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Essays on currency intervention, with particular reference to Chinese economy

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Essays on currency intervention, with particular reference to Chinese economy

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Abstract

While many economists suggest that a central bank should make positive profits from currency intervention to maintain price stability, profits and losses from currency intervention by the China's central bank have not received any attention in the literature. My dissertation will use three chapters to fill in this gap. Chapter 1 investigates the optimal currency intervention policy for a profitability targeting central bank using a two-period framework. It is shown that when foreign interest rate is zero, the optimal policy is nonintervention. If the interest rate is positive, a country may earn positive profits by incurring a trade surplus in the first period. However, there is an upper bound for the currency depreciation rate. A country will lose money under excessive devaluation. Chapter 2 further computes the specific annual and cumulative accounting profits and losses from 1994 when China began its currency intervention. It is shown that China's central bank initially made positive profits but since 2007 has lost a massive amount from the foreign exchange market. Chapter 3 investigates the optimal currency intervention policy for a welfare targeting government using a two period framework. It is shown that if marginal utility of income is decreasing in the exchange rate, then the optimal exchange rate are the equilibrium exchange rates that yields trade balance each period.

Chapter 1: Profits and Losses from Currency Intervention

A paper accepted by *International Review of Economics and Finance*

Hailong Jin and E. Kwan Choi

1.1 Abstract

This paper investigates the possible gains from currency intervention by central banks using a two-period framework in which a trade surplus in one period must be offset by a trade deficit in the next period. It is shown that when the interest rate is zero, the optimal policy is nonintervention. If the interest rate is positive, a country may earn positive profits by incurring a trade surplus in the first period. However, there is an upper bound for optimal trade surplus. A country actually may lose money if the rate of devaluation below the equilibrium is greater than the interest rate. A linear model suggests that China may have been losing money from excessive devaluation of renminbi since 2002.

1.2 Introduction

Due to mounting currency reserves since the 1990s, China's currency policy has been under intense scrutiny. People's Bank of China (PBC) closed the currency swap market,[1] and began to regulate renminbi on January 1, 1994 by moving the official rate to the then prevailing swap market rates (Goldstein and Lardy 2009, page 6). According to State Administration of Foreign Exchange of PBC, China's foreign exchange reserve, which excludes gold, was $22 billion in 1993. China's foreign exchange reserve has since increased steadily, reaching $166 billion in 2000. However, during the first decade of this century,

[1] Goldstein and Lardy (2009, pp. 5-6) noted that before 1994, the swap market was sanctioned by the Chinese government to settle trade transactions. It helped the Chinese government find the equilibrium exchange rate.

China's foreign exchange reserve rose dramatically to $3.3 trillion as of December 2011.[2] Such a 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, 2011)

Most major currencies are free floating vis-à-vis other currencies, except renminbi.[3] There might possibly be some gains or losses from currency intervention in the foreign exchange market. For example, Gylfason and Schmid (1983) show that devaluation has positive output effects in a study of ten countries. Thus, a Keynesian open economy may devaluate its currency during a recession in order to stimulate its economy. Currency devaluation raises a country's trade surplus temporarily. However, any foreign currency reserve so accumulated must eventually be used up, and sold at different exchange rates.

Ghosh (1997) argued that a sharp trader can make profits in currency trading by utilizing the forward contracts on foreign currency. In his model a speculator invests in a foreign currency for a given period and sells the anticipated sum in the forward market. Ghosh and Arize (2003) use the present value concept to compute profits of speculators who do not necessarily liquidate the existing balances. The speculator borrows money at the domestic interest rate and sells the anticipated proceeds in the forward currency market.

Gains from currency speculation by the central bank have not received any attention in the literature.[4] There are two main differences between speculation by private investors and

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[2] Of this amount, current account surplus was $2.2 trillion and the remaining $1.13 trillion was capital and financial flow.

3 Prior to the Asian financial crisis of 1997, most Asian exchange rates were de facto pegged to the U.S. dollar. See Patnaik et al (2011).

[4] Hsiao, Pan and Wu (2012) observe that renminbi-euro rate is not an appropriate intervention object for China.

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.[5] PBC keeps track of the fund to purchase foreign currencies.

The purpose of this paper is to investigate gains from currency intervention by a central bank. We utilize the profit concept from currency intervention (Ghosh, 1997). Since no forward renminbi market exists when it is regulated, we use the concept of anticipated profits from currency intervention in a two-period model. 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.

Section 1.2 considers the effects of yuan appreciation on China's trade surplus. Section 1.3 examines optimal trade surplus and the associated exchange rate in a two-period framework. Section 1.4 illustrates the main proposition for a linear model of exchange rate. Section 1.5 investigates a realistic upper bound for currency depreciation and the associated trade surplus share of GDP. Section 1.6 contains concluding remarks.

1.3 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 $x(\varepsilon P / P^*, Y^*)$ denote China's export in dollars, where P is the yuan price and P^* the

[5] Because of recent internationalization attempts, China is allowing the offshore market for the RMB denominated assets.

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

$$Y = C + I + G + \left(X / \varepsilon - Q\right),$$

where *Y*, *C*, *I*, *G* and *Q* are China's income, domestic consumption, investment, government spending and imports, all expressed in yuan. Assume that no financial flow occurs in the private sector.[6] China's imports in renminbi, $q(\varepsilon P / P^*, Y)$, depends on the price level, exchange rate and its GDP. We normalize Chinese price so that $P = P^*$, but China is free to choose its dollar peg *ε*.

China's net export *S* measured in dollars is defined as

$$S \equiv X(\varepsilon, Y^*) - \varepsilon_i q(\varepsilon, Y). \quad (1)$$

Since China is an open Keynesian economy, its GDP depends on its trade surplus in renminbi, $Y = y(S / \varepsilon)$. China's income depends on the exchange rate. Let $Q(\varepsilon) \equiv q(\varepsilon, y(S / \varepsilon))$ be the reduced form of China's import. China's trade surplus in dollars $S(\varepsilon)$ is defined by:

$$S \equiv X(\varepsilon, Y^*) - \varepsilon Q(\varepsilon). \quad (2)$$

At the equilibrium exchange rate, ε^o, for balanced trade, $S(\varepsilon^o) = X(\varepsilon^o, Y^*) - \varepsilon^o Q(\varepsilon^o) = 0.$

We adopt a two-period framework to investigate the gains from currency intervention. While a country may have a trade surplus in one period, it must be used up subsequently because trade must be balanced in the long run. The U.S. economy is assumed to be

[6] The financial flow was relatively insignificant until 2009, and accounts for roughly one third of China's foreign exchange reserve as of 2011.

stationary, i.e., $Y_i^* = Y^*$. Equation (1) implicitly defines the equilibrium exchange rate ε_i^o in each period; it is the exchange rate which insures zero trade surplus, $X(\varepsilon_i, Y^*) - \varepsilon_i Q(\varepsilon_i) = 0$.

The exchange rate may also be expressed as a function of trade surplus,

$$\varepsilon_i = g(S_i, Y^*). \tag{3}$$

Since Y^* is fixed, we may write the exchange rate as:

$$\varepsilon_i = f(S_i), \tag{4}$$

where trade surplus or deficit is expressed in dollars.

Effect of Yuan Appreciation on Trade Surplus

We now explore the effect of a yuan devaluation from the equilibrium rate on trade balance. 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. Let $\eta_{X\varepsilon} \equiv (\partial X / \partial \varepsilon)(\varepsilon / X)$ and $\eta_{Q\varepsilon} \equiv -(\partial Q / \partial \varepsilon)(\varepsilon / Q)$ denote elasticity of exports and imports with respect to the exchange rate ε, respectively. Equation (5) can be rewritten as:

$$S_\varepsilon = \eta_{X\varepsilon}(X / \varepsilon) + \varepsilon \eta_{Q\varepsilon}(Q / \varepsilon) - Q. \tag{6}$$

As yuan appreciates, China's trade surplus is assumed to decrease, i.e., $S_\varepsilon < 0$. When trade is balanced, $X = \varepsilon Q$, and

$$S_\varepsilon \frac{\varepsilon}{X} = \eta_{X\varepsilon} + \eta_{Q\varepsilon} - 1.$$

Thus, China's trade surplus in dollars decreases as yuan appreciates if, and only if

$$\eta_{X\varepsilon} + \eta_{Q\varepsilon} < 1. \tag{7}$$

We assume that the Marshall-Lerner condition holds. This implies $S_\varepsilon < 0$ and $f'(S) < 0$. Figure 1.1 illustrates that exchange rate ε is decreasing in *S*.

1.4 Optimal Trade Surplus

Consider the base scenario in which China refrains from currency intervention and trade is balanced at the equilibrium exchange rate ε^0 in both periods. Without loss of generality, assume further that the equilibrium exchange rate is unity, $\varepsilon^o = 1$. We now explore whether China can profit from currency intervention. For this purpose we relax the condition that trade must be balanced each period, but we allow a trade surplus in the first period. However, trade must be balanced over two periods. Thus, when China incurs a trade surplus in one period, it must have a trade deficit in the next period so that its trade is balanced over the two periods.

Assume that China pegs yuan below the equilibrium rate in the first period, and it incurs a trade surplus $S_1 = S > 0$. PBC buys dollar reserve with its renminbi, and hence does not incur any interest expense.[7] The yuan cost of obtaining net export of *S* dollars is: S / ε_1. However, the value of China's investment in dollar assets increases to $S(1+r)$ dollars, where *r* is the interest rate on U.S. assets, e.g., Treasury bills.

In the second period, China sells its foreign exchange reserve, $S(1+r)$. When this amount is sold in the second period, yuan revenue is $S_1(1+r)/\varepsilon_2$, where $\varepsilon_2 = f\left(-S(1+r)\right)$ is the exchange rate in the second period. Recall that yuan devaluation below the equilibrium rate in period 1, equal to unity, necessarily causes an appreciation of yuan above unity.

[7] This constitutes an increase in money supply to affect the yuan-dollar exchange rate. PBC issues a certain amount of new money each year. Some of it is used to buy foreign exchange from commercial banks, and is called the "Funds outstanding for foreign exchange" by PBC.

We now explore whether China's currency intervention is motivated by profits. The total profit in yuan realized in the second period from currency intervention is:

$$\pi(S) = \frac{S(1+r)}{\varepsilon_2} - \frac{S}{\varepsilon_1} = S\left(\frac{1+r}{f(-S(1+r))} - \frac{1}{f(S)}\right) \tag{8}$$

Consider the special case where the interest rate is zero. In this case, profit in (8) reduces to

$$\pi(S) = S\left(\frac{1}{f(-S)} - \frac{1}{f(S)}\right). \tag{9}$$

If $S = 0$, then $\pi(S) = 0$. This means that nonintervention in the foreign exchange market yields zero profit. If China chooses to have a trade surplus in the first period, then $\varepsilon < 1$ and $S > 0$.

Since $\varepsilon = f(S)$ is a decreasing function of *S* and *S* is positive in the first period, we have $f(-S) > f(0) > f(S)$, or $\varepsilon_2 > 1 > \varepsilon_1$, and

$$\frac{1}{f(-S)} - \frac{1}{f(S)} < 0, \quad \text{if } S > 0.$$

Thus, $\pi(S) < 0$ for all S > 0. Alternatively, if $S < 0$, then $f(S) > f(-S) > 0$, or $\varepsilon_1 > 1 > \varepsilon_2$, and

$$\frac{1}{f(-S)} - \frac{1}{f(S)} > 0, \quad \text{if } S < 0.$$

Thus, $\pi(S) < 0$ for all S < 0. Therefore, zero trade surplus is the *global* optimal solution to the profit maximization problem in (9). This result is summarized below:

Proposition 1. If $r = 0$, then the optimal trade surplus is zero. That is, neither a trade surplus nor a deficit in the first period is optimal.

Next, consider the general case where the interest rate is positive. Note that since the exchange rate cannot be zero, as depicted in Figure 1, $\varepsilon = f(S)$ approaches the horizontal axis asymptotically as S increases. Differentiating (8) with respect to S gives

$$\pi'(S) = \frac{1+r}{f\left(-S(1+r)\right)} - \frac{1}{f(S)} + S\left(\frac{(1+r)^2 f'\left(-S(1+r)\right)}{f^2\left(-S(1+r)\right)} + \frac{f'(S)}{f^2(S)}\right). \qquad (10)$$

Evaluating (10) at $S = 0$, we get

$$\pi'(0) = \frac{1+r}{f(0)} - \frac{1}{f(0)} = \frac{r}{f(0)} = r > 0. \qquad (11)$$

This implies that profit is increasing in S when evaluated at $S = 0$. Since $\pi(0) = 0$ and marginal profit is increasing in S at S = 0 (i.e., $\pi'(0) > 0$), the optimal profit must be positive, $\pi(S^{opt}) > \pi(0) = 0$. However, when $S < 0$, note that $\varepsilon_2 < \varepsilon_1$ and

$$\pi(S) = S\left(\frac{1+r}{\varepsilon_2} - \frac{1}{\varepsilon_1}\right) = S\left(\frac{(1+r)\varepsilon_1 - \varepsilon_2}{\varepsilon_1\varepsilon_2}\right) < S\left(\frac{(1+r)\varepsilon_1 - \varepsilon_1}{\varepsilon_1\varepsilon_2}\right) < 0,$$

Thus, $\pi(S) < 0$ for $S < 0$. Therefore, the globally optimal policy must be a trade surplus.

Proposition 2. If $r > 0$, then an optimal policy is a trade surplus $S > 0$ and the optimal exchange rate ε_1 in the first period is below unity, i.e., $\varepsilon_1 < 1$.

1.5 The Limiting Surplus Share Model

We now consider a model that imposes limits to the trade surplus share. The reduced form exchange rate equation in (3) indicates that China's trade depends on the exchange rate and U.S. GDP. Let a be the upper physical limit of China's trade surplus share of U.S. GDP. For instance, if $a = .1$, then China's trade surplus can never exceed 10 percent of U.S. GDP.

The yuan-dollar exchange rate function $\varepsilon = f(S)$ takes a specific form:

$$\varepsilon_i = 1 - \frac{s_i}{a}, \tag{12}$$

where $s_i = S_i / Y^*$ is China's trade surplus share of U.S. GDP. Profit from currency intervention is

$$\pi = \frac{S(1+r)}{\varepsilon_2} - \frac{S}{\varepsilon_1}. \tag{13}$$

In the second period, China incurs a trade deficit, equal to $S_2 < 0$. Thus, profit is written as:

$$\pi = saY^*\left(\frac{ar - 2s(1+r)}{(a+s+sr)(a-s)}\right). \tag{14}$$

Recall that $s < a$. If $r = 0$, then

$$\pi = saY^*\left(\frac{-2s}{(a+s)(a-s)}\right) = \frac{-2s^2 aY^*}{a^2 - s^2} \leq 0 \tag{15}$$

which is nonpositive. Thus, if r = 0, nonintervention is optimal as indicated by Proposition 2.

Next, assume $r > 0$. If $s = 0$, then $\pi = 0$, and if $0 < s < \frac{ar}{2(1+r)}$, then $\pi(s) > 0$. Thus, a small trade surplus can yield positive profit, as indicated by Proposition 2.

In Figure 1.2, profit on the vertical axis is expressed as a function of *S* on the horizontal axis. To determine an appropriate value of *a* in equation (12), we choose the year with trade balance. In 1995, China's trade surplus was the lowest ($1.6 billion) and hence China should be deemed to have achieved trade balance. Also, China's GDP was 9.9 percent of U.S. GDP that year.

Given *Y** = $10 trillion, optimal trade surplus is approximately $10 billion, and the intervention profit is about .29 billion yuan, which amounts to about $.29 billion when evaluated at the equilibrium exchange rate. Note that the optimal trade surplus of $10 billion is roughly 0.1 percent of U.S. GDP.

1.6 PRACTICAL LIMITS TO DEVALUATION

How high is the optimal trade surplus? Recall that the market clearing yuan-dollar exchange rate in each period is assumed to be unity, i.e., $\varepsilon^o = 1$. From Proposition 2, we know optimal trade surplus S in the first period is positive. Recall that $\pi(S) = 0$ at $S = 0$, and profit is increasing in S at $S = 0$ ($\pi'(0) > 0$). Thus, an optimal trade surplus S_1 and profit $\pi(S_1)$ in the first period are both positive. From the profit function in (8), profit for the optimal level of trade surplus S is positive, i.e.,

$$\pi(S_1) = S_1\left(\frac{1+r}{f\left(-S_1(1+r)\right)} - \frac{1}{f(S_1)}\right) > \pi(0) = 0. \tag{16}$$

Let $A(S) \equiv \dfrac{1+r}{f\left(-S_1(1+r)\right)} - \dfrac{1}{f(S_1)}$ denote per unit or average profit of holding a trade surplus in the first period. Since $S_1 > 0$, this implies unit profit is positive, i.e.,

$$A(S) = \frac{(1+r)f(S_1) - f\left(-S_1(1+r)\right)}{f\left(-S_1(1+r)\right)f(S_1)} > 0. \tag{17}$$

Thus,

$$(1+r)f(S_1) > f\left(-S_1(1+r)\right) > f(0), \tag{18}$$

since $f(S)$ is a decreasing function of S. Thus, $(1+r)f(S_1) > f(0)$.

Since $\varepsilon^o = f(0) = 1$ by assumption, we get

$$\varepsilon_1 > \frac{1}{1+r}. \tag{19}$$

That is, the optimal exchange rate in the first period is less than unity by Proposition 2, but (19) implies that there is a lower bound for the optimal exchange rate.[8]

Proposition 3. If $r > 0$, then the optimal exchange rate has a lower bound,

$\varepsilon_1^{opt} > \frac{1}{1+r}$, which is independent of trade surplus.

Note that $\frac{1}{1+r} = \frac{1-r}{1-r^2} > 1-r$. Let ε represent δ percent depreciation from the equilibrium exchange rate, $\varepsilon = 1$, i.e., $\varepsilon = 1-\delta$. Then $1-\delta > \frac{1}{1+r}$, or

$$r > \frac{r}{1+r} > \delta. \tag{20}$$

Thus, the optimal exchange rate must be greater than $(1-r)$. Note that if the devaluation rate below the equilibrium were equal to the interest rate, profit is already negative, i.e., if $r = \delta$, $\pi(S_1) < 0$. Thus, for example, if the interest rate is 5 percent, the optimal depreciation rate is below 5 percent, and $\varepsilon_1^{opt} > 0.95$. That is, the exchange rate should be devalued no more than 5 percent from the equilibrium value.

We now consider a practical upper bound for trade surplus. In the linear model, from (18), we get $(1+r)\varepsilon_1 > 1$. Since $\varepsilon_1 > \frac{1}{1+r}$ and $r > \frac{r}{1+r}$, we have

$$r + \varepsilon_1 > 1. \tag{21}$$

[8] Note that in Figure 1, the exchange rate is a decreasing function of *S*, and an optimal trade surplus is positive, so we have $f(0) > f(S_1)$. Thus, $(1+r)f(0) > (1+r)f(S_1) > f\left[-S_1(1+r)\right]$. Thus, (18) implies $(1+r) > \varepsilon_2^o > 1$, where ε_2^0 is the exchange rate in the second period resulting from the optimal exchange rate in the first period.

In the limiting surplus share model, from (12) we get $s_1 / a = 1 - \varepsilon_1$. Thus, (21) reduces to $r + 1 - s_1 / a > 1$, or

$$s_1 < ar. \tag{22}$$

This means that when a conservative limit $a = .1$ is chosen, China's surplus share of U.S. GDP must be below one-tenth of the interest rate on U.S. Treasury bills.

Figure 1.3 shows that China's trade surplus share of U.S. GDP has been below the interest rate on U.S. Treasury bills until 2002. China's trade surplus share of U.S. GDP followed roughly the optimal path of (10 percent of) the interest rates on U.S. Treasury bills until 2002, but have since diverged greatly. In 2008, an upper limit of China's trade surplus share of U.S. GDP should have been about 0.16 percent, but China's actual trade surplus share rose to 2.88 percent, and the actual trade surplus amounted to $412 billion dollars in 2008, and U.S. GDP was $14.30 trillion. These mounting trade surpluses clearly are outside the profitable range, suggesting that China's currency policy is not motivated by profit considerations.

Since China's economy has been steadily growing, a more liberal limit of $a =$ 40 percent might be chosen. China's trade surplus share has been less than $ar = .4r$ until 2006, but has since exceeded even this liberal limit.

1.7 Concluding Remarks

We have explored the gains from currency intervention for a small, open Keynesian economy. In a two-period framework, if a country incurs a trade surplus, it is invested in the US treasury bills earning some interest income. Such foreign assets eventually must be used up in the subsequent period at a different exchange rate. Thus, there exists the possibility for China either to make profits or incur losses.

We have shown that if the interest rate is zero, the optimal trade surplus is zero. If the interest rate is positive, then a small country can make profits from devaluing its currency below the equilibrium rate in the first period. In this case, the associated optimal trade surplus is positive. However, there is a lower bound for the optimal exchange rate, and hence an upper bound for a trade surplus. If the interest rate is 5 percent, then the optimal exchange rate requires a devaluation of not more than 5 percent from the equilibrium exchange rate for balanced trade.

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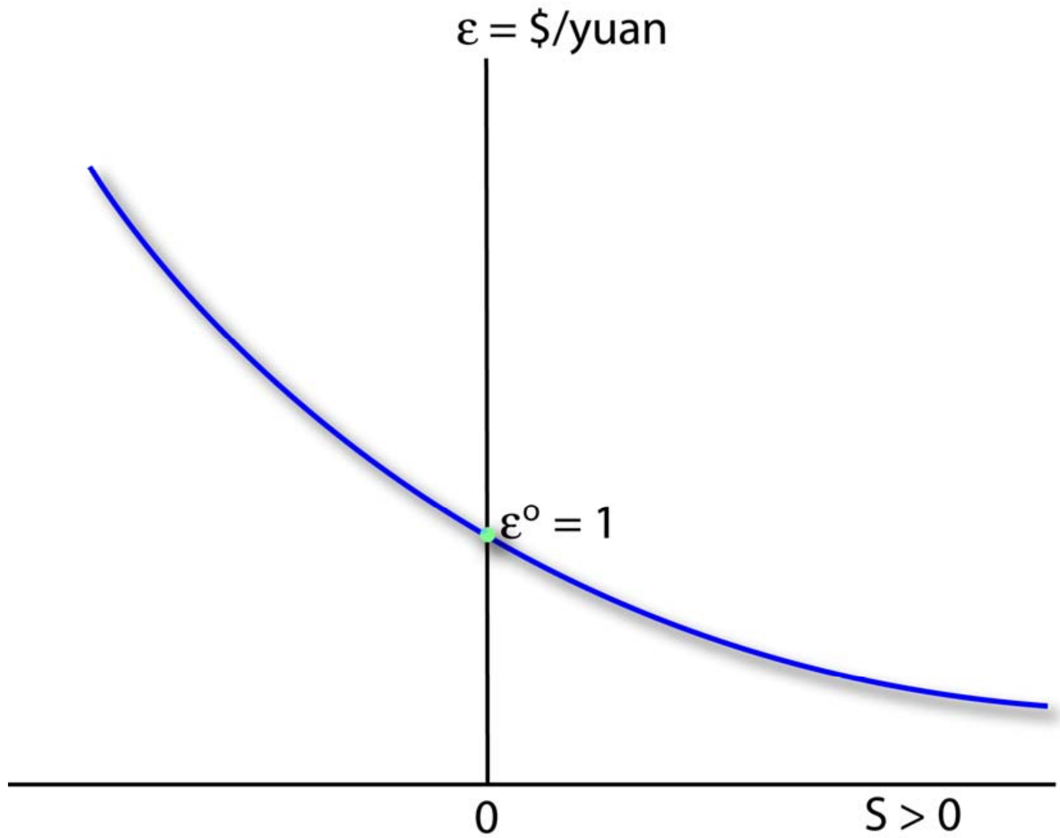

Figure 1.1: Exchange Rate and Trade Surplus

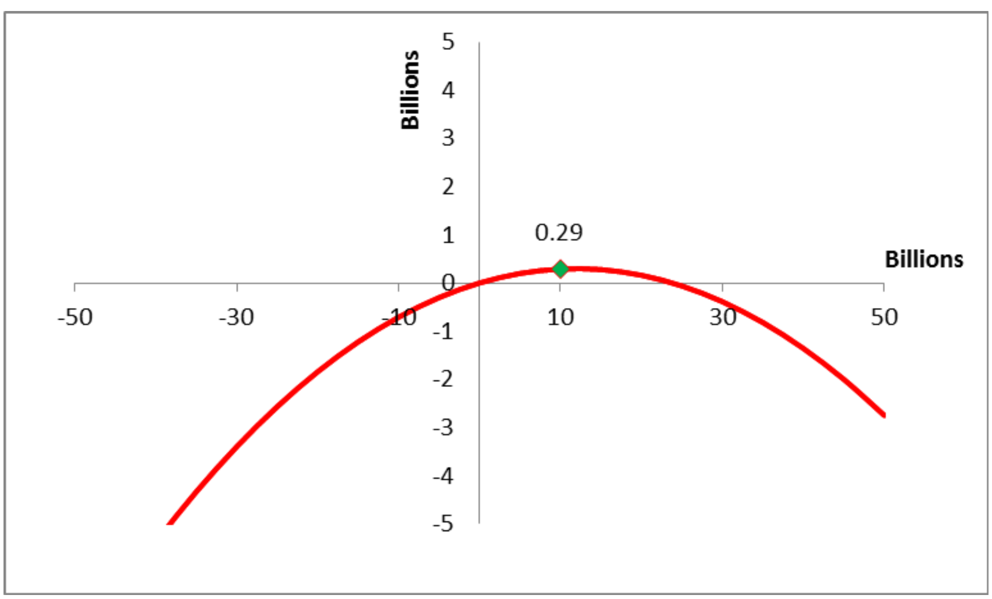

Figure 1.2: Profit and Trade Surplus ($r = 0.05$)

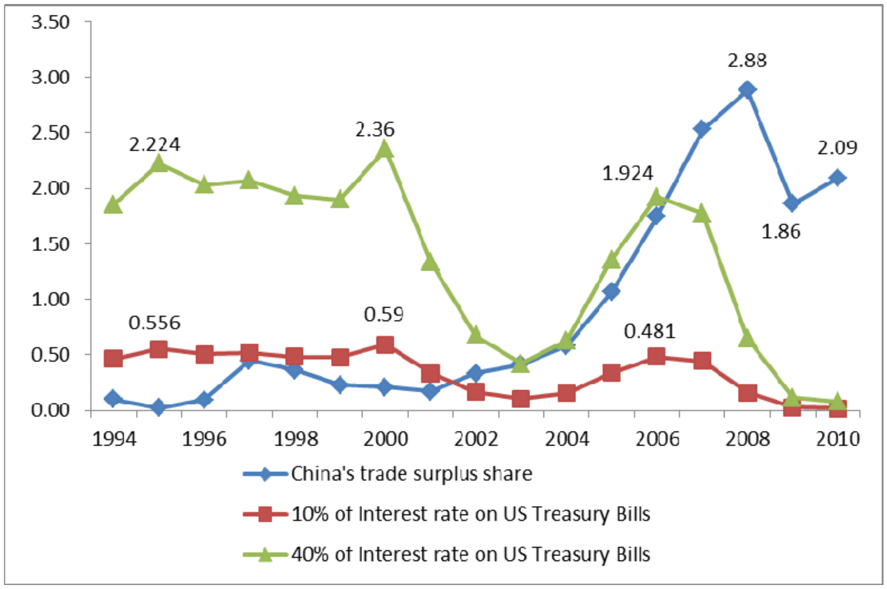

Figure 1.3: China's Trade Surplus Share of U.S. GDP and Interest Rate
Source: World Development Indicators online Database, World Bank, and Board of Governors of the Federal Reserve System.

Chapter 2: China's Profits and Losses from Currency Intervention, 1994-2011

Hailong Jin and E. Kwan Choi

2.1 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 2007 has lost a massive amount from the currency market.

2.2 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. 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, reserves cannot grow indefinitely in a stationary equilibrium. Since reserves are bought and sold at different exchange rates. Hence, the central bank may suffer losses from such intervention.

Many monetarists suggest that a central bank should make positive profits from currency intervention to maintain price stability (e.g., Friedman, 1953). They argue that "the central bank has an information advantage over other market participants; it also intervenes to straighten out destabilizing behavior such as 'disorderly markets'" (Sweeney, 1997, pp. 1668, Taylor, 2005)." Although few governments admit currency intervention is motivated by profitability, but it is used as a measure of success. For instance, Leahy (1995) and Fatum and Hutchison (2006) analyzed profits of currency intervention by the US and Japan, respectively. However, profits and losses from currency intervention by the China's central bank have not received any attention in the literature.

There are two main differences between speculation by private investors and the People's Bank of China (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 deliverable forward currency market for yuan exists due to its regulated status.[9] 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

[9] Because of recent internationalization attempts, China is allowing the offshore market for the RMB-denominated assets. Also, nondeliverable forwards (NDFs) exist in yuan. However, not all non-convertible currencies have a NDF market, which exists in some countries where forward foreign exchange trading is banned by the government.

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; Ghosh and Arize, 2003). We demonstrate that while profits from currency intervention were positive in the 1990s, China has lost a phenomenal sum since 2007.

2.3 Effects of Yuan Appreciation on China's Trade Surplus

Assume that China is an open Keynesian economy in each period 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:

$$Y_i = C_i + I_i + G_i + \left(x_i / \varepsilon_i - q_i\right),$$

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

$$S_i \equiv x(P_i,\varepsilon_i,Y_i^*) - \varepsilon_i q(P_i,\varepsilon_i,Y_i), \qquad (23)$$

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 $F(d, r)$ be capital or financial inflow in dollars, including direct investment, portfolio investment and short-term capital flow, excluding reserve account activities, where *d* and *r* are domestic and foreign interest rate, respectively. A balance of payments (BP) surplus is written as

$$S_i + F_i = X(\varepsilon_i, Y^*) - \varepsilon_i Q(\varepsilon_i, Y_i) + F_i. \tag{24}$$

We first consider the gains from currency intervention in a two-period framework. In a stationary equilibrium reserves cannot grow indefinitely. Thus, we assume a balance of payments surplus in one period is offset by a deficit in the next period. Trade surplus arising from any currency intervention directly affects aggregate expenditure.

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, $X(\varepsilon_i, Y^*) - \varepsilon_i Q(\varepsilon_i, Y_i) + F(d_i, r_i) = 0$.

Note that Y_i depends on S_i and ε_i, i.e., $Y_i = Y_i(S_i, \varepsilon_i, Y^*)$. Equation (24) 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,

$$\varepsilon_i = g(S_i + F_i, Y^*). \tag{25}$$

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

$$\varepsilon_i = f(S_i + F_i), \tag{26}$$

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 $Y_i \equiv Y_i\left(S_i(\varepsilon_i), \varepsilon_i\right)$. The reduced form of China's import may be written as $Q(\varepsilon_i) \equiv Q\left(\varepsilon_i, Y_i(\varepsilon_i)\right)$. Differentiating (24) with respect to ε and suppressing *i* gives:

$$S_\varepsilon = X_\varepsilon - \varepsilon Q_\varepsilon - Q, \tag{27}$$

where subscripts denote partial derivatives. Given that the Marshall-Lerner condition holds,[10] the trade surplus function is negatively sloped, as shown in Figure 2.1. This implies $S_\varepsilon < 0$ and $f'(S) < 0$.

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. Recall that $F(d, r)$ is capital

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[10] China's trade surplus in dollars decreases as yuan appreciates if $\eta_{X\varepsilon} + \eta_{Q\varepsilon} < 1$, where $\eta_{X\varepsilon} \equiv \left(\partial X / \partial \varepsilon\right)(\varepsilon / X)$ and $\eta_{Q\varepsilon} \equiv -\left(\partial Q / \partial \varepsilon\right)(\varepsilon / Q)$ denote elasticity of exports and imports with respect to the exchange rate ε. It can be shown that China's trade surplus in yuan also decreases under the same condition.

inflow. If net capital inflow is positive, it shifts the balance of payments curve, $S+F$, to the right, as shown in Figure 2.1.

2.4 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 BP surplus or deficit occurs. For instance, China may choose to devalue yuan below the equilibrium and invest the resulting BP surplus in the United States. Nevertheless, reserves cannot grow indefinitely in a stationary equilibrium. 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. Subsequently, this assumption is relaxed for multi-period analyses.

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. 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 $(S+F)\left(1+r\right)/\varepsilon_2$,

where $\varepsilon_2 = f\left(-(S+F)(1+r)\right)$ is the exchange rate in the second period.

The total profit realized from currency intervention is:

$$\pi(S+F) = \frac{(S+F)(1+r)}{\varepsilon_2} - \frac{S+F}{\varepsilon_1} = (S+F)\left(\frac{1+r}{f\left(-(S+F)(1+r)\right)} - \frac{1}{f(S+F)}\right). \tag{28}$$

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 $C_1 = S_1 + F_1$. 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_i is the US 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:

$$\pi_1(C_1, r_1, \varepsilon_1, \varepsilon_2) = \frac{(S+F)(1+r_1)}{\varepsilon_2} - \frac{S+F}{\varepsilon_1} = \frac{C_1(1+r)}{\varepsilon_2} - \frac{C_1}{\varepsilon_1}. \tag{29}$$

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 renminibi 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:

$$\pi_2(C_2, r_2, \varepsilon_2, \varepsilon_3) = \frac{C_2(1+r_2)}{\varepsilon_3} - \frac{C_2}{\varepsilon_2}. \tag{30}$$

Similarly, the annual profit in period N is

$$\pi_N\left(C_N, r_N, \varepsilon_N, \varepsilon_{N+1}\right) = C_N\left(\frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}}\right). \tag{31}$$

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 (31), annual accounting profits depend on ε_N, ε_{N+1} and r_N. Differentiating (31) with respect to r_N yields

$$\frac{\partial \pi_N}{\partial r_N} = \left(\frac{1}{\varepsilon_{N+1}} + \frac{1}{\varepsilon_N^2} \frac{\partial \varepsilon_N}{\partial r_N} \right) C_N + \frac{\partial F_N}{\partial r_N} \left(\frac{1+r_N}{\varepsilon_{N+1}} - \frac{1}{\varepsilon_N} \right). \tag{32}$$

Provided that $C_N > 0$, the first term is positive. For the second term, if ε_i satisfies the fundamental martingale property, i.e., $E\left(\varepsilon_{N+1} \mid \varepsilon_1, \cdots, \varepsilon_N\right) = \varepsilon_N$, then by Jensen's inequality, $E_N\left(\frac{1}{\varepsilon_{N+1}}\right) \geq \frac{1}{\varepsilon_N}$, and hence $E_N\left(\frac{1+r_N}{\varepsilon_{N+1}}\right) - \frac{1}{\varepsilon_N} \geq \frac{r_N}{\varepsilon_N} > 0$. Since $\frac{\partial F_N}{\partial r_N} < 0$, the second term on the RHS is positive on average. The sign on the RHS is indeterminate.

Differentiating (31) with respect to ε_N and ε_{N+1}, we get

$$\frac{\partial \pi_N}{\partial \varepsilon_N} = \frac{\partial S_N}{\partial \varepsilon_N} \frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}} + \frac{C_N}{(\varepsilon_N)^2} > 0, \tag{33}$$

$$\frac{\partial \pi_N}{\partial \varepsilon_{N+1}} = -\frac{C_N (1+r_N)}{(\varepsilon_{N+1})^2} < 0. \tag{34}$$

Thus, as yuan appreciates, other things equal, expected 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:

$$\eta_{\pi\varepsilon_{N+1}} \equiv \frac{\varepsilon_{N+1}}{\pi_N} \frac{\partial \pi_N}{\partial \varepsilon_{N+1}} = -\frac{\varepsilon_N (1+r_N)}{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}. \tag{35}$$

Suppose the interest rate were .1 percent (as in 2011) and yuan were undervalued by 10 percent. Then a 1 percent yuan appreciation (from ε =.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 ε = .9 to .91) reduces profit by 27 percent.

These examples suggest that annual 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 and current account data were obtained from the State Administration of Foreign Exchange.[11] The 1994-2011 yuan-dollar exchange rate data are obtained from the World Development Indicators database. To calculate the annual and cumulative profits in 2011, the yuan-dollar exchange rate on July 2, 2012 was used as proxy for the unknown average exchange rate 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 annual profits from currency intervention. Six-month interest rates on U.S. Treasury bills were used as the annual interest rates.[12]

Annual Accounting Profits Financial Flow

Based on Equation (9), we calculated China's annual profits from currency intervention for the period, 1994-2011. The results are listed in Table 2.1. Goldstein and Lardy (2009) 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)."

[11] This data excludes gold from the international reserve assets.
[12] Interest rate data on the 1-year Treasury bills were not available in certain years.

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 2.1 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, 843 billion yuan ($125 billion) in 2010, and 447 billion yuan ($69 billion) in 2011. This amount should be compared to the actual current account surplus of $202 billion in 2011.

Annual Accounting Profits without Financial Flow

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. If no financial flow occurs, i.e., $F_i = 0$, for all i = 1, …, N, then equation (31) reduces to:

$$\pi_N\left(C_N^S, r_N, \varepsilon_N, \varepsilon_{N+1}\right) = C_N^S\left(\frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}}\right). \quad (36)$$

where C_N^S denotes China's FX caused by trade surplus and is estimated by:

$C_N^S = C_{N-1}(1+r_{N-1}) + S_N$, given $C_{1993} = 0$.

Table 2.2 shows that the annual accounting profits without the financial flow also were near zero in 2006, and have since decreased to: -641 billion yuan in 2010. This is somewhat less than -843 billion yuan 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.

2.5 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

$\frac{C_2}{\varepsilon_2} = \frac{C_1(1+r_1) + S_2 + F_2}{\varepsilon_2}$. Note that if China were to liquidate its currency reserve, then

$S_2 + F_2 = -(S+F)(1+r)$ 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:

$T_2 = \frac{S_2 + F_2}{\varepsilon_2} + \frac{S_1 + F_1}{\varepsilon_1}$.

PBC, as China's central bank, does not pay interest. Unlike private speculators, PBC simply prints yuan to buy foreign currencies.[13] No deliverable forward currency market for yuan exists due to its regulated status.

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

[13] This constitutes an increase in money supply to affect the yuan-dollar exchange rate. PBC issues a certain amount of new money each year. Some of it is used to buy foreign exchange from commercial banks, and is called the "Funds outstanding for foreign exchange" by PBC.

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:

$$\Pi_2 = \frac{C_2(1+r_2)}{\varepsilon_3} - \left(\frac{S_2+F_2}{\varepsilon_2} + \frac{S_1+F_1}{\varepsilon_1}\right). \quad (37)$$

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 $S_2 + F_2 = -(S_1 + F_1)(1+r)$ and $C_2 = 0$, and equation (37) reduces to (8), and the accounting profit reduces to the actual or realized profit,

$$\Pi_1 = \frac{(S_1+F_1)(1+r_1)}{\varepsilon_2} - \frac{S_1+F_1}{\varepsilon_1}. \quad (38)$$

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

$$C_2 = C_1(1+r_1) + S_2 + F_2,$$

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:

$$\frac{C_N(1+r_N)}{\varepsilon_{N+1}}. \qquad (39)$$

Cumulative Accounting Profits

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

Thus, the cumulative accounting profit in yuan is:

$$\Pi_3 = \frac{C_3(1+r_3)}{\varepsilon_4} - \left(\frac{S_3 + F_3}{\varepsilon_3} + \frac{S_2 + F_2}{\varepsilon_2} + \frac{S_1 + F_1}{\varepsilon_1} \right). \qquad (40)$$

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

$$F_N = \sum_{i=1}^{N} \frac{S_i + F_i}{\varepsilon_i}. \qquad (41)$$

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

$$\Pi_N = \frac{C_N(1+r_N)}{\varepsilon_{N+1}} - \sum_{i=1}^{N} \frac{S_i + F_i}{\varepsilon_i}. \qquad (42)$$

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 $C_2 = C_1(1+r_1) + S_2 + F_2$. Thus, $S_2 + F_2 = C_2 - C_1(1+r_1)$. Likewise, $S_N + F_N = C_N - C_{N-1}(1+r_{N-1})$, $N > 1$, and $S_1 + F_1 = C_1$. Thus, we have

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

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 3 to compute the cumulative accounting profits.

Differentiating (42) with respect to ε_N gives

$$\frac{\partial \Pi_N}{\partial \varepsilon_N} = \frac{\partial \pi_N}{\partial \varepsilon_N} + \frac{\partial \pi_{N-1}}{\partial \varepsilon_N} = \frac{\partial S_N}{\partial \varepsilon_N} \frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}} + \frac{C_N}{(\varepsilon_N)^2} - \frac{C_{N-1}(1+r_{N-1})}{(\varepsilon_N)^2}$$
$$= \frac{\partial S_N}{\partial \varepsilon_N} \frac{(1+r_N)\varepsilon_N - \varepsilon_{N+1}}{\varepsilon_N \varepsilon_{N+1}} + \frac{S_N + F_N}{(\varepsilon_N)^2} > 0. \tag{43}$$

and from (11) and (12), we also have

$$\frac{\partial \Pi_N}{\partial \varepsilon_{N+1}} = \frac{\partial \pi_N}{\partial \varepsilon_{N+1}} < 0.$$

Table 2.3 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 1,399 billion yuan (or about $217 billion) in 2011, and are expected to rise further as the yuan appreciates. In 2011, the cumulative accounting loss rose to 1,128 billion yuan, or close to $179 billion without the financial flow. Again, inclusion of the financial flow does not make much difference in the cumulative accounting profits.

2.6 Concluding Remarks

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.

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 1,399 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.

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Table 2.1: China's Annual Profits from Currency Intervention, 1994-2011

	Exchange Rate ($/RMB)	Interest Rate (%)	China FX ($Billion)	Annual Profit (Billion Yuan)
1994	0.1160	4.64	52.9	6.0
1995	0.1198	5.56	75.4	32.2
1996	0.1203	5.08	107.0	42.9
1997	0.1206	5.18	142.8	59.3
1998	0.1208	4.83	149.2	59.7
1999	0.1208	4.75	146.2	57.5
2000	0.1208	5.90	165.6	80.9
2001	0.1208	3.34	212.2	58.7
2002	0.1208	1.68	286.4	39.8
2003	0.1208	1.05	403.3	35.1
2004	0.1208	1.58	609.9	29.3
2005	0.1220	3.39	818.9	39.4
2006	0.1254	4.81	1,066.3	2.1
2007	0.1314	4.44	1,528.2	-546.4
2008	0.1440	1.62	1,946.0	-6.2
2009	0.1464	0.28	2,399.2	-98.8
2010	0.1477	0.20	2,847.3	-843.0
2011	0.1548	0.10	3,181.1	-447.2
2012	0.1584			

Table 2.2: China’s Annual Profits from Currency Intervention without Financial Flow

	Current Account ($ Billion)	Estimated FX ($ Billion)	Annual Profit (Billion Yuan)
1994	7.7	7.7	0.9
1995	1.6	9.6	4.1
1996	7.2	17.4	7.0
1997	37.0	55.3	23.0
1998	31.5	89.6	35.8
1999	21.1	115	45.2
2000	20.5	141	68.9
2001	17.4	166.7	46.1
2002	35.4	207.7	28.9
2003	45.9	257.1	22.3
2004	68.7	328.5	15.8
2005	134.1	467.7	22.5
2006	232.7	716.3	1.4
2007	354.0	1,104.8	-395.0
2008	412.4	1,566.2	-5.0
2009	261.1	1,852.7	-76.3
2010	305.4	2,163.3	-640.5
2011	201.7	2,369.3	-333.1

Table 2.3: China's Cumulative Profits from Currency Intervention (billion yuan)

	With Financial Inflow	Without Financial Inflow
1994	6.0	0.9
1995	38.3	5.0
1996	81.1	12.0
1997	140.4	34.9
1998	200.0	70.7
1999	257.5	115.9
2000	338.4	184.8
2001	397.1	230.9
2002	436.9	259.8
2003	472.0	282.1
2004	501.3	297.9
2005	540.7	320.4
2006	542.7	321.8
2007	-3.7	-73.2
2008	-9.9	-78.2
2009	-108.7	-154.5
2010	-951.6	-794.9
2011	-1,398.8	-1,128.0

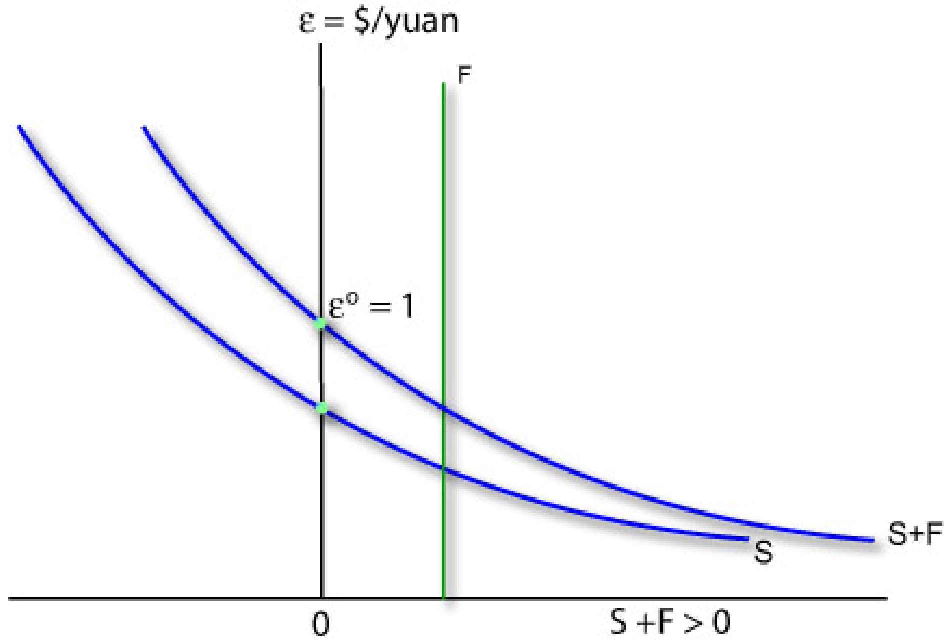

Figure 2.1: Exchange Rate and Balance of Payments Surplus

Chapter 3: Currency Intervention and Consumer Welfare in an Open Economy

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3.1 ABSTRACT

This paper investigates whether China can benefit from a trade surplus (deficit) in one period and use it to pay off the debt in the next period by manipulating the exchange rates. If marginal utility of income is nonincreasing in the exchange rate, then the optimal exchange rates are the equilibrium rates that yields trade balance each period. Numerical examples using the Cobb-Douglas and CES utility functions illustrate the main proposition.

3.2 INTRODUCTION

Due to mounting currency reserves since the 1990s, China's currency policy has been under intense scrutiny. People's Bank of China (PBC) closed the currency swap market,[14] and began to regulate renminbi on January 1, 1994 by moving the official rate to the then prevailing swap market rates (Goldstein and Lardy 2009, page 6). According to State Administration of Foreign Exchange of PBC, China's foreign exchange reserve, which excludes gold, was $22 billion in 1993.

China's foreign exchange reserve has since increased steadily, reaching $166 billion in 2000. However, during the first decade of this century, China's foreign exchange reserve rose dramatically to $3.3 trillion as of December 2011. Such a meteoric rise in China's cumulative trade surplus has provoked much debate concerning China's currency valuation and

[14] Goldstein and Lardy (2009, pp. 5-6) noted that before 1994, the swap market was sanctioned by the Chinese government to settle trade transactions. It helped the Chinese government find the equilibrium exchange rate.

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, 2011)

Most major currencies are freely floating vis-à-vis other currencies, except renminbi. There might possibly be some gains from currency intervention in the foreign exchange market. For example, Gylfason and Schmid (1983) show that devaluation has positive output effects in a study of ten countries. Currency devaluation raises a country's trade surplus temporarily. However, any foreign currency reserve so accumulated must eventually be used up, and sold at different exchange rate.

Ghosh (1997) argued that a sharp trader can make profits in currency trading by utilizing the forward contracts on foreign currency. Ghosh and Arize (2003) suggested the present value concept to compute profits from speculation. However, Jin and Choi (2012) noted that while some profits might be generated by slightly deviating from the equilibrium exchange rates, but excessive hoarding of reserve assets can only result in huge losses.

The purpose of this paper is to investigate optimal currency pegging to a single currency. Section 3.2 considers the effect of yuan appreciation on trade deficit. Section 3.3 investigates optimal currency pegging in a two-period framework. Section 3.4 compares stable exchange rates and yuan appreciation above the equilibrium rate for the case of Cobb-Douglas utility function, whereas Section 3.5 makes the same comparison for the CES utility function. Section 3.6 contains the concluding remarks.

3.3 Exchange Rate and Trade Deficit

In this section we consider the effect of yuan appreciation on trade deficits and welfare to lay the basis for optimal currency pegging that maximize utility over two periods.

Effect of Yuan Appreciation on Trade Deficit

Let the exportable good *C* be the numéraire, i.e., its yuan price $b = 1$, and let ε denote the dollar price of yuan. The dollar price $b^* = \varepsilon$ of the exportable is equal to unity in the benchmark equilibrium. Let *P* be the yuan price of the importable good *Z*. The foreign price of the importable good $P^* = P\varepsilon$ is exogenous. Thus, the relative foreign price of the importable is $P^*/\varepsilon = P,$ equal to the relative domestic price of the importable since there is no tariff.

Let *x* and *q* denote the physical volumes of exports and imports. The dollar value of imports is $qP^* = qP\varepsilon = Q\varepsilon,$ where $Q(\varepsilon) = q(\varepsilon)P$ is the yuan value of imports. China's trade deficit in dollars is written as:

$$D = g(\varepsilon) = qP^* - \varepsilon x = Q(\varepsilon)\varepsilon - X(\varepsilon), \tag{44}$$

where $X = x\varepsilon$ is the dollar value of China's exports.

Differentiating (44) with respect to ε gives

$$D_\varepsilon = Q + \varepsilon Q_\varepsilon - X_\varepsilon, \tag{45}$$

where subscripts denote partial derivatives.

Let $\eta_{X\varepsilon} \equiv (\partial X / \partial \varepsilon)(\varepsilon / X)$ and $\eta_{Q\varepsilon} \equiv -(\partial Q / \partial \varepsilon)(\varepsilon / Q)$ denote elasticity of exports and imports with respect to the exchange rate ε, respectively. Equation (5) can be rewritten as:

$$D_\varepsilon = -\eta_{X\varepsilon}(X/\varepsilon) - \varepsilon\eta_{Q\varepsilon}(Q/\varepsilon) + Q. \tag{46}$$

As yuan appreciates, China's trade deficit is assumed to increase, i.e., $D_\varepsilon > 0.$ When trade is balanced, $X = \varepsilon Q,$ and

$$D_\varepsilon \frac{\varepsilon}{X} = 1 - \eta_{X\varepsilon} - \eta_{Q\varepsilon}.$$

Thus, China's trade deficit in dollars increases as yuan appreciates if

$$\eta_{X\varepsilon} + \eta_{Q\varepsilon} < 1. \tag{47}$$

Note that this is another way of expressing the Marshall-Lerner condition, which states that U.S. trade balance in dollars improves as yuan appreciates. It can be shown that China's trade deficit in yuan also increases under the same condition.[15] We assume that the above condition holds. This implies $D_\varepsilon > 0$ and $f'(D) > 0$. We further assume that China's trade deficit increases at an increasing rate, $f''(D) < 0$, as shown Figure 3.1.

Production and Consumption

Consider an open economy producing two goods over two periods. Let C_i and Z_i denote quantities of the exportable and importable that China produces in period i, $i = 1, 2$. Production possibility frontier is given by $C_i = F(Z_i)$. All resources are assumed to be fully employed, and an optimal output occurs on the frontier. Assume that there are no technological changes so that $F(.)$ is constant over time. Since the yuan price of the exportable C is unity, its dollar price is ε_i in period i. Let P_i^* be the dollar price of China's importable good Z in period i.

In each period, producers are assumed to maximize revenue in dollars from production,

$$R_i = \varepsilon_i C_i + P_i^* Z_i, \tag{48}$$

[15] Let $T = \frac{D}{\varepsilon} = \frac{\varepsilon Q - x}{\varepsilon} = Q - \frac{x}{\varepsilon}$ denote China's trade deficit in yuan. Differentiating T with respect to ε yields

$$T_\varepsilon = x\varepsilon^{-2} - x_\varepsilon / \varepsilon + Q_\varepsilon = x\left(1 - \eta_{x\varepsilon} - \eta_{Q\varepsilon}\right) / \varepsilon^2.$$

Thus, a yuan appreciation increases China's trade deficit in yuan if $\eta_{x\varepsilon} + \eta_{Q\varepsilon} < 1$.

Maximum revenue requires $\varepsilon_i F'(Z_i) + P_i^* = 0$, i.e., the dollar price of the importable is equal to its marginal cost, $-\varepsilon_i F'(Z_i)$. When trade is balanced, consumer expenditure exhausts revenue from production. When yuan appreciates above the equilibrium exchange rate, a trade deficit occurs. Thus, it is the consumers that are incurring trade deficits by consuming more than the economy produces. On the other hand, when a trade surplus is generated, consumers spend less by the amount of trade surplus.

Consumer preferences are represented by a stationary utility function, $U(c_i, z_i)$, where where c_i and z_i are China's consumption of the exportable and importable, respectively. When trade is balanced, the budget constraint in dollars is given by:

$$\varepsilon_i c_i + P_i^* z_i = \varepsilon_i C_i + P_i^* Z_i. \qquad (49)$$

Let $D_i = P_i^* q_i - X_i$ denote trade deficit in dollars in period i, where X_i is the value of exports, and q_i is the physical volume of imports. Consumer expenditure in dollars is $\varepsilon_i c_i + P_i^* z_i$. When trade is balanced, $D_i = 0$, and consumer expenditure is equal to producer revenue, R_i. When the country has a trade deficit ($D_i > 0$), the total expenditure reduces to

$$R_i + D_i = \varepsilon_i c_i + P_i^* z_i. \qquad (50)$$

If China incurs a trade deficit ($D_i > 0$), its expenditure will be greater than if trade is balanced.

Recall that the exportable is the numéraire and its yuan price is unity while its dollar price is ε. Yuan revenue from production is $Y = C + PZ$. Production revenue in dollars is $R = \varepsilon C + P^* Z = \varepsilon Y$. In the absence of trade barriers, maximizing revenue in dollars is equivalent to maximizing revenue in yuan. From the budget constraint in (50), the total yuan expenditure in period *i* is given by

$$c_i + P_i z_i = (R_i + D_i) / \varepsilon_i, \tag{51}$$

The equilibrium condition for optimal consumption in each period is:

$$\frac{U_c^i}{U_z^i} = \frac{1}{P_i} = \frac{\varepsilon_i}{P_i^*}, \; i = 1, 2$$

China's consumer demands in period *i* are written as: $c_i = c(\varepsilon_i, P_i^*, R_i + D_i),$ and $z_i = z(\varepsilon_i, P_i^*, R_i + D_i).$ Since yuan appreciation has no effect on the dollar price of the importable good, we now suppress P_i^*.

Consumer demands are now written as: $c_i = c(\varepsilon_i, R_i + D_i),$ and $z_i = z(\varepsilon_i, R_i + D_i).$

Likewise, the indirect utility is written as: $V_i(\varepsilon_i, R_i + D_i) = U\left(c(\varepsilon_i, R_i + D_i), z(\varepsilon_i, R_i + D_i)\right).$

3.4 Optimal Exchange Rates

We consider a two-period model of currency intervention. Assume that no economic growth occurs over two periods, i.e., the production function $C = F(Z)$ is stationary. In a stationary equilibrium, a country cannot accumulate a trade surplus or deficit indefinitely. Thus, if China incurs a current account deficit in the first period ($D > 0$), the principal plus interest is paid off in the next period. Alternatively, if it incurs a trade surplus in the first period, $D < 0$, and it is invested in the U.S. Any investment plus interest income so obtained is used up in the next period. We assume that the world economy is stable, and the price of the importable, *P**, remains unaffected when China changes its peg to the dollar. This means that a yuan appreciation only affects the dollar price of China's exports. Since the price of the importable is stable, $P_1^* = P_2^* = P*,$ and there is no tariff on imports, producer revenue in dollars depends on the exchange rates. Specifically, $R_1 = \varepsilon_1 C_1 + P^* Z_1$, and $R_2 = \varepsilon_2 C_2 + P^* Z_2$. See Figure 3.2.

We now consider optimal exchange rates over two periods. In the benchmark scenario, the policy maker chooses stable exchange rates over the two periods, i.e., $\varepsilon_1 = \varepsilon_2 = \varepsilon^o = 1$. If China maintains stable exchange rates, trade will be balanced in both periods. Alternatively, the country may allow yuan to appreciate above unity in the first period, which yields a trade deficit. However, any trade deficit D must be borrowed from the U.S. and the debt grows to $D(1+r)$, which must be completely paid off in the second period. That is, a trade deficit in one period must be offset by a trade surplus in the next period.

Two-Period Budget Constraint

The relationship between trade deficit and the exchange rate is given by $D = g(\varepsilon)$. Any exchange rate below (above) unity results in a trade surplus in the first period. If $\varepsilon_1 = 1$, then trade is balanced in the first period, $D_1 = 0$, which requires $D_2 = 0$, and hence trade also must be balanced in the second period.

We investigate whether China can benefit from a trade deficit or surplus in the first period. This means China pegs renminbi to the dollar above the equilibrium level ($\varepsilon_1 > \varepsilon^o = 1$) in the first period. However, the principal plus interest cost of any trade deficit so generated from this debt in period 1 must be completely paid off in period 2. Thus, a two-period budget constraint is given by

$$D_1(1+r) + D_2 = 0, \qquad (52)$$

The slope of the budget constraint is:

$$\frac{dD_2}{dD_1} = -(1+r) < 0. \tag{53}$$

Devaluation and Utility

Next, we consider the effect of yuan appreciation on consumer welfare. We assume an additive two period-utility function,

$$\Phi \equiv U(c_1, z_1) + \frac{U(c_2, z_2)}{(1+r)}. \tag{54}$$

The inverse trade deficit function $\varepsilon = f(D)$ is assumed to be monotonically increasing and concave. Let $\varepsilon_1 = f(D_1)$ and $\varepsilon_2 = f(D_2)$. The total indirect utility over the two periods is given by

$$\Phi(D_1, D_2) = V\left(f(D_1), R_1 + D_1\right) + \frac{V\left(f(D_2), R_2 + D_2\right)}{1+r} \tag{55}$$

Let D_i be the trade deficit and let $I_i = R_i + D_i$ denote the consumer expenditure in dollars in period *i*, where the subscripts denote time periods. The indirect utility in period 1 is written as:

$$V(\varepsilon_1, R_1 + D_1) = U\left[c_1(\varepsilon_1, R_1 + D_1), z_1(\varepsilon_1, R_1 + D_1)\right]. \tag{56}$$

Similarly, the indirect utility in period 2 is:

$$V\left(\varepsilon_2, R_2 + D_2\right) = U\left[c_2\left(\varepsilon_2, R_2 + D_2\right), z_2\left(\varepsilon_2, R_2 + D_2\right)\right]. \tag{57}$$

Since $f(.)$ is a concave function, its inverse function $D(\varepsilon)$ is a convex function. As yuan appreciates, China's trade deficit increases at an increasing rate. Thus, the total utility is:

$$\Phi = V\left(\varepsilon_1, R_1 + D_1\right) + \frac{V\left(\varepsilon_2, R_2 + D_2\right)}{1+r}. \tag{58}$$

Generating a trade deficit requires a yuan appreciation, which in turn affects producer revenue $R = \varepsilon C + P^* Z$. Maximizing GDP in dollars for given P^* requires $\varepsilon F' + P^* = 0$. From (49), we have

$$\frac{dR_i}{d\varepsilon_i} = C_i + \left(F'(Z_i) + P_i^*\right)\frac{dZ_i}{d\varepsilon_i} = C_i.$$

Differentiating (15) with respect to D_1 and using Roy's identity, $V_\varepsilon = -cV_I$, we obtain

$$\Phi_1 = V_I^1\left((-c_1 + C_1) f'(D_1) + 1\right) = V_I^1\left(x_1 f'(D_1) + 1\right).$$

Likewise,

$$\Phi_2 = V_I^2\left((-c_2 + C_2) f'(D_2) + 1\right)/(1+r) = V_I^2\left(x_2 f'(D_2) + 1\right)/(1+r).$$

The optimization problem is illustrated in Figure 3.3. The slope of the indifference curve is

$$\Phi' = -(1+r)\frac{V_I^1\left(x_1 f'(D_1) + 1\right)}{V_I^2\left(x_2 f'(D_2) + 1\right)}. \tag{59}$$

The optimal solution occurs at a point where the indifference curve is tangent to the budget line, i.e., $\frac{V_I^1\left(x_1 f'(D_1) + 1\right)}{V_I^2\left(x_2 f'(D_2) + 1\right)} = 1$, or

$$\frac{V_I^1}{V_I^2} = \frac{x_2 f'(D_2) + 1}{x_1 f'(D_1) + 1}. \tag{60}$$

We demonstrate that balanced trade is a solution to the maximization problem. When $\varepsilon_1 = \varepsilon_2 = 1$, in equation (59), $x_1 = x_2$, $D_1 = D_2 = 0$, and $f'(D_1) = f'(D_2) = f'(0)$. Moreover, producer revenues are equalized, $R_1 = R_2$, and hence $V_I^1(1, R_1) = V_I^2(1, R_2)$. Thus, $\Phi' = -(1+r)$, which implies that the indifference curve is tangent to the budget constraint.

Note that along the 45 degree line, $D_1 = D_2$, $x_1 = x_2 = x^o$ and $x_1 f'(D_1) = x_2 f'(D_2) = x^o f'(0)$. Thus, marginal utility of income is equalized between the two periods, $V_I^1 = V_I^2$ if, and only if $D_1 = D_2$ along the 45 degree line. This path is analogous to the expansion path in consumer demand theory. The intersection of the 45 degree line and the budget constraint yields the optimal solution.

Next, consider the slope of the indifference curve below the 45 degree line in Figure 3.3 where $D_1 > 0 > D_2$. What is the effect of yuan appreciation on the marginal utility of income? A yuan appreciation enables the Chinese consumer to buy more foreign goods and hence he experiences an increase in real income. We assume that marginal utility of income is nonincreasing in the exchange rate.[16]

Below the 45 degree line, $V_I^1 < V_I^2$ and the LHS of (60) is less than or equal to unity. Note that $D_1 > 0 > D_2$ implies $x_1 < x^o < x_2$. Since $f(D)$ is concave in D, $f'(D_1) < f'(0) < f'(D_2)$. Thus, below the 45 degree line ($D_1 > 0 > D_2$), the right hand side (RHS) of (60) is greater than unity,

$$\frac{x_2 f'(D_2)+1}{x_1 f'(D_1)+1} > 1.$$

Hence, we have

[16] Note that using Roy's identity, we have $V_{I\varepsilon} = V_{\varepsilon I} = \partial(-cV_I)/\partial I = -c_I V_I - cV_{II} \leq 0.$ This implies that $(\partial c/\partial I)(I/c) \geq -IV_{II}/V_I$. The right hand side is often called the relative risk aversion, whereas the left hand side is the income elasticity of demand for the exportable good. In typical trade models, income elasticity of demand is assumed to be unity. Thus, the assumption that yuan appreciation does not lower the marginal utility of income means relative risk aversion is less than unity. If marginal utility of income is constant, relative risk aversion is unity.

$$\frac{V_I^1\left(x_1 f'(D_1)+1\right)}{V_I^2\left(x_2 f'(D_2)+1\right)}<1, \quad \text{for } D_1 > D_2$$

which implies in (59), $\Phi' > -(1+r)$. That is, below the 45 degree line ($D_1 > 0 > D_2$), the indifference curve is flatter than the budget constraint.

Above the 45 degree line, $D_1 < 0 < D_2$ implies $x_1 > x^o > x_2$. Since $f(D)$ is concave in D, $f'(D_1) > f'(0) > f'(D_2)$. Thus, above the 45 degree line ($D_1 < 0 < D_2$), the right hand side (RHS) of (60) is less than unity,

$$\frac{x_2 f'(D_2)+1}{x_1 f'(D_1)+1}<1.$$

Moreover, $V_I^1 > V_I^2$ and the LHS of (60) is greater than unity. Thus,

$$\frac{V_I^1\left(x_1 f'(D_1)+1\right)}{V_I^2\left(x_2 f'(D_2)+1\right)}>1, \quad \text{for } D_2 > D_1.$$

That is, if $D_1 < 0$, then in (59), $\Phi' < -(1+r)$, and the indifference curve is steeper than the budget constraint. Thus, the solution $D_1 = D_2 = 0$ maximizes consumer welfare, and balanced trade is the optimal solution.

Proposition 1: Assume that (i) the policy maker maximizes consumer welfare over two periods, and (ii) yuan appreciation does not increase marginal utility of income. Then the equilibrium exchange rate that yields trade balance each period maximizes the total utility over two periods, regardless of the interest rate.

3.5 The Case of Cobb-Douglas Utility Function

In this section, we construct a Cobb-Douglas utility function which illustrates Proposition 1 that optimal intervention is nonintervention, i.e., the optimal exchange rate is that which yields balanced trade each period. Assume that interest rate is $r = 0.05$. A two-period Cobb-Douglas utility function is

$$U(c_1, z_1) + \frac{U(c_2, z_2)}{1+r} = c_1^{.5} z_1^{.5} + \frac{c_2^{.5} z_2^{.5}}{1+.05}, \tag{61}$$

Consider a production possibility function given by:

$$C^2 + 4Z^2 = 100. \tag{62}$$

Recall that trade is balanced when ε = 1. We assume the dollar price of the importable be $P^* = 1$. Since $C = \phi(Z) = \sqrt{100 - 4Z^2}$, we have $\phi'(Z) = -\frac{4Z}{C} = -P^*/\varepsilon$. This implies $C = 4\varepsilon Z$, and $(4\varepsilon Z)^2 + 4Z^2 = (16\varepsilon^2 + 4)Z^2 = 100$. Thus, $Z = \frac{10}{\sqrt{16\varepsilon^2 + 4}} = \frac{5}{\sqrt{1 + 4\varepsilon^2}}$. and $C = \frac{20\varepsilon}{\sqrt{1+4\varepsilon^2}}$.

Balanced Trade

First, consider the case where trade is balanced, i.e., $\varepsilon^o = 1$. Then $Z^o = \sqrt{5}$ and $C^o = 4\sqrt{5}$. Equilibrium condition requires

$$\frac{U_1}{U_2} = \frac{z}{c} = \frac{1}{P^*} = 1,$$

and $c = z$. Maximized income under balanced trade is $I^o = R^o = C^o + Z^o = 5\sqrt{5}$. Consumption under balanced is: $c^o = z^o = 2.5\sqrt{5}$. Trade deficit is $D = z^o - Z^o - (C^o - c^o) = (2.5\sqrt{5} - \sqrt{5}) - (4\sqrt{5} - 2.5\sqrt{5}) = 0$, as expected. The utility under balanced trade is $U^o = (c^o z^o)^{.5} = 2.5\sqrt{5} \approx 5.59$, and the total utility over two periods is approximately 10.91, as shown in Table 3.1.

Consumer Equilibrium with Trade Deficit

The equilibrium condition for optimal consumption is: $\frac{z}{c}=\frac{\varepsilon}{P^*}=\varepsilon.$ Thus, $\varepsilon c=z.$

Budget constraint is: $\varepsilon c+P^*z=\varepsilon c+z=2\varepsilon c=I.$ Equilibrium demands for good

are: $c=\frac{I}{2\varepsilon},\ z=\frac{I}{2}$. Indirect utility is given by

$$V=\left(\frac{I^2}{4\varepsilon}\right)^{.5}=\frac{I\varepsilon^{-.5}}{2}. \qquad (63)$$

Thus, $V_I=.5\varepsilon^{-.5},$ and

$$V_{I\varepsilon}=-(1/4)\varepsilon^{-1.5}<0. \qquad (64)$$

Recall that when ε = 1, income or expenditure is $5\sqrt{5}.$ When China pegs yuan below this equilibrium value, its expenditure falls below the income level under balanced trade, $5\sqrt{5}.$

Let the trade deficit function be given by

$$D=5\sqrt{5}(\varepsilon-1), \qquad (65)$$

where income under balanced trade is $I=5\sqrt{5}.$ Trade surplus is zero when $\varepsilon^o=1$.

If ε rises above the equilibrium level, then a trade deficit occurs. For example, if ε rises 20 percent above 1, then the resulting trade deficit is also 20 percent of the income under balanced trade, i.e., $D=5\sqrt{5}(\varepsilon-1)=2.24.$ Utility in the first period is $U_1=6.95.$ A 20 percent appreciation of yuan above unity in period 1 necessitates an approximately 21 percent devaluation of yuan below unity in the second period. Utility with a trade surplus in the second period falls to $U_2=3.94$. The discounted value of utility in the second period is $U_2/(1+r)=3.76.$ The total utility over the two periods is roughly $\Phi=U_1+\frac{U_2}{1.05}=10.708.$

Alternatively, if a 20 percent devaluation in the first period is followed by a 21 percent revaluation above unity, then total utility is 10.705, which is even worse than the policy of a trade deficit in the first period followed by a trade surplus in the second period. Thus, the reverse policy of overvaluation in the first period and undervaluation in the second period does not improve the overall welfare either. If the interest rate were zero, the reverse policy would yield the same level of utility. But due to the positive interest rate, the reverse policy yields an even lower utility than the policy of devaluation in the first period and revaluation in the second.

When the stable exchange $\varepsilon^o = 1$ is chosen for both periods, $U_1 = 5.59 = U_2$. The total utility over two periods is $U_1 + \frac{U_2}{1.05} = 10.91$. Thus, this example shows that the policy of yuan appreciation in one period and devaluation in the other yields less utility than if stable exchange rates were maintained over the two periods.

3.6 The Case of CES Utility function

A constant elasticity of substitution (CES) utility function is given by

$$U = \left((1-\alpha)c^{\rho} + \alpha z^{\rho}\right)^{1/\rho},$$

where $\rho = 1 - 1/\sigma$ and σ is the elasticity of substitution. Demand functions are given by:

$$c = \frac{(1-\alpha)^{\sigma} I \varepsilon^{-\sigma}}{\alpha^{\sigma} + (1-\alpha)^{\sigma} \varepsilon^{1-\sigma}},$$

$$z = \frac{\alpha^{\sigma} I}{\alpha^{\sigma} + (1-\alpha)^{\sigma} \varepsilon^{1-\sigma}}.$$

Thus, the indirect utility function is

$$V = \left((1-\alpha)^{\sigma}\varepsilon^{1-\sigma} + \alpha^{\sigma}\right)^{1/(\sigma-1)} I. \qquad (66)$$

It follows that

$$V_I = \left((1-\alpha)^{\sigma}\varepsilon^{1-\sigma} + \alpha^{\sigma}\right)^{1/(\sigma-1)}.$$
$$V_{I\varepsilon} = -\left((1-\alpha)^{\sigma}\varepsilon^{1-\sigma} + \alpha^{\sigma}\right)^{(2-\sigma)/(\sigma-1)} (1-\alpha)^{\sigma}\varepsilon^{-\sigma} < 0.$$

Using the same production possibility function, $C^2 + 4Z^2 = 100$, as before, the outputs are:

$Z = \frac{10}{\sqrt{16\varepsilon^2 + 4}} = \frac{5}{\sqrt{1+4\varepsilon^2}}$ and $C = \frac{20\varepsilon}{\sqrt{1+4\varepsilon^2}}$.

Recall that income under balanced trade is $I = 5\sqrt{5}$. If ε rises 20 percent above 1, then the resulting trade deficit is also 20 percent of the income under balanced trade, i.e., $D = 5\sqrt{5}(\varepsilon - 1) = 2.24$. Utility in the first period is $U_1 = 7.26$. A 20 percent appreciation of yuan above unity in period 1 necessitates an approximately 21 percent devaluation of yuan below unity in the second period. Utility with a trade surplus in the second period falls to $U_2 = 4.34$. The discounted value of utility in the second period is $U_2/(1+r) = 4.14$ The total utility over the two periods is roughly $\Phi = U_1 + \frac{U_2}{1.05} = 11.396$. See Table 3.2.

Alternatively, if a 20 percent devaluation in the first period is followed by a 21 percent revaluation above unity, then total utility is 11.399, which is slightly above that under the policy of a trade deficit in the first period followed by a trade surplus in the second period. Thus, the reverse policy of overvaluation in the first period and undervaluation in the second period does not improve the overall welfare either.

When the stable exchange $\varepsilon^o = 1$ is chosen for both periods, $U_1 = 5.99 = U_2$. The total utility over two periods is $U_1 + \frac{U_2}{1.05} = 11.698$. Thus, this example shows that the policy of yuan appreciation in one period and devaluation in the other yields less utility than if stable exchange rates were maintained over the two periods.

3.7 Concluding Remarks

China has been criticized for maintaining a large amount of foreign exchange reserve to take unfair advantage of its trading partners. This paper investigated whether a country can benefit from generating a trade deficit or surplus by arbitrarily changing the yuan-dollar peg. In a two-period framework, if a country incurs a trade deficit in one period, the principal plus interest must be paid off subsequently. Alternatively, if a country accumulates a trade surplus, the investment plus interest income must be spent in the next period. It is shown that under reasonable condition on marginal utility of income, the optimal exchange rate is the equilibrium rate that yields trade balance over both periods.

The analysis is easily extended to the multiperiod framework. Any accumulation of trade surplus or deficit must be eventually offset by opposing deficit or surplus in the terminal period. Such deviation of exchange rates from the balanced trade always yields uneven utilities and marginal utilities of income, which contribute to lower consumer welfare, provided that indirect utility is concave in expenditure. Therefore, there are no gains from deviating from the equilibrium exchange rates.

China's acquisition of a large foreign exchange reserve suggests that the current exchange rate policy may be harmful to consumer welfare, contrary to the prevailing view that China pursues its self-interest by taking unfair advantage in the global market.

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Table 3.1: Exchange Rates and C-D Utility, $P^* = 1, U = c^{1/2}z^{1/2}$.

ε_1	0.8000	0.9000	1.0000	1.1000	1.2000
D_1	-2.2361	-1.1180	0.0000	1.1180	2.2361
C_1	8.4800	8.7416	8.9443	9.1037	9.2308
Z_1	2.6500	2.4282	2.2361	2.0690	1.9231
R_1	9.4340	10.2956	11.1803	12.0830	13.0000
I_1	7.1979	9.1776	11.1803	13.2011	15.2361
c_1	4.4987	5.0987	5.5902	6.0005	6.3484
z_1	3.5990	4.5888	5.5902	6.6005	7.6180
U_1	4.0238	4.8370	5.5902	6.2934	6.9543
r	0.0500	0.0500	0.0500	0.0500	0.0500
D_2	2.3479	1.1739	0.0000	-1.1739	-2.3479
ε_2	1.2100	1.1050	1.0000	0.8950	0.7900
C_2	9.2420	9.1107	8.9443	8.7300	8.4498
Z_2	1.9095	2.0612	2.2361	2.4386	2.6740
R_2	13.0924	12.1286	11.1803	10.2520	9.3493
I_2	15.4402	13.3025	11.1803	9.0780	7.0015
c_2	6.3803	6.0192	5.5902	5.0715	4.4313
z_2	7.7201	6.6513	5.5902	4.5390	3.5007
U_2	7.0183	6.3274	5.5902	4.7979	3.9386
Φ	10.7078	10.8631	10.9141	10.8628	10.7054

Table 3.2: Exchange Rates and CES Utility, $P^* = 1, \alpha = .25, \sigma = .5.$

ε_1	0.8000	0.9000	1.0000	1.1000	1.2000
D_1	-2.2361	-1.1180	0.0000	1.1180	2.2361
C_1	8.4800	8.7416	8.9443	9.1037	9.2308
Z_1	2.6500	2.4282	2.2361	2.0690	1.9231
R_1	9.4340	10.2956	11.1803	12.0830	13.0000
I_1	7.1979	9.1776	11.1803	13.2011	15.2361
c_1	5.4679	6.3393	7.0881	7.7402	8.3146
z_1	2.8236	3.4722	4.0923	4.6869	5.2586
U_1	4.4306	5.2546	5.9915	6.6561	7.2598
r	0.0500	0.0500	0.0500	0.0500	0.0500
D_2	2.3479	1.1739	0.0000	-1.1739	-2.3479
ε_2	1.2100	1.1050	1.0000	0.8950	0.7900
C_2	9.2420	9.1107	8.9443	8.7300	8.4498
Z_2	1.9095	2.0612	2.2361	2.4386	2.6740
R_2	13.0924	12.1286	11.1803	10.2520	9.3493
I_2	15.4402	13.3025	11.1803	9.0780	7.0015
c_2	8.3683	7.7706	7.0881	6.2989	5.3727
z_2	5.3146	4.7160	4.0923	3.4405	2.7570
U_2	7.3172	6.6877	5.9915	5.2156	4.3427
Φ	11.3993	11.6238	11.6977	11.6234	11.3957

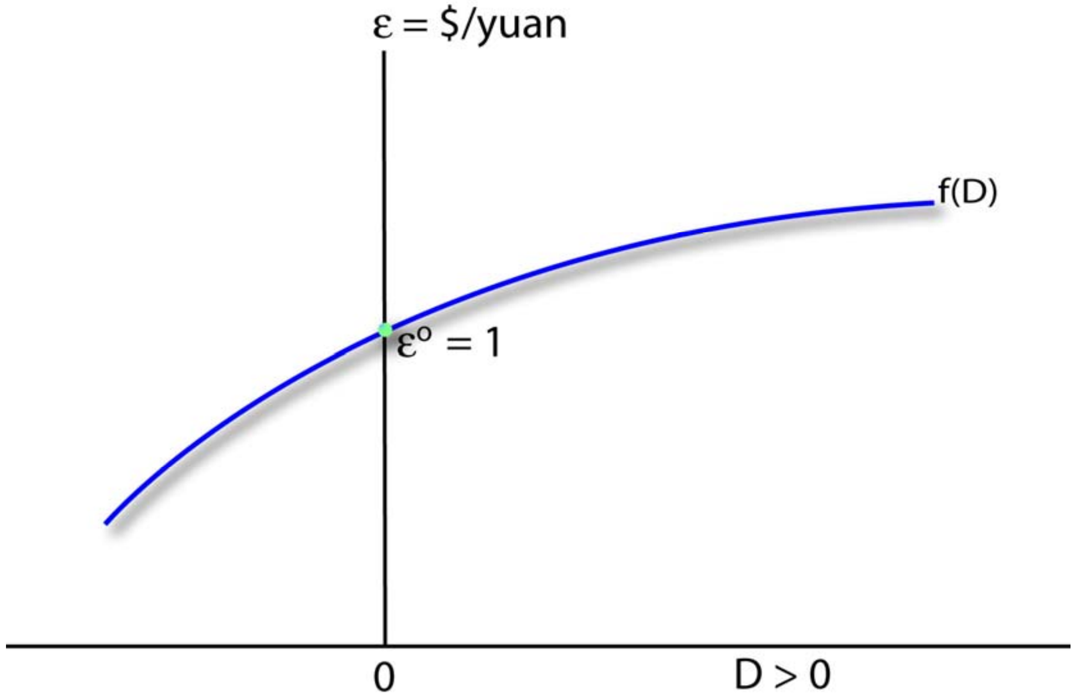

Figure 3.1: Exchange Rate and Trade Surplus

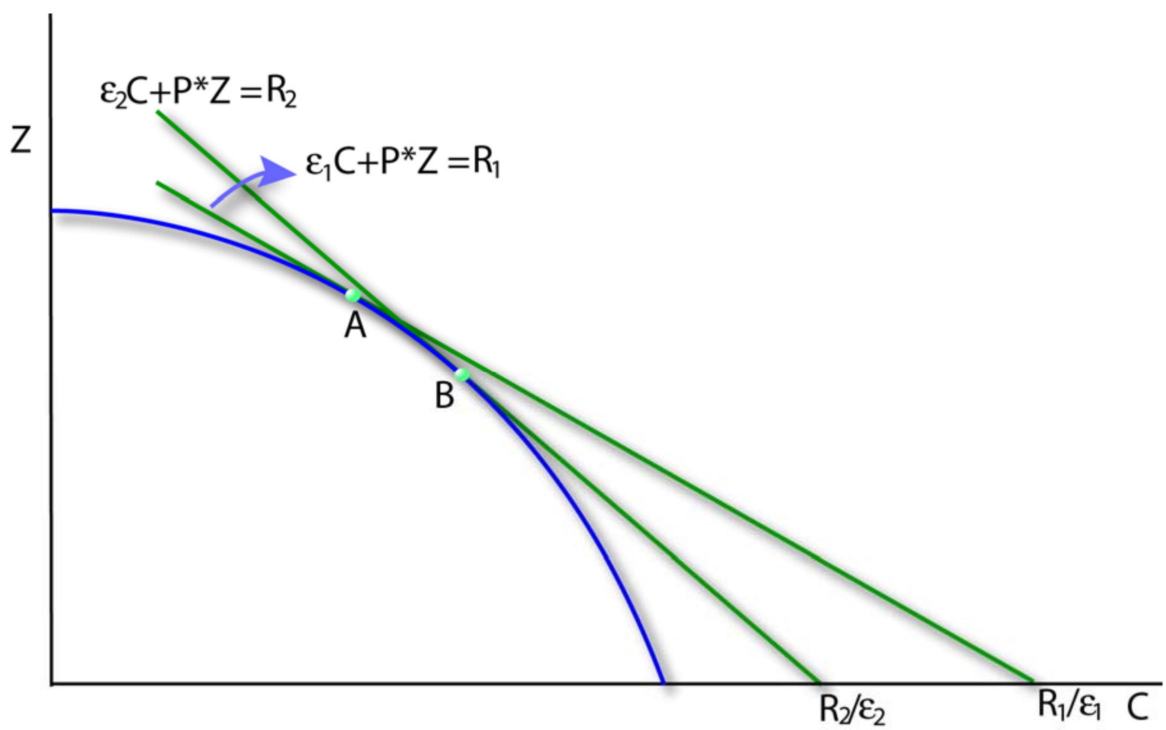

Figure 3.2: Yuan Appreciation and Revenue in Dollars

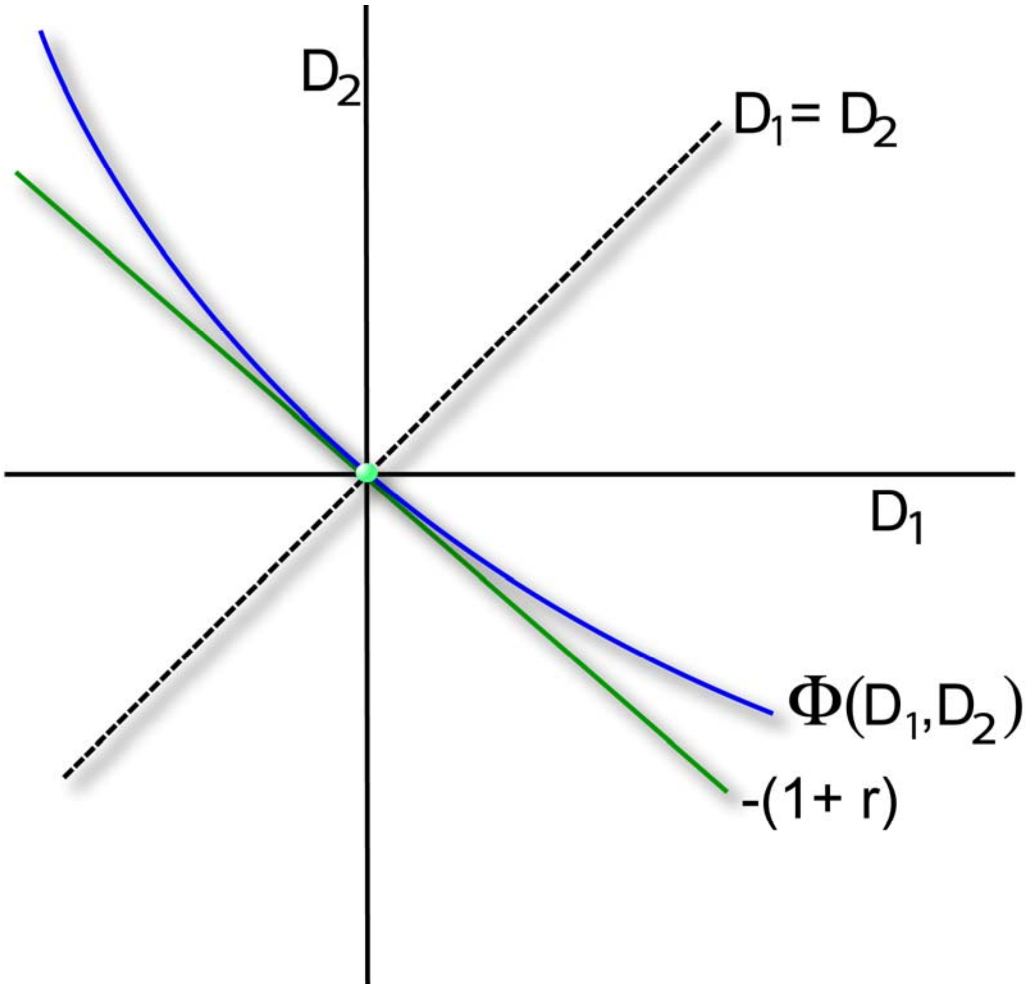

Figure 3.3: Maximizing Consumer Welfare subject to a Two-Period Budget Constraint