Making Sense of China’s Excessive Foreign Reserves*

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Abstract

Large uninsured risk, severe borrowing constraints, and fast income growth can imply excessively high household saving rates and large current account surplus for an emerging economy. Therefore, the massive foreign-reserve buildups by China are not necessarily the intended outcome of any government policies or an undervalued home currency, but instead a natural consequence of rapid economic growth in conjunction with an inefficient financial system (or lack of timely financial reform). A tractable growth model of precautionary saving is provided to quantitatively explain China’s extraordinary path of trade surplus and foreign-reserve accumulation in the recent decades. Ironically, the analysis suggests that without a well developed domestic financial market, the value of RMB may significantly depreciate, instead of appreciate, once the government in China abandons the linked exchange rate and the massive amount of precautionary savings of Chinese households unleashed toward the international financial markets in seeking for better returns.

Keywords: Current Account, Foreign Reserve, Trade Deficit, Buffer Stock Saving, Global Imbalance, Incomplete Markets, Uninsured Risk.

JEL Codes: E21, F11, F30, F31, F32, F34, F40, F41, O16.

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1 Introduction

China’s trade balance has risen from a small deficit (-$1.1 billion) in 1978 (the beginning year of economic reform) to a huge surplus ($400 billion) in the first half of 2009. The bulk of the surplus results in trade with the United States. During the same period, China’s foreign exchange reserves (mostly U.S. dollars) have increased even more dramatically, from $2 billion to $2.4 trillion—a more than one thousand fold expansion, making China the world’s largest holder of foreign exchange reserves.\(^1\) If every Chinese had bought more American goods, trade between China and the United States would have been more balanced. Why don’t Chinese spend their dollars and buy more American goods?

Many annalists believe that the steady increase in America’s trade deficit with China is the consequence of a significantly undervalued Chinese currency (RMB). Namely, Chinese goods are too cheap relative to American goods. Hence, Americans can buy lots of Chinese goods while the Chinese can hardly afford American goods. Indeed, some economists and politicians in the United States alleged that the Chinese government has been manipulating its currency to deliberately achieve a large trade surplus and excessive amount of foreign reserves.\(^2\)

Why, let alone how, would the Chinese government do that? One popular argument is that an undervalued home currency promotes domestic employment. However, selling goods at significantly low prices to the United States and holding American dollars as a store of value is equivalent to lending goods to American consumers in return for IOUs that pay negative interest (due to inflation). Chinese workers may be better off by spending the dollars they earn instead of hoarding them. Why would the Chinese tighten their belts and lend to Americans when they are still struggling with very low per capita income? Shouldn’t they borrow from Americans instead to increase their current consumption and pay back in the future when they all become rich?

The truth is that imbalanced trade may have nothing to do with the exchange rate. Even a layman can understand the following arithmetic: Suppose the real exchange rate between China- and America-made products is 1:1—e.g., one Chinese orange for one American apple. When China gives up one orange for one American apple, trade is balanced between the two countries because total Chinese exports (1 orange) equal total imports (1 apple) in value. Suppose Chinese government is able to manipulate and depreciate the real exchange rate so that Chinese workers must give up

\(^1\) This is equivalent to 50% of China’s GDP in 2009.

\(^2\) E.g., a bipartisan group of 14 U.S. senators announced new legislation in March 2010 to punish China for unfair currency manipulation (see http://schumer.senate.gov/record.cfm?id=323135). Paul Krugman joined the ranks of many U.S. legislators in calling for substantial tariffs to be put on Chinese imports "if sweet reason won’t work" and the Chinese authorities fail to heed demands to revalue their currency (see Paul Krugman, "Taking on China," New York Times, 15 March 2010.)
100 oranges for 1 American apple. Despite the extremely cheap Chinese products with a real exchange rate of 100:1, trade between the two nations is still balanced—the total value of Chinese exports (worth 1 American apple) still equals the total value of Chinese imports (1 American apple). Therefore, trade can be always balanced regardless of the exchange rate.

Imbalances of trade (or current account surplus) would arise if the following situation occurs: Suppose Chinese workers gave up 100 oranges for 1 US dollar, with which they could buy 1 American apple; but instead of spending the $1 entirely by importing 1 American apple, Chinese workers bought only half American apple and kept the remaining 50¢ as savings. In this case, China would incur a trade surplus of \( \frac{1}{2} \) American apple, equivalent to lending 50 oranges to American consumers in return for 50¢ as IOU. Again, why would Chinese workers do that—tightening their belts and lending to Americans when they are still struggling with very low consumption level?

Standard economic theory of incomplete markets and precautionary saving provides one plausible explanation: Even though China has had impressive economic growth over the past 30 years since its economic reform and joining the globalization process, its financial reform has not caught up with its economic growth. Because of the lack of social safety nets and severely underdeveloped insurance and financial markets, Chinese must save excessively to insure themselves against idiosyncratic uncertainty, such as bad income shocks, unemployment risk, accidents, and many unexpected spending needs in housing, education, health care, and so on.

Theory predicts that when households face large uninsured risk and are subject to severe borrowing constraints, not only do they save excessively, but their marginal propensity to save also increases with income growth. That is, the more income they earn, the larger portion of the income will they save—in sharp contrast to the conventional wisdom based on Friedman’s (1957) permanent-income-hypothesis (PIH).

Indeed, during the past 30 years of rapid economic growth, China’s private consumption-to-GDP ratio has fallen from roughly 50% in 1980 to 35% in 2008—see the \( C/Y \) ratio in the top panel of Figure 1, while government spending as a fraction of total national income has remained roughly constant at about 14%.\(^3\) Hence, Chinese consumers have been reducing their propensity to consume significantly despite the rapidly rising per capita income and average GDP growth rate. Since trade surplus is part of national savings, China’s national saving rate (private investment plus net exports) has also been increasing steadily over the past 30 years, from 34% to 51% (see the \( (I + NX)/Y \) ratio in Figure 1).

\(^3\)Data Source: China Statistical Year Book (2008). The average growth rate in GDP is defined as a 14 year moving average, following Modigliani and Cao (2004).
Similar pattern of saving behavior is also revealed at the household level. Figure 2 depicts the household saving ratio (line with diamonds, left axis) and the long-term growth rate of household income (line with squares, right axis) for the period of 1953-2006. The household saving rate is defined as the ratio between net wealth changes and disposable income, and the long-term income-growth rate is defined as the average growth rate of the past 14 years, following Modigliani and Cao (2004).\(^4\) The figure shows that the household saving rate tracks the long-term income growth rate very closely and has been increasing steadily since 1978. The household saving rate peaked in 2006 at 37\%. The bulk of the household saving is contributed by bank deposits despite low deposit rates, suggesting that safe and low yield assets have been the major means of saving for Chinese households.\(^5\) The average real interest rates remained essentially at zero or negative values in the post-reform period. For example, the average nominal 3-month deposit rate was 3.3\%, the average 1-year rate was 5.6\% (line with triangles, left axis), while the average inflation rate was about 6\% in the 1991-2007 period.\(^6\)

\(^4\)Household wealth includes deposits, bonds, and individual investments. Excluding individual investments lowers the saving rate slightly but does not change the dynamic pattern of the household saving ratio. See Wen (2009a) for details of the data source.

\(^5\)Wen (2009b) shows that in China and India the share of cash and bank deposits accounts for more than 90\% of total household financial wealth.

\(^6\)Data for the interest rates before 1990 are not available.
Consistent with the pattern of rising saving rates and declining consumption-to-income ratios, China’s total imports-to-exports ratio has also been falling during the fast growth period, from 1.6 in 1985 to around 0.8 in 2008, halved in less than a quarter of a century. That is, while exports have been growing at double-digit annual rate, total imports have failed to catch up. As a result, China’s trade surplus and foreign reserves have exploded.

Therefore, data suggest that Chinese households may have been saving an increasingly larger portion of their income (including dollars earned from international trade) to provide the safety net and self-insurance that are not available to them from markets, and such precautionary saving behavior is precisely what economic theory would predict. Similar patterns of excessive saving behaviors have also been observed in other emerging economies during their rapid growth periods, such as Japan in the 1960-70s, Hong Kong in the 1980s, and Taiwan and South Korea in the 1990s. But it is the gigantic size of China that had made the phenomenon so much more alarming and astonishing to trade economists and commentators.

The analysis suggests that the linked exchange rate between RMB and Dollar is not the culprit of the trade imbalance between China and the rest of the world. It is the rapid income growth and lagging financial development in China that has created the problem and only financial development can ultimately resolve it. By forcing China to appreciate its currency against the U.S. dollar may

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7 The first half of 2009 recorded an even much smaller number of 0.23.
8 We defer the discussion of the trade data to a latter section.
9 Ironically, if Chinese savers were free to put their money anywhere in the world, there could be a large outflow of RMB into other currencies and a resulting depreciation rather than appreciation.
succeed in discouraging Americans from buying Chinese goods, but will not stop the Chinese households from precautionary saving and consequently, China will not buy significantly more goods from America than they used to. Such policy proposal is thus highly unproductive with undesirable consequences—it reduces American imports of Chinese goods at the cost of American consumers (because of rising import prices) yet without stimulating the US exports to China, hurting the welfare of both Americans and Chinese workers.\textsuperscript{10}

2 A Brief Review of the Literature

The above arguments are formalized in this paper using an open-economy model featuring time-varying long-run growth, uninsured risk, and borrowing constraints. The model is an extension of the closed-economy model of Wen (2009a) and the analysis is related to the existing literature on global imbalances, most notably Caballero, Farhi, and Gourinchas (2008), Mendoza, Quadrini, and Rios-Rull (2009), Ju and Wei (2010).\textsuperscript{11} Caballero et al. (2008) attempt to explain the triple phenomena of the sustained rise in US current account deficits, the persistent decline in long-run world real interest rates, and the rise in US assets in global portfolios as an equilibrium outcome of an economic environment where different regions of the world differ in their capacity to generate financial assets from real investments. They argue that fast growth in emerging economies coupled with their inability to generate sufficient local store-of-value instruments would increase their demand for saving instruments from developed world. This leads to a rise in capital flows toward the US, a decline in real interest rates in the world financial market, and an increase in the importance of American assets in global portfolios.

Mendoza, Quadrini, and Rios-Rull (2007) argue that persistent global imbalances and their portfolio composition could be the result of international financial integration among countries with heterogeneous domestic financial markets. In particular, countries with more advanced financial markets attract financial capital from countries with less developed financial markets and maintain positive net holdings of non-diversifiable equity and FDI.

Ju and Wei (2010) study how domestic institutions affect patterns of international capital flows. They argue that inefficient financial system and poor corporate governance may be bypassed by two-way capital flows in which domestic savings leave the country in the form of financial capital outflows but domestic investment takes place via inward FDI from countries with more efficient financial systems.

\textsuperscript{10}A better alternative to reducing the excessive savings of the Chinese households is to encourage Chinese firms to invest more aggressively in fixed capital, both domestically and abroad. But to effectively channel the household savings to firm investment also requires the existence of an efficient banking and financial sector. In addition, given that the ratio of total private fixed investment-to-GDP in China is already as high as 40–45\%, how to make additional investment more efficient is a challenge closely linked to further financial development in China.

\textsuperscript{11}For the related literature, also see Blanchard, Feldstein (2008), Dooley and Garber (2007), Giavazzi, and Sa (2005), Gourinchas and Jeanne (2007), Jeanne (2007), Jeanne and Ranci\`ere (2008), Jin (2008), Obstfeld and Rogoff (2005, 2009), Song, Storesletten, and Zilibotti (2009), and Yu (2007), among many others.
financial system and better corporate governance.

These papers all emphasize differences in cross-country financial deepness in affecting the composition of asset portfolios and international capital flows. However, by focusing on financial deepness alone, this literature does not directly and quantitatively explain the excessively high saving rate and massive foreign reserves in China. In contrast, this paper explains why the Chinese saving rate is so high and that it is precisely this high propensity to save that has led to the large trade surplus and foreign reserve buildups in China, irrespective of exchange rates. However, this paper will use the key insight of this global-imbalance literature to argue that the Chinese currency may have been significantly overvalued instead of undervalued, despite the large trade surplus. Because the poor financial institutions in China are incapable of generating sufficient local store-of-value instruments to satisfy the strong asset demand of Chinese households, capital controls in China have effectively blocked the outflows of financial capital toward developed countries and insulated the RMB from devaluation. Therefore, the strong need of international risk diversification and demand for foreign assets imply that further revaluation of the RMB by the Chinese Government may lead to catastrophic disasters in the future once China’s capital control is lifted—because of the possible destructive effect of a sudden and large depreciation of RMB on the Chinese domestic asset markets, as during the 1997 Asian financial crisis.

A similar point that links precautionary saving motives to exchange-reserve buildups is also made by Durdu, Mendoza, and Terrones (2007), Sandri (2008), and Carroll and Jeanne (2009), among others. Durdu, Mendoza, and Terrones (2007) use an open-economy neoclassical model with uninsured risk and borrowing constraints to study the increase in foreign assets due to optimal self-insurance against sudden stops. Sandri (2008) argues that growth acceleration in a developing country can cause a larger increase in saving than in investment because capital market imperfections induce entrepreneurs not only to self-finance investment but also to accumulate precautionary wealth outside their business enterprise. Using a tractable model of precautionary savings due to unemployment risk, Carroll and Jeanne (2009) show that rapid income growth and an associated increase in unemployment risk can lead to large buildup of domestic savings relative to domestic capital demand, hence outflows of financial capital from developing countries to developed ones.

This paper can be viewed as an extension of this segment of the literature. However, we differ in focus, analytical approaches, and solution methods. For example, this paper emphasizes idiosyncratic risk, rather than aggregate risk, in determining household saving rates and a nation’s current account surplus. Also, this paper deals explicitly with nominal foreign reserves and the determination of exchange rate, and calibrates the model to match Chinese data. On the solution-technique side, this paper relies on quasi-linear utility function to obtain closed-form solutions under uninsured idiosyncratic risk and borrowing constraints. Analytical tractability makes the model’s working mechanisms transparent.
The rest of the paper is organized as follows. Section 3 provides a one-sector benchmark model to illustrate the main points of the paper. Section 4 extends the benchmark model to a more general setting with both tradable and nontradable goods, capital accumulation, linked exchange rate and capital controls. Section 5 studies the robustness of the results by relaxing capital controls and linked exchange rate. Section 6 concludes the paper.

3 Benchmark Model

There are two countries—a home country H (China) and a foreign country F (the rest of the world). For simplicity, assume that (i) the rest of the world (F) is large enough so that the price of tradable goods is not affected by home country’s exports and imports; and (ii) home-produced goods are for export only and home residents consume only foreign-produced goods. Denote $P^*_t$ as the nominal price of goods sold in country F in terms of foreign currency (dollars), which is also the price that households of H pay for imported goods from abroad. So trade involves the same goods and the law of one price holds. The inflation rate, $\frac{P_t - P_{t-1}}{P_{t-1}}$, is assumed to be zero over time.\(^{12}\)

Although a foreign currency exists in the model—which serves as the means of payment for tradable goods, it is not required for home-country residents to hold it. In other words, we do not impose the standard cash-in-advance constraint or the money-in-utility assumption to induce money demand. Instead, we motivate money demand by precautionary saving motives as in Bewley (1980) and Wen (2009b). Thus, if households opt to hold the foreign currency, it is purely for precautionary saving reasons. This modeling strategy allows us to combine precautionary saving behavior with money demand without making other additional assumptions about why people hold money.

There is a continuum of households in country H indexed by $i \in [0, 1]$. Income earned from exports in the tradable sector can be either consumed or saved (in dollars). Foreign reserves are thus measured in dollars and are kept by households instead of by the government.\(^{13}\) For simplicity, assume that holding foreign currency earns zero nominal interest rate; hence, the real rate of return to foreign currency is the inverse of the inflation rate in Country F, which is zero.\(^{14}\)

Households are borrowing- and short-sale constrained, as in Bewley (1980), Aiyagari (1994), and Huggett (1993). That is, they cannot hold negative amount of any assets. Each household is subject to an idiosyncratic shock $\theta_t(i)$, which has support $\theta \in [\underline{\theta}, \overline{\theta}]$ and cumulative density function $F(\theta)$. Since the exact source of the idiosyncratic uncertainty does not matter for our

\(^{12}\)The results are not sensitive to this assumption.

\(^{13}\)Alternatively, we can allow households to sell dollars to the government and use the proceeds to purchase local government bonds. In this way, all foreign currency will then be held by the government in Country H instead of by households, but the results will be similar.

\(^{14}\)The results would be similar if we allow the government to bear the inflation risk by holding foreign reserves or paying households interest rate on their foreign currency accounts.

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results, we consider idiosyncratic preference shocks to make the model analytically tractable. Such shocks represent unexpected consumption needs (e.g., illness and medical emergency) that are not insured by markets (as in Lucas, 1980).

### 3.1 Technology and Market Structure

 Tradable goods are produced using the production technology $Y_t = A_t N_t$, where $N_t$ denotes labor and $A_t$ productivity, which grows over time according to

$$A_t = A_0 (1 + \bar{g})^t. \quad (1)$$

Perfect competition implies that the real wage is given by $W_t = A_t$. Since the economy has a balanced growth path, we can transform the model into a stationary economy by scaling (normalizing) all endogenous variables, except hours worked, by the growth factor, $(1 + \bar{g})^t$. All normalized variables are denoted by lower-case letters (e.g., $x_t = \frac{x_t}{(1+\bar{g})^t}$). Note that the re-scaled real wage $w_t \equiv A_0$.

### 3.2 Preference

 Denote $M_t(i)$ as the stock of money balances held by household $i$ by the end of period $t - 1$, $C_t(i)$ real consumption for imported goods in period $t$, and $N_t(i)$ hours worked in period $t$. Applying the transformation, we have

$$m(i) = \frac{M_t(i)/P_{t-1}^*}{(1+\bar{g})^t}, \quad m'(i) = \frac{M_{t+1}(i)/P_{t+1}^*}{(1+\bar{g})^{t+1}}, \quad c_t(i) = \frac{C_t(i)}{(1+\bar{g})^t}. \quad (2)$$

To make the model analytically tractable, we follow Wen (2009a) by assuming that (i) the utility function is quasi-linear (indivisible labor) and (ii) labor supply is determined in each period before observing the idiosyncratic preference shock $\theta_t(i)$.

Household $i$’s problem is to solve

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \{ \theta_t(i) \log c_t(i) - aN_t(i) \} \quad (2)$$

subject to

$$c(i) + (1 + \bar{g}) m'(i) \leq m(i) + wN(i) \quad (3)$$

$$m'(i) \geq 0, \quad (4)$$

15For the sake of argument, ignore aggregate uncertainty for a moment.

16Because of quasi-linear preference, assumption (ii) is needed to ensure that agents cannot use perfectly elastic labor income to fully insure themselves for idiosyncratic risk. This assumption is not needed if the marginal cost of labor supply is increasing, but then closed-form solutions are not possible.
and \( N(i) \in [0, \bar{N}] \). Equation (3) is the budget constraint, which states that total wage income earned from working in the tradable-good sector can be used to finance purchases of foreign produced goods \((c)\) and the accumulation of foreign currency (foreign reserve \( m' - m \)), subject to the borrowing constraint (4). Without loss of generality, assuming \( \alpha = 1 \) in the utility function.

Note the following implications of the model:

(i) If there are no idiosyncratic uncertainty, households would set consumption equal to wage income. Hence, trade would always be balanced and there would be no accumulation of foreign reserves.

(ii) If there were no borrowing constraints, households would set consumption equal to permanent income by borrowing from outside. Hence, the home country would run trade deficit with \( F \), as predicted by the PIH.

3.3 Characterization of General Equilibrium

A general equilibrium is defined as a balanced growth path characterized by

(i) A sequence of decision rules for each household \( i \), \( \{c_t(i), m_{t+1}(i), N_t(i)\}_{t=0}^{\infty} \), such that given the sequence of prices \( \{P^*_t, W_t\}_{t=0}^{\infty} \), these decision rules maximize each household’s lifetime utility subject to constraints (3)-(4).

(ii) A sequence of demand function for labor, \( \{N_t\}_{t=0}^{\infty} \), such that given the sequence of prices \( \{P^*_t, W_t\}_{t=0}^{\infty} \), the demand function maximizes firms’ profits.

(iii) The law of large numbers hold and all markets clear:

\[
\int N_t(i) di = N_t \tag{5}
\]

\[
\int C_t(i) di + \int \frac{M_{t+1}(i) di - \int M_t(i) di}{P^*} = Y_t, \tag{6}
\]

where equation (5) represents labor market clearing condition, and equation (6) represents balanced budget in the tradable-goods sector. Because this is a small open economy, there is no market-clearing condition for foreign currency. Hence, equation (6) states that all revenues generated from exports \((P^*Y_t)\) are used to finance either imports \((P^* \int C_t(i) di)\) or the accumulation of foreign reserves. In other words, the trade deficit is represented by net increase in foreign reserves, \( M_{t+1} - M_t \).

(iv) The transversality condition hold: \( \lim_{t \to \infty} \beta^t \frac{1}{W_t} \int M_{t+1}(i) di = 0 \).
3.4 Household Decision Rules

**Proposition 1** Denoting \(x_t(i) \equiv m_t(i) + w_t N_t(i)\) as cash-in-hand, the decision rules of consumption, asset demand, and cash-in-hand for household \(i\) are given by

\[
c(i) = \min \left\{ \frac{\theta(i)}{\theta^*}, 1 \right\} x
\]

(7)

\[
(1 + g) m'(i) = \max \left\{ \frac{\theta^* - \theta(i)}{\theta^*}, 0 \right\} x
\]

(8)

\[
x = \theta^* \frac{(1 + g)}{\beta} A_0,
\]

(9)

where the cutoff \(\theta^*\) is determined by the following equation,

\[
1 + \bar{g} = \beta R(\theta^*),
\]

(10)

with the liquidity-premium function satisfying

\[
R(\theta^*) \equiv \int_{\theta < \theta^*} dF(\theta) + \int_{\theta \geq \theta^*} \frac{\theta}{\theta^*} dF(\theta) > 1.
\]

(11)

**Proof.** See the Appendix I. □

3.5 Discussion

The decision rules for consumption and saving in Proposition 1 are quite intuitive. Optimal consumption is a concave function of a target level of cash-in-hand, \(x_t\), with the marginal propensity to consume given by the function, \(\min \left\{ \frac{\theta(i)}{\theta^*}, 1 \right\}\). When the urge to consume is low \((\theta(i) < \theta^*)\), the marginal propensity to consume is less than 1; when the urge to consume is high \((\theta(i) \geq \theta^*)\), the marginal propensity to consume equals 1 and the individual does not save in this period. Therefore, saving is a buffer stock: The household saves \((m'(i) > 0)\) in the case of low consumption demand for a rainy day because consumption demand may be high in the future. These properties are consistent with the buffer-stock saving literature (see, e.g., Deaton, 1991; Aiyagari, 1994, and Carroll, 1992, 1997), except here they are shown analytically instead of numerically.

Notice that both the cutoff \(\theta^*\) and the optimal cash-in-hand \(x\) are independent of \(i\) (i.e., they are identical across households). The intuition that optimal cash-in-hand \(x\) is independent of \(i\) is that it is predetermined before the realization of \(\theta(i)\) and that labor supply \(N(i)\) can adjust elastically to target any level of cash-in-hand under a constant marginal cost of leisure. That is, since all households face the same distribution of idiosyncratic shocks, the quasi-linear utility
function makes it feasible and optimal that households adjust labor supply to target the same level of cash-in-hand regardless of the individual’s history of asset holdings. That is, \( x \) is optimal \( \text{ex ante} \) given the distribution of \( \theta(i) \) and the macroeconomic environment (e.g., the real wage, real interest rate, and inflation), regardless of initial wealth \( \frac{m(i)}{P} \). This property is key to obtaining closed-form solutions but the main messages of this paper do not hinge on this property.

Also notice that \( R(\theta^*) > 1 \) because it captures the liquidity value (premium) of the buffer saving stock under borrowing constraints. Hence, the effective rate of return to saving is determined by the real interest rate compounded by the liquidity premium \( R \). The liquidity premium is decreasing in the cutoff \( \theta^* \): \( \frac{\partial R}{\partial \theta^*} < 0 \). That is, with a higher cutoff, the liquidity constraint is less likely to bind, thus the liquidity value of savings is lower.

The LHS of equation (10) is the shadow marginal cost of saving—the opportunity cost of not consuming a rapidly rising income is proportional to the income growth rate. The RHS of the equation measures the effective rate of return to saving, including the real interest rate \( \beta \) and the liquidity premium \( R \). Hence, optimal saving of an asset is determined by equating the marginal cost with the marginal benefit, taking into account of the liquidity premium of the asset. In equilibrium, the liquidity premium \( R \) is thus an increasing function of income growth \( g \).

The main intuition is that uninsured risk and borrowing constraints induce precautionary savings, even if the real interest rate is low or even negative \( (\beta < 1) \). Agents would want to maintain a stable buffer stock of savings relative to trend income because of the need for self-insurance. Since income is a flow and savings a stock, when income grows, the stock-to-flow ratio would decline if the saving rate remain unchanged—which would hinder the buffer-stock function of savings and reduce the extent of self-insurance when the degree of idiosyncratic uncertainty remains constant relative to trend consumption.\(^{17} \) Thus, the liquidity premium \( R \) will rise with \( g \). A higher liquidity premium thus induces a higher saving rate.

### 3.6 Aggregation

Using letters without index \( i \) to denote aggregate variables and by the law of large numbers, aggregate (or average) consumption, saving, and asset demand are given, respectively, by

\[
c = D(\theta^*)x  
\]

\[
(1 + g) m' = H(\theta^*)x  
\]

\(^{17}\)Multiplicative preference shocks imply that as consumption grows over time, the degree of uncertainty relative to trend consumption does not change (neither increase nor shrink). This is similar to the setup in Carroll and Jeanne (2009) where unemployment risk rises with income growth. Wen (2009a) argues that such assumptions are consistent with empirical data because consumption dispersion and income inequality do not show a declining trend as the economy grows over time, suggesting that idiosyncratic uncertainty rises proportionally with income growth.
where the functions \( \{D(\cdot), H(\cdot)\} \) are defined by

\[
D(\theta^*) = \int_{\theta < \theta^*} \frac{\theta}{\theta^*} dF(\theta) + \int_{\theta \geq \theta^*} dF(\theta) \in (0, 1) \tag{14}
\]

\[
H(\theta^*) = \int_{\theta < \theta^*} \frac{\theta^* - \theta}{\theta^*} dF(\theta) \in (0, 1). \tag{15}
\]

Note \( D(\cdot) + H(\cdot) = 1 \) because \( D(\cdot) \) is the average marginal propensity to consume out of cash-in-hand and \( H(\cdot) \) is the marginal propensity to save. The equilibrium path of the model is characterized by the sequence \( \{c, m', x, \theta^*\} \), which can be solved uniquely and explicitly from equations (9)-(13) once the distribution function \( F(\theta) \) is specified.

### 3.7 Saving Behavior

Clearly, the cutoff \( \theta^* \) determines the aggregate saving-to-income ratio. A higher cutoff implies a larger fraction of savers in the population versus non-savers since \( \frac{\partial H}{\partial \theta^*} > 0 \) and \( \frac{\partial D}{\partial \theta^*} < 0 \). More precisely, the saving rate \( \tau \) in the economy is defined as the ratio of net changes in asset position to disposable income: \( \tau_t = \frac{M_{t+1} - M_t}{P_t x_t} = \frac{(1+g) m' - m}{x - m}. \) Along a balanced growth path, equation (13) implies that the saving rate is given by

\[
\tau = \frac{g H(\theta^*)}{1 + g - H(\theta^*)}. \tag{16}
\]

**Proposition 2** The saving rate is increasing in income growth, \( \frac{d\tau}{dg} > 0 \), provided that \( g \) is below a threshold \( g^* > 0 \).

**Proof.** See Appendix II.  

For example, \( \frac{d\tau}{dg} > 0 \) when \( g = 0 \). By continuity, the saving rate increases with income growth for small values of \( g \). This proposition shows that higher income growth can lead to a higher saving rate instead of a higher marginal propensity to consume, in sharp contrast to the prediction of the conventional wisdom based on the PIH. The PIH predicts that forward looking consumers should increase their marginal propensity to consume when they expect income to be permanently higher in the future. However, with uninsured uncertainty and borrowing constraints, this prediction is no longer necessarily correct when the growth rate of income is below a threshold level \( (g^*) \).

The PIH is based on two critical assumptions: (i) Agents are able to consume their higher future income by borrowing, and (ii) agents do not face any uninsured risk. However, with borrowing constraints, people are not able to consume their future income; and with uninsured risk, they
also need to keep a buffer stock as self-insurance against idiosyncratic demand shocks.\footnote{That is, with uninsured risks, having a binding borrowing constraint by setting $s_{t+1}(i) = 0$ for all $t$ is not optimal.} The key insight of Proposition 2 is that under both borrowing constraints and uninsured risk, the optimal saving rate will increase with income growth, consistent with much of empirical evidence.\footnote{See, e.g., Carroll and Weil (1994), Carroll, Overland, and Weil (2000) and the references therein.} Since saving provides liquidity, it has a liquidity premium $R$ (shadow rate of return), which determines the optimal buffer stock-to-income ratio. Since income is a flow, a higher growth rate of income will lead to a lower stock-to-income ratio if the saving rate remains unchanged. Consequently, the liquidity premium will increase with $g$, and a higher liquidity premium will induce a higher saving rate.

On the other hand, since the function $R(\cdot)$ is bounded above by $R(\theta) = \frac{E\theta}{\bar{\theta}} > 1$, there exists a maximum value of the growth rate $g_{\text{max}} = \beta \frac{E\theta}{\bar{\theta}} - 1$ such that if $g \geq g_{\text{max}}$, the borrowing constraint (4) binds for all households and nobody saves. Hence, the saving function $\tau(g)$ must be hump-shaped, increasing with $g$ first and then decreasing with $g$ for $g \geq g^* > 0$. So if the growth rate is sufficiently high, then the opportunity cost of not consuming the rapidly growing income outweighs the benefits of precautionary savings, causing the optimal saving rate to decline, starting to be consistent with the prediction of the PIH.

\section{Predicting China’s Foreign Reserves}

\subsection{Calibration}

The parameters needed to compute the saving rate in the benchmark model include $\{\beta, \bar{g}\}$ and the parameters in the distribution of the idiosyncratic shocks $F(\theta)$. For tractability, we assume $\theta$ follow the Pareto distribution,

$$F(\theta) = 1 - \theta^{-\sigma},$$

with $\sigma > 1$ and $\theta \in (1, \infty)$. A value of $\theta = \infty$ may indicate a life-threaten medical need. But the probability of such events is zero or infinitely small. The results remain robust to alternative distributions, such as Lognormal and Uniform distributions. With Pareto distribution, we have $R(\theta^*) = 1 + \frac{1}{\sigma-1} \theta^{\sigma-\sigma}, \quad D(\theta^*) = \frac{\sigma}{\sigma-1} \theta^{\sigma-1} - \frac{1}{\sigma-1} \theta^{\sigma-\sigma}, \quad H(\theta^*) = 1 - \frac{\sigma}{\sigma-1} \theta^{\sigma-1} + \frac{1}{\sigma-1} \theta^{\sigma-\sigma}$. Equation (10) then implies the cutoff $\theta^* = \left[\left(\sigma - 1\right) \left(\frac{1+g}{\beta} - 1\right)\right]^{-\frac{1}{\sigma}}$.\footnote{That is, with uninsured risks, having a binding borrowing constraint by setting $s_{t+1}(i) = 0$ for all $t$ is not optimal.}
Table 1. Expenditure Inequality for Developing Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Burkina Faso</th>
<th>Guatemala</th>
<th>Kazakhstan</th>
<th>Kyrgyzstan</th>
<th>Paraguay</th>
<th>South Africa</th>
<th>Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gini (C)</td>
<td>0.43</td>
<td>0.39</td>
<td>0.37</td>
<td>0.45</td>
<td>0.47</td>
<td>0.54</td>
<td>0.39</td>
</tr>
<tr>
<td>Country</td>
<td>Burkina Faso</td>
<td>Guatemala</td>
<td>Kazakhstan</td>
<td>South Africa</td>
<td>Paraguay</td>
<td>Zambia</td>
<td>Thailand</td>
</tr>
<tr>
<td>Gini (H)</td>
<td>0.43</td>
<td>0.42</td>
<td>NA</td>
<td>0.67</td>
<td>0.18</td>
<td>0.32</td>
<td>0.38</td>
</tr>
</tbody>
</table>


Let the time period $t$ be a year and set $\beta = 0.96$. The most crucial parameter to calibrate is $\sigma$, which pertains to the degree of idiosyncratic risk (the variance of the idiosyncratic shocks) and hence the strength of precautionary saving motives. Limited by the availability of panel data for developing countries, we have to rely on information from the dispersion of consumption expenditure across households in developing countries to calibrate this parameter.

Table 1 shows the Gini coefficients for consumption expenditure (top panel) and health-care expenditure (bottom panel) in several developing countries. The average consumption Gini across those countries is 0.43 and the average health-care Gini is 0.4; these values are both significantly larger than the consumption Gini (0.28) in the United States, indicating far larger idiosyncratic risks in developing countries. Based on the information, a consumption Gini in the interval of $[0.3 \sim 0.5]$ seems reasonable for China. We choose $\sigma = 1.25$ as our benchmark value so that the model implied consumption distribution has a Gini coefficient around 0.4 when the growth rate is 10% per year.\(^{20}\)

4.2 Predictions

With the calibrated parameter values, the relationship between the aggregate saving rate and the growth rate ($\bar{g}$) is graphed in Figure 3. It shows that a higher income growth induces a higher marginal propensity to save even if the real rate of return to foreign reserves is negative (the inverse of the inflation rate). In particular, when the income growth rate is 1%, the saving rate is about 8%; and when the income growth rises to 10%, the saving rate increases to 26%.

\(^{20}\)The exact Gini is 0.43 if the growth rate is 10% per year.
Data show that, between 1978-2009, China’s current account surplus has increased dramatically, reached 426 billion U.S. dollars in 2008, as seen in the left panel in Figure 4 (solid circles). The bulk of the increase in the current account is due to the rapidly rising trade surplus (solid squares in the left panel). Associated with the rising current account is the massive buildup of China’s foreign reserves. For example, the year-to-year changes of foreign reserves (solid circles in the right panel) show very similar magnitude and trends to the annual current account, suggesting that the accumulation of foreign reserves are driven mainly by surpluses from foreign trade.

In our model, trade surplus is determined by households’ precautionary saving. Because of uninsured risk and borrowing constraints, a substantial fraction of income earned from exports is saved, which leads to imbalances between exports and imports. Most importantly, the precautionary saving rate rises with the growth rate of income. Given that the average growth rate of export income in China is about 17% per year between 1978-2009, our model implies that the precautionary saving rate in the tradable sector is 28.5%. In other words, our model predicts that more than a quarter of the foreign currency (U.S. dollars) earned from total exports is saved each year. Based on this figure, multiplying China’s total exports by 0.28 would generate the predicted year-to-year changes in foreign reserves in the model (see the line with empty circles in the right panel of Figure 3).

\[21\text{ The world-wide financial crisis in 2008 had a large negative impact on China’s net exports and foreign reserves in 2009.}\]
4). The predicted value tracks the trends of China’s foreign reserves very well, explaining about 75% of the data on average.

Figure 4. Current Account (Left) and Year-to-Year Changes in Foreign Reserves (Right).

4.3 Dynamic Analyses

The relationship between saving and growth can also be analyzed under aggregate uncertainty with stochastic TFP growth. Suppose aggregate technology grows according to $A_t = (1 + g_t)A_{t-1}$, where the stochastic growth rate $g_t$ satisfies the law of motion

$$\log\left(\frac{1 + g_t}{1 + \bar{g}}\right) = \rho \log\left(\frac{1 + g_{t-1}}{1 + \bar{g}}\right) + \varepsilon_t,$$

where $\bar{g} \geq 0$ is the mean and $\varepsilon_t$ is an i.i.d. process. To compute the stochastic equilibrium path of the model, we re-scale all variables (except $N_t$) by the level of technology $A_{t-1}$. In order for the transformed stock variable $m_t$ to remain as a state variable—that does not respond to changes in $A_t$ in period $t$, we use $A_{t-1}$, instead of $A_t$, as the scaling factor.\footnote{The particular ways of transformation do not affect the dynamics of the original variables.} Using lower-case letters to
denote the transformed variables, $x_t \equiv \frac{X_t}{M_t}$, the production function becomes $y_t = (1 + g_t) N_t$, the real wage becomes $w_t = 1 + g_t$, and the aggregate household resource constraint becomes

$$c_t + (1 + g_t) m_{t+1} = m_t + (1 + g_t) N_t. \quad (19)$$

**Proposition 3** In a dynamic equilibrium, the year-to-year changes in foreign reserves are given by

$$M_{t+1} - M_t = \left[ \frac{H(\theta^*_t) \theta^*_t R(\theta^*_t) - \frac{1}{(1+g_t)} H(\theta^*_t-1) \theta^*_t R(\theta^*_t)}{\theta^*_t R(\theta^*_t) - \frac{1}{(1+g_t)} H(\theta^*_t-1) \theta^*_t R(\theta^*_t)} \right] P^*_t Y_t \equiv \tau_t P^*_t Y_t, \quad (20)$$

which is proportional to total nominal exports $P^*_t Y_t$ with a time-varying saving rate $\tau_t$.

**Proof.** See Appendix III. ■

To calibrate the process $\{g_t\}$, data for aggregate exports, price deflator, and hours worked in the tradable sector are needed. The growth rate of the nominal exports is given by

$$\frac{P^*_t Y_t}{P^*_{t-1} Y_{t-1}} = (1 + v_t)(1 + g_t) \frac{N_t}{N_{t-1}}. \quad (21)$$

Since data for price deflator $(1 + v_t)$ and hours worked in the tradable-goods sector $N_t$ are not available and since TFP growth typically mimics output growth, we follow the methodology in Durdu, Mendoza, and Terrones (2007) by approximating the growth rate of technology in the tradable-goods sector by the growth rate of total exports adjusted by a constant inflation rate.$^{23}$

With the process $\{g_t\}$ in hand and assuming that $g_t$ follows equation (18), the mean growth $\bar{g}$, the autocorrelation $\rho_{g_t}$, and the variance $\sigma_g^2$ can all be estimated.

To obtain closed-form solution for the model’s dynamic equilibrium path, further assume that technology innovation $\varepsilon_t$ follows log-normal distribution, $\log \varepsilon \sim N(0, \sigma^2_{\varepsilon})$. Appendix III shows that the cutoff $\theta^*_t$ can then be solved explicitly as

$$\theta^*_t = (\sigma - 1) \frac{1}{\sigma^2} \left( \left[ \beta \left( \frac{1 + \bar{g}}{1 + g_t} \right)^{\frac{1}{2}} - \frac{1}{1 + \bar{g}} \right]^{-1} - 1 \right)^{-\frac{1}{\sigma}}. \quad (22)$$

So given the shape parameter of the Pareto distribution ($\sigma$), all endogenous variables in the model can be solved explicitly in closed forms.

---

$^{23}$ We assume a 4% annual inflation rate but the results are not sensitive to this value.
Figure 5. Dynamic Relationship between Growth and Saving.

Notice that when $g_t$ is i.i.d. (i.e., $\rho_g = 0$), the cutoff is constant and the implied saving rate ($\tau_t$) based on equation (20) would be highly contemporaneously correlated with $g_t$ because $\frac{\partial R(\theta^*)}{\partial \theta} < 0$. On the other hand, if $g_t$ is serially correlated, then the implied saving rate will not only be positively correlated with current $g_t$ but also with lagged $g_t$ because high growth in the last period also tend to induce high saving in the current period. Estimation of $\rho_g$ based on $E(\dot{g}_t)(\dot{g}_{t-1} - \ddot{g})/\sigma_g^2$ gives $\rho_g = 0.2$ with a standard error of 0.06, which is highly significant.

Given the uncertainty in the estimated parameter $\rho_g$ and the importance of $\sigma$ in determining the saving rate, we use the method of moments to re-estimate the values of two key parameters, so that the model can best match the time series data of total exports and the changes in foreign reserves. The re-estimated parameter values under the method of moments are given by $\hat{\sigma} = 1.3$ and $\rho_g = 0.16$, close to the original calibration and estimation.\(^24\) The newly calibrated parameter values are summarized in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Parameter Values</th>
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<tbody>
<tr>
<td>$\beta$</td>
</tr>
<tr>
<td>0.96</td>
</tr>
</tbody>
</table>

Using the calibrated parameter values and feeding the implied sequence $\{\theta_t^*\}$ in equation (22) into equation (20) gives the predicted saving rate $\tau_t$. Figure 5 shows that the predicted saving rate

\(^24\)The implied consumption Gini under $\hat{\sigma} = 1.3$ is 0.404 when the steady-state TFP growth is 10% per year.
(dashed line with empty circles) comoves with the TFP growth rate (solid line with solid circles). Most importantly, the predicted saving rate lags the income growth rate by about one period (year). This suggests that income growth Granger causes saving rate, instead of the other way around. These predictions are consistent with much of the empirical evidence on the causal relationship between income growth and saving rates (see, e.g., Carroll and Weil, 1994; Carroll, Overland, and Weil, 2000).

The predicted total exports and year-to-year changes in foreign reserves in the model are shown in the left and right panels in Figure 6, respectively, where the solid lines (with solid circles) are data and dashed lines (with empty circles) are predictions. The model explains more than 90% of the data (the OLS $R^2$ is 0.93). In particular, the model tracks the surge in total exports and foreign reserves since 2002 quite well (China joined the WTO by December 2001), mainly because unanticipated changes in TFP growth generate larger swings in the saving rate along a transitional path than anticipated changes in the steady state. The model also tracks well the slump in 2009 due to the current financial crisis.

![Figure 6. Predictions of Exports (left) and Foreign Reserves (right).](image-url)
The analysis shows that China’s trade surplus and excessive foreign reserves can be well explained by precautionary saving behavior based on the rapid growth path of China’s export income. Namely, because of large uninsured risk and severe borrowing constraints, the saving rate is a positive function of income growth. Given the high growth rate of income in China (especially in the tradable sector), Chinese workers opt to save a substantial fraction (more than a quarter) of their income earned from trade, which leads to the massive buildup of China’s foreign reserves. Therefore, the linked exchange rate between RMB and U.S. dollar is irrelevant and Deardorff’s (2010) paradox can be resolved without assuming distortionary government policies.\(^{25}\)

5 General Model

This section adds nontradable goods, capital accumulation, and capital controls into the benchmark model. The general model is meant to better capture the reality in China and serves to demonstrate the robustness of the results in the previous section. Real exchange rate determination will be studied in the general model. It is shown that, even though China’s domestic investment rate is already one of the highest in the world, it may never be high enough to completely absorb China’s domestic savings when financial markets are incomplete.

There are two production sectors in the home country—a domestic sector (sector 1) that produces nontradable goods and an export sector (sector 2) that produces tradable goods. The nominal exchange rate is fixed and there exist capital controls in the home country (H). Under capital controls, home currency is not exchangeable for foreign currency. Because of currency inconvertibility, residents of home country cannot use foreign currency earned from the export sector to purchase domestic goods and assets, nor to use income earned from nontradable-good sector to buy foreign goods and assets. In other words, non-tradable goods are purchased by home currency (RMB) and tradable goods are purchased by foreign currency (dollars). However, households in country H can bypass the capital control though working in both nontradable and tradable sectors. Therefore, despite the capital control, households are able to adjust their baskets of consumption goods for tradable and nontradable goods by choosing an optimal mixture of hours worked in each sector.

Because of capital controls, Chinese workers cannot invest their savings of foreign currencies directly in foreign assets. The Chinese government buys dollars from residents by issuing bonds to retrieve the local currency. This practice (called sterilization) enables the government to absorb dollars without increasing the supply of local currency when trade surplus increases. This is essentially how the dollars earned by Chinese workers in the export sector end up in the central bank of

\(^{25}\)Deardorff (2010) pondered on the paradoxical phenomenon that countries (such as China) with a comparative advantage in future production are running trade surplus while countries (such as the U.S.) with a comparative advantage in current producing are running trade deficits. He argued that, from a standard trade theoretic view point, China should be borrowing from the United States instead because China’s production frontier is much higher in the future than at the present.
China as foreign reserves.\(^{26}\) Thus, sterilization is equivalent (in outcome) to a situation where the Chinese government meets the savings demands of its domestic residents by selling them Chinese government bonds and using the proceeds to purchase foreign (especially U.S.) bonds. If the private sectors want to increase spending on American goods, in principle they can exchange dollars back from the government by selling bonds. In this sense, the Chinese government is functioning like a bank, enabling savers to invest their foreign income. Therefore, foreign-exchange reserves held by the Chinese Government are effectively owned by the private sector in China and they reflect nothing but private savings of Chinese households and firms.\(^{27}\)

Firms in the domestic sector must use income earned from domestic sales to rent capital from a domestic rental market, while firms in the export sector can use foreign currency to rent capital from an international market with a constant world real interest rate \(\bar{r}_w\). Capital is not mobile across sectors but labor is. This setup of segregated capital markets allows us to study the Balassa-Samuelson effect of technology shock on the real exchange rate even though the rate of productivity growth in both non-tradable-goods and tradable-goods sectors are the same.

### 5.1 Technology

Sector \(j\) \((j = 1, 2)\) has the following production technology,

\[
Y_{jt} = K_{jt}^\alpha (A_t N_{jt})^{1-\alpha},
\]

where \(A_t\) denotes aggregate technology level with a stochastic growth rate specified in equation (18). Optimal demand for capital and labor in sector \(j\) are given by

\[
r_{jt} + \delta = \alpha \frac{Y_{jt}}{K_{jt}} = \alpha \left( \frac{N_{jt}}{K_{jt}} \right)^{1-\alpha} A_t^{1-\alpha},
\]

\[
W_{jt} = (1 - \alpha) \frac{Y_{jt}}{N_{jt}} = (1 - \alpha) \left( \frac{K_{jt}}{N_{jt}} \right)^\alpha A_t^{1-\alpha},
\]

where

\[
r_{2t} = \bar{r}_w
\]

is a constant world interest rate in the international rental market.

Labor mobility across sectors implies \(\eta_{1t} W_{1t} = \eta_{2t} W_{2t}\), where \(\eta_{jt}\) denotes the marginal utility of income received from sector \(j\). Hence, the real price of tradable goods in terms of nontradable

\(^{26}\)Officially, the government is also obligated to buy dollars from the private sector to maintain a fixed exchange rate.

\(^{27}\)Caballero, Farhi, and Gourinchas (2008, p361) also point out that "most of these reserves are indirectly held by the local private sector through (quasi-collateralized) low-return sterilization bonds in a context with only limited capital account openness."
goods—the real exchange rate in the economy—is given by \( e_t = \frac{\hat{e}_t}{\hat{e}_t} = \frac{W_1}{W_2} \). Equations (24)-(25) imply

\[
e_t = \left( \frac{\hat{r}_w + \delta}{\hat{r}_t + \delta} \right)^{\frac{\alpha}{1-\alpha}}.
\]

So the real exchange rate is influenced by aggregate technology shocks through changes in the domestic real interest rate. In particular, a higher TFP growth leads to a higher domestic interest rate, which implies that nontradable goods become more expensive relative to tradable goods, so the real exchange rate appreciates (\( e_t \) decreases). This captures the Balassa-Samuelson effect in an environment with identical productivity growth across tradable and non-tradable sectors.

Along a balanced growth path, the real wages \( \{W_{1t}, W_{2t}\} \) and outputs \( \{Y_{1t}, Y_{2t}\} \) in both sectors all grow at the rate of long-run productivity growth (\( \bar{g} \)) in the absence of aggregate uncertainty (\( \varepsilon_t = 0 \)), while hours worked in both sectors are constant over time. To facilitate the analysis of stochastic equilibrium path under aggregate uncertainty, we re-scale all variables in the model by the level of technology \( A_{t-1} \) except for hours worked. Using lower-case letters to denote the transformed variables, \( z_{jt} = \frac{Z_{jt}}{A_{t-1}} \), the production functions become

\[
y_{jt} = (1 + \bar{g})^{1-\alpha} k_{jt}^\alpha N_{jt}^{1-\alpha}
\]

and the real wages become

\[
w_{jt} = (1 - \alpha) \frac{y_{jt}}{N_{jt}} = (1 - \alpha) \left( \frac{k_{jt}}{N_{jt}} \right)^\alpha (1 + \bar{g})^{1-\alpha}.
\]

### 5.2 Households

As in the benchmark model, there is a continuum of households in country H indexed by \( i \in [0,1] \). Each household has two members (husband and wife), one works in the nontradable sector and the other works in the exporting sector. Each household consumes two types of goods, nontradable goods produced at home and foreign goods produced abroad.

Households put their savings in banks and earn a real gross rate of return \( 1 + r_t^a \). As documented by Wen (2009a), financial repression in China leads to low and even negative real deposit rate for household savings; despite this, the bulk of household wealth is kept in the form of bank deposits because of underdeveloped financial markets in China. On the other hand, firms must borrow funds from monopolistic state-owned banks at market interest rate \( r_t \). To capture such reality, we assume that the real rate of return to household savings is zero (\( r^a = 0 \)), and state-owned banks earn monopoly profits \( (r_t - r^a) s_t \), which are distributed in lump sum back to households. We will
show that households still save excessively despite of the low real deposit rate, which captures the precautionary saving motive of households in China in a more stark manner.

Denote $s_t(i) \equiv \frac{S_t(i)}{A_{t-1}}$ as the re-scaled home asset and $m_t(i) \equiv \frac{M_t(i)}{A_{t-1}P_t^*}$ as the re-scaled real money balances for foreign currency held by household $i$. Denote household $i$’s consumption for home goods as $c_{1t}(i) \equiv \frac{C_{1t}(i)}{A_{t-1}}$, for imported goods as $c_{2t}(i) \equiv \frac{C_{2t}(i)}{A_{t-1}}$, and hours worked in sector $j$ as $N_{jt}(i)$. For simplicity, assume $P_t^* = P_{t-1}$, as in the benchmark model. Household $i$’s problem is to solve

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \{ \theta_t(i) [\gamma_1 \log c_{1t}(i) + \gamma_2 \log c_{2t}(i)] - N_{1t}(i) - N_{2t}(i) \}$$

subject to

$$c_{1t}(i) + (1 + g_t) s_{t+1}(i) \leq x_{1t}(i)$$
$$s_{t+1}(i) \geq 0$$
$$c_{2t}(i) + (1 + g_t) m_{t+1}(i) \leq x_{2t}(i)$$
$$m_{t+1}(i) \geq 0,$$

where $x_{1t}(i)$ is net wealth (cash-in-hand) in terms of income earned in sector 1:

$$x_{1t}(i) \equiv w_{1t}N_{1t}(i) + s_t(i) + \Pi_t,$$

and $x_{2t}(i)$ is cash-in-hand in sector 2:

$$x_{2t}(i) \equiv w_{2t}N_{2t}(i) + m_t(i),$$

where $\Pi_t = r_{1t} \int s_t(i)di$ denotes average profit income distributed from domestic banks. The parameter $\gamma_j$ in the preference controls the relative equilibrium size of the domestic and export sectors.

Equation (31) is the budget constraint pertaining to domestic income, which states that total real wage income earned from the nontradable sector can be used to finance consumption of nontradable goods ($c_{1t}$) and the accumulation of home asset $((1 + g) s' - s)$ subject to the borrowing constraint (32). Analogously, equation (33) is the budget constraints pertaining to foreign income, which states that total real wage income earned from working in the tradable-good sector can be used to finance purchases of foreign produced goods ($c_{2t}$) and the accumulation of foreign currency (real foreign reserves, $(1 + g) m' - m_t$) subject to the borrowing constraint (34).
5.3 Household Decision Rules

**Proposition 4** Denoting $\xi_{1t} \equiv s_t$ and $\xi_{2t} \equiv m_t$, the decision rules of consumption, savings, and cash-in-hand for household $i$ are given by

\[
c_{jt}(i) = \min \left\{ \frac{\theta_t(i)}{\theta_t^*}, 1 \right\} x_{jt} \tag{37}
\]

\[
(1 + g_t) \xi_{jt+1}(i) = \max \left\{ \frac{\theta_t^* - \theta_t(i)}{\theta_t^*}, 0 \right\} x_{jt} \tag{38}
\]

\[
x_{jt} = \gamma_j w_{jt} \theta_t^* R(\theta_t^*), \tag{39}
\]

where the cutoff variables $\theta_t^*$ are determined by the following equation,

\[
\frac{1 + g_t}{w_{jt}} = \beta R(\theta_t^*) E_t \frac{1}{w_{jt+1}}, \tag{40}
\]

where the function $R(\cdot)$ is given by $R(\theta^*) \equiv \int_{\theta < \theta^*} dF(\theta) + \int_{\theta > \theta^*} \frac{\theta}{\theta^*} dF(\theta)$.

**Proof.** See Appendix IV. ■

These decision rules are similar to those in the benchmark model. However, the optimal cutoff in each sector—determined by equation (40)—may differ because the real wage may differ across sectors (because of different capital markets and real interest rates).

Denoting aggregate variable $z_t \equiv \int z_t(i) di$, market clearing for domestic capital market implies $\int s_t(i) di = k_t$. Hence, the general equilibrium path of the model can be characterized by the sequences of 14 variables, $\{c_{jt}, \xi_{jt+1}, \theta_t^*, x_{jt}, w_{jt}, y_{jt}, N_{jt}\}_{t=0}^{\infty}$, which can be solved by the following system of 14 equations:

\[
c_{jt} = D(\theta_t^*) x_{jt} \tag{41}
\]

\[
(1 + g_t) \xi_{jt+1} = H(\theta_t^*) x_{jt} \tag{42}
\]

\[
\frac{1 + g_t}{w_{jt}} = \beta E_t \frac{1}{w_{jt+1}} R(\theta_t^*) \tag{43}
\]

\[
x_{jt} = \gamma_j \theta_t^* R(\theta_t^*) w_{jt} \tag{44}
\]

\[
c_{1t} + (1 + g_t) k_{1t+1} - (1 - \delta) k_{1t} = y_{1t} \tag{45}
\]

\[
c_{2t} + (1 + g_t) m_{t+1} - m_t + (\tilde{r}^w + \delta) k_{2t} = y_{2t} \tag{46}
\]
where \( \bar{r}^w + \delta = \alpha \frac{w_1}{x_1} \), plus equation (28)-(29) and standard transversality conditions. The profit income from financial intermediaries is given by

\[
\Pi_t = (r_{1t} - r_t^0) \int s_t(i) di = r_{1t}k_{2t}.
\]  

(47)

Hence, equation (45) is also the goods-market clearing condition for the nontradable-goods sector. Equation (46) is the household’s budget constraint in the export sector, where \((\bar{r}^w + \delta) k_{2t}\) is rental payment for capital services. So income from exports is used to finance imports of consumption goods \((c_2)\), capital rental costs \(((\bar{r}^w + \delta) k_{2t})\), and foreign reserve accumulation \((m_{t+1} - m_t)\).

The model has a unique steady state. It can be easily confirmed by the eigenvalue method that the steady state is a saddle, so the general equilibrium path implied by the above system of dynamic equations is unique near the steady state.

Equations (41) and (44) imply

\[
\frac{c_{1t}}{c_{2t}} = \frac{D(\theta_1^* k_{1t}^*) \theta_1^* R(\theta_1^* k_{1t}^*) \gamma_1 w_{1t}^*}{D(\theta_2^* k_{2t}^*) \theta_2^* R(\theta_2^* k_{2t}^*) \gamma_2 w_{2t}^*} = \varphi_t \frac{\gamma_1 w_{1t}}{\gamma_2 w_{2t}}.
\]

(48)

where the coefficient \(\varphi \neq 1\) measures efficiency loss (or deadweight loss) due to capital control. The allocation would be efficient if \(\varphi = 1\). However, it is possible for \(\varphi = 1\) under capital control if \(\theta_1^* = \theta_2^*\), which would be true if \(w_{1t} = w_{2t}\), according to equation (43). That is, there would be no efficiency loss under capital control if and only if the real exchange rate \(e = \frac{w_1}{w_2} = 1\). This is unlikely to hold in general unless the production functions are identical in the 2 sectors and the domestic real interest rate equals the world interest rate \((r_{1t} = \bar{r}^w)\).

Define \(\varphi_j\) as the total real disposable income in sector \(j\), which includes wage income plus real capital gains (i.e., interest income, if any), we have

\[
\varphi_{1t} = W_{1t}N_{1t} + \Pi_t = X_{1t} - S_t
\]

(49)

\[
\varphi_{2t} = W_{2t}N_{2t} = X_{2t} - \frac{M_t}{P_t^*}.
\]

(50)

The saving rate for each type of income in the economy is defined as the ratio of net changes in asset position to disposable income in the respective sector:

\[
\tau_1 = \frac{S_{t+1} - S_t}{\varphi_{1t}} = \frac{(1 + g_t) s_{t+1} - s_t}{x_{1t} - s_t}
\]

(51)

\[
\tau_2 = \frac{(M_{t+1} - M_t) / P^*}{\varphi_{1t}} = \frac{(1 + g) m_{t+1} - m_t}{x_{2t} - m_t}.
\]

(52)
Proposition 5 The steady-state household saving rate in sector $j$ is given by

$$\tau_j = \frac{\bar{g}H(\theta_j^*)}{1 + \bar{g} - H(\theta_j^*)}. \quad (53)$$

Proof. Substituting equation (42) in equations (51)-(52) gives the result. ■

These saving rates in equation (53) are identical to equation (16) in the benchmark model. So, as before, higher income growth can lead to a higher saving rate instead of a higher propensity to consume, in sharp contrast to the prediction of the PIH. Also, the saving rates are independent of the exchange rates, suggesting that China’s trade surplus and large foreign reserves are not related to a undervalued home currency, in contrast to the widely-held belief in the profession and news media (see, e.g., Krugman, 2010).

The national saving rate (the ratio of investment and net exports to GDP) in the economy is given by $\frac{gk + \epsilon gm}{y_1 + eY_2}$ and the aggregate investment-to-GDP ratio is given by $\frac{gk}{y_1 + eY_2}$. Because of trade surplus ($\epsilon m > 0$), the national savings exceeds domestic investment even if the investment rate is high. For example, under the following parameter values, $\beta = 0.96$, $\delta = 0.1$, $\gamma_1 = 0.8$, $\gamma_2 = 0.2$, $\sigma = 1.25$, and $\bar{g} = 0.05$, we have $\frac{gk}{y_1 + eY_2} = 0.4$ and $\frac{gk + \epsilon gm}{y_1 + eY_2} = 0.44$. So aggregate investment is 40% of GDP and net exports account for 4% of GDP, consistent with Chinese data.

5.4 Exchange Rate Determination

The analysis so far indicates that attributing the trade imbalances between China and the rest of the world to a linked exchange rate and undervalued RMB is unfounded. Even though the home country in our model runs current account surplus and holds a large amount of foreign reserves, the linked nominal exchange rate is irrelevant for the results because the supply of dollars in the local exchange market ($= P_t^* Y_t^*$) always equals the total demand of dollars ($= P_t^* C_t + M_{t+1} - M_t + (\bar{r} - \bar{w}) K_t$). Hence, there is no pressure for the RMB to appreciate. This conclusion holds true even if households do not want to use dollars as a saving device, because they can always opt to exchange the amount $M_{t+1} - M_t$ in each period with their government for home currency or bonds. In this case, the government will become the holder of foreign reserves. Also, the government should have no fear of inflation because households will save, instead of spend, the home currency they exchanged from the government.

In contrast, the home currency may likely depreciate against foreign currency once capital controls in the model are lifted, in light of the analyses of the existing literature on global imbalances—most notably, Caballero et al. (2008), Mendoza et al. (2009), Ju and Wei (2010) all predict that savings in country H will flow out to developed regions (country F) in seeking for better yields. Based on this literature, suppose that capital controls are lifted and households in country H (more
specifically, workers in the nontradable sector) opt to convert $\eta \in [0, 1]$ fraction of their net savings from domestic assets into country F’s assets. This implies that total demand for dollars in the exchange market of country H would become,

$$P_t^* C_{2t} + \eta \frac{P_t (K_{1t+1} - K_{1t})}{e^*} + (M_{2t+1} - M_{2t}) + (\bar{r}^w + \delta) K_{2t}, \quad (54)$$

which would exceed the total supply of dollars, $P_t^* Y_{2t}$, by the exact amount of $\eta \frac{P_t (K_{1t+1} - K_{1t})}{e^*}$. Thus, to clear the exchange market, the floating nominal exchange rate ($e^t$) must rise above the original linked exchange rate ($\bar{e}$) by an amount so that the following equation holds:

$$P_t^* C_{2t} + \eta \frac{P_t (K_{1t+1} - K_{1t})}{e^t} + (M_{2t+1} - M_{2t}) + (\bar{r}^w + \delta) P_t^* K_{2t} = \frac{e^t}{\bar{e}} P_t^* Y_{2t}, \quad (55)$$

which implies that the market-clearing exchange rate of RMB relative to the initial linked exchange rate ($\bar{e}$) is determined by the following equation:

$$\frac{e^t}{\bar{e}} = 1 - \eta \frac{P_t (K_{1t+1} - K_{1t})}{e^t P_t^* Y_{2t}}. \quad (56)$$

In the steady state, the above equation becomes

$$e^* = \left[ 1 + \eta (1 - \alpha) \frac{\gamma_1}{\gamma_2} \frac{g_H}{1 + g - H} \right] \bar{e}. \quad (57)$$

Suppose $\eta = 0.5$ (i.e., 50% of net savings in the nontradable sector are converted to dollars), $\alpha = 0.4$, the output ratio of nontradable sector and tradable sector is $\frac{\gamma_1}{\gamma_2} = 5$, the saving rate is 25%. Then $\left[ 1 + \eta (1 - \alpha) \frac{\gamma_1}{\gamma_2} \frac{g_H}{1 + g - H} \right] = 1.375$, so RMB would depreciate by nearly 40% if capital controls are lifted under the assumption that households in the nontradable sector are willing to hold half of their portfolio in foreign assets.

In contrast, if the precautionary saving demand for foreign assets are totally ignored in both the nontradable and tradable sectors, then the market clearing exchange rate would be determined by

$$P_t^* C_{2t} + (\bar{r}^w + \delta) P_t^* K_{2t} = \frac{e^t}{\bar{e}} P_t^* Y_{2t}, \quad (58)$$

Given a 25% saving rate in the tradable-goods sector (i.e., $\frac{C_{2t} + (\bar{r}^w + \delta) K_{2t}}{Y_2} = 0.75$), the above equation suggests that $e^t = 0.75 \bar{e}$, or RMB would have to appreciate 25% to rebalance the trade between

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28 In recent years of China, total exports account for 20 – 25% of GDP while net exports account for 4 – 5% of GDP. This suggests that the domestic sector is about 5 times larger than the export sector.
country H and country F. This value of appreciation is close to what is proposed by the Peterson Institute for International Economics (e.g., Cline and Williamson, 2009) and Krugman (2010). Clearly, such an estimate is biased because it ignores the demand for international assets driven by precautionary saving motives in China.

The Balassa-Samuelson Effect. The Balassa-Samuelson effect says that if PPP holds—that is, if the real price of tradable goods are equal across country boarders and if productivity grows faster in the tradable-goods sector than in the nontradable-goods sector, then a country’s real exchange rate will appreciate over time because the relative price of nontradable goods becomes more expensive relative to tradable goods.

Since the assumption of a higher productivity growth in the tradable sector than in the nontradable sector will violate balanced growth in a two-sector growth model, we instead assumed that productivity growth is the same across sectors in the model. Consequently, the Balassa-Samuelson effect is absent if the common TFP growth rate remains constant. However, if $g$ increases over time, then the Balassa-Samuelson effect can re-emerge in the model even though TFP growth rate is the same across sectors.

To see this, recall that the relative price of tradable goods in terms of nontradable goods is given by equation (27) where $r_1 + \delta = \alpha \frac{1+g}{H(\alpha)} - \alpha (1 - \delta)$. Since $\frac{dH}{dg} < 0$, we have $\frac{\partial r_1}{\partial g} = \alpha \frac{H - (1+g) \frac{dH}{dg}}{H^2} > 0$ and $\frac{\partial e}{\partial g} < 0$. So a higher TFP growth leads to a lower $e$ through a higher domestic interest rate. That is, the real exchange rate will appreciate—non-tradable goods become more expensive relative to tradable goods when an emerging economy starts to take off.

This "secondary Balassa-Samuelson effect" exists because with capital immobility, the tradable goods sector has infinitely elastic supply of capital whereas the non-tradable goods sector has finite supply of capital. So an higher capital demand in the non-tradable goods sector due to a higher TFP growth will lead to a higher domestic real interest rate, making non-tradable goods more expensive relative to tradable goods.

On the other hand, because of underdeveloped financial market and financial repression in emerging economies, the tendency of a continuous outflows of financial capital in these economies will exercise a depreciating pressure on home currency. To see this, notice that the term on the right-hand side of equation (57) is proportional to the household saving rate. Since the household saving rate is an increasing function of income growth, the excess demand for foreign assets rises with $g$. So if $\eta$ is large enough, this asset-demand effect on the real exchange rate can dominate the "secondary Balassa-Samuelson effect".

Figure 7 shows the two opposing effects on the real exchange rate when the growth rate of the economy increases (under the assumption $\eta = 1$). The line with circles represent the precautionary saving effect on the real exchange rate (defined as $\frac{e^*}{e}$ based on equation (57)) under the
normalization that the market-determined nominal exchange rate equals the linked exchange rate when \( g = 0 \).\(^{29}\) The curve shows that the real exchange rate increases (depreciates) with the income growth rate because the outflows of domestic financial capital rises with the precautionary saving rate. The line with squares represent the secondary Balassa-Samuelson effect on the real exchange rate, as determined by equation (27). The curve shows that the real exchange rate decreases (appreciates) with the growth rate because a higher domestic real interest rate renders nontradable goods more expansive relative to tradable goods under segregated capital markets. For example, when the income growth rate jumps from 0% to 1% per year, the real exchange rate would depreciate by nearly 24% under the precautionary-saving effect and would appreciate by 11% under the secondary Balassa-Samuelson effect. Even if \( \eta = 0.5 \), the real exchange rate would still depreciate by 12% under the precautionary-saving effect, larger than the Balassa-Samuelson effect.\(^{30}\)

![Figure 7. Growth Effects on Real Exchange Rate.](image)

The basic message from the above analyses is that the market value of RMB is determined not only by excess demand of tradable goods between China and the United States, but also by excess demand of foreign assets between the two countries. Given that China has a underdeveloped financial system that offers very limited opportunities for households to invest their precautionary savings, the demand for foreign assets by Chinese households is very strong and such a strong asset

\(^{29}\) When \( g = 0 \), equation (57) implies \( e^* = \bar{e} \) because the steady-state saving rate \( (\tau) \) equals zero.

\(^{30}\) A dynamic analysis under a transitory increase in the TFP growth rate \( g_t \) would generate similar results. To conserve space, such exercises are omitted in this paper.
demand will put an extraordinary downward pressure on the RMB to depreciate against the dollar. Yet most of the existing literature about the determination of the exchange rate (including the Balassa(1964)-Samuelson(1964) analysis) has completely ignored the role of asset demand behind the exchange rate determination.

Therefore, the claim that a developing country’s currency will unavoidably appreciate in the long run is unfounded. Even if one ignores the strong precautionary saving demand for foreign assets in an emerging economy, the Balassa-Samuelson effect may still be offset by the very fact that rapid productivity growth in China means that its tradable goods should become cheaper over time in the world market relative to goods produced by a slower-growing developed country. In reality, it is precisely this counter-Balassa-Samuelson effect that has caused (or partly caused) American firms to move to China in the past decade.

6 A Robustness Analysis

Large trade surplus and foreign-reserve buildups are not a unique feature of the Chinese economy. Other emerging economies during their rapid economic growth phase, such as Japan in the 1960-70s, Hong Kong in the 1980s, and Taiwan and South Korea in the 1990s, also exhibited similar saving behaviors and registered large trade surplus and exchange reserves. However, because capital controls and linked exchange rate are not universal features of all emerging economies, it is thus desirable to show that the previous results do not hinge on the assumptions of capital controls or linked exchange rate.

This section assumes a floating nominal exchange rate without any capital controls. As in the general model, there are two production sectors in the home country. The nominal exchange rate is flexible and the real exchange rate (the relative price of the tradable goods in terms of the nontradable goods) is denoted by \( e_t \). Households can choose to work in either sector and receive real wage \( W_{jt} \) in sector \( j \). For simplicity and without loss of generality, there is no fixed capital in the model. The production technology in sector \( j \) is given by \( Y_{jt} = A_t F(N_{jt}) \), and the competitive real wage is given by \( W_{jt} = \frac{dY_{jt}}{dN_{jt}} \). Applying the re-scaling factor \( A_{t-1} \), we have \( y_{jt} = (1 + g_t) F(N_{jt}) \) and \( w_{jt} = (1 + g_t) F'(N_{jt}) \).

Household \( i \)'s problem is to solve

\[
\max E \sum_{t=0}^{\infty} \beta^t \{ \theta_t(i) [\gamma_1 \log c_{1t}(i) + \gamma_2 \log c_{2t}(i)] - N_{1t}(i) - N_{2t}(i) \} \tag{59}
\]

subject to

\[
c_{1t}(i) + c_{2t}(i) + (1 + g_t) \bar{m}_{t+1}(i) \leq \bar{m}_t(i) + w_{1t}N_{1t}(i) + e_t w_{2t}N_{2t}(i) + \Pi_{1t} + e_t \Pi_{2t} \tag{60}
\]
where $\tilde{m}_t$ denotes a portfolio of assets with real gross rate of return equal to 1, and $\Pi_{jt}$ denotes profit income distributed from firms in sector $j$. Because different currencies are fully convertible, the household faces only one budget constraint. The budget constraint implies that household can combine income received from either sector to finance consumption of both nontradable goods and tradable goods, as well as asset accumulations.

**Proposition 6** Denoting cash-in-hand as

$$x_t \equiv \tilde{m}_t(i) + w_{1t}N_{1t}(i) + e_t w_{2t}N_{2t}(i) + \Pi_{1t} + e_t \Pi_{2t},$$

the decision rules for consumption, imports, saving, and cash-in-hand are given by

$$c_{1t}(i) = \frac{\gamma_1}{\gamma_1 + \gamma_2} \min \left\{ 1, \frac{\theta_t(i)}{\theta_t^*} \right\} x_t,$$

$$e_t c_{2t}(i) = \frac{\gamma_2}{\gamma_1 + \gamma_2} \min \left\{ 1, \frac{\theta_t(i)}{\theta_t^*} \right\} x_t,$$

$$e_t = \frac{w_{1t}}{w_{2t}},$$

$$(1 + g_t) \tilde{m}_{t+1}(i) = \max \left\{ \frac{\theta_t^* - \theta(i)}{\theta(i)}, 0 \right\} x_t,$$

$$\frac{1 + g_t}{w_{1t}} = \beta E_t \frac{1}{w_{1t+1}} R(\theta_t^*),$$

$$x_t = (\gamma_1 + \gamma_2) \theta_t^* R(\theta_t^*) w_{1t}.$$

**Proof.** See Appendix V. $\blacksquare$

Equations (63)-(65) imply that

$$\frac{c_{1t}}{c_{2t}} = \frac{\gamma_1}{\gamma_2} e_t.$$

Compared to equation (48), lifting capital controls implies efficient allocation here. However, this efficiency gain has no effect on the household saving rate, as the following proposition shows.

**Proposition 7** The current account surplus is given by

$$CA_t = (\gamma_1 + \gamma_2) \left[ (1 + g_t) \theta_t^* R(\theta_t^*) H(\theta_t^*) - \theta_{t-1}^* R(\theta_{t-1}^*) H(\theta_{t-1}^*) \right],$$

and the aggregate saving rate is given by

$$\tau_t = \left[ (1 + g_t) \theta_t^* R(\theta_t^*) - \theta_{t-1}^* R(\theta_{t-1}^*) H(\theta_{t-1}^*) \right] \left[ (1 + g_t) \theta_t^* R(\theta_t^*) - \theta_{t-1}^* R(\theta_{t-1}^*) H(\theta_{t-1}^*) \right].$$
Proof. See Appendix VI. ■

Notice that the saving rate is precisely the same as that in equation (20) in the benchmark model and is also identical to that in the general model (if $\alpha = 0$, or there is no capital in production). Clearly, both the current account and the national saving rate are independent of the exchange rate $e_t$. In the steady state, the current account surplus are given by

$$CA = g\theta R(\theta^*) H(\theta^*),$$

and the saving rate equals

$$\tau = \frac{\check{g} H(\theta^*)}{1 + \check{g} - H(\theta^*)},$$

which is identical to equation (53) in the general model.

7 Conclusion

This paper offers two main insights:

- China’s 2.4 trillion excessive foreign reserves can be a natural consequence of rapid economic growth in conjunction with an inefficient financial system (or lack of timely financial reform) that has hindered Chinese households from consuming their rapid growing future income, instead of the intended outcome of any government policies or an undervalued home currency.

- The fundamental determinates of the exchange rate include not just excess demand of tradable goods but also excess demand of tradable assets. Taking into account the excessive amount of precautionary savings of Chinese households and capital controls, the current exchange rate of RMB may have been overvalued, instead of undervalued.

The intuition is simple. Trade can be always balanced whether the exchange rate be "1 orange for 1 apple", or "100 oranges for 1 apple". A trade imbalance would occur if Chinese workers gave up 100 oranges in exchange for $1 but opt not to spend the entire dollar on American apples. Instead, they bought only half American apple and saved the remaining 50¢ as IOU. The question therefore is: Why would the Chinese do that when the real rate of return to American IOUs is so low (negative) and they expect to be much richer in the future than they are today? The answer is that Chinese workers have a much stronger need to save than do Americans due to large uninsured risk and severe borrowing constraints, and more paradoxically, the richer they expect to be in the future, the more they opt to save today. Such a precautionary saving behavior appears contradicting sharply with the conventional wisdom (Friedman, 1957), but is nonetheless perfectly rational when financial markets are incomplete.
Based on these insights, we can conclude that revaluating the RMB will not resolve the U.S. trade-imbalance problem with China and may prove to be counter-productive. First, the very reason for developing countries to adopt a linked exchange rate is to facilitate trade by removing uncertainties in relative prices and returns to foreign investment, not by selling low and buying high (as argued by Krugman, 2010). Thus, forcing China to appreciate its currency destroys the stability of RMB and undermines the very rationale of having a linked exchange rate. Second, such a political pressure generates market expectations and leads to speculations and capital inflows to China, which in turn may result in inflation and asset bubbles in China.\(^{31}\)

True, if the elasticity of American demand respect to prices of Chinese goods is high—which is a big "if" because Chinese goods are labor intensive and not substitutable easily by American goods, then under the assumption of sticky prices, a revaluation of RMB may reduce American demand for Chinese goods, thereby reducing the volume of trade between China and the U.S. But the reduced imports of Chinese goods will be replaced by goods from other developing countries that have similar comparative advantages in low-labor costs and similar precautionary saving behaviors like China—because the high wage costs in the U.S. make it unprofitable to produce such goods domestically. Also, a revalued RMB is unlikely to change the precautionary saving motives of Chinese households. Thus, Chinese will not buy significantly more American goods simply because of a revalued RMB.

A more productive approach would be to help speeding up financial development in China and to encourage Chinese firms to increase investment spending on capital goods both domestically and abroad. In this regard, the United States has much to offer because it is good at producing both financial products (such as assets and financial services) and capital-intensive goods (such as machineries).\(^{31}\)

\(^{31}\) Thus, a dramatic appreciation of the RMB may lead to potentially large economic disasters in the future given that RMB may have been actually overvalued. Sudden collapses of domestic asset markets may happen when the capital controls are lifted (similar to what happened during the Asian financial crisis in 1997). Such outcomes can do no good to the World economy because a collapse of Chinese asset markets could trigger a world-wide recession larger than the aftermath of the Asian financial crisis, given the sheer size of the Chinese economy and its current integration with the world.
Appendix

A. I. Proof of Proposition 1.

Proof. Denote \( \{ \lambda_t(i), \pi_t(i) \} \) as the Lagrangian multipliers associated with equations (3)-(4), respectively. The first-order conditions for \( \{ c_t(i), N_t(i), m_{t+1}(i) \} \) are given, respectively, by

\[
\frac{\theta_t(i)}{c_t(i)} = \lambda_t(i) \tag{74}
\]

\[
1 = A_0 \int \lambda_t(i) dF(\theta) \tag{75}
\]

\[
(1 + \bar{g}) \lambda_t(i) = \beta E_t \int \lambda_{t+1}(i) dF(\theta) + \pi_t(i), \tag{76}
\]

where equation (75) reflects the fact that labor supply must be determined before the realization of \( \theta_t(i) \) in each period. The optimal decision rules are characterized by a cutoff strategy. In the anticipation that the cutoff \( \theta^* \) is independent of \( i \), consider two possible cases:

Case A. \( \theta(i) \leq \theta^* \). In this case, the urge to consume is low. It is then optimal to save to prevent possible borrowing constraints in the future when the urge to consume may be high. So \( m'(i) \geq 0, \pi(i) = 0 \), and equation (76) implies that the shadow value of good \( \lambda(i) = \frac{\beta}{(1+\bar{g})A_0} \).

Equation (74) then implies that \( c_t(i) = \theta(i) \frac{(1+\bar{g})A_0}{\beta} \). The household budget constraint then implies \( (1 + \bar{g}) m'(i) = x(i) - \theta(i) \frac{(1+\bar{g})A_0}{\beta} \). The requirement \( m'(i) \geq 0 \) then implies

\[
\theta(i) \leq x(i) \frac{\beta}{(1 + \bar{g}) A_0} \equiv \theta^*, \tag{77}
\]

which defines the cutoff \( \theta^*_i \).

Case B. \( \theta(i) > \theta^* \). In this case, the urge to consume is high. It is then optimal not to save, so \( \pi_t(i) > 0 \) and \( m'(i) = 0 \). By the household budget constraint, we have \( c(i) = x(i) \), which by equation (77) implies \( c(i) = \theta^* \frac{(1+\bar{g})A_0}{\beta} \). Equation (74) then implies that \( \lambda_t(i) = \frac{\theta(i)}{\theta^*} \frac{\beta}{(1+\bar{g})A_0} \). Since \( \theta(i) > \theta^* \), equation (76) confirms that \( \pi(i) = \frac{\beta}{A_0} \left[ \frac{\theta(i)}{\theta^*} - 1 \right] > 0 \).

The above analyses imply that \( \lambda_t(i) \) takes two possible values, depending on the realization of \( \theta_t(i) \). Hence, the expected value, \( \int \lambda_t(i) dF(\theta) \), can be expressed analytically. That is, equation (78) implies

\[
1 = \frac{\beta}{1 + \bar{g}} R(\theta^*), \tag{78}
\]
where the implicit function \( R(\theta^*) \equiv \int_{\theta < \theta^*} dF(\theta) + \int_{\theta > \theta^*} \theta^* dF(\theta^*) \). As a result, the optimal cutoff, \( \theta_t^* \), is determined by equation (78), which determines optimal labor supply. Equation (78) implies that the cutoff \( \theta_t^* \) is independent of \( i \) because \( \theta(i) \) is i.i.d. Hence, equation (77), which defines the cutoff, in turn implies that the optimal cash in hand \( (x_t) \) is also independent of \( i \). ■

A. II. Proof of Proposition 2.

Proof. Differentiating the saving rate with respect to \( \bar{g} \) gives

\[
\frac{d\tau}{d\bar{g}} = \frac{H(1 - H) + \bar{g}(1 + \bar{g}) \frac{\partial H}{\partial \bar{g}}}{(1 + \bar{g} - H)^2},
\]

(79)

The definition of the function \( R(\theta^*) \) in equation (11) implies \( \frac{\partial R}{\partial \bar{g}} < 0 \), so equation (10) then implies \( \frac{\partial \theta^*}{\partial \bar{g}} < 0 \). Given that \( \frac{\partial H}{\partial \bar{g}} > 0 \), it must be true that \( \frac{\partial H}{\partial \bar{g}} = \frac{\partial H}{\partial \theta^*} \frac{\partial \theta^*}{\partial \bar{g}} < 0 \). Hence, the second term in the numerator of equation (79) is negative while the first term is positive. Because \( \frac{d\tau}{d\bar{g}} = 0 \) if \( \bar{g} = 0 \) and \( \frac{d\tau}{d\bar{g}} < 0 \) if \( \bar{g} = \infty \), continuity implies there exists a threshold \( g^* \in (0, \infty) \) that renders \( \frac{d\tau}{d\bar{g}} = 0 \) or \( g^*(1 + g^*) = -H(1 - H) / \frac{\partial H}{\partial \bar{g}} \). So it must be true that \( \frac{d\tau}{d\bar{g}} > 0 \) if \( \bar{g} < g^* \) and \( \frac{d\tau}{d\bar{g}} < 0 \) if \( \bar{g} > g^* \). ■

A. III. Proof of Proposition 3.

Proof. When technology \( A_t \) is stochastic and follows the law of motion (18), the general equilibrium path of the re-scaled benchmark model can be characterized by the set of variables, \( \{c_t, m_{t+1}, \theta_t^*, x_t, N_t, \} \), which can be solved uniquely by the following system of equations:

\[
c_t = D(\theta_t^*) x_t \tag{80}
\]

\[
(1 + g_t) m_{t+1} = H(\theta_t^*) x_t \tag{81}
\]

\[
\frac{1 + g_t}{w_t} = \beta E_t \frac{1}{w_{t+1}} R(\theta_t^*) \tag{82}
\]

\[
x_t \equiv m_t + w_t N_t = \theta_t^* R(\theta_t^*) w_t, \tag{83}
\]

plus equation (19) and standard transversality conditions.

In general equilibrium, \( w_t = 1 + g_t \). So equation (82) solves implicitly for the cutoff \( \theta_t^* \). Given the cutoff, equations (80) and (83) solve for the optimal consumption path as

\[
c_t = D(\theta_t^*) \theta_t^* R(\theta_t^*) (1 + g_t); \tag{84}
\]
and equations (81) and (83) solve for the optimal foreign reserves as

\[(1 + g_t) m_{t+1} = H(\theta_t^* \theta_t^* R(\theta_t^*)) (1 + g_t). \tag{85}\]

Equation (83) implies \( w_t N_t = \theta_t^* R(\theta_t^*) w_t - m_t \), which in turn implies employment in the tradable sector:

\[N_t = \theta_t^* R(\theta_t^*) - \frac{m_t}{(1 + g_t)} = \theta_t^* R(\theta_t^*) - \frac{H(\theta_t^* \theta_t^* R(\theta_t^*))}{(1 + g_t)}. \tag{86}\]

Therefore, year-to-year changes in foreign reserves in period \( t \) are given by

\[(1 + g_t) m_{t+1} - m_t = y_t \left[ 1 - \frac{c_t}{(1 + g_t) N_t} \right] = y_t \left[ 1 - \frac{D(\theta_t^* \theta_t^* R(\theta_t^*))}{\theta_t^* R(\theta_t^*)} \right]. \tag{87}\]

Multiplying the lower-case variables by \( A_{t-1} \) gives equation (20).

Using the law of motion in equation (18) and assuming lognormal distribution for \( \varepsilon_t \) with mean zero and variance \( \sigma_\varepsilon^2 \), equation (82) implies

\[1 = \beta R(\theta_t^*) E_t \frac{1}{1 + g_{t+1}} = \beta R(\theta_t^*) \left( \frac{1 + \tilde{g}}{1 + g_t} \right)^{\frac{\sigma_\varepsilon^2}{1 + \tilde{g}}}. \tag{88}\]

With \( \theta \) following the Pareto distribution \( F = 1 - \theta^{-\sigma} \), we have \( R(\theta^*) = 1 + \frac{1}{\sigma-1} \theta^{1-\sigma} \), so the above equation solves for the cutoff explicitly as in equation (22).

**A. IV. Proof of Proposition 4 (general model).**

**Proof.** Denote \( \{\lambda_{1t}(i), \pi_{1t}(i), \lambda_{2t}(i), \pi_{2t}(i)\} \) as the Lagrangian multipliers associated with equations (31)-(34), respectively. By the assumption that \( \theta_t(i) \) is orthogonal to aggregate shocks, the first-order conditions for \( \{c_{jt}(i), N_{jt}(i), \xi_{jt+1}(i)\} \) are given, respectively, by

\[\gamma_{jt}(i) \frac{\partial c_{jt}(i)}{\partial \theta_t(i)} = \lambda_{jt}(i) \tag{89}\]

\[1 = w_{jt} \int \lambda_{jt}(i) dF(\theta) \tag{90}\]

\[(1 + g_t) \lambda_{jt}(i) = \beta E_t \left[ \int \lambda_{jt+1}(i) dF(\theta) \right] + \pi_{jt}(i), \tag{91}\]

where equation (90) reflects the fact that labor supply must be determined before the realization of \( \theta_t(i) \) in each sector and each period. The household decision rules can then be derived straightforwardly following the same steps as in Appendix I.
A. V. Proof of Proposition 6 (Robustness Analysis).

Proof. The first-order conditions for \( \{c_{1t}, c_{2t}, N_{1t}, N_{2t}, \tilde{m}_{t+1}\} \) are given, respectively, by

\[
\frac{\gamma_1 \theta_t(i)}{c_{1t}(i)} = \lambda_t(i) 
\]

(92)

\[
\frac{\gamma_2 \theta_t(i)}{c_{2t}(i)} = e_t \lambda_t(i) 
\]

(93)

\[
1 = w_{1t} \int \lambda_t(i) dF(\theta) 
\]

(94)

\[
1 = e_t w_{2t} \int \lambda_t(i) dF(\theta) 
\]

(95)

\[
(1 + g_t) \lambda_t(i) = \beta E_t \lambda_{t+1}(i) + \pi_t(i). 
\]

(96)

These first-order conditions imply

\[
e_t = \frac{w_{1t}}{w_{2t}} 
\]

(97)

\[
\frac{c_{1t}(i)}{c_{2t}(i)} = \frac{\gamma_1}{\gamma_2} e_t. 
\]

(98)

Using the relation between \( c_{1t} \) and \( c_{2t} \), the household decision rules can be derived following the same steps as in Appendix I. ■

A. VI. Proof of Proposition 7.

Proof. Aggregation by the law of large numbers, the household decision rules become

\[
c_{1t} = \frac{\gamma_1}{\gamma_1 + \gamma_2} D(\theta_t^*) x_t 
\]

(99)

\[
e_t c_{2t} = \frac{\gamma_2}{\gamma_1 + \gamma_2} D(\theta_t^*) x_t 
\]

(100)

\[
(1 + g_t) \tilde{m}_{t+1} = H(\theta_t^*) x_t 
\]

(101)

\[
x_t = (\gamma_1 + \gamma_2) \theta^* R(\theta_t^*) w_{1t}. 
\]

(102)

The budget constraint becomes

\[
c_{1t} + e_t c_{2t} + (1 + g_t) \tilde{m}_{t+1} = \tilde{m}_t + w_{1t} N_{1t} + e_t w_{2t} N_{2t} + \Pi_{1t} + e_t \Pi_{2t}. 
\]

(103)
Since households own firms, wage income plus profit income should equal the value of output in each sector:

\[ w_{jt}N_{jt} + \Pi_{jt} = y_{jt}. \]  

(104)

Hence, market clearing in the nontradable-goods sector imply

\[ c_{1t} = w_{1t}N_{1t} + \Pi_{1t}. \]  

(105)

Equation (103) then implies

\[ e_{t}c_{2t} + (1 + g_{t}) \bar{m}_{t+1} = \bar{m}_{t} + e_{t}y_{2t}. \]  

(106)

So the current account surplus are given by

\[ CA_{t} = e_{t}y_{2t} - e_{t}c_{2t} = (1 + g_{t}) \bar{m}_{t+1} - \bar{m}_{t}. \]  

(107)

Using equation (101), we have

\[ CA_{t} = H(\theta_{t}^{*})x_{t} - \frac{1}{1 + g_{t-1}}H(\theta_{t-1}^{*})x_{t-1} \]  

(108)

\[ = (\gamma_{1} + \gamma_{2}) [(1 + g_{t}) \theta_{t}^{*}R(\theta_{t}^{*})H(\theta_{t}^{*}) - \theta_{t-1}^{*}R(\theta_{t-1}^{*})H(\theta_{t-1}^{*})]. \]

The aggregate saving rate is given by

\[ \tau_{t} = \frac{y_{1t} + e_{t}y_{2t} - [c_{1t} + e_{t}c_{2t}]}{y_{1t} + e_{t}y_{2t}} = \frac{CA_{t}}{y_{1t} + e_{t}y_{2t}}, \]  

(109)

where the denominator is given by

\[ y_{1t} + e_{t}y_{2t} = w_{1t}N_{1t} + \Pi_{1t} + e_{t}w_{2t}N_{2t} + e_{t}\Pi_{2t} \]  

(110)

\[ = x_{t} - \bar{m}_{t} \]  

\[ = x_{t} - \frac{1}{1 + g_{t-1}}H(\theta_{t-1}^{*})x_{t-1} \]  

\[ = (\gamma_{1} + \gamma_{2}) [(1 + g_{t}) \theta_{t}^{*}R(\theta_{t}^{*}) - \theta_{t-1}^{*}R(\theta_{t-1}^{*})H(\theta_{t-1}^{*})]. \]

So we have

\[ \tau_{t} = \frac{[(1 + g_{t}) \theta_{t}^{*}R(\theta_{t}^{*})H(\theta_{t}^{*}) - \theta_{t-1}^{*}R(\theta_{t-1}^{*})H(\theta_{t-1}^{*})]}{[(1 + g_{t}) \theta_{t}^{*}R(\theta_{t}^{*}) - \theta_{t-1}^{*}R(\theta_{t-1}^{*})H(\theta_{t-1}^{*})]} \].  

(111)
References


