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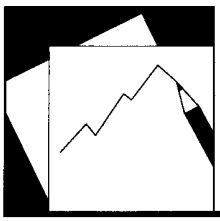

IMF Working Paper

A Real Model of Transitional Growth and Competitiveness in China

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A Real Model of Transitional Growth and Competitiveness in China[1]

Prepared by Leslie Lipschitz, Céline Rochon and Geneviève Verdier[2]

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Abstract

We present a stylized *real* model of the Chinese economy with the objective of explaining two features: (1) domestic production is highly competitive in the sense that an accumulation of capital that raises the marginal product of labor elicits increases in employment and output rather than only in wages; and (2) even though the domestic saving rate is high, foreign direct investment is also substantial. We explain these features in terms of a conventional neoclassical growth model—with no monetary or nominal exchange rate policy—by including two aspects of the economy explicitly in the model: (1) low production wages are sustained by a large reserve army of rural labor which drives internal migration, and (2) domestic capital is distinct from importable capital and complementary with it in production. The results suggest that underlying real phenomena are important in explaining recent history; while nominal renmimbi appreciation may dampen price and wage increases, it would probably not change the real factors that have sustained rapid growth.

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I. INTRODUCTION

The Chinese economy has experienced remarkable growth since the late 1970s. The last decade has been marked by clear signs of Chinese success: rapid export-led growth sustained by highly competitive real wages, and high investment financed both by substantial domestic saving and by large inflows of foreign direct investment (FDI). China's surprising performance has enabled its economy to absorb some of its large underemployed or unemployed labor force — its so-called surplus labor.

There has been a sharp debate among economists on the economic strategy of the Chinese authorities-especially their exchange rate policy. Some have argued that this strategy is sustainable and that, indeed, it will force other countries back into a system of fixed exchange rates (Dooley, Folkerts-Landau and Garber (2004a, b)). Others have taken a much less benign view: they see the Chinese strategy as essentially a mercantilist "beggar-thy-neighbor" stance that is undermining the mechanisms of international balance-of-payments adjustment and that, moreover, will prove detrimental to containing inflation and maintaining financial stability in China itself (Goldstein and Lardy (2005)). But a surprising element of much of the discussion is the implicit assumption that *nominal* exchange rate policy can exert protracted influences on the real economy.

This paper starts from the view that an understanding of the extraordinary real economic conditions is fundamental to an assessment of the implications (and the sustainability) of the Chinese development strategy. Consider the following stylized facts:

- per capita growth has averaged 8.5 percent over the last decade;
- investment has averaged over 36 percent of GDP since 1996;
- the national saving rate (with both households and entreprises contributing) has been extraordinarily high by any standard of comparison — in 2006, it was 54 percent (Table 1);
- notwithstanding the high national saving rate, there has been a significant inflow of foreign direct investment (Figure 1);
- wages in manufacturing have been very low by any international standard (Table 2) and rural incomes have been even lower than urban incomes — by a considerable margin (Table 3).

The research strategy of this paper is straightforward. We propose a simple neoclassical growth model that takes cognizance of the fundamental real features of the Chinese economy. It is a real model with no monetary-cum-nominal-exchange-rate policy, and the objective is to determine which of the basic characteristics of the Chinese pattern of development will be captured by this model.

In our model, China is a small open economy in the sense that its actions cannot affect the interest rate at which it borrows, but is a monopolistic producer in the goods market. The model has two important features. The first is imperfect capital mobility of a particular type: the model economy has two types of capital — domestic and foreign — and, while the latter can be borrowed on international capital markets at a fixed rate, the former can be generated only by domestic saving. (This is intuitive if one thinks of domestic capital as, for example, human capital.) Both kinds of capital are necessary for production, and the two are complements in the production process — that is, the marginal product of one type of capital is increasing in the level of the other. This means that saving more domestic capital increases the marginal product of foreign capital, and increases

inflows of FDI. Monopolistically competitive firms combine domestic and foreign capital with labor to produce a domestic good which is sold on both domestic and foreign markets.

The second crucial feature of the model is surplus labor. The economy depicted is an urban economy where all production takes place. The agricultural sector is assumed to be exogenous. It produces a homogeneous agricultural good with no growth. The rural sector has an excess of laborers willing to move to the urban areas whenever the urban wage exceeds the rural wage. The speed at which migration occurs depends on the degree of labor mobility.

These two features of the model drive the results. We calibrate the model to the Chinese economy and find that the model can explain the combination of high saving coupled with FDI inflows, high investment, low wages, and competitively-priced domestic goods on world markets. For example, any increase in the domestic capital stock raises the marginal product of foreign capital and labor; this immediately attracts labor in from the rural sector and foreign capital in from the rest of the world such that output increases to the point where the marginal products of capital and labor are back to their initial levels.

We look at various experiments — the response to productivity, foreign demand and interest rate shocks — to illustrate the mechanics of the model. We also simulate the model and compare the moments of key variables under various assumptions about parameters. We find that the variance of both wages and the real exchange rate is lower in a model with higher labor mobility, particularly if the source of the shock is foreign demand. In addition, we characterize the transition of the Chinese economy to its steady state from an initial condition for surplus labor close to what is currently being observed in China. We conclude that if there is still a substantial surplus of labor, then the current transition could last an additional decade.

Our analysis is undertaken without ever specifying a monetary channel. This may seem surprising as much research has focused on how monetary policy is being used to maintain an undervalued currency. In addition, much press, academic and popular, has been given to the large accumulation of international reserves by the Chinese monetary authorities. We make two observations on these points. The first observation relates to the accumulation of reserves and the relative fixity of the exchange rate of the renminbi. Prasad and Wei (2005) argue that reserve accumulation since 2001 may have been due to an undervalued currency and/or speculative inflows. Our paper is largely silent on the issue of reserve accumulation unrelated to FDI flows; this may be important but it is beyond the scope of the current analysis. We do imply, however, that, while monetary policy may have influenced the value of the renminbi, an appreciation of the currency now would not change the underlying real phenomena —in this case the particular combination of imperfect capital mobility and an excess supply of labor — that have played an important role in the recent history of rapid growth. On the other hand, any monetary/exchange rate policy that seeks to restrain an equilibrating real appreciation as underlying conditions change will probably set off a serious inflationary spiral.

Our second observation relates to the unusual pattern of Chinese saving, investment, FDI and terms of trade: a multiplicity of complex explanations have been suggested but the one that emerges from our model is clean and simple. On saving, some have argued that observed household savings are largely demographic. Modigliani and Cao (2004), for example, make life-cycle/retirement arguments for the high Chinese saving rate: saving by the young, spurred by high growth, offsets any dissaving by the old. In addition, the one-child policy in China has forced families to substitute financial

saving for children in the planning for retirement. Both Kuijs (2006) and Chamon and Prasad (2007) find that a decrease in savings in China is to be expected because of the aging of the population, but that this will be offset by the increase in a share of high savers, namely workers in the latter halves of their working lives. Chinese savings are also seen by some as precautionary and a response to various distortions that leave households unable to insure themselves through other means. Blanchard and Giavazzi (2005) and Kuijs (2006) among others cite in particular the lack of government spending on health, and social safety, the existence of credit constraints, and the lack of financial sector development. Aziz (2006) argues that the high saving and investment rate may be the result of distorted financial incentives that encourage low ratios of consumption to GNP and high investment/GDP ratios. Other arguments include the uncertainty linked to the transition to a market economy and the lack of international portfolio diversification (Chamon and Prasad (2005)).

A variety of explanations have also been suggested for observed FDI flows: directed policy in the form of tax incentives or legal restrictions on other capital flows (Prasad and Wei (2005)); incentives such as open economic zones, the size of the Chinese market and the available infrastructure (Tseng and Zebregs (2002)); institutional weaknesses such as preferential bank credit flows to state-owned enterprises that have required private firms to seek financing through ventures with foreign firms.

Many authors have examined China's exchange rate system (e.g. Mundell (2004), McKinnon (2007)). One of the most well-known and controversial explanation for recent developments in China is that advanced by Dooley, Folkerts-Landau and Garber (2004a, b). It is perhaps closest to our effort in the sense that the paper attempts to explain a large number of stylized facts at the same time. In addition, part of the explanation relies on the existence of a large supply of unemployed labor. The authors describe the so-called revived Bretton Woods system as China accumulating reserves in the form of US securities which then serve as collateral for US firms investing in China. The resulting export-led growth allows China to absorb its large surplus of unemployed or underemployed workers.

Our story however, does not rely on any implicit agreement between China and the United States, or indeed upon the notion — something of a stretch in our view — that net official reserves are seen as collateral by private FDI investors. What matters instead is a structure of production that depends on three complementary factors and the particular supply of these factors. With these features, our exogenous growth model with optimizing agents provides a reasonable explanation for the recent behavior of saving, investment, capital inflows and goods prices in China.

Note that our work cannot be used as a faithful representation of the Chinese economy. Our model is much too simple and stylized to be tested quantitatively against the data. It does, however, provide plausible channels through which key stylized facts can be explained.

The paper is organized as follows. Section II reviews the stylized facts we propose to match. Section III presents the model. Section IV presents the dynamics of the model as well as its qualitative predictions while Section V concludes.

II. THE STYLIZED FACTS

The characteristics of Chinese growth are well known. Nevertheless, we document a list of three stylized facts which our model will either take as given or will try to reproduce. Our view is that China's economy can be described by the following key facts: (i) China's recent economic performance is due

in large part to its high investment rate fueled by both domestic and foreign sources of financing; (ii) Chinese wages are very low by international standards but relative wages are much higher in the urban areas; (iii) China's agricultural sector has a large reserve of surplus labor. We turn to each of these in turn.

Fact 1: Saving, Investment and FDI are high

As illustrated in Table 1, China's saving rate is substantially higher than average. It is twice the level observed in low-income countries and almost 15 percentage points higher than the average for upper-middle income economies. Figure 2 shows that this has been the case for some time, as the saving rate has remained around 40 percent for the past twelve years.

Households savings are high, at about 20% of GDP, but are not the only contributor to overall savings as shown in Figure 2. Savings by firms constitute a large portion of observed savings. In fact, many authors (Kuijs (2005, 2006), Aziz (2006), Barnett and Brooks (2006)) have documented the Chinese enterprises' tendency to reinvest profits and to follow a low-dividend policy. As shown in the next sections, this is consistent with our model in which monopolistic competitive domestic firms who collect excess rents must invest in domestic capital in order to attract foreign capital. Government savings also contribute to the total. Kuijs (2005) notes that this is a result of a growth-oriented policy promoting investment. Government consumption is thus less favored than government-financed investment.

Figure 2 also illustrates the behavior of the investment rate over the past decade. It has averaged around 40% so that a large portion of it has been financed by domestic saving. Both households and government have been generating a positive gap between saving and investment while firms have run a large deficit. This is despite the fact that there is a high degree of financing by enterprise retained earnings. Investment of non-financial enterprises has come from own savings (from retained earnings), government capital transfers, bank loans, and FDI.

Figure 1 illustrates how important FDI has been in financing firm investment: most inflows into China since the early 1980s have been in the form of FDI. As noted by Prasad and Wei (2005), China accounts for 60 percent of FDI going to emerging markets.

Fact 2: Manufacturing wages are low relative to international levels but high relative to rural levels

The popular press has made much of the fact that wages in China are uncommonly low. Recent work by Banister (2005) now makes it possible to compare hourly compensation rates between China and other economies for the year 2002. Banister estimates that the average hourly compensation of China's manufacturing workers was 57 cents in 2002. The hourly manufacturing wage was \$0.95 in cities while it was only \$0.41 in rural area. As shown in Table 2, this is 3% of the equivalent American wage. Even in comparison to emerging Asian markets, the Chinese wage seems unusually low.

Although the manufacturing wage is very low, it has risen in real terms. This urban wage however, remains significantly higher than compensation in rural areas. Table 3 illustrates this point: the urban-rural income gap has been rising steadily since the late 1980s.

Fact 3: China's agricultural sector has a large reserve of surplus labor which drives internal migration

There is a wide range of views on the size of rural surplus labor in China. One of the most cited views (Banister (2005), Brooks and Tao (2003)) estimates that 100 to 200 million surplus workers live in China's countryside. As noted in Banister and Taylor (1989), this range of estimates comes from comparing actual and required employment. Required employment is computed using some productivity measure in a benchmark year (cultivated acreage per worker or labor requirements per crop weighted by total acreage per crop). The OECD (2002) estimates on rural hidden unemployment range from 150-275 million, depending on the benchmark adopted (the exact proportion of GDP contribution per worker in nonagricultural jobs). The Ministry of Agriculture estimates rural underemployment at about 150 million people.

Others have estimated surplus labor using measured unemployment. This is problematic because multiple existing measures and definitions make it difficult to ascertain the exact level of the unemployment rate in China[3]. As detailed in Brooks and Tao (2003), the measure of registered unemployed workers provides a misleading measure according to International Labor Organization guidelines because the distinction between unemployed and underemployed is not clearly drawn. The authors report that another measure of unemployment more consistent with ILO guidelines is the difference between the labor force (the sum of the employed and unemployed) and employment published by the National Bureau of Statistics (NBS) from the quarterly labor force survey. Unemployment, according to this measure, was 2% of total labor force in 2002. For their part, Giles, Park and Zhang (2004) estimate the unemployment rate, using data from the 2001 China Urban Labor Survey and China 2000 population census, but it concerns urban labor only. They estimate the unemployment rate among urban permanent residents to be 11.1 percent in September 2002.

In 2004, the labor force in China was approximately 768 million workers[4] so that surplus labor using the range of unemployment rates is between 15 and 85 million. This adds up to between 2% and 11% of the labor force willing to migrate in order to enter the export-oriented high(er)-wage export sector. We use this estimate to assess the potential length of the transition.

[3]This difficulty is underscored in Banister (2005) :

"The rural unemployed are completely ignored in the calculation. China's unemployment rate is based on city data only. The figure used in the numerator for calculating the unemployment rate is the so-called "urban registered unemployment". These are adults living in cities whose permanent population registration (hukou) is located in that city where they live, who are in the legal working ages, and who are formally registered as unemployed. "Urban registered unemployment"does not include laid-off workers who are still associated in any formal way with their former work unit, and does not include workers who have been forced to retire early and does not include in-migrants whose permanent population registration is outside that city. The denominator of the unemployment rate is the sum of employed workers in legal working ages whose permanent population registration is in the city where they live plus the urban registered unemployed."

She also notes: "China's NBS and Labor Ministry published a figure of 83 million manufacturing employees in China of whom 45 million were called rural and 38 million were classified as urban. But these data do not take full account of the 71 million town and village enterprises (TVE) manufacturing workers reported by the Ministry of Agriculture. On the basis of the assumption that the 38 million urban and 71 million TVE manufacturing employment categories are mutually exclusive the total manufacturing employment at year end 2002 was about 109 million. There is evidence that the official figure of 83 million manufacturing workers excludes millions of migrant manufacturing workers."

[4]See the Asian Development Bank key indicators for China.

Whalley and Zhang (2004) and Zhao (2005) among others argue that the existence of a huge labor surplus as well as the income gap between urban and rural populations have driven most of the internal migration in China. Labor mobility is somewhat restricted by the legal restrictions on the movement of people. The Hukou registration system operates like a domestic passport system (see Au and Henderson (2002) and references therein). One's legal residence is usually defined by maternal residential status. Legal status in a locality entitles the holder to social services (education, health care, housing, sometimes grain rations), land for farming, job opportunities etc. Changing one's legal residence status is difficult. It is possible through the education system (a successful graduate may move to the city and be given an urban job commensurate with his newly acquired skills) or through occasional government action that allows urban factories to hire rural workers. 'Illegal' migration is costly: the migrant loses all entitlements associated with residence. The 'illegal' migrant can however work in the informal sector in poor conditions. In later section, we argue that these migration costs may imply a low level of labor mobility and lengthen the transition.

III. THE MODEL

Consider a small open urban economy populated by identical infinitely-lived households who consume baskets of differentiated domestic and foreign goods. Domestic goods are produced by monopolistically competitive firms with three inputs: labor, tradable capital and non-tradable capital. Non-tradable capital must be financed by domestic saving whereas tradable capital can be borrowed on world markets. This urban economy receives a flow of rural labor whenever the urban wage exceeds the rural wage.

Domestic firms have access to a standard Cobb-Douglas production function with three inputs: raw labor L, domestic capital Z and foreign capital K. Domestic capital is capital that cannot be borrowed internationally whereas foreign capital is available on international capital markets. The production function is

$$Y_t = F(K_t, Z_t, L_t) = a_t K_t^{\alpha} Z_t^{\eta} (E_t L_t)^{1-\alpha-\eta} \tag{1}$$

where $0 < \alpha < 1$, $0 < \eta < 1$. E_t is the efficiency of labor and grows at a deterministic rate g. a_t is a temporary technology shock. Aggregate output in efficiency units is

$$y_t = a_t k_t^{\alpha} z_t^{\eta} l_t^{1-\alpha-\eta}$$

where lowercase letters denote variables in efficiency units, i.e. $q_t = \frac{Q_t}{E_t}$

There are many ways of interpreting Z and K. First, one can think of domestic capital as human capital and foreign capital as physical capital as in Barro, Mankiw and Sala-i-Martin (1995). Human capital is inherently more difficult to borrow in international capital markets. A second interpretation is that K is capital used in the tradable sector whereas Z is capital used in the non-tradable sector. This is the approach followed by Lane (2001). The production function (1) could then represent the reduced form of a more complicated model with two sectors. A final option is to define Z as capital used in the informal sector and K as capital used in the formal sector as suggested by Easterly (1993). More generally, we think of domestic capital as any type of capital that is hard to borrow against internationally and which must be saved for domestically (see Verdier (2006)).

In this economy households must make intratemporal and intertemporal decisions. They must decide the fraction of total consumption they will devote to each good, foreign and domestic. They must also decide their overall consumption and savings level, as well as which asset they will accumulate, i.e. domestic or foreign capital. In addition, rural households must decide whether or not to migrate to the cities. Domestic monopolistically competitive firms must make a pricing decision, as well as determine how much of each input to employ. We consider each of these decisions in turn.

A. Households

Intratemporal decision

Households consume two types of tradable goods, domestic and foreign goods, C_h and C_f respectively where $C_h = \left[\int_0^1 C_h(i)^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$ and $C_f = \left[\int_0^1 C_f(i)^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$ with $\theta > 1$. Aggregate consumption is a CES aggregate of C_h and C_f, i.e.

$$C_t = \left[\gamma^{\frac{1}{\rho}} C_{ht}^{\frac{\rho-1}{\rho}} + (1-\gamma)^{\frac{1}{\rho}} C_{ft}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{2}$$

where $0 < \gamma < 1$ is the share of home-produced goods in consumption and ρ is the elasticity of substitution between C_h and C_f. We can define an aggregate utility-based price index P_t

$$P_t = \left[\gamma p_{ht}^{1-\rho} + (1-\gamma) p_{ft}^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{3}$$

where $p_h = \left[\int_0^1 p_h(i) di\right]^{\frac{1}{\theta}}$ and $p_f = \left[\int_0^1 p_f(i) di\right]^{\frac{1}{\theta}}$ are expressed in units of domestic goods. Optimal intratemporal optimization implies the following demands for domestic and foreign good i:

$$C_{ht}(i) = \left(\frac{p_{ht}(i)}{p_{ht}}\right)^{-\theta} C_{ht} \tag{4}$$

$$C_{ft}(i) = \left(\frac{p_{ft}(i)}{p_{ft}}\right)^{-\theta} C_{ft} \tag{5}$$

so that the optimal allocation of expenditure between domestic and foreign goods is

$$C_{ht} = \gamma \left(\frac{p_{ht}}{P_t}\right)^{-\rho} C_t \tag{6}$$

$$C_{ft} = (1-\gamma) \left(\frac{p_{ft}}{P_t}\right)^{-\rho} C_t \tag{7}$$

Note that we assume a similar demand structure for foreigners so that

$$C_{ht}^*(i) = \left(\frac{p_{ht}^*(i)}{p_{ht}^*}\right)^{-\theta} C_{ht}^* = \left(\frac{p_{ht}(i)}{p_{ht}}\right)^{-\theta} C_{ht}^* \tag{8}$$

and

$$C_{ht}^{*} = \gamma^{*}\left(\frac{p_{ht}^{*}}{P_{t}^{*}}\right)^{-\rho} C_{t}^{*} = \gamma^{*} p_{ht}^{-\rho} C_{t}^{*} \tag{9}$$

where we have normalized the foreign price level P_t^* to 1 and $*$ denotes foreign variables.

Intertemporal decision

Household income can be used to consume and to accumulate three types of assets: domestic capital z_t, foreign capital k_t and external debt d_t, i.e. total assets are $z_t + k_t - d_t$. The small open economy therefore earns interest on capital of both types and pays interest on accumulated debt. The budget constraint faced by the infinitely-lived representative consumer is

$$(1+g)(1+n)(k_{t+1} + z_{t+1} - d_{t+1}) = (1 + R_{kt} - \delta)k_t + (1 + R_{zt} - \delta)z_t - (1+r)d_t + w_t - c_t P_t \tag{10}$$

where R_{zt} and R_{kt} are the rental prices of domestic and foreign capital, r is the constant world interest rate on debt. We assume that foreign and domestic capital depreciate at the same rate, δ. The population growth rate is denoted by n.

We have assumed that k can be borrowed from international capital markets whereas z cannot. This means that our small-open economy is *credit-constrained*. In a standard neoclassical growth model with perfect capital mobility, convergence to the steady state is instantaneous once access to international capital markets is granted. Here an economy cannot fully borrow to finance its transition to the steady state.[5] Debt cannot exceed the level of foreign capital, i.e. borrowing can only finance k_t and not z_t. Whether or not an economy is constrained depends on its initial level of assets. If $z_0 + k_0 - d_0 > z^*$, then the economy is unconstrained. On the contrary, if $z_0 + k_0 - d_0 < z^*$, then the economy is constrained and its debt must satisfy $d_t \leq k_t$.

Under these assumptions, the household's problem is

$$\underset{\{c_t, z_{t+1}, d_{t+1}, k_{t+1}\}_{t=0}^{\infty}}{Max} \sum_{t=0}^{\infty} \beta^t U(c_t)$$

under the constraints

$$\begin{aligned} P_t c_t + x_t + (1+g)(1+n)k_{t+1} - (1-\delta)k_t - (1+g)(1+n)d_{t+1} + d_t &= w_t + R_{zt} z_t + R_{kt} k_t \\ &- r_t d_t + \pi_t \\ x_t &= (1+n)(1+g)z_{t+1} - (1-\delta)z_t \\ d_t &\leq k_t \end{aligned}$$

Under the small-open-economy assumption, $r = R_k - \delta$. Since d_t and k_t have the same rate of return, in equilibrium, the household will borrow up to its level of collateral, i.e. $d_t = k_t$. Intertemporal

[5] The model we present in this paper predicts that China is a net recipient of capital flows. This appears to be at odds with the observed Chinese current account surplus. We do not however present a model of the current account but rather a model of the capital account — the flows of FDI, portfolio investment and debt — and predict correctly that China will receive more flows of these types than it will invest abroad. To fully characterize the current account, we would need a much richer model of saving and reserve accumulation. The model however, can be made technically consistent with the observation of a current account surplus. See the Appendix for details.

optimality therefore requires

$$
\begin{aligned}
U_t^c &= \frac{\beta}{(1+n)(1+g)} E_t \frac{P_t}{P_{t+1}} U_{t+1}^c \left(1 - \delta + \frac{R_{zt+1}}{P_{t+1}}\right) && (11)\\
R_{kt} - \delta &= r_t && (12)\\
P_t c_t + x_t &= w_t + R_{zt} z_t + \pi_t && (13)\\
x_t &= (1+n)(1+g) z_{t+1} - (1-\delta) z_t && (14)
\end{aligned}
$$

Migration decision

This small open economy has an exogenous reserve army of surplus rural labor. Rural labor do not have access to the technology described by (1). They are subsistence farmers and their labor earns them a constant wage $\bar{w}$. Each period, these workers can decide to stay in the rural region or permanently move to the city.

The benefit from a permanent move to the city at time t is the present value wage income in the city b_t:

$$b_t = \sum_{s=t}^{\infty} \beta^{*s} w_t \tag{15}$$

where $b_t = \frac{B_t}{E_t}$. This implies the following law of motion for the present value of wage income:

$$(1+g) b_{t+1} = \frac{1}{\beta^*} b_t - w_t \tag{16}$$

The benefit from staying in the rural area is the present value of wage income in that location $\bar{b}$:

$$
\begin{aligned}
\bar{b} &= \sum_{s=t}^{\infty} \beta^{*s} \bar{w} \\
&= \frac{\bar{w}}{1-\beta^*} && (17)
\end{aligned}
$$

Labor is assumed to enter or exit at a rate proportional to the log difference between the urban and rural net present value of wage income:

$$\log l_{t+1} - \log l_t = \chi \left(\log b_t - \log \bar{b}\right) \tag{18}$$

where χ measures the degree of labor mobility. This labor mobility function is similar to that assumed by Braun (1993) and more recently by Rappaport (2004).

B. Firms

Domestic firms operate in two markets with different structures. Factor markets are perfectly competitive but final goods markets are not. Firms produce differentiated products in a monopolistically

competitive market. For ease of exposition, it is useful to think of individual firms as having two independent units, a pricing unit and a production unit.

Pricing decision

Each firm i sells its differentiated product at price $p_h(i)$ to both domestic and foreign consumers. A representative firm maximizes profits π_t:

$$\underset{p_{ht}(i)}{Max} \left(p_{ht}(i) - mc_t\right) Y_t^d$$

s.t.

$$Y_t^d = \left(\frac{p_{ht}(i)}{p_{ht}}\right)^{-\theta} [C_{ht} + C_{ht}^*]$$

where Y_t^d is the demand faced by the monopoly firms from both domestic and foreign consumers. Profits are equal to the difference between the price and the marginal cost of production times the amount sold Y_t^d. The first order condition is

$$p_{ht}(i) = \frac{\theta}{\theta - 1} mc_t. \tag{19}$$

Firms choose to charge a constant markup over marginal costs, the standard monopolistic competition result.

Production decision

Since factor markets are perfectly competitive, profit maximization requires that factors of production be remunerated at their marginal product:

$$w_t = mc_t(1 - \alpha - \eta)\frac{y_t}{l_t} \tag{20}$$

$$R_{zt} = mc_t \eta \frac{y_t}{z_t} \tag{21}$$

$$R_{kt} = mc_t \alpha \frac{y_t}{k_t} \tag{22}$$

Profits are

$$\pi_t = P_{ht} y_t - mc_t \alpha y_t - mc_t \eta y_t - (1 - \alpha - \eta) mc_t y_t = (P_{ht} - mc_t) y_t$$

C. Exogenous Shocks

The economy is subject to three types of temporary shocks: a technology shock ε^a, a foreign interest rate shock ε^r and a foreign demand shock ε^{y^*}. Technology, the foreign interest rate and the foreign demand shock have the following laws of motion:

$$\begin{aligned} a_t &= a_{t-1}^{\rho^a} \exp \varepsilon_t^a \\ r_t &= r_{t-1}^{\rho^r} \exp \varepsilon_t^r \\ y_t^* &= {y^*}_{t-1}^{\rho^{y^*}} \exp \varepsilon_t^{y*} \end{aligned} \tag{23}$$

D. Equilibrium

We can now define the equilibrium. An equilibrium is a sequence of quantities

$$\{y_t, x_t, mc_t, c_{ht}, c_{ht}^*, c_{ft}, k_t, b_t, c_t, z_{t+1}, l_{t+1}, a_t, y_t^*\}_{t=0}^{\infty}$$

and prices

$$\{P_t, p_{ht}, r_t, R_{zt}, R_{kt}, w_t\}$$

such that

1. Domestic and foreign household decisions are optimal, i.e. equations (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), and (18) hold.
2. Firm decisions are optimal, i.e. (19), (20), (21)and (22) hold
3. Markets clear i.e. (12), (14) hold and

$$\begin{aligned} k_t &= d_t \\ P_t c_t + x_t &= \left(\frac{\theta}{\theta - 1} - \alpha\right) mc_t y_t \end{aligned}$$

4. a_t, $r_t = i_t^*$, and y_t^* follow

$$\begin{aligned} \log a_t &= \rho^a \log a_{t-1} + \mu_t^a \\ \log r_t &= \rho^r \log r_{t-1}^* + \mu^r \\ \log y_t^* &= \rho^{y*} \log y_{t-1}^* + \mu^{y*} \end{aligned}$$

Let p_f be the numeraire. Equilibrium conditions are therefore

$$P_t = \left(\gamma p_{ht}^{1-\varrho} + (1-\gamma)\right)^{\frac{1}{1-\varrho}} \tag{24}$$

$$p_{ht} = \frac{\theta}{\theta - 1} mc_t \tag{25}$$

$$
\begin{aligned}
P_t c_t + x_t &= \left(\frac{\theta}{\theta - 1} - \alpha\right) mc_t y_t && (26)\\
c^*_{ht} + c_{ht} + x_t &= y_t && (27)\\
c_t &= \left(\gamma^{\frac{1}{\rho}} c_{ht}^{\frac{\rho-1}{\rho}} + (1-\gamma)^{\frac{1}{\rho}} c_{ft}^{\frac{\rho-1}{\rho}}\right)^{\frac{\varrho}{\varrho-1}} && (28)\\
c_{ht} &= \gamma \left(\frac{p_{ht}}{P_t}\right)^{-\rho} c_t && (29)\\
c_{ft} &= (1-\gamma) \left(\frac{1}{P_t}\right)^{-\rho} c_t && (30)\\
c^*_{ht} &= p_{ht}^{-\rho} y^*_t && (31)\\
y_t &= a_t k_t^{\alpha} z_t^{\eta} && (32)\\
mc_t \alpha \frac{y_t}{k_t} - \delta &= i^*_t && (33)\\
x_t &= (1+g) z_{t+1} - (1-\delta) z_t && (34)\\
U^c_t &= \beta^* E_t \frac{P_t}{P_{t+1}} \left[U^c_{t+1} \left(1 - \delta + mc_{t+1} \eta \frac{y_{t+1}}{z_{t+1}}\right)\right] && (35)\\
\log l_{t+1} - \log l_t &= \chi \left(\log b_t - \log \bar{b}\right) && (36)\\
(1+g) b_{t+1} &= \frac{1}{\beta^*} b_t - \left(mc_t (1 - \alpha - \eta) \frac{y_t}{l_t}\right) && (37)\\
\log a_t &= \rho^a \log a_{t-1} + \mu^a_t && (38)\\
\log i^*_t &= \rho^{i*} \log i^*_{t-1} + \mu^{i*} && (39)\\
\log y^*_t &= \rho^{y*} \log y^*_{t-1} + \mu^{y*} && (40)
\end{aligned}
$$

where $\beta^* = \frac{\beta}{(1+g)(1+n)}$

IV. RESULTS

A. Calibration

The model is solved using a log-linear approximation of the equilibrium around a balanced-trade steady state. We choose $U(c) = \frac{c^{1-\sigma}-1}{1-\sigma}$ with $\sigma = 1$. It is customary in the growth literature to assume that the growth rate of technological progress is approximately 2%. China's recent per capita growth rate however, has consistently been much higher. The average growth rate of per capita income since 1953 has been around 5.7% according to the Penn World Tables whereas this growth rate has averaged around 8.2% since 1977. We set the growth rate of technological progress at $g = 5.7\%$ but this assumption makes little difference to the results. $\beta = 0.9972$ is chosen so that the steady state interest rate is equal to 6%. Following the open-economy Phillips curve literature, we set $\theta = 6$ so that the steady state markup is 20%. γ is chosen so that the sum of imports and exports as a percentage of GDP in the steady state is equal to 54.4%, which is the value of the Chinese ratio in 2004 according to the Penn World Tables. The elasticity of substitution between domestic and foreign consumption is set at $\rho = 3$. Calibrating the migration parameter χ is difficult. Labor mobility estimates vary widely even for the United States. Barro and Sala-i-Martin (1991)'s estimates imply that $\chi = \frac{1}{25}$, whereas it is closer to $\frac{1}{5}$ according to the work by Greenwood et al. In his work on labor mobility and convergence, Rappaport (2004) also considers the Gallin (2004)

estimates which imply $1.5 \leq \chi \leq 2$. The degree of labor mobility in China is hard to gauge. We consider a range of possibilities between high ($\chi = 4$) and low ($\chi = 0$) labor mobility and contrast the results. Our exercises on the potential length of the transition is based on the assumption that the size of urban labor is 10% below what it will be once all rural labor has moved to the cities. Before presenting results on the length of the transition, we also consider the performance of the model following various shocks. For all three shocks (productivity, foreign interest rate and foreign output), we assume that the degree of persistence is $\rho^a = \rho^{i^*} = \rho^{y^*} = 0.9$. We assume that the standard deviation of all shocks is the same and equal to 1%.

B. Impulse Response Functions

It is useful to illustrate the dynamics and properties of the model by examining the impulse responses of this small open economy to standard shocks. These exercises underscore the roles of the complementarity between foreign and domestic capital as well as migration flows in driving the results of the model. First, the complementarity between k and z explains the comovements between FDI flows and saving in China. Second, migration flows explain why in response to supply or demand shocks, the Chinese economy can remain competitive — through low real wages or competitive terms of trade — without relying on monetary policy.

Consider first a supply shock as illustrated in Figure 3. The temporary increase in productivity has a positive and persistent effect on output. Higher productivity reduces marginal costs and puts downward pressure (a depreciation) on the relative price of the domestic good, our measure of the real exchange rate or terms of trade. Since the world interest rate has remained unchanged, inflows of foreign capital must rise to reduce the increase in the marginal product of k resulting from the shock. Since domestic and foreign capital are complementary in production, the increase in foreign capital induces a rise in domestic capital investment. Higher profits and savings are generated by the supply shock, reinforcing the already existing huge savings that finance the investments.

Figure 4 shows the result of a negative shock to the world interest rate. A fall in the world interest rate increases the inflow of foreign capital which is necessary to close the gap between the marginal product of k and the world return. The fall in the cost of foreign capital reduces marginal costs. Since the price of the domestic good is the monopolistic markup over marginal costs, this results in a real depreciation and a rise in foreign demand for the domestic good. Inflows of foreign capital increase the return to domestic capital which in turn leads to a rise in domestic investment fueled by higher profits. The increase in output is reflected both in an increase in consumption and savings.

Finally, consider the foreign demand shock illustrated in Figure 5. The rise in foreign demand puts upward pressure on the terms of trade and gives the domestic monopolistic firms an opportunity to increase prices. Higher profits are observed, redistributed into domestic investment and savings. As before, output and consumption rise, as do the complementary foreign and domestic capital.

In each case, migration flows amplify impulse responses. [6] For example, following the productivity shock, the present value of the wage differential between urban and rural compensation rises. In response, labor flows into urban production and exerts downward pressure on the wage. Higher labor

[6]Note that this exercise does not allow us to make predictions about the relative sizes of employment and wage responses. The model simply predicts that labor mobility dampens the wage response.

mobility leads to faster downward wage adjustment, and therefore larger output movements. More profits and more savings are channeled to investment in domestic capital.

C. Simulation

What general characteristics does the model imply for key macroeconomic variables? Table 7 shows the results of the simulated model under various assumptions about the speed of labor mobility. For each of the statistics presented in the table, the model is simulated 5000 times with all shocks or with each shock individually. For example, in the first panel of Table 7, the model is subjected to random realizations of technology, foreign interest rate and foreign demand shocks with all three following the specified AR(1) process. In the panels below, the model is subjected to individual shocks. Recall that all shocks are assumed to have the same normalized standard deviation. In general, the presence of foreign-domestic complementarity and labor mobility considerably lowers the variability of wages relative to output and lowers the level of the wage relative to output. When the model is subjected to all shocks, the relative variability of the real exchange rate p_h is also lower when labor mobility is higher ($\chi = 4$). This reduction however, is driven by the foreign demand shock. If the economy is mostly driven by foreign demand shocks and labor mobility is high, the model predicts that the real exchange rate will be relatively more stable.

What can we conclude from this exercise? We cannot make quantitative statements: the model is calibrated and simulated and none of the parameters are estimated. The exercise however does provide some qualitative insights into the Chinese economy. If there is surplus labor that can move to respond to wage differentials, wages are lower and less volatile whereas the real exchange rate is much more stable particularly in response to foreign demand shocks. The model makes these predictions without the presence of a monetary channel. It implies that competitiveness may be more a function of labor mobility than monetary policy. The Chinese central bank may be trying to maintain an undervalued currency; our analysis however, implies that nominal exchange rate policy is not needed to ensure real competitiveness.

D. Transition to Steady State

Many authors in the literature have argued that the performance of the Chinese economy is the direct result of a policy that aims to achieve an undervalued currency. The literature differs however on how long such a policy can be sustained and on the consequences of maintaining such a policy. Some (DLG) argue that the policy can be maintained for decades while others (Blanchard and Giavazzi (2005), Eichengreen (2004), Kuijs (2006), Prasad and Rajan (2006)) think important changes must be made to policy objectives. In particular, the latter group identifies policy priorities: a re-evaluation of the currency or change of exchange rate regime (Blanchard and Giavazzi (2005), Eichengreen (2004), Prasad and Rajan (2006)), a focus on increasing consumption (Kuijs (2006)), financial sector reforms (Prasad and Rajan (2006)). Our model says nothing explicitely about nominal exchange rate policy, but it implies that other factors — real factors — may be critical to tthe international competitiveness of Chinese labor.

These ideas can be illustrated by examining the transition to the steady state of the economy depicted by our model. Figure 6 shows the dynamics of key macroeconomic variables when initial

state variables (labor and domestic capital) are 90 percent below the steady state for high and low mobility of labor. Because of decreasing marginal productivities, the low level of l and z implies a high wage and a high rental price for z. As a result, the marginal cost of production is high and monopolistic competitors charge a high price for the domestic good. The initial high wage however attracts labor from the rural areas and exerts downward pressure on the wage during the transition. As domestic capital rises, the rental price of domestic capital falls, foreign capital — a complement to domestic capital — flows in. The resulting movements in factor prices reduces marginal costs and exerts downward pressure on the terms of trade. Throughout the transition, profits feed into saving and investment in domestic capital.

The model implies a number of things for the Chinese economy. Two crucial assumptions explain the results: first, the existence of mobile surplus rural labor, and second, the complementarity of saving and investment. The entry of new workers into the growing sector of the economy — the export-led cities — keeps wages and therefore the terms of trade lower than they otherwise would have been. In addition, the complementarity of foreign and domestic capital in the production function and limited capital mobility — modeled here as a credit constraint — implies that saving and foreign direct investment will move together. With higher labor mobility, the economy's transition to the steady state is faster with a lower real wage and a lower relative price for the domestic good. How long could the transition last? The model implies that depending on how mobile rural labor is in China, the transition could potentially last over a decade. Tables 5 and 6 show the speed of convergence for various values of labor mobility — as measured by χ — and openness, as measured by α. Recall that α measures the share of foreign capital in output. As χ and α rise, the tables show that the speed of convergence rises whereas the half life of the transition falls. These numbers show that openness and labor mobility can have a sizeable impact on the speed of transition.

Note that our story, although reminiscent of the DLG mercantilist approach both in its reliance on surplus labor and predictions for the length of the transition, does not depend on a particular monetary policy, nor does it rely on an implicit arrangement between a center and a periphery. The economy we consider is an open economy (small in financial markets but with monopolistic power in goods markets) without a monetary authority. Note also that we do not claim that monetary policy has had no role in shaping macroeconomic performance in China. Rather, we posit that if money is neutral in the long run, China's persistent impressive performance cannot be explained solely by an artificially maintained undervalued currency. In fact, our analysis suggests that China does not need to manipulate the nominal value of its currency to ensure competitiveness. Such measures are fraught with dangers — e.g. inflationary pressures. Our model suggests that real measures — for example lowering migration barriers across regions — may be more effective in sustaining competitiveness and growth.

V. CONCLUSION

In this paper, we present a stylized model of the Chinese economy with the objective of explaining three stylized facts: (1) Saving, Investment and FDI are high; (2) Wages are low; (3) There is a large reserve of surplus labor which drives internal migration. The model has two key features. First, there is a complementarity between domestic saving and foreign investment. Domestic and foreign capital are complements in production i.e. increasing domestic saving raises the marginal product of foreign capital and attracts capital flows. Second, wage movements are largely determined by the

mobility of low-earning rural workers. We find that these two features of the model help explain, at least qualitatively, the three stylized facts of the Chinese economy.

Our analysis cannot be used to explain the accumulation of reserves in China or the observed level of the exchange rate. What our work points out is that there may be intrinsic features of the Chinese economy that may help suppress wage levels relative to those in competitor countries. The model is too simple and stylized to fully help understand recent economic developments in China. However, it does provide some leads. It is very difficult to maintain a fixed real exchange rate for a long period of time. Our model implies that rural-urban labor mobility and limited openness — whether structural or self-imposed — may dampen movements in the real exchange rate.

Table 1: National Saving, 2006

	(in percent of GDP)
China	54
Newly industrialized Asian economies	31.6
Other emerging markets and developing countries	32.6
Advanced economies	20
Africa	26

Source: World Economic Outlook (October 2007)

Table 2: Relative hourly wage in manufacturing, selected economies, 2002

Country	Wage relative to the U.S.
United States	100
Europe	92
Japan	87
Asian NIE	33
Mexico	12
China	3

Source: Bureau of Labor Statistics, " International comparisons of hourly compensation costs for production workers, Supplementary Tables, 1975-2005". For China, datum is from Banister (2005) from which this table is reproduced. The data for China refer to all employees rather than just production workers.

Table 3: Income of urban and rural households and the urban-rural gap (RMB)

Year	Per capita income of rural households	Per capita income of urban households	Ratio of urban income to rural income
1980	191	439	2.30
1981	233	458	2.05
1982	270	500	1.83
1983	310	526	1.70
1984	355	608	1.71
1985	398	685	1.72
1986	424	828	1.95
1987	463	916	1.98
1988	545	1119	2.05
1989	602	1261	2.10
1990	686	1387	2.02
1991	709	1544	2.18
1992	784	1826	2.33
1993	922	2337	2.54
1994	1221	3179	2.60
1995	1578	3893	2.47
1996	1926	4839	2.27
1997	2090	5160	2.48
1998	2162	5425	2.52
1999	2210	5854	2.65
2000	2253	6316	2.80

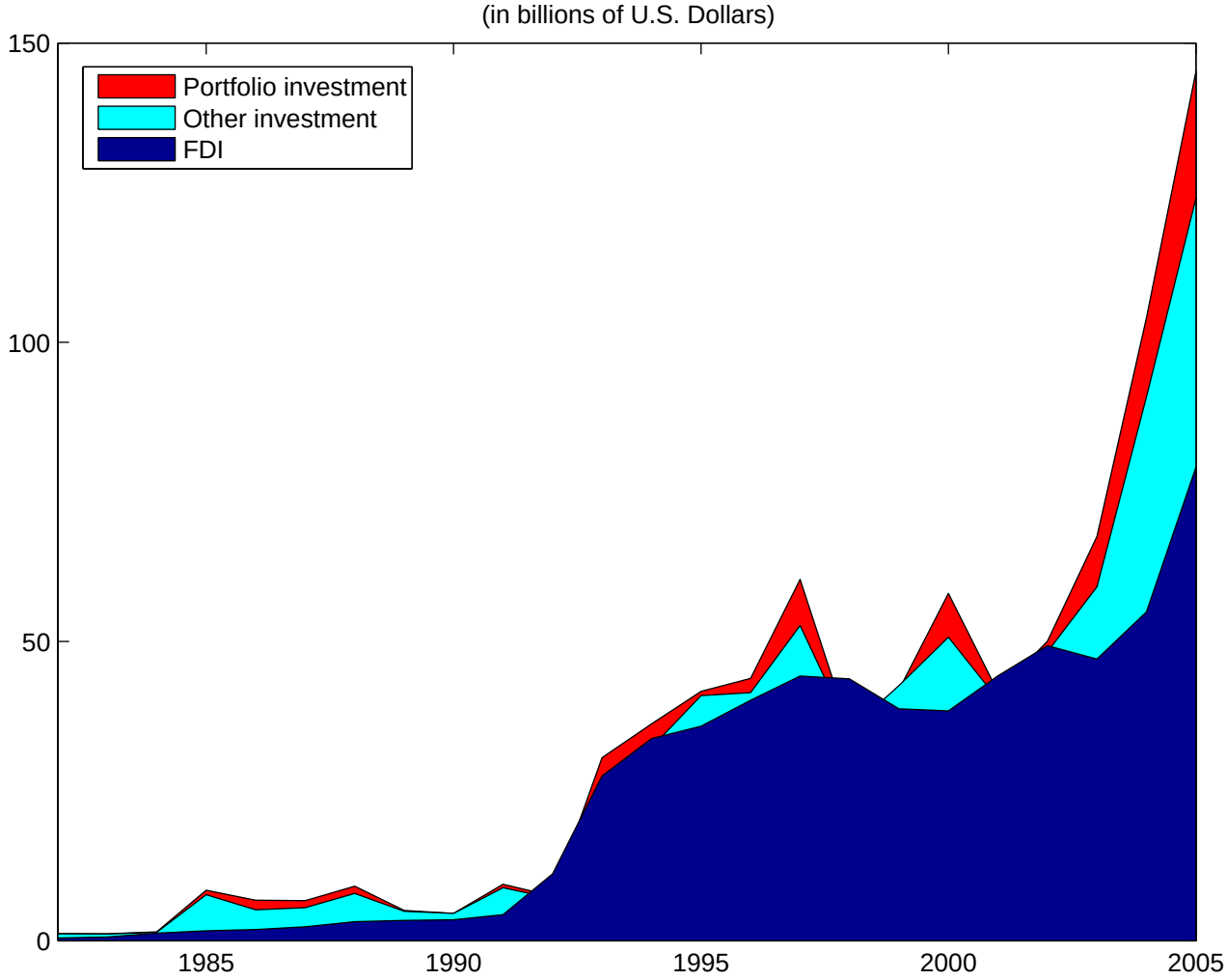
Source: China Statistical Yearbook, 1994, 1996 and 2001.

Table 4: Summary Indicators of Saving and Investment

	2003	2004	2005	2006
	(In percent of GDP)			
Total capital formation	41	43	44	45
Of which: Fixed capital formation	39	41	42	43
Gross national saving	44	47	51	54
Current account	2.8	3.6	7.2	9.4
	(In billions of U.S. dollars)			
Capital and financial account balance	53	111	63	10
Of which: direct investment inflows (net)	47	53	68	60

Source: World Economic Outlook (October 2007)

Figure 1: Net capital flows into China



Source: CEIC. This figure is taken from Prasad and Wei (2005)

Figure 2: Saving and Investment

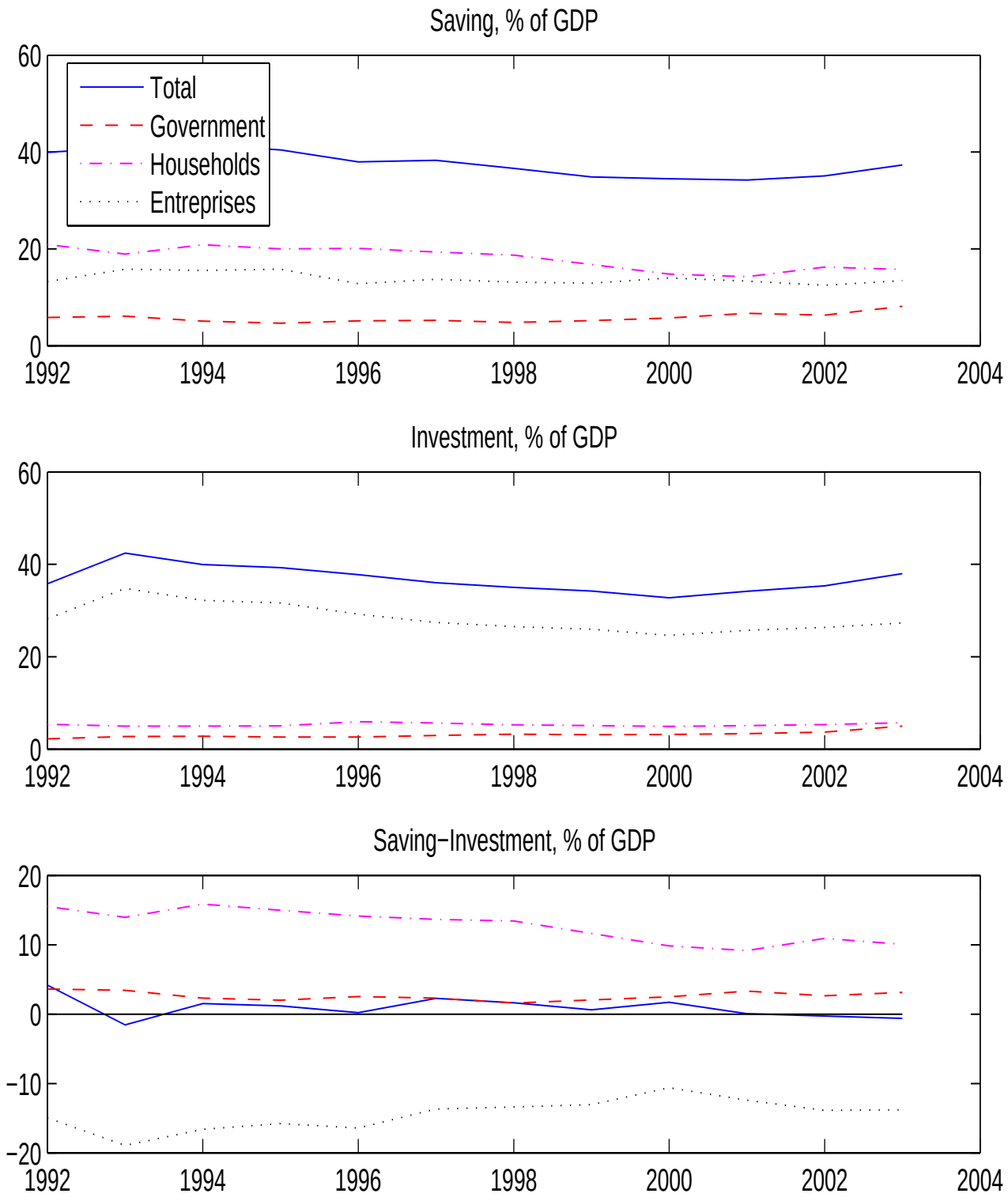


Figure 3: Productivity Shock

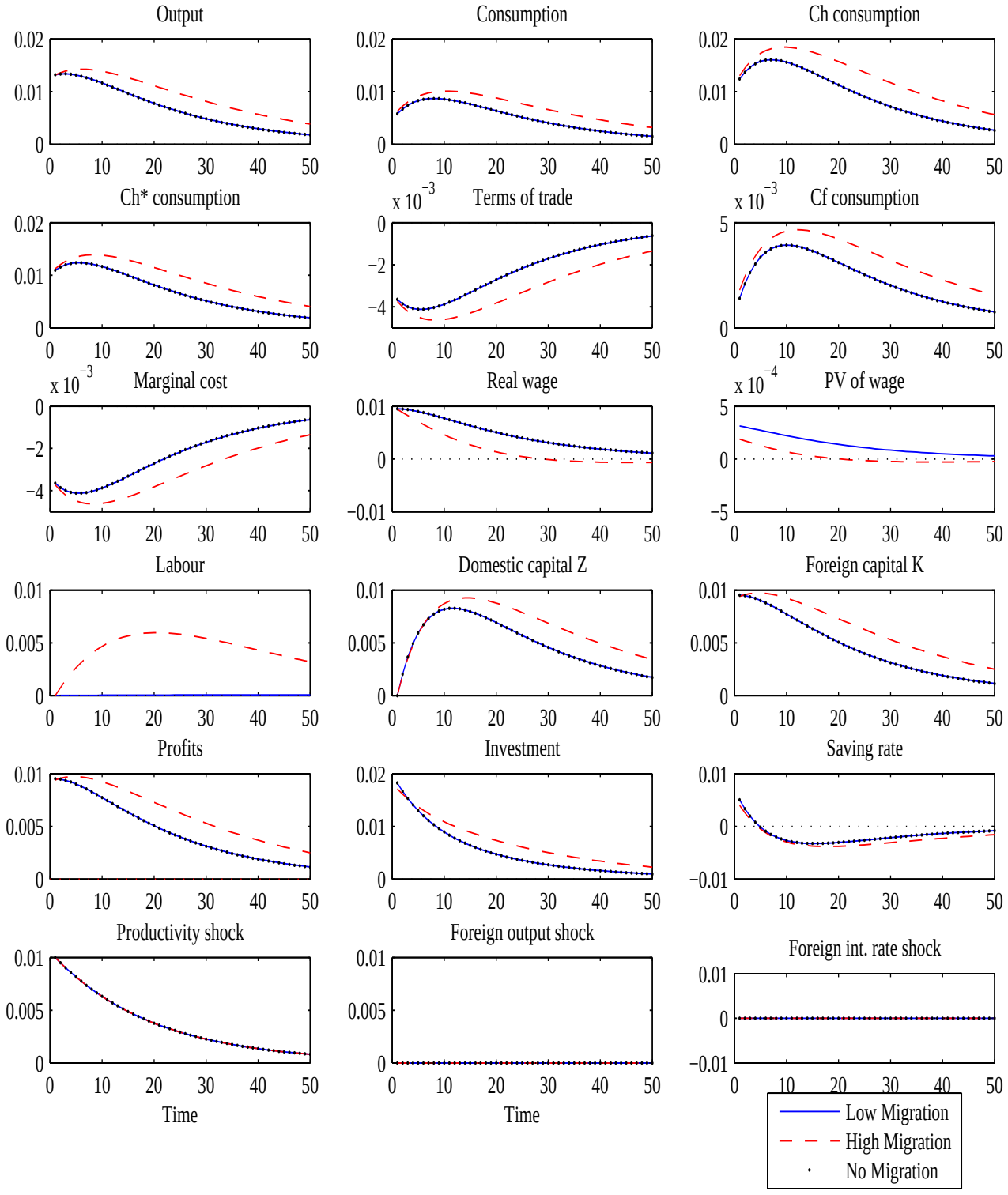


Figure 4: Foreign Interest Rate Shock

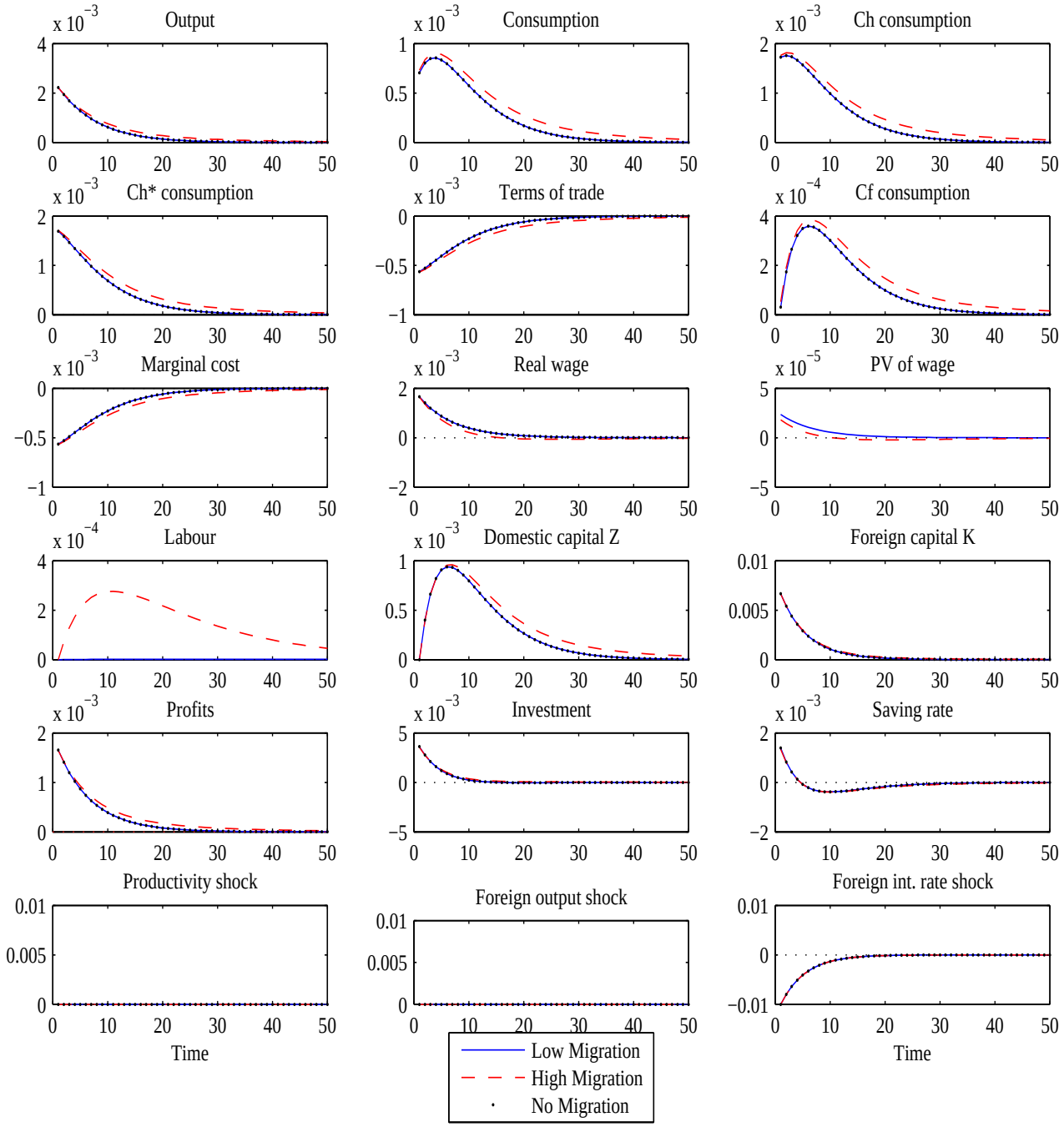


Figure 5: Foreign Output Shock

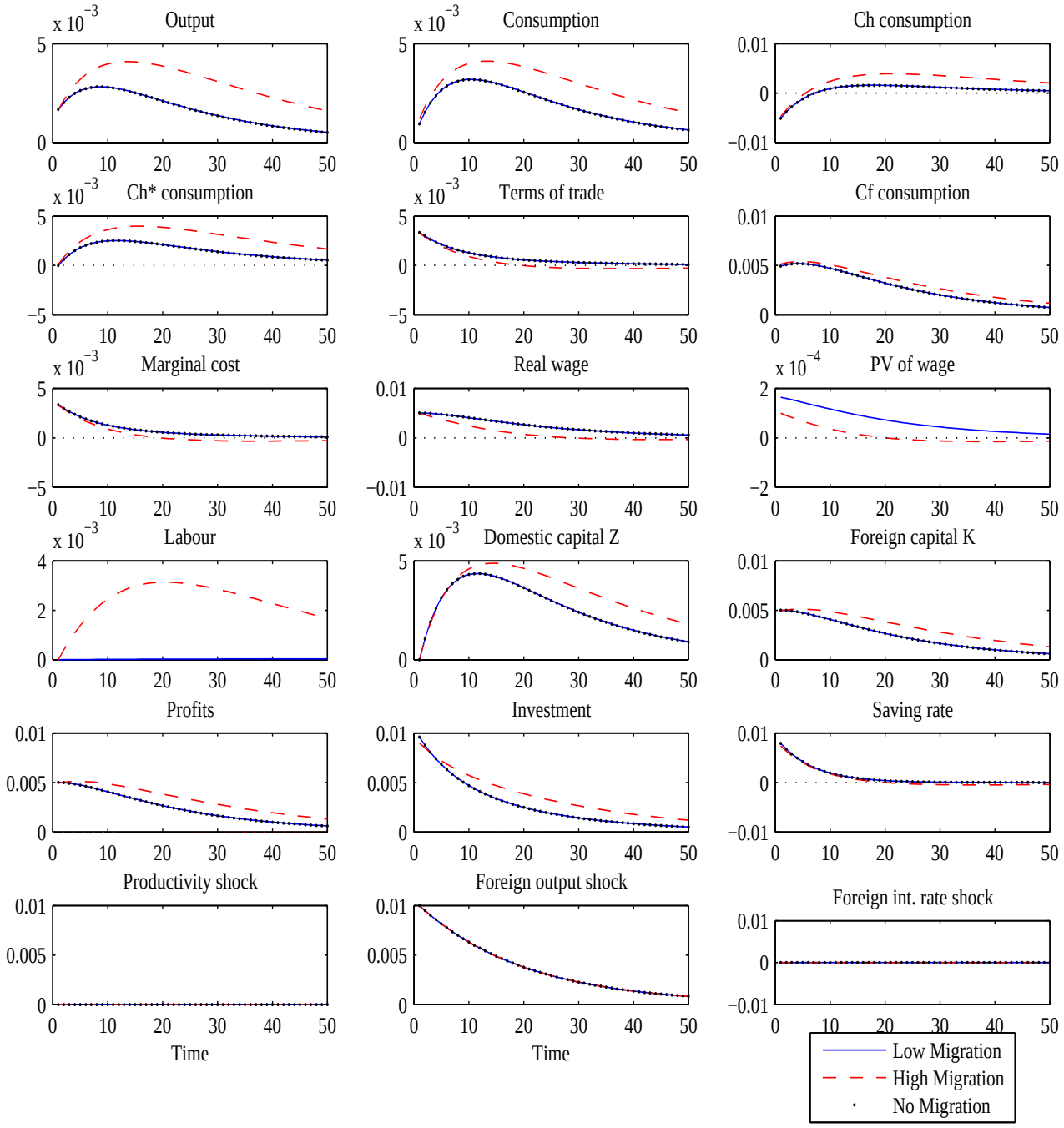


Figure 6: Transition to Steady State when $\frac{l_0}{l^*} = \frac{z_0}{z^*} = 0.9$

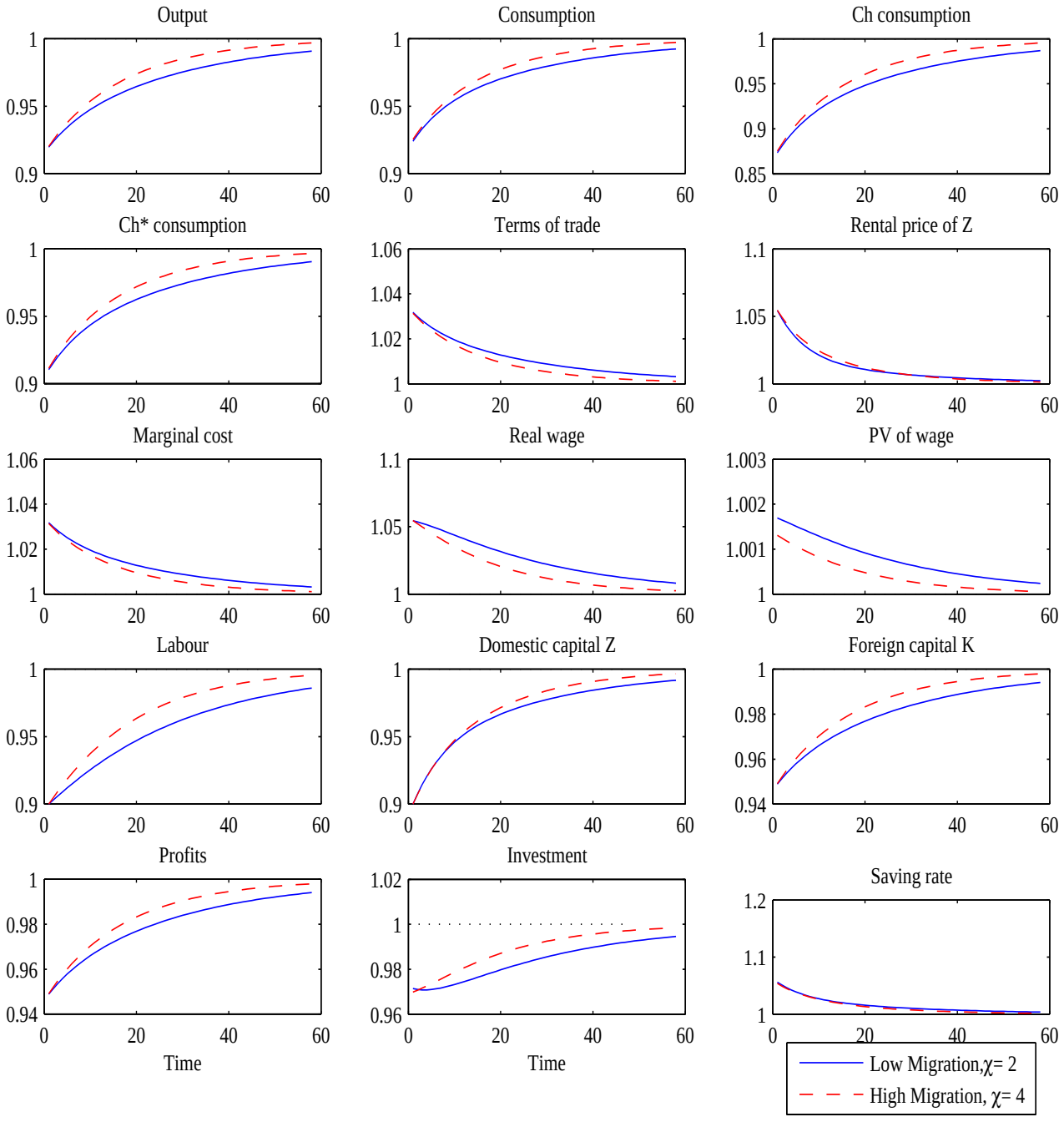


Table 5: Convergence and Transition Half Life $\alpha = \frac{1}{3}$

χ	0.00	2.00	4.00
convergence	0.04	0.05	0.06
half life	17.78	12.48	10.55

Table 6: Convergence and Transition Half Life $\alpha = \frac{1}{2}$

χ	0.00	2.00	4.00
convergence	0.06	0.07	0.08
half life	11.16	9.02	8.09

Table 7: Simulation results

All shocks	χ	$\frac{\bar{w}}{\bar{y}}$	$\frac{\sigma_w}{\sigma_y}$	$\frac{\tilde{p_h}}{\bar{y}}$	$\frac{\sigma_{p_h}}{\sigma_y}$
	0.000	0.982	0.721	0.972	0.328
	4.000	0.792	0.347	0.178	0.058

Technology shock	χ	$\frac{\bar{w}}{\bar{y}}$	$\frac{\sigma_w}{\sigma_y}$	$\frac{\tilde{p_h}}{\bar{y}}$	$\frac{\sigma_{p_h}}{\sigma_y}$
	0.000	0.980	0.658	0.974	0.312
	4.000	0.796	0.323	0.179	0.058

Foreign demand shock	χ	$\frac{\bar{w}}{\bar{y}}$	$\frac{\sigma_w}{\sigma_y}$	$\frac{\tilde{p_h}}{\bar{y}}$	$\frac{\sigma_{p_h}}{\sigma_y}$
	0.000	1.003	1.478	0.998	0.534
	4.000	0.830	0.596	0.186	0.063

Foreign interest rate shock	χ	$\frac{\bar{w}}{\bar{y}}$	$\frac{\sigma_w}{\sigma_y}$	$\frac{\tilde{p_h}}{\bar{y}}$	$\frac{\sigma_{p_h}}{\sigma_y}$
	0.000	0.999	0.676	0.999	0.325
	4.000	0.832	0.344	0.186	0.061

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Appendix

A. Steady State

To determine the steady state we have to choose the ratio $\frac{y}{y^*}$ or the relative price p_h. For example if we choose $p_h = 1$, this implies balanced trade in the steady state. The relevant equation is

$$c^*_{ht} + c_{ht} + x_t = y_t$$

In the steady state[7]

$$\begin{aligned}
c^*_h + c_h + x &= y && (.41)\\
p_h^{-\rho} y^* + \gamma \left(\frac{p_h}{P}\right)^{-\rho} c + x &= y && (.42)\\
p_h^{-\rho} y^* &= y - \gamma \left(\frac{p_h}{P}\right)^{-\rho} c - x && (.43)\\
\frac{y^*}{y} &= p_h^{\rho} - \gamma \left(\frac{1}{P}\right)^{-\rho} \frac{c}{y} - p_h^{\rho} \frac{x}{y} && (.44)
\end{aligned}$$

$$\begin{aligned}
mc &= \frac{\theta - 1}{\theta} p_h && (.45)\\
\frac{y}{z} &= \frac{1}{\eta mc} \left(\frac{1}{\beta^*} - (1 - \delta)\right) && (.46)\\
\frac{y}{k} &= \frac{\delta + i^*}{\alpha mc} && (.47)\\
\frac{x}{y} &= ((1 + n)(1 + g) - (1 - \delta)) \frac{z}{y} && (.48)\\
\frac{c}{y} &= \frac{mc}{P} \left(\frac{\theta}{\theta - 1} - \alpha\right) - \frac{x}{Py} && (.49)\\
\frac{c_h}{y} &= \gamma \left(\frac{p_h}{P}\right)^{-\rho} \frac{c}{y} && (.50)\\
\frac{c_f}{y} &= (1 - \gamma) \left(\frac{1}{P_t}\right)^{-\rho} \frac{c}{y} && (.51)\\
l &= 1 && (.52)
\end{aligned}$$

[7] To compute levels:

$$\begin{aligned}
y &= k^{\alpha} z^{\eta} l^{1-\alpha-\eta}\\
l &= 1\\
y &= k^{\alpha} z^{\eta}\\
\frac{y}{k} &= \left(\frac{z}{k}\right)^{\eta} k^{-(1-\alpha-\eta)}\\
k &= \left[\frac{k}{y} \left(\frac{z}{k}\right)^{\eta}\right]^{\frac{1}{1-\alpha-\eta}}
\end{aligned}$$

$$
\begin{aligned}
k &= \left[\frac{k}{y}\left(\frac{z}{k}\right)^{\eta}\right]^{\frac{1}{1-\alpha-\eta}} \\
z &= \frac{z}{y}\frac{y}{k}k && (.53)\\
y &= k^{\alpha}z^{\eta} && (.54)\\
w &= \bar{w} && (.55)\\
\bar{w} &= mc(1-\alpha-\eta)y && (.56)\\
b &= \bar{b} && (.57)\\
\bar{b} &= \frac{\bar{w}}{\frac{1}{\beta^*}-(1+g)} && (.58)
\end{aligned}
$$

So first, we choose p_h which allows us to compute all variables with the exception of $\frac{y^*}{y}$, which can be computed at the end.

B. Linear system

The two additional equations are

$$
\begin{aligned}
\hat{b}_{t+1} &= \frac{1}{\beta^*}\hat{b}_t - \frac{\bar{w}}{\bar{b}}\hat{mc}_t - \frac{\bar{w}}{\bar{b}}\hat{y}_t + \frac{\bar{w}}{\bar{b}}\hat{l}_t && (.59)\\
\hat{l}_{t+1} - \hat{l}_t &= \chi\hat{b}_t && (.60)
\end{aligned}
$$

Static equations

$$
\begin{aligned}
\hat{P}_t - \gamma\frac{p_h^{1-\rho}}{P}\hat{p}_{ht} &= 0 && (.61)\\
\hat{p}_{ht} - \hat{mc}_t &= 0 && (.62)\\
\frac{Pc}{Pc+x}\hat{P}_t + \frac{Pc}{Pc+x}\hat{c}_t + \frac{x}{Pc+x}\hat{x}_t - \hat{mc}_t - \hat{y}_t &= 0 && (.63)\\
\frac{c_h^*}{y}\hat{c}^*_{ht} + \frac{c_h}{y}\hat{c}_{ht} + \frac{x}{y}\hat{x}_t - \hat{y}_t &= 0 && (.64)\\
\hat{c}_{ht} + \rho\hat{p}_{ht} - \rho\hat{P}_t - \hat{c}_t &= 0 && (.65)\\
\hat{c}_{ft} - \rho\hat{P}_t - \hat{c}_t &= 0 && (.66)\\
\hat{c}^*_{ht} + \rho\hat{p}_{ht} &= \rho^{y*}\hat{y}^*_{t-1} + \hat{\mu}_t^{y*} && (.67)\\
\hat{y}_t - \alpha\hat{k}_t &= \eta\hat{z}_t + (1-\alpha-\eta)\hat{l}_t + \rho^a\hat{a}_{t-1} + \hat{\mu}_t^a && (.68)\\
\frac{\delta+i^*}{i^*}\hat{mc}_t + \frac{\delta+i^*}{i^*}\hat{y}_t - \frac{\delta+i^*}{i^*}\hat{k}_t &= \hat{i}_t^* && (.69)\\
\hat{b}_t &= E_{t-1}\hat{b}_t + \eta_t^b && (.70)\\
\hat{c}_t &= E_{t-1}\hat{c}_t + \eta_t^c && (.71)
\end{aligned}
$$

Dynamic equations

$$
\begin{aligned}
(1+n)(1+g)\frac{z}{x}\hat{z}_{t+1} &= \hat{x}_t + (1-\delta)\frac{z}{x}\hat{z}_t && (.72)\\
\hat{b}_{t+1} &= \frac{1}{\beta^*}\hat{b}_t - \frac{\bar{w}}{\bar{b}}\hat{mc}_t - \frac{\bar{w}}{\bar{b}}\hat{y}_t + \frac{\bar{w}}{\bar{b}}\hat{l}_t && (.73)
\end{aligned}
$$

$$\hat{l}_{t+1} = \chi \hat{b}_t + \hat{l}_t \quad (.74)$$

$$E_t \hat{P}_{t+1} + \sigma E_t \hat{c}_{t+1} - [1 - \beta^*(1-\delta)] E_t \hat{mc}_{t+1} - [1 - \beta^*(1-\delta)] E_t \hat{y}_{t+1} + [1 - \beta^*(1-\delta)] E_t \hat{z}_{t+1} = \sigma \hat{c}_t + \hat{P}_t \quad (.75)$$

$$\hat{a}_t = \rho^a \hat{a}_{t-1} + \hat{\mu}^a_t \quad (.76)$$

$$\hat{i}^*_t = \rho^{i*} \hat{i}^*_{t-1} + \hat{\mu}^{i*} \quad (.77)$$

$$\hat{y}^*_t = \rho^{y*} \hat{y}^*_{t-1} + \hat{\mu}^{y*} \quad (.78)$$

We want to write the system as

$$U_X \mathcal{X}_t = U_Y \mathcal{Y}_{t-1} + U_\epsilon \epsilon_t + U_\eta \eta_t \quad (.79)$$

$$G^O_Y \mathcal{Y}_t + G^0_X E_t \mathcal{X}_{t+1} = G^1_Y \mathcal{Y}_{t-1} + G^1_X \mathcal{X}_t + G_\epsilon \epsilon_t + G_\eta \eta_t \quad (.80)$$

with vectors

$$\mathcal{X}_t = (\hat{y}_t, \hat{x}_t, \hat{mc}_t, \hat{c}_{ht}, \hat{c}^*_{ht}, \hat{c}_{ft}, \hat{k}_t, \hat{p}_{ht}, \hat{P}_t, \hat{b}_t, \hat{c}_t)$$

$$\mathcal{Y}_t = (\hat{z}_{t+1}, \hat{l}_{t+1}, \hat{a}_t, \hat{y}^*_t, \hat{i}^*_t, E_t \hat{b}_{t+1}, E_t \hat{c}_{t+1})$$

$$\epsilon_t = \left(\hat{\mu}^A_t, \hat{\mu}^{i^*}_t, \hat{\mu}^{Y^*}_t\right), \qquad \eta_t = \left(\eta^b_t, \eta^c_t\right)$$

C. Reserve accumulation

The model we present in this paper predicts that China is a net recipient of capital flows, seemingly implying that China has a current account deficit. This appears to be at odds with the observed Chinese current account surplus. We do not however, present a model of the current account but rather a model of the capital account — the flows of FDI, portfolio investment and debt —, and predict correctly that China will receive more flows of these types than it will invest abroad. To fully characterize the current account, we would need a much richer model of saving, for example one with the possibility of precautionary saving or liquidity constraints with more sophisticated and liquid instruments for saving. For now, our model has nothing to say about the motivation for reserve accumulation. The model however, can be made technically consistent with the observation of a current account surplus. We present one possibility here.

Suppose that some amount τ_t must be exogenously allocated to a foreign instrument q_t. There is a cost to accumulating this instrument however so that some fraction ϕ of the stock "depreciates" every period $q_{t+1} = (1-\phi)q_t + \tau_t$.[8] Let $\tau_t = \bar{s} y_t$ so that only $(1-\bar{s})$ is left for consumption and investment.

Under these assumptions, the household's problem is

$$\underset{\{c_t, z_{t+1}, d_{t+1}, k_{t+1}\}_{t=0}^{\infty}}{Max} \sum_{t=0}^{\infty} \beta^t U(c_t)$$

[8]This "depreciation" assumption also insures that this accumulation tends to zero. If we do not assume some type of cost to asset accumulation,the level of this asset will tend to infinity. This is a well-known problem of small open economy models.

under the constraints

$$\begin{aligned} P_t c_t + x_t + (1+g)(1+n)k_{t+1} - (1-\delta)k_t - (1+g)(1+n)d_{t+1} + d_t + \tau_t &= (1-\bar{s})\left(w_t + R_{zt}z_t + R_{kt}k_t\right) \\ &- r_t d_t + \pi_t \\ x_t &= (1+n)(1+g)z_{t+1} - (1-\delta)z_t \\ d_t &\leq k_t \\ \tau_t &= \bar{s}\left(w_t + R_{zt}z_t + R_{kt}k_t\right) \\ q_{t+1} &= (1-\phi)q_t + \tau_t \end{aligned}$$

If we substitute in the additional constraints, the problem looks exactly the way it did before (except for the fact that all marginal products will now be multiplied by $1-\bar{s}$; the dynamics of the model however will be identical). However, the current account could now be in surplus. Under the previous version the current account was simply minus foreign capital accumulation, i.e.

$$ca_t = -\left[(1+n)(1+g)k_{t+1} - (1-\delta)k_t\right] < 0$$

Under this version, the current account is minus foreign capital accumulation plus reserve accumulation, i.e.

$$ca_t = -\left[(1+n)(1+g)k_{t+1} - (1-\delta)k_t\right] + \bar{s}y_t$$

and can be in surplus.

As an example, let's suppose that consumers save a fixed fraction of income s. In that case the current account is

$$ca_t = s(1-\bar{s})y_t + \bar{s}y_t - x_t - ((1+n)(1+g)k_{t+1} - (1-\delta)k_t)$$

Since $s(1-\bar{s})y_t = x_t = (1+n)(1+g)z_{t+1} - (1-\delta)z_t$, i.e. private saving is used for domestic capital accumulation, the current account is

$$ca_t = \bar{s}y_t - ((1+n)(1+g)k_{t+1} - (1-\delta)k_t)$$