuan from currency intervention for the period, 1994-2011. Goldstein and Lardy (2009, pp. 5-6) noted that before 1985, the swap market was sanctioned by the Chinese government to settle trade transactions. They argue that the official yuan-dollar rate was above the equilibrium market exchange rate, and was used for intergovernmental transactions. Nevertheless, the swap market was helpful to the Chinese government for settling trade transactions at the equilibrium exchange rate. They argued that “the official exchange rate during mid-1990s was probably a reasonable approximation of an equilibrium rate (pp. 6).”

Also, the method of computing the foreign exchange reserve was changed in 1992 to exclude foreign exchange deposits of state-owned entities with Bank of China. Thus, it would be necessary to choose a base year after 1992. The current account surplus was only about \$5 billion in 1992, and the current account deficit was about \$12 billion in 1993. Few economists argue that China’s intervention started before 1993. Thus, the period 1993-1994 may be the time in which China refrained from currency intervention. Accordingly, profits and losses from subsequent attempts to moderate exchange rate changes can be computed from 1994.

Table 1 shows annual profits in yuan from currency intervention, which rose to 81 billion yuan in 2000, equal to approximately 1/10 of 1 percent of U.S. GDP, but fell to zero in 2006. Since 2006, China began to incur huge losses, which rose to 546 billion yuan in 2007, 824 billion yuan (\$122 billion) in 2010, and 537 billion yuan (\$83 billion) in 2011.

This amount should be compared to the actual current account surplus of \$305 billion in 2010.

Table 1. China's Annual Profits from Currency Intervention, 1994-2011

	Exchange Rate	U.S. TB interest	China FX	Annual Profit	
	(\$/RMB)	%	\$Billion	Billion Yuan	\$ Billion
1994	0.1160	4.64	52.9	6.0	0.7
1995	0.1198	5.56	75.4	32.2	3.9
1996	0.1203	5.08	107.0	42.9	5.2
1997	0.1206	5.18	142.8	59.3	7.1
1998	0.1208	4.83	149.2	59.7	7.2
1999	0.1208	4.75	146.2	57.5	6.9
2000	0.1208	5.90	165.6	80.9	9.8
2001	0.1208	3.34	212.2	58.7	7.1
2002	0.1208	1.68	286.4	39.8	4.8
2003	0.1208	1.05	403.3	35.1	4.2
2004	0.1208	1.58	609.9	29.3	3.5
2005	0.1220	3.39	818.9	39.4	4.8
2006	0.1254	4.81	1066.3	2.1	0.3
2007	0.1314	4.44	1528.2	-546.4	-71.8
2008	0.1440	1.62	1946.0	-6.2	-0.9
2009	0.1464	0.28	2399.2	-98.8	-14.5
2010	0.1477	0.20	2847.3	-823.5	-121.6

2011	0.1546	0.10	3181.1	-536.8	-83.0
2012	0.1589				

Annual Accounting Profits without Financial Flow

Estimated Interest Rates and FX

	US TB interest (%)	Estimated interest rate (%)	China FX (\$billion)	Estimated China FX (\$ billion)
1994	4.64	0.04	52.9	53.6
1995	5.56	0.30	75.4	77.8
1996	5.08	0.07	107.0	111.0
1997	5.18	-0.02	142.8	148.2
1998	4.83	-7.71	149.2	156.6
1999	4.75	6.05	146.2	164.9
2000	5.90	-0.44	165.6	163.7
2001	3.34	-0.62	212.2	222.7
2002	1.68	-0.04	286.4	294.8
2003	1.05	0.06	403.3	408.2
2004	1.58	-6.82	609.9	613.9
2005	3.39	-4.55	818.9	870.1
2006	4.81	0.11	1066.3	1131.4
2007	4.44	-4.04	1528.2	1578.3
2008	1.62	2.82	1946.0	2075.7

2009	0.28	-0.98	2399.2	2375.9
2010	0.20	-1.90	2847.3	2877.6
2011	0.10		3181.1	3240.8

Financial flows are made to take advantage of different interest rates between countries. The presence of the financial flows indicates that there are temporary differences in the financial returns or profitability of investment between the two economies. However, we assume that the interest rates are equal, in which case no financial flow should occur, i.e., $F_i = 0$, for all $i = 1, \dots, N$. Thus, equation (9) reduces to:

$$\begin{aligned} \pi_N(C_N, r_N, \varepsilon_N, \varepsilon_{N+1}) &= \frac{(C_{N-1}(1+r_{N-1})+S_N)(1+r_N)}{\varepsilon_{N+1}} - \frac{(C_{N-1}(1+r_{N-1})+S_N)}{\varepsilon_N} \\ &= C_N \left(\frac{1+r_N}{\varepsilon_{N+1}} - \frac{1}{\varepsilon_N} \right) = C_N \left(\frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}} \right). \end{aligned} \quad (14)$$

Table 2 shows that the annual accounting profits without the financial flow also were near zero in 2006, and have since increased to \$92.6 billion in 2010.⁷ This is somewhat less than \$121.6 billion when the financial flow is included. As expected, if the interest rate differential is negligible, accounting profits should be roughly equal, whether financial flows are included or not.

Table 2. China's Annual Profits from Currency Intervention without Financial Flow,
1994-2010

	Current Account (\$ Billion)	Foreign Reserve from Trade Surplus (\$ Billion)	Annual Profit (Billion Yuan)	Annual Profit (\$ Billion)
1994	7.7	7.7	22.9	0.1
1995	1.6	9.6	20.9	0.5
1996	7.2	17.4	24.1	0.8
1997	37.0	55.3	-1.2	2.8
1998	31.5	89.6	-25.0	4.3
1999	21.1	115.0	-12.6	5.5
2000	20.5	141.0	-10.0	8.3
2001	17.4	166.7	29.9	5.6
2002	35.4	207.7	40.1	3.5
2003	45.9	257.1	71.1	2.7
2004	68.7	328.5	137.7	1.9
2005	134.1	467.7	116.5	2.7
2006	232.7	716.3	52.0	0.2
2007	354.0	1,104.8	106.7	-51.9
2008	412.4	1,566.2	67.2	-0.7
2009	261.1	1,852.7	137.3	-11.2
2010	305.4	2,163.3	166.3	-92.4
2011	201.7	2,369.3	186.1	-61.8

4. Cumulative Profits from Currency Intervention

In each period, the currency reserve is evaluated at the official exchange rate. Thus, the yuan value of the cumulative foreign exchange reserve in period 2 is $\frac{C_2}{\varepsilon_2} = \frac{C_1(1+r_1) + S_2}{\varepsilon_2}$.

Note that if China were to liquidate its currency reserve, then $S_2 = -S(1+r)$ and the cumulative currency reserve at the end of period 2 reduces to $C_2 = 0$. The total yuan cost of the cumulative foreign exchange reserve in period 2 is: $T_2 = \frac{S_2}{\varepsilon_2} + \frac{S_1}{\varepsilon_1}$.

PBC, as China's central bank, does not pay interest. Unlike private speculators, PBC simply prints yuan to buy foreign currencies.⁸ Also, no forward currency market for yuan exists due to its regulated status.⁹

Since China holds on to some currency reserve and does not necessarily liquidate it each period, we may consider the cumulative accounting profit which is obtained by assessing the value of currency reserves at the current pegged rate each period. The currency reserve is treated as the bank's investment in dollar assets made during the current period, and should be separated from current profits.

Cumulative Accounting Profit to be realized in period 2 is defined as:

$$\Pi_2 = \frac{C_2(1+r_2)}{\varepsilon_3} - \left(\frac{S_2}{\varepsilon_2} + \frac{S_1}{\varepsilon_1} \right). \quad (15)$$

Note however, that the exchange rate ε_2 depends on C_2 , and liquidation of the foreign exchange reserve will lower ε_2 below the rate that would prevail if it is retained. If the

country liquidates its foreign exchange reserve in the second period, then $S_2 = -S_1(1+r)$ and $C_2 = 0$, and equation (15) reduces to (6), and the accounting profit reduces to the actual or realized profit,

$$\Pi_1 = \left(\frac{S_1(1+r_1)}{\varepsilon_2} - \frac{S_1}{\varepsilon_1} \right). \quad (16)$$

Market Value of Foreign Exchange Reserve

If the country does not liquidate the existing foreign exchange reserve in period 2, its cumulative reserve balance is

$$C_2 = C_1(1+r_1) + S_2,$$

and the value of the cumulative foreign exchange reserve in yuan at the end of period 2 grows to $C_2(1+r_2)/\varepsilon_3$. Note that cumulative investment of C_3 dollars grows to $C_3(1+r_3)$, and its market value is: $\frac{C_3(1+r_3)}{\varepsilon_4}$, which is known in period 4. Likewise, the total yuan

revenue that would be obtained from liquidating the cumulative foreign exchange reserve at the terminal period N is:

$$\frac{C_N(1+r_N)}{\varepsilon_{N+1}}. \quad (17)$$

Cumulative Accounting Profits

The cumulative yuan cost of foreign exchange reserve in period 3 is: $F_3 = \sum_{i=1}^3 \frac{S_i}{\varepsilon_i}$.

Thus, the cumulative accounting profit in yuan is:

$$\Pi_3 = \frac{C_3(1+r_3)}{\varepsilon_4} - \left(\frac{S_3}{\varepsilon_3} + \frac{S_2}{\varepsilon_2} + \frac{S_1}{\varepsilon_1} \right). \quad (18)$$

Likewise, the total yuan cost up to the terminal period N is:

$$F_N = \sum_{i=1}^N \frac{S_i}{\varepsilon_i}. \quad (19)$$

Cumulative accounting profit in period N is the market value of the currency reserve less cost, i.e.,

$$\Pi_N = \frac{C_N(1+r_N)}{\varepsilon_{N+1}} - \sum_{i=1}^N \frac{S_i}{\varepsilon_i}. \quad (20)$$

Note that the cumulative foreign exchange reserve in any period can be obtained by adding the new trade surplus to the cumulative reserve at the end of the previous period. However, in practice, the reported cumulative reserves generally deviate from these derived cumulative reserves.

We now consider an alternative method to compute the cumulative accounting profit, which is obtained by adding annual accounting profits. Note that $C_2 = C_1(1+r_1) + S_2$. Thus, $S_2 = C_2 - C_1(1+r_1)$. Likewise, $S_N = C_N - C_{N-1}(1+r_{N-1})$, $N > 1$, and $S_1 = C_1$. Thus, we have

$$\Pi_N = \frac{C_N(1+r_N)}{\varepsilon_{N+1}} - \sum_{i=1}^N \frac{S_i}{\varepsilon_i} = \frac{C_1(1+r_1)}{\varepsilon_2} - \frac{C_1}{\varepsilon_1} + \frac{C_2(1+r_2)}{\varepsilon_3} - \frac{C_2}{\varepsilon_2} + \dots = \pi_1 + \pi_2 + \dots = \sum_{i=1}^N \pi_i.$$

That is, the cumulative accounting profit in each period can be obtained by adding up the annual accounting profits. This method is used in Table 1 to compute the cumulative accounting profits.

Differentiating (20) with respect to ε_N gives

$$\frac{\partial \Pi}{\partial \varepsilon_N} = \frac{S_N}{\varepsilon_N^2} (1 + \eta_{NN}), \quad (21)$$

where $\eta_{NN} \equiv \frac{\varepsilon_N}{S_N} \frac{\partial S_N}{\partial \varepsilon_N}$ is the contemporaneous elasticity of trade surplus with respect to the

exchange rate in period N. If the Marshall-Lerner condition is satisfied, then $\partial S_N / \partial \varepsilon_N < 0$.

Equation (21) states that if $1 + \eta_{NN} < 0$, cumulative profit declines.

Table 3 displays the cumulative accounting profits since 1994. It shows that in the early years of currency intervention, cumulative profits in yuan from currency intervention steadily increased, reaching 543 billion yuan in 2006. PBC began to lose money in 2007 when its cumulative profit was completely wiped out. It has since found it difficult to recover from the mounting losses, which reached 1,469 billion yuan (or about \$227 billion) in 2011, and are expected to rise further as the yuan appreciates.

Table 3. China's Cumulative Profits from Currency Intervention, 1994-2011

	Cumulative Profit
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	Billion Yuan	\$ Billion
1994	6.0	0.7
1995	38.3	4.6
1996	81.1	9.8
1997	140.4	16.9
1998	200.0	24.2
1999	257.5	31.1
2000	338.4	40.9
2001	397.1	48.0
2002	436.9	52.8
2003	472.0	57.0
2004	501.3	60.6
2005	540.7	66.0
2006	542.7	68.1
2007	-3.7	-0.5
2008	-9.9	-1.4
2009	-108.7	-15.9
2010	-932.2	-137.7
2011	-1,469.0	-227.1

Table 4 shows the cumulative accounting profits without the financial flow. In 2010, the cumulative accounting loss rose to \$115.2 billion, or close to \$137.7 billion without the financial flow. Again, inclusion of the financial flow does not make much difference in the cumulative accounting profits.

Table 4. Cumulative Accounting Profits without Financial Flow

	Cumulative Profit (Billion Yuan)	Cumulative Profit (\$ Billion)
1994	0.9	0.1
1995	5.0	0.6
1996	12.0	1.4
1997	34.9	4.2
1998	70.7	8.5
1999	116.0	14.0
2000	184.8	22.3
2001	230.9	27.9
2002	259.8	31.4
2003	282.2	34.1
2004	298.0	36.0
2005	320.5	38.7
2006	321.8	38.9
2007	-73.2	-13.0
2008	-78.2	-13.7
2009	-154.5	-24.9
2010	-780.2	-117.3
2011	-1,180.0	-179.1

5. Concluding Remarks

Throughout the 1990s, China's profits from currency markets were negligible and China did not intentionally speculate in the currency market. In 1994, China merged the official and swap markets, effectively adopting the exchange rates from the swap market. Initially, the exchange rate rose to the equilibrium level. However, after 1994, the currency peg apparently was below the equilibrium level and China began to accumulate trade surpluses. Such intervention yielded profits until 2006, but the continued appreciation of the yuan resulted in the ballooning of the cumulative losses. This result does not change whether or not the financial flow is included.

The cumulative profits of about 543 billion yuan in 2006 were wiped out completely the next year, and the mounting losses from currency intervention rose to 1,469 billion yuan in 2011. Current account surpluses since 2007 hovered around \$300 billion, and are expected to be above this level, despite the continued appreciation of yuan. If this trend continues, China's losses will continue to mount.

The primary intent of currency intervention may be to stimulate outputs and exports. Nevertheless, PBC may earn profits or incur losses from such intervention attempts. Thus, any benefits from expanded exports should be weighed against the possible losses from currency intervention.

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Endnotes

¹ Unlike Japan, China does not allow its citizens to invest in dollar assets.

² Because of recent internationalization attempts, China is allowing the offshore market for the RMB-denominated assets.

³ China's trade surplus in dollars decreases as yuan appreciates if $\eta_{X\varepsilon} + \eta_{Q\varepsilon} < 1$, where

$\eta_{X\varepsilon} \equiv (\partial X / \partial \varepsilon)(\varepsilon / X)$ and $\eta_{Q\varepsilon} \equiv -(\partial Q / \partial \varepsilon)(\varepsilon / Q)$ denote elasticity of exports and imports with respect to the exchange rate ε .

⁴ Foreign direct investment earns dividends which can vary from year to year. We assume that the dividends on direct investment are equal to the interest rate on Treasury bills.

⁵ This data excludes gold from the international reserve assets.

⁶ Interest rate data on the 1-year Treasury bills were not available in certain years.

⁷ The current account data for 2011 is not available.

⁸ PBOC keeps track of the fund to purchase foreign currencies. PBOC had closed the swap market and began to regulate RMB by moving the official rate to the prevailing swap market rates on January 1, 1994 (Goldstein and Lardy 2009, page 4) PBOC issues a certain amount of new money each year. Some of the funds will be used to buy foreign exchange from commercial banks. This money is called the "Funds outstanding for foreign exchange" by PBOC.

⁹ Because of recent internationalization attempts, China is allowing the offshore market for the RMB-denominated assets.