NBER WORKING PAPER SERIES

CAPITAL ACCOUNT POLICIES AND THE REAL EXCHANGE RATE

Olivier Jeanne

Working Paper 18404
http://www.nber.org/papers/w18404

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2012

This paper was prepared for the National Bureau of Economic Research (NBER) International Seminar on Macroeconomics (ISoM), Oslo, June 15-16, 2012. The first version of this paper was circulated in February 2011. I thank the conference participants, and especially my discussants Javier Bianchi and Lars Svensson for their comments on the conference draft, as well as Nicholas Borst and Patrick Douglass for their help in collecting the data. The views expressed herein are those of the author and do not necessarily reflect the views of the National Bureau of Economic Research.

Capital Account Policies and the Real Exchange Rate
Olivier Jeanne
NBER Working Paper No. 18404
September 2012
JEL No. F31,F32,F36

ABSTRACT

This paper presents a simple model of how a small open economy can undervalue its real exchange rate using its capital account policies. The paper presents several properties of such policies, and proposes a rule of thumb to assess their welfare cost. The model is applied to an analysis of Chinese capital account policies.

Olivier Jeanne
Department of Economics
Johns Hopkins University
454 Mergenthaler Hall
3400 N. Charles Street
Baltimore, MD 21218
and NBER
ojeanne@jhu.edu

1 Introduction

There are debates about the extent to which emerging market and developing countries that have accumulated large amounts of foreign exchange reserves in the 2000s are doing so in order to undervalue their currency. However, we do not have a simple model of how a country can achieve persistent *real* exchange rate distortions through reserve accumulation. The main purpose of this paper is to present such a model and to use it to answer a few questions about undervaluation policies.

Real exchange rate undervaluation is often presented, in policy debates, as the result of a monetary operation. For example, it is argued that the People's Bank of China (PBOC) has resisted the appreciation of the renminbi by pegging the nominal exchange rate and accumulating reserves. But pegging the nominal exchange rate is not the same thing as pegging the real exchange rate, and we know that in an environment without nominal frictions monetary policy has virtually no impact on real variables. It is unlikely, furthermore, that nominal frictions alone give monetary policy enough leverage to have a persistent impact on the real exchange rate. Standard estimates suggest that nominal stickiness is not persistent enough to induce large and persistent deviations of the real exchange rate from its flexible-price equilibrium value (Rogoff, 1996; Chari, Kehoe and McGrattan, 2002). In order to achieve persistent real undervaluation, thus, monetary policy must rely on something else than just nominal stickiness.

I focus in this paper on the role of imperfect capital mobility. Imperfect capital mobility can be defined, for the purpose of my analysis, as any friction inducing a deviation from Ricardian equivalence in capital flows.[1] Imperfect capital mobility could result from "natural causes," such as financial frictions that prevent the private sector from borrowing abroad, or deviations from rational expectations that mitigate or delay the private sector's Ricardian response to reserve accumulation. Imperfect capital mobility could also be policy-induced and result from capital account restrictions that are imposed by the government. The fact that the country that has accumulated the most reserves in the 2000s, China, also imposes tight restrictions on its capital account suggests that the link between the two is worth looking at. Thus, this paper will focus on the question of how the real exchange rate is affected

[1] Ricardian equivalence—a property of frictionless rational expectations models—stipulates that an accumulation of foreign assets by the public sector should have no impact on net capital flows because it is offset by an inflow of capital to the private sector.

by capital account policies, defined in a broad way as the accumulation of foreign assets and liabilities by the public sector plus all the policies that affect the private sector's access to foreign capital. However, most of my results can be extended to the case where Ricardian equivalence fails because of frictions other than capital account restrictions.

In order to simplify and streamline the analysis, I use a model that is entirely real—there is no money and no monetary policy. I consider a small open economy that consumes a tradable good and a nontradable good. The government accumulates foreign assets and imposes controls on capital flows. This combination of policies allows the government to effectively control the level of net foreign assets for the country as a whole. The other properties of the model then follow in a straightforward way. The government controls the current account balance (since it is the change in net foreign assets) and therefore the trade balance. The real exchange rate, then, has to be consistent with the trade balance. Other things equal, accumulating more net foreign assets will depreciate the real exchange rate.

I then use the model to look at several questions related to capital account policies and real exchange rates. How can we detect in the data that these policies influence the real exchange rate? Are there limits to the impact of capital account policies on real exchange rates and how are they determined? If capital account policies can lead to real exchange rate undervaluation, how different are they from trade protectionism? What is the welfare cost from resisting to currency appreciation? I also look at the recent experience of China through the lenses of the model.

The paper is related to several lines of literature. First, it is related to the literature on global imbalances, the "global savings glut," and the "upstream" flow of capital from relative poor high-growth countries to relatively rich low-growth countries. The problem in that literature is to explain high saving rates in emerging market economies. One line of explanation is precautionary savings against idiosyncratic risk: see e.g. Mendoza, Quadrini and Ríos-Rull (2009), Carroll and Jeanne (2009) or Sandri (2010). Chamon and Prasad (2010) argue that precautionary savings against idiosyncratic risk is the most likely cause of the high saving rate in China. Precautionary savings could also be against aggregate risk, in particular the risk of sudden stop (Durdu, Mendoza and Terrones, 2009; Jeanne and Rancière, 2011). Capital outflows from high-growth countries could also result from domestic financial frictions as in Caballero, Farhi and Gourinchas (2008) or Song, Storesletten and Zilibotti (2011). A common feature of these contributions is that the

saving rate is determined by the behavior of the private sector. Reserve accumulation and capital account policies play no role and it is by happenstance that a substantial share of foreign assets ends up being accumulated as reserves.

The evidence however suggests that the upstream flow in capital is linked to public flows and in particular reserve accumulation (Aguiar and Amador, 2011; Gourinchas and Jeanne, 2011). My model explains the link between reserve accumulation and net capital flows as more than a coincidence. In equilibrium, reserve accumulation must reduce net capital inflows by reducing saving (keeping investment constant). Another way of looking at the real undervaluation policy in my model, thus, is that the accumulation of foreign assets induces "forced saving" in the domestic economy. The capital controls prevent the domestic private sector from offsetting the public accumulation of foreign assets by borrowing abroad. The model thus provides a simple explanation for the high saving rate in countries such as China.[2]

Second, the paper is related to the literature on exchange rate undervaluation. Dooley, Folkerts-Landau and Garber (2004) argue that China and several other emerging markets and developing countries have been resisting the appreciation of their currencies in order to promote exports-led growth, a phenomenon that they dub "Bretton Woods II." An empirical literature has studied whether real exchange rate undervaluations increase growth (see for example Rodrik, 2008). Policy discussions often take for granted that a country can resist the real appreciation of its currency by accumulating reserves but the literature lacks a clear model of how this comes about. Ghosh and Kim (2008) showed, in a two-period small-open-economy model, that in the presence of capital account restrictions, sterilized interventions can have the same effects as export subsidies or a tax on consumption.

Third, the paper is related to the literature about optimal capital account policies. One recent line of literature has studied the normative case for prudential capital controls aimed at smoothing the boom-bust cycle in capital flows (Bianchi, 2011; Korinek, 2011; Schmitt-Grohé and Uribe, 2012). Another line of literature has studied the case for "mercantilist" real exchange rate undervaluations (Aizenman and Lee, 2007; Korinek and Serven, 2010). Costinot, Lorenzoni and Werning (2011) study equilibrium capital account policies in a two-country model. By contrast with that literature, I take

[2]The model presented here explains the saving rate for the economy as a whole. It does not predict the breakdown of saving between the household and the corporate sectors.

capital account policies as given and do not look at the reasons that real exchange rate undervaluation might be desirable from a welfare perspective.

Fourth, the paper is a contribution to the literature on the impact of sterilized foreign exchange reserve interventions. The empirical literature until the 2000s was primarily focused on advanced economies and motivated in part by the apparent success of concerted interventions following the 1985 Plaza Accord (see Sarno and Taylor, 2001 for a review). The focus of the attention has shifted more recently on how the sterilized accumulation of reserves can help emerging markets and developing countries deal with large capital inflows and resist the appreciation of their currency (see for example, Disyatat and Galati, 2007 and Adler and Tovar, 2011). Adler and Tovar (2011) examine whether the impact of sterilized foreign exchange interventions for a panel of 15 economies (mostly in Latin America) covering 2004—2010. They find that interventions slow the pace of appreciation, but that (consistent with the model presented here) this effect is stronger for countries with more closed capital accounts. On the theoretical side, the Ricardian irrelevance result for sterilized interventions was stated by Sargent and Smith (1988), and Backus and Kehoe (1989) showed that it holds under more general conditions. However, it is possible to design realistic stochastic environments with incomplete markets in which sterilized interventions have real effects (Kumhof, 2010). In the deterministic model presented here, sterilized interventions matter because of a simple policy-induced friction in international capital flows.

The paper is structured as follows. Section 2 motivates the model by looking at the capital account policies of China. Section 3 presents the model. Sections 4 to 7 present various properties of the model and section 8 goes back to the Chinese experience, this time examining it through the lenses of the model.

2 Capital Account Policies of China

The capital account is very restricted in China. On the side of inflows, foreign direct investment (FDI) is largely liberalized and even encouraged in some cases through tax incentives but other inflows are constrained. Inward FDI in manufacturing is almost completely liberalized with the exception of

restrictions in some strategic sectors.[3]

As for financial inflows, the financial assets that foreigners might want to invest in are equity, debt securities, and bank deposits, but their access to these assets is severely restricted. These assets are not scarce. Figure 1 reports the outstanding stocks of the different types of financial assets as shares of GDP. At $3,408 billion at the end of 2011, the Chinese stock market capitalization is significant even relative to that in advanced economies.[4] The market for debt securities is less developed. The market for government bonds is not very large(about 17 percent of GDP at the end of 2010) and the local market for corporate bonds remains small and dominated by a handful of large state-owned institutions.

The main vehicle for households' and firms' financial saving is bank deposits, which have amounted to about 140 percent of GDP on average in the 2000s, and have been increasing over time. Most of those deposits are time and saving deposits that bear an interest rate.

The access of foreign investors to Chinese financial assets is severely limited. For equity, two types of shares are traded in the Shanghai and Shengzhen stock markets, "A shares" that can be owned only by domestic investors and "B shares" that can be purchased by foreigners. The value of B shares has never exceeded 3 percent of total stock market capitalization since 2000. Foreign investors can invest in financial assets other than B shares through the Qualified Foreign Institutional Investor (QFII) program. This program allows about 100 selected foreign institutional investors to invest in a limited range of Chinese domestic financial assets. The overall quota allocated to this program has remained small and the range of investable assets limited (Lardy and Douglass, 2011; Cappiello and Ferrucci, 2008).[5] Foreign investors cannot otherwise invest in domestic debt securities or hold bank deposits.

Capital outflows are restricted too. The restrictions on outbound FDI were relaxed over the past decade as the authorities have begun to view it as a valuable way to secure commodities and further integrate China into the global trading system. But Chinese investors cannot, as a rule, hold

[3]There are more restrictions on FDI in China's service sector, particularly telecommunications and financial services.

[4]It amounted to more than one-fifth of the US stock market capitalization, and twice the size of stock market capitalization of the United Kingdom, Germany, or France.

[5]The QFII quota was increased from $30 billion to $80 billion in April 2012, which remains a small fraction of the stock of Chinese domestic financial assets.

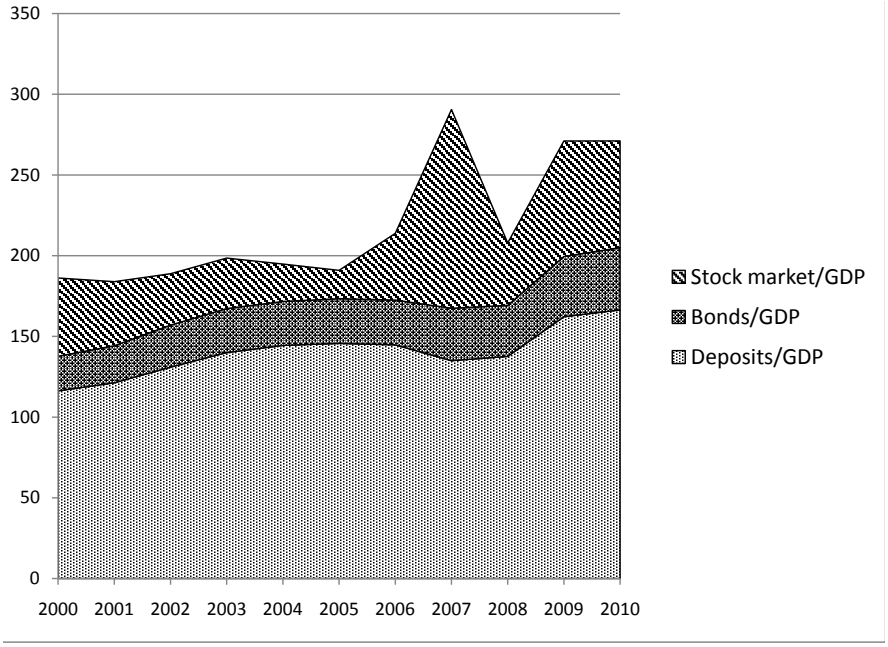

Figure 1: Outstanding stocks of Chinese financial assets: bank deposits, bonds, and stock market (percent of GDP, 2000—2010). Source: People's Bank of China, China Securities Regulatory Commission, Shanghai and Shenzhen Stock Exchanges.

foreign financial assets. The Qualified Domestic Institutional Investor (QDII) program, introduced in 2006, allows selected domestic financial institutions to invest abroad using a structure similar to that of QFIIS, but the quota allocated to this program has remained small. The state-controlled policy banks do the bulk of China's external lending, often to accompany the FDI of state-owned enterprises.

Obviously, the Chinese capital controls are not perfectly tight and there have been leakages. Chinese banks can draw down their overseas claims on international banks and the corporate and household sector can take advantage of the more liberalized current account through leads and lags in trade payments and remittances. However, the large and persistent spread between the onshore yield on the renminbi and its offshore counterpart suggest that Chinas existing official capital controls on inflows have been binding, especially after 2002 (Ma and McCauley, 2008; Cappiello and Ferrucci, 2008). Furthermore, the composition of China's capital flows and external assets and liabilities reflects the constraints imposed by the capital account restrictions. As shown in figure 2, which reports the breakdown of Chinese foreign assets and liabilities at the end of 2010, most of the foreign liabilities are accounted for by FDI and most of the foreign assets take the form of foreign exchange reserves.

It should be noted that inward FDI is not completely liberalized as it is subject to authorizations from the Chinese authorities. In principle, thus, the Chinese authorities can influence the level of FDI inflows. However, it is unlikely that this influence is used for macroeconomic fine-tuning as most of the decision-making power regarding the screening and approval of FDI is held by local governments. This being said, even if it takes FDI inflows as given, the central government can still infuence total *net* capital inflows through reserve accumulation as long as a change in international reserves is not offset one-for-one by a change in FDI inflows. The Chinese authorities could in this way indirectly control the current account balance—a key feature of the model presented in the next section.

3 Model

The model aims at capturing in the most simple possible way the essential features of the Chinese capital account documented in the previous section. The model is deterministic and in continuous time. It features a small open econ-

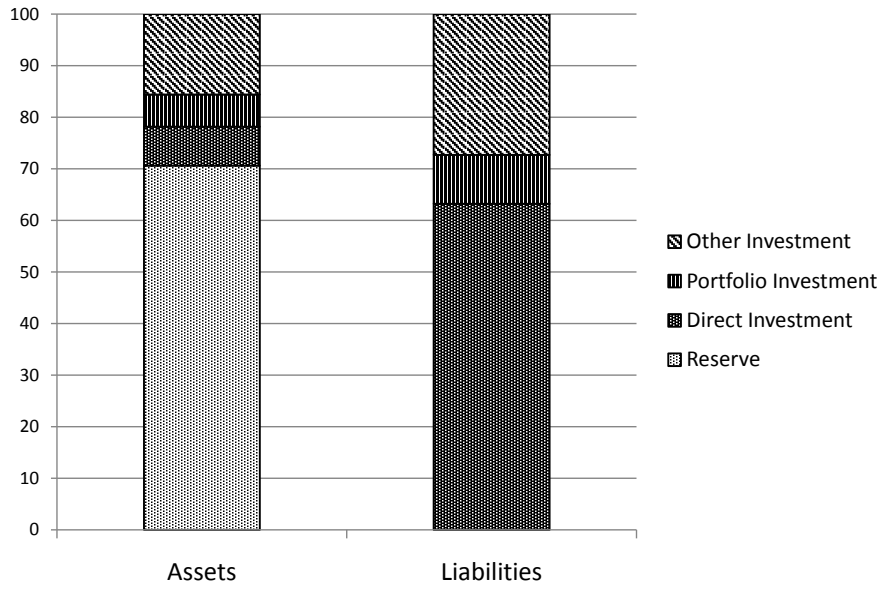

Figure 2: Composition of Chinese foreign assets and liabilities (percent, 2010). Source: State Administration of Foreign Exchange (SAFE).

omy populated by an infinitely-lived representative consumer who consumes a tradable good and a nontradable good. The utility of the representative consumer is given by

$$U_t = \int_0^{+\infty} e^{-\rho s} u(c_{t+s}) ds, \tag{1}$$

where $c_t = c(c_{Tt}, c_{Nt})$ is a function of the consumption of the tradable good, c_T, and the consumption of the nontradable good, c_N, which is homogeneous of degree 1. I denote by p_t the price of the nontradable good in terms of the tradable good, and by q_t the price of the tradable good in terms of domestic consumption. I will call q_t is the real exchange rate (an increase in q is a real depreciation) and by an abuse of language that is common in the literature, I will sometimes call the tradable good "dollar."

The domestic consumer receives exogenous flows of nontradable and tradable goods. The budget constraint of the domestic consumer is

$$c_t + \dot{a}_t + q_t \dot{a}_t^* = q_t(y_{Tt} + p_t y_{Nt}) + r_t a_t + q_t r^* a_t^* + z_t, \tag{2}$$

where a_t and a_t^* are the consumer's holdings of bonds respectively denominated in consumption good and tradable good; y_{Tt} and y_{Nt} are the country's

endowments of the tradable good and nontradable good; and z_t is a lump-sum transfer from the government. I will call a_t and a_t^* the private sector's holdings of "domestic bonds" and "foreign bonds," respectively. The assumption that the output of tradable good and nontradable good are endowments can be interpreted as the fact that labor is not mobile between the two sectors. I will assume, to simplify the analysis, that the consumer's psychological discount rate is equal to the interest rate, $\rho = r^*$, but this assumption can easily be relaxed.

The budget constraint of the government is

$$q_t \dot{b}_t^* + \dot{b}_t + z_t = q_t r^* b_t^* + r_t b_t, \tag{3}$$

where b_t^* and b_t are the government's holdings of bonds denominated in dollars and in domestic consumption good respectively. I call b_t^* "international reserves." If the government accumulates foreign assets by issuing domestic liabilities, b_t is negative and $-b_t$ is the government's domestic debt.

Government policy consists in the announcement of paths for public assets, (b_t^*, b_t), that satisfy the transversality condition,

$$\lim_{t \to +\infty} (b_t^* + b_t/q_t) e^{-r^* t} \geq 0. \tag{4}$$

The impact of government policy crucially depends on the extent of capital mobility between the country and the rest of the world. With perfect capital mobility, government policy has no effect on the domestic economy and the real exchange rate (Ricardian equivalence). This result is well-known but going through the proof will allow us to make some points that are useful for future reference.

First, adding the budget constraints for the representative consumer and the government, (2) and (3), using interest parity $r_t = r^* + \dot{q}_t/q_t$ as well as the fact that the consumption of nontradable good is equal to its supply in each period, $c_{Nt} = y_{Nt}$, one derives the consolidated budget constraint for the country as a whole,

$$c_{Tt} + \dot{n}_t^* = y_{Tt} + r^* n_t^*, \tag{5}$$

where n_t^* denotes the country's net foreign assets,

$$n_t^* = a_t^* + b_t^* + \frac{a_t + b_t}{q_t}.$$

Second, using the first-order condition, $q_t = \partial c_t / \partial c_{Tt}$, and again $c_{Nt} = y_{Nt}$, the real exchange rate can be written in reduced form as a function of c_{Tt} and y_{Nt},

$$q_t = q(c_{Tt}, y_{Nt}).$$

The equilibrium under perfect capital mobility is then characterized by the following two conditions,

$$u'\left(c(c_{Tt}, y_{Nt})\right) q(c_{Tt}, y_{Nt}) = \mu, \tag{6}$$

$$\int_0^{+\infty} c_{Tt} e^{-r^* t} dt = \int_0^{+\infty} y_{Tt} e^{-r^* t} dt + b_0^* + a_0^* + \frac{b_0 + a_0}{q(c_{T0}, y_{N0})}. \tag{7}$$

The first equation says that the marginal utility of consuming the tradable good must be constant over time (since the dollar interest rate is equal to the consumer's psychological discount rate). The second equation is the country's intertemporal budget constraint. Together, these conditions pin down the path for the consumption of tradable good, $(c_{Tt})_{t \geq 0}$, and through the country's budget constraint (5), the path for the country's total net foreign assets, $(n_t^*)_{t \geq 0}$, but they do not determine the individual components of foreign assets.[6] In particular, an open market operation in which the government purchases reserves by issuing domestic debt has no impact on the domestic economy. This is clear if the government makes the transaction with foreign investors, since in this case nothing changes for the domestic private sector. This is also true if the government's debt is not traded internationally and must be sold to the domestic private sector. In this case, the domestic private sector simply finances the purchase of domestic government debt by selling foreign assets (or issuing foreign liabilities) to foreign investors. Government policy is irrelevant if the domestic private sector is connected to the international financial market through the frictionless trade of one asset or liability.[7]

The situation is quite different if the access of the domestic private sector to foreign borrowing and lending is restricted. To simplify, let us consider the extreme case where the government is the only agent in the economy that can enter into financial relationships with the rest of the world (a closed capital

[6] Given μ, equation (6) determines the whole path $(c_{Tt})_{t \geq 0}$. One then needs to determines the unique value of μ such that the path $(c_{Tt})_{t \geq 0}$ satisfies equation (7).

[7] The various classes of assets and liabilities are perfectly substitutable, in our model, because of the absence of risk.

account).[8] Let us assume that domestic government debt can be held only by the domestic private sector ($a_t + b_t = 0$) and that foreign assets can be held only by the government ($a_t^* = 0$). This assumption is meant to capture Chinese-style capital account policies in which the access of foreign investors to domestic financial assets and the access of domestic private investors to foreign assets are very limited. Then, the country's net foreign assets are equal to its reserves ($n_t^* = b_t^*$) and its consolidated budget constraint can be written,

$$c_{Tt} = y_{Tt} + r^* b_t^* - \dot{b}_t^*.$$

By setting the path for reserves, $(b_t^*)_{t\geq 0}$, the government completely determines the paths for the consumption of the tradable good, $(c_{Tt})_{t\geq 0}$, and for the trade balance, $(y_{Tt} - c_{Tt})_{t\geq 0}$. It also determines the path for the real exchange rate, $q_t = q(c_{Tt}, y_{Nt})$.

This result is, as a matter of accounting, obvious. If the government can determine the country's total net foreign assets, then it can also determine the current account balance (the change in the country's net foreign assets) and the trade balance (the change in the country's net foreign assets minus the return on these assets). In particular, the government can induce "forced saving" in the domestic economy by forcing the private sector to buy domestic debt and by using the proceeds to buy foreign assets. With a closed capital account, the domestic private sector cannot undo this operation by selling assets to—or borrowing from—the rest of the world.

Denoting by $c_T(q, y_N)$ the level of tradable good consumption when the real exchange rate is q, we have the following result.

Proposition 1 *With a closed capital account, the government can implement any real exchange rate path, $(q_t)_{t\geq 0}$, satisfying the country's external budget constraint*

$$\int_0^{+\infty} c_T(q_t, y_{Nt}) e^{-r^* t} dt \leq \int_0^{+\infty} y_{Tt} e^{-r^* t} dt + b_0^*. \tag{8}$$

Proof. See discussion above. ■

Inequality (8) is binding if the stock of reserves satisfy the transversality condition as an equality,

$$\lim_{t\to+\infty} b_t^* e^{-r^* t} = 0. \tag{9}$$

[8] We will consider the case where the government can impose a tax on capital flows in section 5.

But the left-hand side of (9) could be strictly positive if the government lets the rest of the world play a Ponzi game with domestic reserves (which is equivalent to "throwing away" a fraction of the reserves, as in Korinek and Serven, 2010).

A realistic application of the model is the case where the government uses capital account policies to resist a real exchange rate appreciation resulting from a takeoff in the tradable good sector. One can capture this case in the model by assuming that the endowment of tradable good, y_{Tt}, increases over time. This could lead to a trade deficit if the consumption of tradable good, reflecting the anticipation of higher future tradable income, exceeds the endowment.

I will assume that (for a reason outside of the model), the government tries to smooth the trade balance by limiting trade deficits, or even maintaining a surplus. This is possible if the government closes the capital account and accumulates reserves. More formally, I will define an episode of "resistance to real exchange rate appreciation" as follows.

First, I denote with tilde the values of the variables in the undistorted equilibrium (with free capital mobility). For example, $(\tilde{c}_{Tt})_{t\geq 0}$ is the path for the consumption of tradable good when the domestic consumer has unrestricted access to foreign borrowing and lending, and $(\tilde{b}^*_t)_{t\geq 0}$ is the path for foreign exchange reserves that is consistent with the undistorted equilibrium (assuming that reserves are the only foreign assets). An episode of resistance to appreciation is when the government depreciates the real exchange relative to the undistorted level by purchasing reserves.

Definition 2 *There is resistance to real exchange rate appreciation between time* 0 *and time* t *if:*

- *the government closes the capital account between time* 0 *and time* t*;*
- *the government accumulates more reserves than in the undistorted equilibrium while the capital account is closed:* $b^*_s > \tilde{b}^*_s$ *for* $0 < s \leq t$*;*
- *the initial real exchange rate is depreciated relative to its undistorted value:* $q_0 > \tilde{q}_0$*.*

The difference $q_0/\tilde{q}_0 - 1$ is a measure of the initial real exchange rate *undervaluation*. Note that the resistance to appreciation is assumed to last a

finite time t, after which there is free capital mobility and Ricardian equivalence applies. After time t, the economy follows its undistorted path conditional on the initial level of foreign assets b_t^*. This assumption is analytically convenient and is not very restrictive since t can be arbitrarily large.

Observe that in the long run (after time t), the effects of the resistance to appreciation are reversed. If the government does not "throw away" the reserves, the real exchange rate is appreciated in the long run ($q_t > \tilde{q}_t$) as the country consumes the return on the foreign assets that have been accumulated during the episode of resistance to appreciation.

4 Capital Account Policies and Trade Protectionism

Because capital account policies affect the real exchange rate and the trade balance, it is natural to ask how these policies compare with standard protectionist measures, such as a tariff on imports and a subsidy on exports. This section shows an equivalence result: Capital account policies can achieve the same outcomes as trade protectionism.

The most natural instrument of trade policy, in this model with one single tradable good, is a tariff on import associated with a subsidy on exports of the same size. The combination of tariff and subsidy raises the relative price of the tradable good and induces a real depreciation.[9] This policy is equivalent to imposing a tax on the domestic consumption of tradable good.

More formally, let us assume that the government imposes a time-varying tariff (subsidy) τ_t on imports (exports). The tax receipts are rebated to the domestic consumer in a lump-sum way. We then have the following result.

Proposition 3 *Any real allocation that can be achieved with a time-varying tariff (subsidy) on imports (exports) under perfect capital mobility can also be implemented with capital account policies.*

Proof. The tax (subsidy) on imports (exports) is equivalent to a tax τ_t on the consumption of tradable good, so that the first-order condition (6) becomes,

$$u'\left(c(c_{Tt}, y_{Nt})\right) q(c_{Tt}, y_{Nt}) = \mu(1+\tau_t).$$

[9]It is well understood since at least Johnson (1953) that it is possible to achieve the same effects as a real depreciation with a tariff on imports and a subsidy on exports.

This equation and the country's intertemporal external budget constraint (which remains equation (7) since the tax receipts are rebated and consumed domestically) pin down the paths $(c_{Tt})_{t\geq 0}$ and $(q_t)_{t\geq 0}$. Since the path $(q_t)_{t\geq 0}$ satisfies condition (8) it can be implemented with capital account policies. ■

This result is interesting in light of the recent debates on whether there is a need for international rules for capital account policies in the same way as there are rules for international trade. The status quo is characterized by a strong international regime to discourage the use of policies distorting international trade (with most notably the World Trade Organization) whereas capital account policies are largely left to the discretion of countries.[10] The status quo is often justified by the fact that the welfare gains from international integration seem larger for free trade in goods than for free trade in assets, so that the international community has a stronger stake in maintaining the former than the latter (Bhagwati, 1998).

The insight that Proposition 3 brings to this debate is that capital account policies may (under certain conditions) be used to achieve exactly the same outcomes as trade protectionism.[11] From this point of view, the case for international rules would be no less strong—and not fundamentally different—for capital account policies than for trade policies (Jeanne, Subramanian and Williamson, 2012).

5 Excess Returns

Restrictions on free capital mobility introduce a wedge between domestic and foreign returns. I study in this section the behavior of this wedge, because it plays a role in measuring the welfare consequences of capital account policies

[10]There is no international regime to discipline capital account policies. In particular, the International Monetary Fund (IMF) does not have jurisdiction over its members' capital accounts. There are regional exceptions: For example, members of the European Union must maintain an open capital account, and bilateral free trade agreements with the United States often limit the use of capital account policies.

[11]The equivalence between trade policies and capital account policies does generalize to environments with several tradable goods. Capital account policies do not affect the relative prices of tradable goods (and the terms of trade) in the same way as taxes on trade flows can. See Costinot, Lorenzoni and Werning (2011) for an analysis of the impact of capital account restrictions in a two-country model with several tradable goods.

(as discussed in section 6), and because it can be measured (as I will do for China in section 8), thus offering an interesting point of contact and comparison between the model and the data.

Based on an exogenous path for reserve accumulation, $(b_t^*)_{t\geq 0}$, one can compute (if the capital account is closed) the paths for tradable consumption, c_{Tt}, total consumption, c_t, the marginal utility of consumption $\lambda_t = u'(c_t)$, and the real exchange rate q_t. The interest rate on domestic bonds is given by

$$r_t = r^* - \frac{\dot{\lambda}_t}{\lambda_t}. \tag{10}$$

The dollar return on domestic bonds is then equal to this interest rate plus the rate of real exchange rate appreciation, $r_t - \dot{q}/q$. The excess dollar return on domestic bonds is the difference with the dollar interest rate,

$$\epsilon_t = r_t - \frac{\dot{q}_t}{q_t} - r^*. \tag{11}$$

If this excess return is positive, foreign capital "wants" to flow into the country and must be kept at bay with controls on inflows. Conversely, if the excess return is negative, domestic capital wants to flow out and can be retained in the country using control on outflows.

The path for the excess return depends on the path of reserve accumulation in a way that is not easy to characterize in general. However, economic intuition suggests that foreign capital should try to flow into the countries that resist the appreciation of their currency in order to take advantage of the real exchange rate appreciation. The following proposition spells out a rigorous formulation of this intuition.

Proposition 4 *Assume that the government resists to appreciation between time* 0 *and time* t *(according to Definition 2). Then the cumulated excess return on domestic bonds between time* 0 *and time* t *is positive and larger than the amount of undervaluation at time* 0*,*

$$\int_0^t \epsilon_s ds > \log\left(\frac{q_0}{\tilde{q}_0}\right). \tag{12}$$

Proof. Using $\epsilon_s = -\frac{\dot{\lambda}_s}{\lambda_s} - \frac{\dot{q}_s}{q_s}$, the cumulated excess return can be written

$$\int_0^t \epsilon_s ds = \log\left(\frac{u'(c_0)q_0}{u'(c_t)q_t}\right).$$

In the undistorted equilibrium with free capital mobility, there is no excess return and one has,

$$\frac{u'(\tilde{c}_0)\tilde{q}_0}{u'(\tilde{c}_t)\tilde{q}_t} = 1.$$

At time t, the real exchange rate is lower and consumption is higher in the distorted equilibrium than in the undistorted one because of the larger level of foreign assets ($b_t^* > \tilde{b}_t^*$). This implies $u'(\tilde{c}_t)\tilde{q}_t > u'(c_t)q_t$. Hence,

$$\frac{u'(c_0)q_0}{u'(c_t)q_t} > \frac{u'(c_0)q_0}{u'(\tilde{c}_t)\tilde{q}_t} = \frac{u'(c_0)q_0}{u'(\tilde{c}_0)\tilde{q}_0} > \frac{q_0}{\tilde{q}_0}.$$

The last inequality results from $c_0 < \tilde{c}_0$ because $q_0 > \tilde{q}_0$. ■

To illustrate, a country that undervalues its currency by 20 percent by closing its capital account for 10 years will have a cumulated excess return on its domestic bonds of at least 20 percent during the 10 years that the capital account is closed, or 2 percent per year on average. The average annual excess return can be reduced by lengthening the time t during which the capital account is closed.

There is an excess return on domestic bonds for two reasons. First, as mentioned above, there is a valuation gain coming from the real appreciation of the domestic currency relative to the dollar. In addition, the domestic real interest between time 0 and time t is higher than the dollar interest rate because resistance to appreciation works by repressing and postponing domestic consumption. The cumulated excess return, thus, is larger than the undervaluation at time 0.

The consumer's preferences determine the difference between the cumulated excess return on domestic bonds and the initial undervaluation (the two sides of equation (4). This difference is decreasing with the consumer's elasticity of intertemporal substitution of consumption (which mitigates the change in the domestic real interest rate). In the limit case where the consumer has a linear utility, the cumulated excess return on domestic bonds is exactly equal to the initial undervaluation. The difference between the cumulated excess return and the initial undervaluation is also determined by the intratemporal elasticity of substitution between the tradable good and the nontradable good. Increasing this elasticity implies that larger changes in the consumption of tradable good are required to achieve the same degree of real exchange rate undervaluation, which magnifies the changes in total

consumption, the real interest rate, and the excess return. In the limit case where the tradable good and the nontradable good are perfect substitutes, the government cannot change the real exchange rate and the right-hand side of equation (12) is equal to zero.

Note that Proposition 4 says that the excess return on domestic bonds is positive *on average* during the episode of resistance to appreciation, not that it should be positive at every point in time during that episode. Thus, one should not conclude that a country is not undervaluing its exchange rate from the observation that the excess return is zero or even negative at a given point in time. It is not difficult to construct examples where the excess return is negative at some times by assuming that the domestic authorities keep the growth rate in domestic consumption below the level that would be observed in the undistorted equilibrium.

Proposition 4 is also useful to derive an upper abound on the amount of undervaluation that can be achieved with price-based capital controls. Many real world controls are price-based, i.e., they take the form of a tax on capital flows (like for example in Brazil since 2009). It is interesting to know how much these controls can "buy" in terms of real exchange rate undervaluation.

I now assume that instead of completely closing the capital account, the government taxes the purchase of domestic bonds by foreigners at a constant rate τ between time 0 and time t. The tax is removed after time t. Like for the controls on capital inflows that Brazil has been using since 2009 or the Chilean capital controls of the 1990s, the tax is paid on the purchase of the assets and does not depend on how long the foreign investor holds the asset. Namely, a foreign investor can buy $(1-\tau)q_s$ units of domestic bonds in exchange of one unit of the tradable good at any time $s \leq t$. He can sell the bonds and repatriate the proceeds at any time (there are no controls on outflows).

The government still accumulates reserves to depreciate the real exchange rate but there is now a limit to the extent of depreciation that can be achieved in this way. If pushed too far, this policy will raise the excess return on domestic bonds above the level where it is worth for foreign investors to buy domestic bonds in spite of the tax, and the impact of reserve accumulation will be undone by capital inflows. An implication of Proposition 4 is that because of this constraint, it is not possible for the government to undervalue the real exchange rate by more than the amount of the tax.

Corollary 5 *Assume that the government resists appreciation by taxing the*

purchase of domestic assets by foreigners at rate τ between time 0 and time t. Then the extent of the undervaluation that can be achieved by reserve accumulation is bounded by the tax rate,

$$(1-\tau)\frac{q_0}{\tilde{q}_0} \leq 1. \tag{13}$$

Proof. Let us consider the problem of a foreign investor who considers buying domestic bonds at time 0 and keep them until period t. For reserve accumulation to work (not be offset by capital inflows) this must yield a lower return than investing in dollar bonds, i.e.,

$$(1-\tau)\exp\left(\int_0^t \epsilon_s ds\right) \leq 1.$$

Using (12) this gives (13). ■

To illustrate, Corollary 5 says that a country that imposes a 6 percent tax on its capital inflows (as Brazil did in 2010) cannot undervalue its real exchange rate by more than 6 percent. One advantage of tax-based capital account policies, thus, is that they imply a transparent upper bound on the level of undervaluation that a country can achieve by accumulating reserves.

6 Welfare Cost of Resistance to Appreciation

In this model, resisting the real appreciation of the currency reduces domestic welfare. This might increase welfare if, for example, growth were endogenous to the real exchange rate, as in Korinek and Serven (2010), but under our assumptions, the first welfare theorem applies and an undervaluation policy unambiguously reduces welfare. What is the welfare cost of the undervaluation?

This question is related to the question of the appropriate way of measuring the cost of holding reserves, a question on which, as noted in IMF (2011), "there is little consensus". The carrying cost of reserves is often measured as the difference between the cost of borrowing to finance the reserves and the return on the reserves. But there are different ways of measuring the cost of financing the reserves—for example, as the interest rate on long-term external debt or as the interest rate on sterilization bonds issued by the central

bank.[12] Another question is how to take into account the valuation loss on the reserves that occurs when the domestic currency appreciates. It would seem natural to count this valuation loss as a cost, although one could also argue that it should not because the appreciation of the domestic currency does not affect the purchasing power of the reserves in terms of tradable good.

I study the welfare impact of resistance to appreciation by looking first at a small change in the accumulation of foreign assets. Let us assume that the government changes the path $(b_s^*)_{s\geq 0}$ by an infinitesimal (first order) amount $(\delta b_s^*)_{s\geq 0}$. If δb_s^* is continuously differentiable (so that c_{Ts} and q_s are continuous), then the impact on welfare can be written

$$\delta U_0 = \int_0^{+\infty} u'(c_s) \frac{\partial c_s}{\partial c_{Ts}} \, \delta c_{Ts} \, e^{-r^* s} ds,$$

where $\delta c_{Ts} = r^* \delta b_s^* - \dot{\delta b}_s^*$. Then using $\partial c_s / \partial c_{Ts} = q_s$, $\dot{\lambda}_s / \lambda_s = r^* - r_s$ (where $\lambda_s = u'(c_s)$) and integrating by parts gives,

$$\delta U_0 = -\int_0^{+\infty} u'(c_s) q_s \epsilon_s \, \delta b_s^* e^{-r^* s} ds, \tag{14}$$

where ϵ_s is the excess dollar return on domestic bonds. The term $\epsilon_s \delta b_s^*$ is the quasi-fiscal cost of financing the marginal increase in reserves by issuing domestic debt. The impact of the marginal increase in reserves on welfare is the present discounted value of this flow cost weighted by the marginal utility of consumption.

This formula can be extended to the case where the real exchange rate is discontinuous as would be the case, for example, if resistance to appreciation were abandoned and the capital account completely liberalized at a given point in time. Let us assume that c_s, c_{Ts}, and q_s are discontinuous at time t, and denote with a subscript t^- (t^+) the levels of the variables just before (after) that time. The discrete jump $q_{t^-} - q_{t^+}$ is the real exchange rate appreciation that occurs when resistance to appreciation is abandoned. The variation of the welfare is then given by

$$\delta U_0 = -\int_{s\geq 0, s\neq t} u'(c_s) q_s \epsilon_s \, \delta b_s^* \, e^{-r^* s} ds - u'(c_t) \left(q_{t^-} - q_{t^+}\right) \delta b_t^*,$$

[12] For the former approach see for example Edwards (1985) and Rodrik (2006), and for the latter see Flood and Marion (2001).

where $u'(c_t)$ is a weighted average of the marginal utility of consumption before and after the discrete real appreciation, $u'(c_t) = [q_{t^-}u'(c_{t^-}) + q_{t^+}u'(c_{t^+})]/(q_{t^-} + q_{t^+})$. The term that is added by the discontinuity is the valuation loss on the change in foreign assets held at time t, δb_t^*. Thus it is legitimate to fully count this valuation loss as part of the welfare cost of the resistance to appreciation.

The results so far were local since they were based on first-order perturbations to reserve accumulation. To derive global results, define $U(x)$ as time-0 welfare when the reserve path is given by

$$b_s^* = \tilde{b}_s^* + x(b_s^* - \tilde{b}_s^*), \tag{15}$$

for $s \leq t$, where x is between 0 and 1. For $x = 0$, this path corresponds to the undistorted equilibrium. For $x = 1$, it corresponds to the equilibrium with resistance to appreciation. By increasing x from 0 to 1 we continuously move from the undistorted equilibrium to the equilibrium with resistance to appreciation. Using equation (14) we have

$$U'(x) = -\int_0^t u'(c_s)q_s\epsilon_s(b_s^* - \tilde{b}_s^*)e^{-r^*s}ds, \tag{16}$$

where ϵ_s is the excess return corresponding to the x-path (15) for reserves.

The welfare cost of resistance to appreciation is equal to $U(1) - U(0)$. In order to derive an expression for this cost we use the quadratic approximation,

$$U(x) \simeq U(0) + \alpha x + \beta x^2,$$

where α and β are two coefficients that can be determined by observing that $\alpha = U'(0) = 0$ and $\beta = U'(1)/2$. The welfare cost of resistance to appreciation, thus, can be approximated by $U'(1)/2$, where $U'(1)$ is given by equation (16). This result is summarized in the following proposition.

Proposition 6 *A quadratic approximation to domestic welfare under resistance to currency appreciation is*

$$U = \widetilde{U} - \frac{1}{2}\int_0^t u'(c_s)q_s\epsilon_s(b_s^* - \tilde{b}_s^*)e^{-r^*s}ds, \tag{17}$$

where $\widetilde{U}$ is welfare in the undistorted equilibrium.

Proof. See discussion above. ■

This proposition gives a "rule of thumb" for assessing the welfare cost of resisting to appreciation with capital account policies. First, one needs to assess the "excess net foreign assets" by taking the difference between the observed level of net foreign assets and the counterfactual level of net foreign assets that would be observed in the absence of capital account distortion (see figure 3). Second, one has to measure the excess dollar return on domestic bonds. The welfare cost of resisting to appreciation, then, is approximately equal to the excess net foreign assets times one-half the excess dollar return on domestic bonds. The factor one-half comes from the fact that the welfare loss is a triangle, not a rectangle.

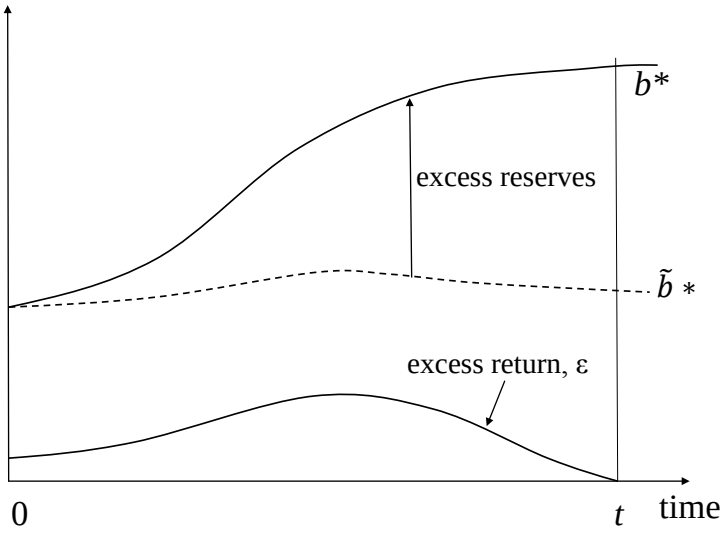

Figure 3: Estimating the welfare cost of resisting real appreciation (Proposition 6).

The model, thus, gives a precise answer to the question of how the carry-cost of reserves should be measured. First, if reserves are accumulated at the margin through the current account (with trade surpluses) rather than through the financial account (by borrowing abroad), the carry-cost of reserves is the cost of repressing and postponing domestic consumption rather than the cost of external borrowing. However, the carry-cost can still be

measured as a return differential because the welfare cost of postponing consumption is reflected in the excess dollar return on domestic bonds. This excess return can be measured for example by looking at the differential between the interest rate on central bank bonds and the return on reserves, a measure that is often used (without welfare foundations) to assess the quasi-fiscal cost of reserve holdings. But one should add to this differential the rate of appreciation of the domestic currency (because the valuation loss on the reserves is part of the carrying cost) and then divide the result by two (because the welfare loss is a triangle).

7 Numerical Illustration

This section illustrates the properties of the model in a calibrated version of the model. I assume that domestic consumption is a constant elasticity of substitution (CES) index of the consumption of the tradable good and that of the nontradable good,

$$c(c_T, c_N) = \left[\eta^{1/\theta} c_T^{(\theta-1)/\theta} + (1-\eta)^{1/\theta} c_N^{(\theta-1)/\theta}\right]^{\theta/(\theta-1)},$$

and that the consumer has a constant relative risk aversion,

$$u(c) = \frac{c^{1-\gamma} - 1}{1-\gamma}.$$

The economy is in a steady state and is subject, at time 0, to an unexpected increase in the endowment of tradable good. Namely, the endowment of tradable good unexpected increases from y_T to a higher level $y_T + \Delta y_T$ and then remains constant. For simplicity, the supply of the nontradable good, y_N, remains constant. The economy has no foreign assets in the initial steady state. This experiment is meant to capture, in a very stylized way, the case of a country whose tradable good sector is taking off.

Under free capital mobility, the real exchange rate would appreciate at the time of the shock, i.e., q would jump downward from $q_0 = q(y_T, y_N)$ to $\tilde{q}_0 = q(y_T + \Delta y_T, y_N)$ at time 0. But I assume that the government wants to smooth the impact of the shock on the real exchange rate and let the currency appreciate gradually over the time interval $[0, t]$, according to

$$q_s = q_0 + \frac{s}{t}\Delta q. \tag{18}$$

The real exchange rate is constant and equal to $q_0 + \Delta q$ from time t onwards. In order to achieve this objective, the government closes the capital account and accumulates reserves during the time interval $[0, t]$.

Table 1.Calibration

y_N	y_T	Δy_T	r^*	γ	η	θ	t
1	1	0.1	0.05	1	0.3	1	10

The values of the parameters used in the numerical exercise are reported in Table 1. The pre-shock endowments of nontradable and tradable goods are both normalized to 1. The endowment of tradable good increases by 10 percent at the time of the shock. Utility is logarithmic. The share of the tradable good in the consumption index is 0.3, and the elasticity of substitution between the tradable good and the nontradable good is set to 1 (the value assumed by Obstfeld and Rogoff (2005) in their three-country model of the world). Finally, the government resists appreciation for a period of 10 years. The equilibrium level of appreciation, Δq, is the solution to a fixed-point problem that must be solved numerically.[13]

For these parameter values, the real exchange rate falls from $q_0 = 0.3$ to $\tilde{q}_0 = 0.281$ at the time of the shock under free capital mobility, an appreciation of 6.7 percent. This is also the amount of the real undervaluation at time 0 if the government resists appreciation. Figure 4 shows the impulse responses of the real exchange rate, the ratio of the trade balance to GDP, the ratio of foreign assets (reserves) to GDP, and the excess dollar return on domestic assets if the government resists appreciation according to (18). The real exchange rate is equal to $q_t = 0.276$ after 10 years. The real exchange rate eventually appreciates by 8.4 percent, more than if it had appreciated at the time of the shock because of the accumulated foreign assets. The trade balance increases to 2.9 percent of GDP at the time of the shock and then decreases smoothly over the following 10 years. Foreign assets increase to 15.1 percent of GDP after 10 years and then remain equal to that level in the new steady state. The annual excess return on domestic assets remains close to 1.2 percent over the whole episode. The cumulated excess return over the 10-year period, at 12.1 percent, is larger than the initial amount of undervaluation, as predicted by Proposition 4.

[13]The details are available upon request to the author.

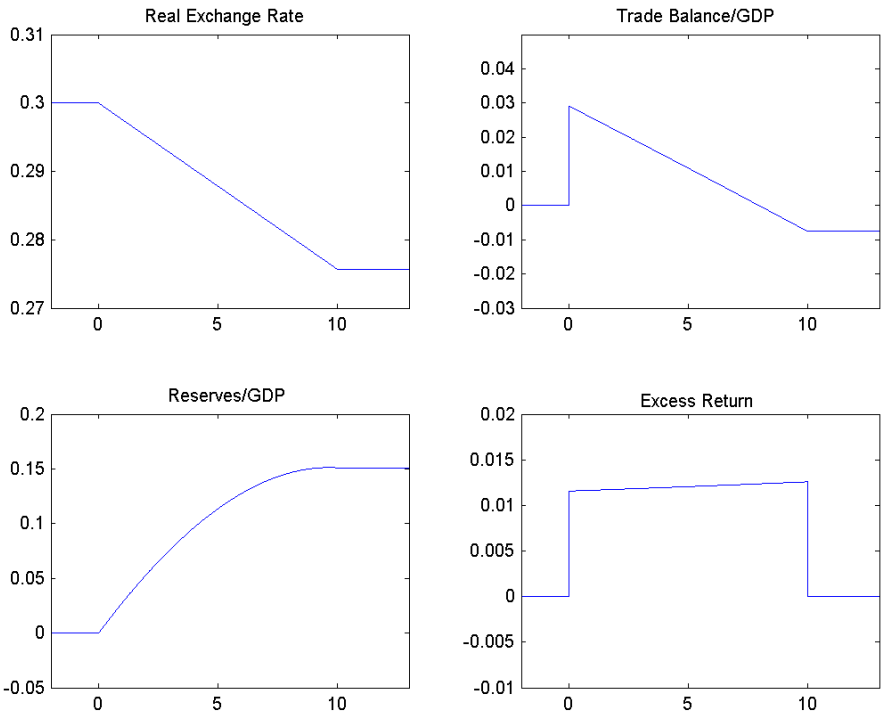

Figure 4: Real exchange rate, trade balance, reserves, and excess return on domestic assets in a path of resistance to appreciation. Source: author's computations.

Although resistance to appreciation has a nonnegligible impact on trade flows and foreign assets, its impact on welfare is small. The fall in domestic welfare due to government intervention is equivalent to a permanent consumption loss of about 0.022 percent.[14] However the welfare loss increases more than proportionately with the size of the initial undervaluation. To see this, I computed the sizes of the undervaluation and of the welfare loss when the shock Δy_T varies between 0 and 0.5. Figure 5 reports how the welfare loss (still expressed as the equivalent consumption loss, on the vertical axis)

[14]As is standard in the literature, the welfare cost of the distortion is measured as the permanent fall in consumption that reduces the level of welfare in the undistorted equilibrium to the welfare level in the distorted equilibrium. Here, consumption is constant and equal to $\tilde{c} = y_t + \Delta y_T$ in the undistorted equilibrium so that $\tilde{U} = u(\tilde{c})/r^*$. The welfare cost of the distortion is measured as the level of ℓ such that $u(\tilde{c}(1-\ell))/r^* = U_0$.

varies with the size of the initial undervaluation (on the horizontal axis). The welfare loss from a 25 percent undervaluation amounts to a consumption loss of 0.3 percent, or a one-time wealth loss of about 6 percent of GDP. The figure also shows that the rule of thumb given in Proposition 6 (equation (17)) provides a good approximation to the true welfare loss, although it tends to slightly overestimate it for high levels of undervaluation.

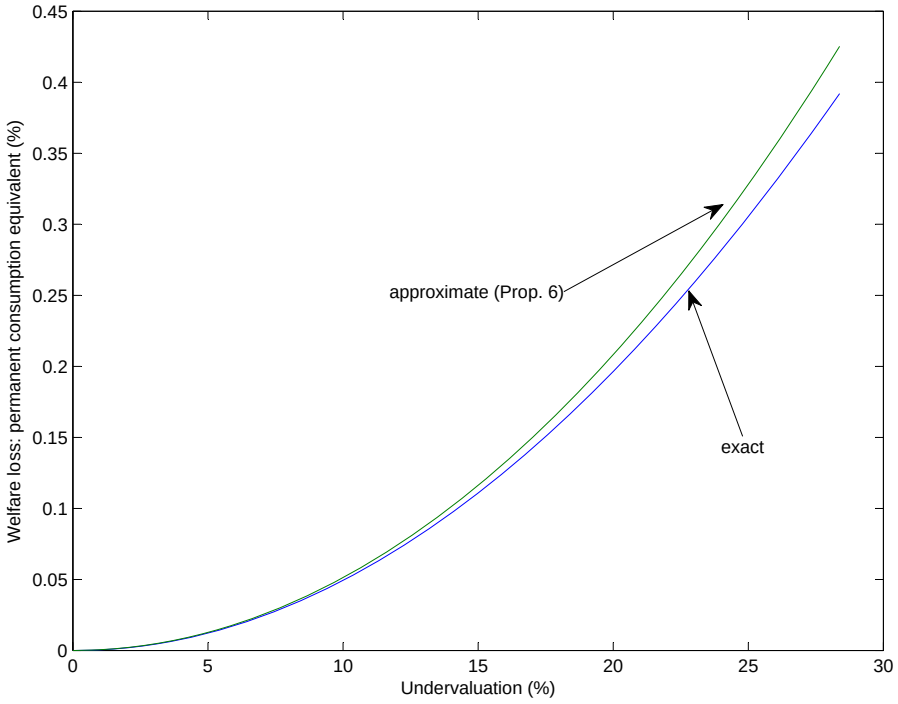

Figure 5: Welfare loss from undervaluation. Source: author's computations.

8 China Again

This section comes back to the case of China, but takes advantage of the framework developed in the previous sections. The objective is to present an interpretation of the Chinese exchange rate policy in the 2000s based on the model (rather than test the model against alternatives). Clearly, the

model is very stylized and does not capture significant aspects of the Chinese experience,[15] but it provides a consistent view of the Chinese experience that may differ in interesting ways from more conventional accounts.

The real-world analog of the "government" in the model is the Chinese government plus the Chinese banking sector, including the central bank. The domestic banking sector issues most of the domestic liabilities that are the counterpart of reserve accumulation, and it is tightly controlled by the domestic authorities. Leaving the central bank aside, most of the banking sector is composed of four large banks that are owned or controlled by the government. In addition, the interest rates on deposits and loans are controlled by the authorities, which also have considerable influence over the lending policies, the credit flows, and the sectors to which they are directed.[16] From this point of view, it makes sense to consider the banking sector as a branch of the government.

Figure 6 gives a stylized representation of how the balance sheet of the banking sector fits into the Chinese economy. The banking sector issues deposits that are held by the domestic real sector and uses them to buy foreign assets and finance loans to the real sector. The banking sector's foreign assets can be interpreted as variable b^* in the model. Variable b (the government's domestic debt in the model) can be measured as government debt in the hands of domestic nonbank investors plus the banking sector *net* debt vis-à-vis the real sector, i.e., bank deposits *minus* the banking sector's claim on the domestic real sector.

Figure 7 reports the main items in the balance sheet of the Chinese financial institutions (including the central bank) between the beginning of 2000 and the end of 2011.[17] The variables are expressed as shares of GDP. Like in figure 6, the two components on the asset side are foreign assets and credit to the domestic real sector. Foreign assets are composed mainly of reserves at the central bank. The liability side is composed mainly of bank deposits held by households and firms. The difference between total liabilities and

[15]For example, the model does not capture risk, in particular the domestic expropriation risk that may have motivated Chinese investors to invest a part of their wealth in foreign safe havens.

[16]There has been a partial liberalization since the end of the 1990s, most notably with the elimination of the ceiling on lending rates in 2004 (Lardy and Douglass, 2011). But the benchmark deposit rates set by the central bank remain a hard constraint on the up side.

[17]Details about the construction of the variables can be found in the data appendix.

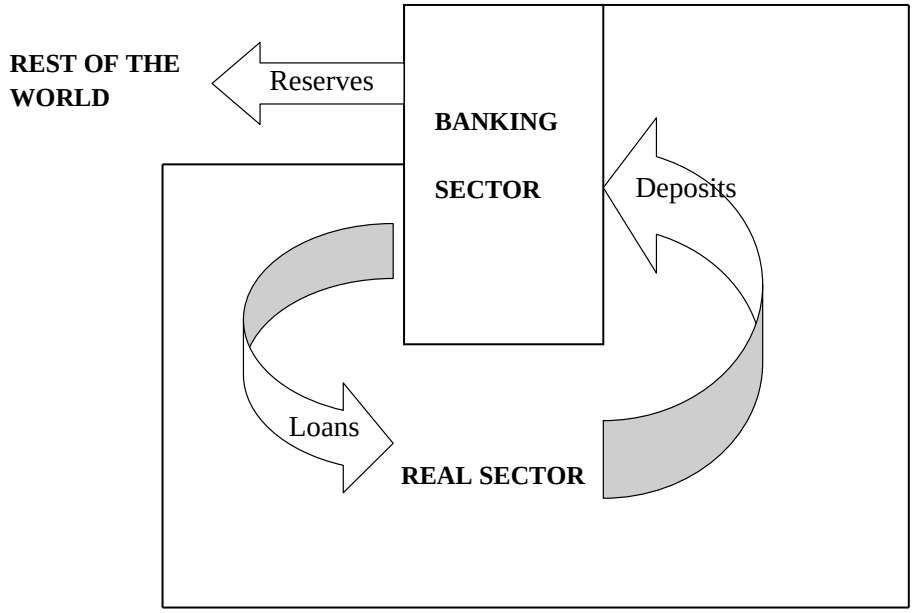

Figure 6: Banking sector and real economy.

domestic assets can be interpreted as variable b in the model, and it is by construction equal to foreign assets, b^*.

One can distinguish different epochs in the Chinese capital account and banking policies. From the middle of 2003 to the end of 2008, the financial sector sector accumulated foreign assets at a high pace, mostly in the form of foreign exchange reserves at the central bank. Total liabilities did not significantly increase during this period (as a share of GDP) because credit to the domestic real sector was reduced to offset the increase in foreign exchange reserves.[18] In terms of the model, the Chinese authorities induced forced saving by allocating the Chinese loanable funds to the accumulation of foreign

[18]The monetary authorities have used different policies to mitigate the impact of reserve accumulation on deposits. The central bank issued an increasing amount of sterilization bonds and steadily increased the regulatory cash reserves of banks. These policies reduced the impact of reserve accumulation on deposit creation, at the cost of reducing the amount of funds that banks could lend to the real sector.

reserves rather than credit to the domestic sector. This was reflected in significant increase in the net domestic liabilities of the financial sector, b, from about 20 percent to about 50 percent of GDP.

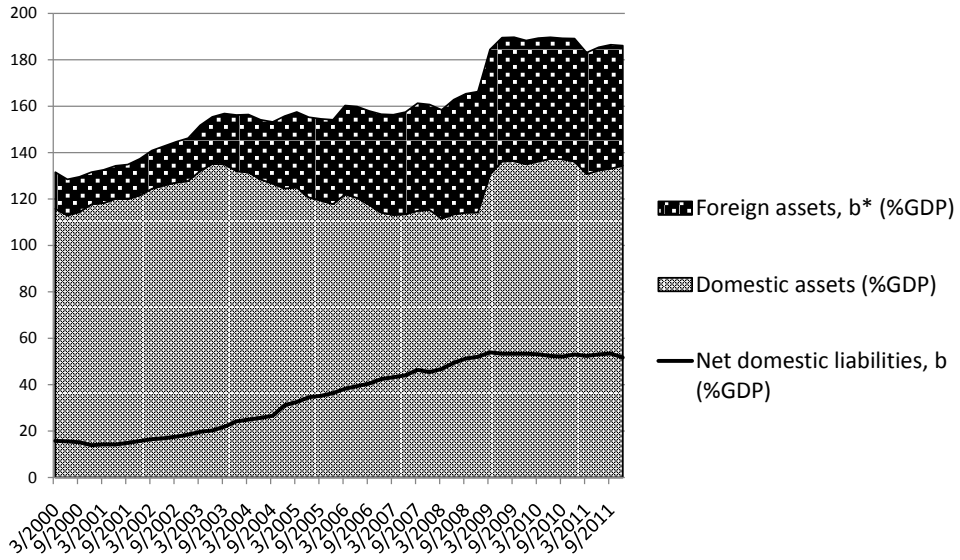

Figure 7: Balance sheet of Chinese financial institutions (percent of GDP). Source: People's Bank of China.

As shown in figure 7, this policy mix was reversed in 2009 when the global financial crisis started. The Chinese authorities stopped increasing reserves (relative to GDP) and instead started to increase lending to the real sector in an attempt to stimulate the economy. Domestic spending was increased because less loanable funds were used to finance the accumulation of foreign exchange reserves, as reflected by the fact that variable b stops increasing after 2008.

This policy course can be interpreted as follows in light of the model. Throughout the 2000s, the Chinese growth rate was very high and growth was pulled primarily by the development of the Chinese tradable sector. This should have led to an appreciation of the renminbi because of the Balassa-Samuelson effect. However, between 2002 and 2008, the Chinese authorities were resisting currency appreciation by accumulating reserves and repressing domestic demand. They stopped doing that and started to stimulate domestic demand once the global financial crisis started. Figure 8 shows the

macroeconomic correlates of this interpretation in the data. Between 2002 and 2008, the renminbi did not appreciate relative to the US dollar in real terms, whereas the underlying pressure was reflected instead in a booming trade surplus.[19] After 2008, when reserve accumulation slowed down, the trade surplus was reduced at the same time as the renminbi appreciated relative to its initial level.

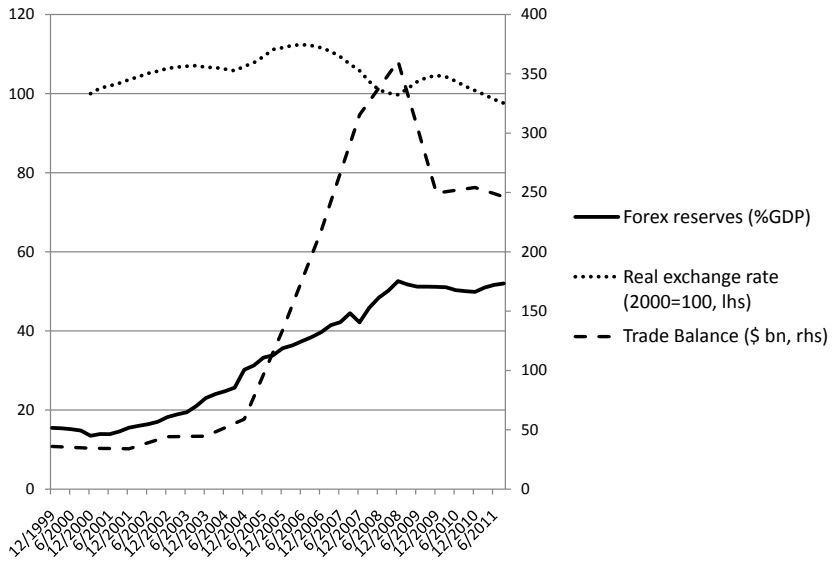

Figure 8: Chinese foreign exchange reserves, trade surplus, and real exchange rate with the US Dollar. Source: People's Bank of China.

The evidence so far is consistent with the view (analyzed in the model) that at least until 2008 the Chinese authorities were constraining domestic demand by accumulating reserves and restricting capital inflows. An important implication of the model, if this was going on, is that Chinese financial assets should have delivered an excess return relative to foreign assets. Was this the case in the data?

Estimating returns on Chinese fixed-income assets is difficult because the observed interest rate levels do not reflect market forces in a repressed financial system. Presumably, foreign investors would invest in the fixed-income assets with the highest interest rates. In China this would mean

[19]The real exchange rate is CPI-based and normalized to 100 in 2000.

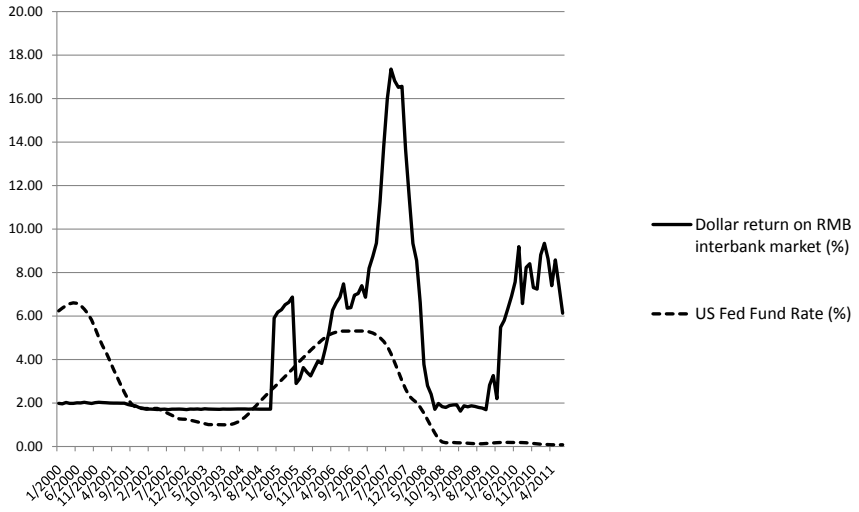

Figure 9: Dollar returns on one-month renminbi interbank market and US Federal Funds Rate (percent). The returns are computed in a six-month rolling window. Source: People's Bank of China, US Federal Reserve, and author's computations.

lending in the interbank market.[20] Figure 9 reports the dollar return on investing in the Chinese one-month interbank market, which was computed as the one-month interest rate in the Chinese interbank market plus the one-month rate of appreciation of the renminbi relative to the dollar, and compares it to the US Federal Funds rate. The data are monthly from January 2000 to July 2011. To smooth out the high-frequency noise and facilitate comparison with figure 10, I show the cumulated return over a six-month rolling window starting in the month under consideration. We observe that after 2002 the dollar return on the Chinese interbank market is almost always larger than the Federal Funds Rate. The difference starts to be large in 2007, and it is mostly due to the nominal appreciation of the renminbi, which started in 2006, and resumed in 2010 after an interruption in 2008.

The behavior of households and firms, however, should be determined by the interest rate to which they have access, which is lower than the interbank market rate. A large fraction of the households' and firms' financial wealth

[20]The Chinese interbank market rate should not be affected by a default risk since banks are public.

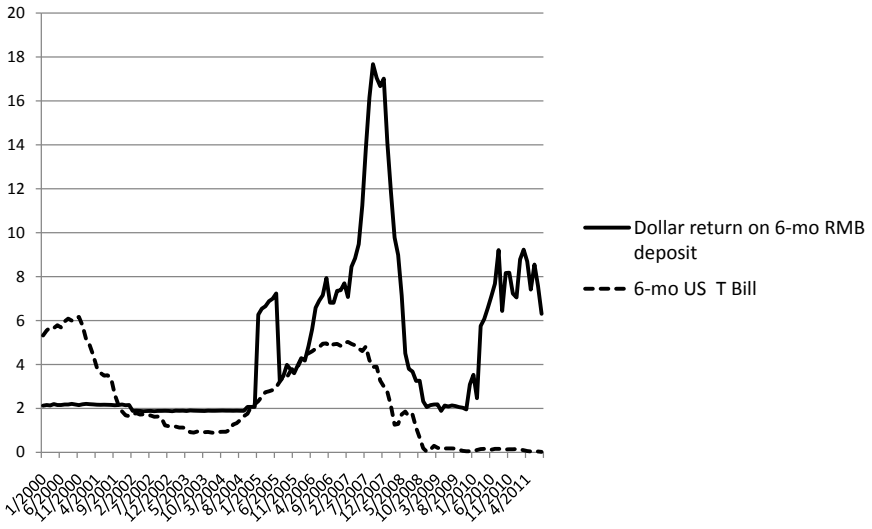

Figure 10: Dollar returns on six-month renminbi saving deposits and return on six-month US Treasury Bills. Source: People's Bank of China, US Federal Reserve, and author's computations.

is held in the form of time and savings deposits, on which banks pay a lower return than the interbank interest rate.[21] The excess dollar return on the six-month deposits in Chinese banks is reported in figure 10. It is very close to that reported in figure 9 because most of the variation in the excess return is explained by changes in the exchange rate.

The model also suggests a measure of the welfare cost of the Chinese resistance to appreciation.[22] Proposition 6 tells us that the flow welfare cost is approximately equal to the excess dollar return on domestic assets times one-half the "excess reserves" (i.e., the reserves in excess of what China would hold in the absence of distortion). If, for example, one assumes that the undistorted level of reserves was 20 percent of GDP (about the level observed at the beginning of the 2000s), excess reserves amounted to about 30 percent of GDP at the end of the decade. The average excess dollar return

[21] To the extent that the interest rate is lower on deposits because of the transaction services that they provide, this would tend to lower the excess dollar return on deposits and to bias downward the welfare cost of holding reserves.

[22] Again, those policies might have welfare benefits which are not taken into account by the model.

on Chinese deposits was 7.1 percent in 2010-11, implying a flow welfare cost of about $\frac{1}{2} * 0.3 * 7.1 = 1.1$ percent of GDP per year in 2010-11. This cost is significant but not very large, bearing in mind that it has to be paid only for a few years, and it might be worth paying if the exchange rate undervaluation had even a moderate impact on growth.

The analysis presented in this paper does not involve money or monetary policy. This may seem surprising since popular accounts of the Chinese exchange rate policies give a central role to monetary policy and the monetary implications of reserve accumulation. For example, it is argued that the accumulation of reserves is the consequence of resisting the nominal appreciation of the renminbi, and that such a policy can successfully prevent a *real* appreciation only so long as the accumulation of reserves is sterilized by the central bank—otherwise the resulting increase in money supply leads to the internal appreciation of the currency through inflation.

It would not be difficult to add money to the model—for example by putting real balances in the consumer's utility function—but this would not alter the main features of the analysis. The economy would then have two types of domestic liabilities, government debt, b, and bank deposits, m, and domestic inflation and the nominal exchange rate would be endogenous. But in the absence of nominal stickiness the behavior of real variables would be essentially unaffected by monetary policy. In particular, resistance to nominal appreciation would have to be supplemented with policies that repress domestic demand in order to prevent an internal real appreciation. The adjustment might be delayed by nominal stickiness—but not by very long for standard assumptions about the persistence of nominal rigidity.

A significant difference between the model and popular explanations of Chinese policies is the role of reserve accumulation and sterilization. According to popular explanations, whether resistance to appreciation is successful depends on the extent to which the monetary authorities manage to sterilize the impact of reserve accumulation on money supply. In the model, by contrast, sterilization is irrelevant for the real exchange rate. Whether they sterilize reserve accumulation or not, the authorities can prevent a real appreciation only by repressing domestic demand. Without such repression, the central bank has a choice between two ways of letting the real exchange rate appreciate—through a nominal appreciation or through domestic inflation.[23]

[23]This is an implication of Mundell's impossible trinity: in the absence of capital controls, a nominal exchange rate objective implies the loss of monetary autonomy and so of

What matters for the real exchange rate is how the public accumulation of foreign assets influence domestic absorption, not the extent to which this accumulation is financed internally by money or debt creation. The foreign assets, furthermore, do not need to take the form of liquid international reserves or to be backed by money creation. The impact of foreign assets accumulation on domestic demand is exactly the same if these assets are purchased directly by the government and invested in a sovereign wealth fund as if they are accumulated as reserves at the central bank.[24]

9 Conclusions

I have presented a model of "real exchange interventions" explaining how a small open economy can persistently resist the real appreciation of its currency. The model was very stylized and there are several directions in which the analysis could be extended.

First, the model could be made more realistic by adding capital and investment, allowing to study how capital account policies affect flows of foreign direct investment. Second, productivity growth could be endogenized in order to study how capital account policies can address the type of externalities assumed in the endogenous growth literature. This would lead to a nontrivial welfare analysis in which an undervaluation policy may have some benefits in addition to the costs analyzed in this paper.[25]

Third, it would be interesting to explicitly incorporate money and monetary policy in the model in order to study the role of money and nominal stickiness in resisting real appreciation, and further clarify the difference between the model proposed in this paper and popular interpretations of the

control on domestic inflation.

[24]If the foreign assets are initially accumulated as reserves, they can be removed from the central bank's balance sheet by a swap against newly issued government debt. This is how the China Investment Corporation (CIC), a sovereign wealth fund responsible for managing part of China's foreign exchange reserves, was established in 2007. Sterilization is then achieved when the central bank sells the newly issued government debt to the private sector. In principle, there is no limit on the amount of reserve accumulation that can be sterilized in this way.

[25]An example of this approach is Korinek and Serven (2010). They assume a simple externality à la Romer in the accumulation of capital and show that undervaluation may increase domestic welfare under plausible assumptions. The literature offers several other endogenous growth frameworks in which optimal capital account policies can be studied.

exchange rate policies of China and similar countries.

Fourth, one could look at multi-country versions of the model in order to assess the general equilibrium effects of capital controls and the international spillovers involved in resistance to currency appreciation.

Finally, stepping further away from the model, one would like to understand better how the public accumulation of foreign assets might affect the real exchange rate even in countries with a fairly open capital account. Although capital account restrictions provide a simple and clean departure from Ricardian equivalence, there is evidence that the real impact of reserve accumulation is not weaker in countries with more open capital accounts (Gourinchas and Jeanne, 2011; Gagnon, 2012). This suggests that there might be more fundamental underlying frictions behind the failure of Ricardian equivalence, and it would seem important to understand better what they are. This is left for further research.

References

Adler, Gustavo, and Camilo Tovar. 2011. "Foreign Exchange Intervention: A Shield Against Appreciation Winds?" *IMF Working Paper 11/165.*

Aguiar, M., and M. Amador. 2011. "Growth in the Shadow of Expropriation." *The Quarterly Journal of Economics*, 126(2): 651–697.

Aizenman, J., and J. Lee. 2007. "International reserves: precautionary versus mercantilist views, theory and evidence." *Open Economies Review*, 18(2): 191–214.

Backus, D.K., and P.J. Kehoe. 1989. "On the Denomination of Government Debt: a Critique of the Portfolio Balance Approach." *Journal of Monetary Economics*, 23(3): 359–376.

Bhagwati, Jagdish. 1998. "The Capital Myth: the Difference between Trade in Goods and in Dollars." *Foreign Affairs*, 77(May/June): 7–12.

Bianchi, Javier. 2011. "Overborrowing and Systemic Externalities in the Business Cycle." *American Economic Review*, 101(7): 3400–3426.

Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas. 2008. "An Equilibrium Model of "Global Imbalances" and Low Interest Rates." *American Economic Review*, 98(1): 358–393.

Cappiello, L., and G. Ferrucci. 2008. *The sustainability of China's exchange rate policy and capital account liberalisation.* European Central Bank.

Carroll, Christopher D., and Olivier Jeanne. 2009. "A Tractable Model of Precautionary Reserves, Net Foreign Assets, or Sovereign Wealth Funds." *NBER Working Paper No. 15228.*

Chamon, M.D., and E.S. Prasad. 2010. "Why are saving rates of urban households in China rising?" *American Economic Journal: Macroeconomics*, 2(1): 93–130.

Chari, V.V., P.J. Kehoe, and E.R. McGrattan. 2002. "Can Sticky Price Models Generate Volatile and Persistent RealExchange Rates?" *Review of Economic Studies*, 69(3): 533–563.

Costinot, Arnaud, Guido Lorenzoni, and Ivan Werning. 2011. "A Theory of Optimal Capital Controls." *Manuscript, MIT*.

Disyatat, P., and G. Galati. 2007. "The Effectiveness of Foreign Exchange Intervention in Emerging Market Countries: Evidence from the Czech Koruna." *Journal of International Money and Finance*, 26(3): 383–402.

Dooley, M.P., D. Folkerts-Landau, and P. Garber. 2004. "The Revived Bretton Woods System." *International Journal of Finance & Economics*, 9(4): 307–313.

Durdu, Ceyhun Bora, Enrique G. Mendoza, and Marco E. Terrones. 2009. "Precautionary Demand for Foreign Assets in Sudden Stop Economies: an Assessment of the New Merchantilism." *Journal of Development Economics*, 89: 194 – 209.

Edwards, S. 1985. "On the Interest-Rate Elasticity of the Demand for International Reserves: Some Evidence From Developing Countries." *Journal of International Money and Finance*, 4(2): 287–295.

Flood, Robert, and Nancy Marion. 2001. "Holding International Reserves in an Era of High Capital Mobility." 1–68, JSTOR.

Gagnon, Joseph. 2012. "Global Imbalances and Foreign Asset Expansion by Developing Economy Central Banks." *Working Paper 12-5, Peterson Institute for International Economics*.

Ghosh, Atish R., and Jun Il. Kim. 2008. "An Itsy-Bitsy Model of Bretton Woods II: Export Subsidies, Pegged Exchange Rates, and the Costs of Sterilized Intervention." *Manuscript, International Monetary Fund*.

Gourinchas, Pierre-Olivier, and Olivier Jeanne. 2011. "Capital Flows to Developing Countries: The Allocation Puzzle." Manuscript, Johns Hopkins University.

IMF. 2011. "Assessing Reserve Adequacy." *http://www.imf.org/external/np/pp/eng/2011/021411b.pdf*.

Jeanne, O., A. Subramanian, and J. Williamson. 2012. *Who Needs to Open the Capital Account?* Peterson Institute for International Economics.

Jeanne, Olivier, and Romain Rancière. 2011. "The Optimal Level of Reserves for Emerging Market Countries: Formulas and Applications." *Economic Journal*, 121(555): 905–930.

Johnson, Harry G. 1953. "Optimum Tariffs and Retaliation." *The Review of Economic Studies*, 21(2): pp. 142–153.

Korinek, Anton. 2011. "The New Economics of Prudential Capital Controls: A Research Agenda." *IMF Economic Review*, 59: 523–561.

Korinek, Anton, and Luis Serven. 2010. "Undervaluation Through Foreign Reserve Accumulation: Static Losses, Dynamic Gains." *World Bank Policy Research Working Paper No.5250*.

Kumhof, M. 2010. "On the Theory of Sterilized Foreign Exchange Intervention." *Journal of Economic Dynamics and Control*, 34(8): 1403–1420.

Lardy, N., and P. Douglass. 2011. "Capital Account Liberalization and the Role of the Renminbi." *Peterson Institute for International Economics Working Paper 11-6*.

Ma, Guonan, and Robert N. McCauley. 2008. "Efficacy of China's capital controls: Evidence from price and flow data." *Pacific Economic Review*, 13(1): 104–123.

Mendoza, Enrique G., Vincenzo Quadrini, and José-Víctor Ríos-Rull. 2009. "Financial Integration, Financial Development, and Global Imbalances." *Journal of Political Economy*, 117(3).

Obstfeld, M., and K.S. Rogoff. 2005. "Global current account imbalances and exchange rate adjustments." *Brookings Papers on Economic Activity*, 2005(1): 67–123.

Rodrik, D. 2006. "The Social Cost of Foreign Exchange Reserves." *International Economic Journal*, 20(3): 253–266.

Rodrik, Dani. 2008. "The Real Exchange Rate and Economic Growth." *Brookings Papers on Economic Activity*, 2008(2): 365–412.

Rogoff, K. 1996. "The purchasing power parity puzzle." *Journal of Economic literature*, 34(2): 647–668.

Sandri, Damiano. 2010. "Growth and Capital Flows with Risky Entrepreneuship." *IMF Working Paper No.10/37*.

Sargent, Thomas, and Bruce Smith. 1988. "The Irrelevance of Government Foreign Exchange Operations." *Economic Effects of the Government Budget*, , ed. Elhanan Helpman Assaf Razin and Efraim Sadka, 328–45. Cambridge, Mass: MIT Press.

Sarno, L., and M.P. Taylor. 2001. "Official Intervention in the Foreign Exchange Market: Is It Effective and, If So, How Does It Work?" *Journal of Economic Literature*, 39: 839–868.

Schmitt-Grohé, S., and M. Uribe. 2012. "Prudential Policy For Peggers." *Manuscript, Columbia University*.

Song, Z., K. Storesletten, and F. Zilibotti. 2011. "Growing like China." *The American Economic Review*, 101(1): 196–233.

Data Appendix

The data on China come from various national sources and were downloaded through the CEIC database. The data sources and construction method are indicated below.

Figure 1. The deposits are Deposits of Other Depository Corporations (source: People's Bank of China (PBOC)). The total stock market capitalization is the sum of the end-of-year Shanghai and Shenzhen stock market capitalizations (source: Shanghai and Shenzhen stock exchanges). Bond market capitalization is the sum of the outstanding stocks of Treasury bonds, policy financial bonds, and corporate bonds (source: China Securities Regulatory Commission). The data for corporate bonds were missing from 2002 to 2005 and were interpolated.

Figure 7. The source is the PBOC data about financial institutions. Total liabilities are the sum of deposits, financial bonds, currency in circulation, liabilities to international financial institutions, and other. (In principle the liabilities to international financial institutions should not be included but the amount is very small.) Foreign assets are the position for forex purchase of financial institutions. The domestic assets are the sum of loans, portfolio investments, equity and other investments, position for bullion and silver purchase, assets with international financial institutions and advances to treasury. (Claims on international financial institutions, gold, and an unknown fraction of portfolio investments should be counted foreign assets but the amounts are small.) Domestic assets and foreign assets sum up to total liabilities. GDP was obtained at the quarterly frequency by interpolating annual data.

Figure 9. The renminbi/US dollar exchange rate and the renminbi interbank market rate data come from the PBOC. The interbank market rate is the Interbank Offered Rate: Weighted Avg: 1 Month. The source for the Effective Federal Funds Rate is the US Federal Reserve.

Figure 10. The renminbi/US dollar exchange rate and the renminbi deposit interest rate data come from the PBOC. The deposit interest rate is

the Household saving rate six-month. The interest rate on the US six-month Treasury Bills comes from the US Federal Reserve.