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## Changing economic structures and impacts of shocks: evidence from a DSGE for China

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Aaron Mehrotra, Riikka Nuutilainen  
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Changing economic structures and  
impacts of shocks - evidence from  
a DSGE for China



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# Contents

Tiivistelmä .....	
Abstract .....	
1 Introduction .....	1
2 The Model .....	2
2.1 Households .....	4
2.2 Firms.....	5
2.3. Monetary policy .....	6
2.4 Equilibrium .....	7
3 Analysis .....	8
3.1 Parameterization .....	8
3.2 Simulations.....	12
4 Conclusions .....	16
References .....	17

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## Changing economic structures and impacts of shocks - evidence from a DSGE for China

### Tiivistelmä

Tässä tutkimuksessa rakennetaan dynaaminen yleisen tasapainon makromalli Kiinan talouden tutkimiseksi. Malli sisältää hintajäykkyyden, jäykät kulutustottumukset (habit formation) ja pääoman sopeuttamisen kustannukset. Malli kalibroidaan Kiinan talouden tilastoista lasketuilla parametreilla. Tutkimuksessa arvioidaan kahdessa eri skenaariossa, miten tekniikka- ja rahapolitiikkasokit vaikuttavat Kiinan talouteen. Perustilassa investointien osuus kokonaiskysynnästä on suuri. Uudessa tasapainon tilassa talouskasvu perustuu selvästi nykyistä suurempaan kotimaisen kulutuksen osuuteen. Tutkimuksessa selvitetään, miten Kiinan talouden rakenteiden uudistaminen vaikuttaa sokkien välittymismekanismeihin. Tutkimuksen päätulos on, että talouden rakenteiden uudistaminen vähentää reaalitalouden herkkyyttä tekniikkasokille. Tulosten mukaan suositus Kiinan talouden kasvumallin muuttamisesta kulutusvetoiseksi näyttää perustellulta.

Avainsanat: DSGE, rakenteen uudistaminen, rahapolitiikkasokki, tekniikkasokki, Kiina

# Changing economic structures and impacts of shocks – evidence from a DSGE model for China\*

Aaron Mehrotra<sup>†</sup>   Riikka Nuutilainen<sup>‡</sup>   Jenni Pääkkönen<sup>§</sup>

March 14, 2011

## Abstract

We construct a small-scale dynamic stochastic general equilibrium (DSGE) model that features price rigidities, habit formation in consumption and costs in capital adjustment, and calibrate the model with data for the Chinese economy. Our interest centers on the impact of technology and monetary policy shocks for different structures of the Chinese economy. In particular, we evaluate how a rebalancing of the economy from investment-led to consumption-led growth would affect the economic dynamics after a shock occurs. Our findings suggest that a rebalancing would reduce the volatility of the real economy in the event of a technology shock, which provides support for policies aiming to increase the consumption share in China.

**Keywords:** DSGE, rebalancing, monetary policy shocks, technology shocks, China.

**JEL Classification:** E52, E60.

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# 1 Introduction

In 2010, China passed Japan to become the second largest economy in the world at market exchange rates. Since the start of reforms in 1978, the country has recorded annual real GDP growth rates averaging 10 percent, and has been able to lift hundreds of millions of its citizens from poverty. Despite this success, measured in terms of macroeconomic performance, there is now a consensus among both Chinese policymakers and international observers that the economy's growth model would benefit from a broad rebalancing away from investment and export-led growth to growth based on domestic consumption.<sup>1</sup>

China's 12th Five Year Plan (2011-15) aims to shift from export-led sectors to domestic demand by raising the incomes of Chinese workers (Xinhua, 2010). In its 2010 Article IV Consultation on China, the International Monetary Fund (IMF) noted that the current policy challenge is to maintain growth while at the same time changing to an economy "powered by the Chinese consumer" (IMF, 2010). The IMF argues that continued progress is needed, e.g. in terms of exchange rate policy, financial liberalization and development, healthcare, pensions and education, in order to meet the goal of rebalancing. Similarly, the Asian Development Bank (ADB) argues that failure to rebalance the Chinese economy would jeopardize the sustainability of growth (ADB, 2010). The ADB states that a greater role for private consumption demand would "promote longer-term growth and raise living standards".<sup>2</sup>

In this paper, we evaluate the impact of a rebalancing of the Chinese economy on its response to different shocks. To this aim, we present a small-scale dynamic

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<sup>1</sup>The investment ratio (gross fixed capital formation as share of GDP) in China was 44% of GDP in 2008, with final consumption expenditure amounting to 48% of GDP. In the US economy, final consumption-to-GDP was close to 88%, but some emerging economies also feature a high ratio of final consumption expenditure to GDP. In India, the ratio was close to 71%.

<sup>2</sup>Not all economists agree on the need to lower the investment share of GDP in China. Woo (2009) states that consumption-led growth is an oxymoron, as growth requires expansion of productive capacity and this cannot be done by lowering investment. According to Woo, the correct rebalancing would be to increase consumption at the expense of the trade surplus. As our model economy is closed, we do not address this method of rebalancing. However, we note that the contribution of net exports to GDP growth in China is minor for most years (and actually negative in 2009).



stochastic general equilibrium (DSGE) model featuring price rigidities, habit formation in consumption and adjustment costs in investment, calibrated for the Chinese economy. While such models, based on microfoundations, have emerged as the basis of much current policy analysis, the literature employing DSGE models is still relatively sparse for China.<sup>3</sup> As an example of recent work in a closed-economy DSGE framework, Zhang (2009) explores whether money supply or interest rate rules are more effective in managing the Chinese macroeconomy. In an open-economy multi-country DSGE framework, Straub and Thimann (2010) analyze macroeconomic adjustment in China under flexible and fixed exchange rate regimes.

Our analysis centers on the response of the economy to shocks of both the technology and monetary type in two different scenarios. In the first one, the share of investment in GDP is maintained at its current high level by international comparison. In the second scenario, after a substantial rebalancing of the economy, China's investment-to-GDP ratio is lower by 25 percentage points and the share of consumption is raised accordingly. We find a less persistent and smaller long-run response of the real economy to technology shocks in the scenario where rebalancing has changed the economy to one fuelled by domestic consumption. The lower volatility in the face of technology shocks is enhanced if the rebalancing also involves a greater role for monetary policy in the stabilization of output. The impact of monetary policy shocks in the economy remains similar in the new scenario. These results are robust to various changes in the model parameters. The results indicate that a structural rebalancing would make the real economy less prone to large fluctuations due to technology shocks, providing support for policies aiming to increase the consumption share in China's GDP.

This paper is structured as follows. The following section describes our

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<sup>3</sup>One may question the suitability of the general equilibrium paradigm for an economy undergoing significant structural change. Nevertheless, Chow (2010) mentions that "good quantitative relations are valid for different periods in China, including both the periods of planning and after market reform". Moreover, the social and economic development targets of the Central Economic Working Commission have included GDP growth targets ranging between 7 and 9 percent since 1994, which could be seen as an implicit assumption of a steady-state growth path.

general equilibrium model. Section 3 discusses the calibration parameters and presents the simulation results. Section 4 concludes with policy implications.

## 2 The Model

The economy consists of four types of agents: an infinitely-lived representative household, a representative final-good producer, a continuum of intermediate-good producers, and a monetary authority. All agents maximize their utility (with firms maximizing profits), subject to an intertemporal budget constraint. Rigidities in the model stem from staggered price setting of firms, habit formation in consumption and capital adjustment costs. The labor market is fully competitive, however, which is easily justified especially in the Chinese industrial sector.<sup>4</sup> In our model, the size of the labor force remains unchanged. This is in line with current Chinese demographics; as the growth of labor force is expected to stall within a few years, the environment of labor abundance is fast approaching its end in China.<sup>5</sup>

We consider a closed-economy model, in line with Zhang (2009), as capital controls have been largely binding in China.<sup>6</sup> Therefore, uncovered interest parity need not hold and domestic monetary policy has enjoyed relative independence despite the *de facto* US dollar peg for substantial periods of time.<sup>7</sup>

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<sup>4</sup>Using data for 2008 and adding up the number of official urban workers (302 million) and migrant workers (some 200 million; see e.g. Zhang and Wang, 2009), the urban job market now accounts for two thirds of the total Chinese labor market.

<sup>5</sup>From a cyclical perspective, the labor market has become significantly tighter since the global crisis, as the numbers of underemployed workers in both rural and urban areas have fallen.

<sup>6</sup>See Ma and McCauley, 2008, for evidence on the efficacy of capital controls in China.

<sup>7</sup>Clarida et al. (2001) explore the conditions under which the problem of monetary policy design for a small open economy is isomorphic to the problem for a closed economy. They show that all the qualitative results for the closed economy carry over to the open economy. International factors are relevant to the extent that they affect domestic inflation or the equilibrium real rate; such transmission is arguably of limited importance in the Chinese case due to restrictions on capital flows.

## 2.1 Households

The representative household in the model maximizes utility from consumption  $C_t$  and hours worked  $N_t$  over an infinite life horizon:

$$E_{t-1} \sum_{l=0}^{\infty} \beta^l \left\{ \frac{(C_{t+l} - H_{t+l})^{1-\sigma}}{1-\sigma} - \frac{N_{t+l}^{1+\varphi}}{1+\varphi} \right\}, \quad (1)$$

where  $\sigma$  gives the intertemporal elasticity of substitution and  $\varphi$  is a measure of the inverse elasticity of labor supply. The model takes account of external habit formation *via* the variable  $H_t$ . It is assumed that the external habit stock is proportional to aggregate past consumption,  $H_t \equiv bC_{t-1}$ , where  $0 \leq b < 1$ .

Maximization of life-time utility, (1), is subject to periodic budget and investment constraints:

$$P_t(C_t + I_t) + Q_t B_t \leq B_{t-1} + W_t N_t + R_t^k K_t + D_t \quad (2)$$

$$K_{t+1} = (1 - \delta)K_t + F(I_t, I_{t-1}) = (1 - \delta)K_t + \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t. \quad (3)$$

At period  $t$ , the household possesses capital goods  $K_t$  and  $B_{t-1}$  of coupon bonds. In addition, it receives labor income  $W_t N_t$  for hours worked ( $N_t$ ) and rental income of  $R_t^k K_t$  for renting the capital services  $K_t$ . Any net lump sum transfers (e.g. dividends and net transfers from the government) are collected in the variable  $D_t$ . Final goods are purchased at price  $P_t$  and used for consumption  $C_t$  and investment  $I_t$ .  $R_t^k$  denotes the rental rate of capital, and the price of the bond is  $Q_t \equiv \frac{1}{1+r_t^b}$  where  $r_t^b$  is the (riskless) short-term nominal interest rate. The household takes prices  $(P_t, W_t, Q_t)$  as given and is subject to a solvency constraint,  $\lim_{T \rightarrow \infty} E_t \{B_T\} \geq 0$ .

The household makes investment decisions in terms of physical capital. Capital formation is described by (3), where  $\delta$  is the depreciation rate of capital and the function  $F(I_t, I_{t-1})$  summarizes the technology transforming investment into installed capital. Adjustment costs in the model  $S(\cdot)$  result from changes in the level of investment relative to the previous period. Following Christiano et al. (2005), we assume that the investment adjustment cost function has the following steady state features:  $S(1) = S'(1) = 0$  and  $S''(1) = \kappa > 0$  representing the adjustment costs. As usual, the timing convention is such that  $K_t$  denotes capital at the end of period  $t - 1$  (and thus does not depend on time  $t$  shocks).

The first-order conditions for the household's optimization problem can be summarized by (4)-(7), where the variable  $P_t^k$  denotes the value of invested capital (i.e. shadow value of capital in consumption good), and  $\bar{R}_t^k \equiv \frac{R_t^k}{P_t}$ .

$$\frac{W_t}{P_t} = N_t^\varphi (C_t - H_t)^\sigma, \quad (4)$$

$$\beta E_t \left\{ \left[ \frac{C_{t+1} - H_{t+1}}{C_t - H_t} \right]^{-\sigma} \frac{P_t}{P_{t+1}} \right\} = Q_t, \quad (5)$$

$$P_t^k F'_{I_t}(I_t, I_{t-1}) + Q_t E_t \left\{ \frac{P_{t+1}}{P_t} P_{t+1}^k F'_{I_t}(I_{t+1}, I_t) \right\} = 1, \quad (6)$$

$$P_t^k = \beta E_t \left\{ \left[ \frac{C_{t+1} - H_{t+1}}{C_t - H_t} \right]^{-\sigma} \left[ \bar{R}_{t+1}^k + (1 - \delta) P_{t+1}^k \right] \right\}. \quad (7)$$

## 2.2 Firms

As is standard in the literature, we assume that there is a single final good  $Y_t$  in the closed economy that is produced by a perfectly competitive representative firm. As production inputs, the final-good producer uses a continuum of intermediate goods  $Y_t(i)$ , indexed by  $i \in [0, 1]$ , each produced by a monopolistically competitive firm. The production technology for packaging intermediate goods into  $Y_t$  units of the final good is given by

$$Y_t = \left[ \int_0^1 Y_t(i)^{\frac{1}{\lambda}} di \right]^\lambda, \quad (8)$$

where  $1 \leq \lambda < \infty$ , and  $\lambda$  is a measure of the elasticity of substitution between different intermediate goods.

Given the prices of differentiated intermediate goods  $P_t(i)$  and profit maximization in the final-good sector, the demand for good  $i$  is given by

$$Y_t(i) = \left[ \frac{P_t(i)}{P_t} \right]^{\frac{\lambda}{1-\lambda}} Y_t. \quad (9)$$

In the environment of perfect competition, the price of the final good  $P_t$  can be written as:

$$P_t = \left[ \int_0^1 P_t(i)^{\frac{1}{1-\lambda}} di \right]^{1-\lambda}. \quad (10)$$

In the intermediate-goods sector, production possibilities are given by a Cobb-Douglas production function:

$$Y_t(i) = A_t K_t(i)^\alpha N_t(i)^{1-\alpha}, \quad (11)$$

for all intermediate firms  $i \in [0, 1]$ , i.e. all firms use the same technology. In the production function (11),  $K_t(i)$  and  $N_t(i)$  denote time  $t$  capital and labor services, respectively, used to produce an amount  $Y_t(i)$  of the  $i$ th intermediate good, and  $\alpha$  is the elasticity of output with respect to capital. Technology is subject to the following path:  $\ln(A_t) = (1 - \rho_a) \ln(\bar{A}) + \rho_a \ln(A_{t-1}) + \varepsilon_t^a$ , where  $\bar{A}$  is the mean of  $A_t$  and  $\varepsilon_t^a$  denotes the technology shock.

As a result to firm  $i$ 's optimization problem, real marginal costs can be expressed as

$$MC_t = \frac{1}{A_t} \bar{R}_t^{k\alpha} \left( \frac{W_t}{P_t} \right)^{1-\alpha} \left( \frac{1}{\alpha} \right)^\alpha \left( \frac{1}{1-\alpha} \right)^{1-\alpha}. \quad (12)$$

Note that marginal costs are equal for all firms and the index  $i$  can therefore be dropped.

Staggered price setting of firms is in line with conventional Calvo pricing (Calvo, 1983). We assume that in each period intermediate firms are able to adjust their prices, but only a constant fraction  $1 - \theta$  of firms are able to set their prices optimally. The remaining fraction  $\theta$  of firms that cannot reoptimize are assumed to index their prices to lagged inflation:  $P_t(i) = \Pi_{t-1} P_{t-1}(i)$ , where  $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ . Firms that are able to reoptimize, will set prices so as to maximize the present value of future profits. All the firms that can reoptimize at time  $t$  will choose the same price,  $P_t^*$ . Using the demand function for firm  $i$  (9), the aggregate price level  $P_t$  (10) at period  $t$  takes the familiar form:

$$P_t = \left[ (1 - \theta) P_t^{*\frac{1}{1-\lambda}} + \theta (\Pi_{t-1} P_{t-1})^{\frac{1}{1-\lambda}} \right]^{1-\lambda}. \quad (13)$$

### 2.3 Monetary policy

Monetary policy follows a Taylor rule for setting the nominal short term interest rate:

$$r_t^b = v + \phi_y \hat{y}_t + \phi_\pi \pi_t + v_t, \quad (14)$$

where  $\hat{y}_t$  denotes the output gap and  $v_t$  is an exogenous component of the interest rate that follows an autoregressive process similarly to technology:  $v_t =$

$\rho_v v_{t-1} + \varepsilon_t^v$ . The monetary policy rule is expressed in logarithms as in the original formulation of Taylor (1993). The policy reaction parameters  $\phi_y$  and  $\phi_\pi$  determine the magnitude of the central bank's reactions to deviations of inflation and output from the steady state. Zhang (2009) argues that following an interest rate rule is indeed superior to a money supply rule for China, as it leads to less fluctuations in the economy. Nevertheless, some of the previous research has applied McCallum-type rules for China; see e.g. Burdekin and Siklos (2008) and Mehrotra and Sánchez-Fung (2010).

## 2.4 Equilibrium

Equilibrium is described by the market clearing conditions:  $\int_0^1 K_t(i) di = K_t$  and  $\int_0^1 N_t(i) di = N_t$ . In addition, in the closed-economy equilibrium, the goods market clearing condition requires  $Y_t = C_t + I_t$ .

The model is characterized by equations (15)-(26), expressed as logarithmic deviations from the zero inflation steady state.<sup>8</sup>

The household's first-order conditions (4)-(7) yield the consumption Euler equation (15), the investment Euler equation (16) and the optimality condition for the capital stock (17):

$$(\hat{c}_t - b\hat{c}_{t-1}) = E_t\{\hat{c}_{t+1} - b\hat{c}_t\} - \frac{1-b}{\sigma} (\hat{r}_t^b - E_t\{\pi_{t+1}\}), \quad (15)$$

$$\hat{p}_t^k = \kappa[(\hat{i}_t - \hat{i}_{t-1}) - \beta E_t\{\hat{i}_{t+1} - \hat{i}_t\}], \quad (16)$$

$$\begin{aligned} \hat{p}_t^k = & -\frac{\sigma}{1-b} [E_t\{\hat{c}_{t+1} - b\hat{c}_t\} - (\hat{c}_t - b\hat{c}_{t-1})] \\ & + [1 - \beta(1 - \delta)] E_t\{\hat{r}_{t+1}^k\} + \beta(1 - \delta) E_t\{\hat{p}_{t+1}^k\}. \end{aligned} \quad (17)$$

Combining the intermediate firm's and household's first-order conditions, marginal costs and optimal labor demand can be linearized:

$$\widehat{mc}_t = (1 - \alpha) \left[ \frac{\sigma}{1-b} (\hat{c}_t - b\hat{c}_{t-1}) + \varphi \hat{n}_t \right] + \alpha \hat{r}_t^k - \hat{a}_t, \quad (18)$$

$$\hat{r}_t^k = \frac{\sigma}{1-b} (\hat{c}_t - b\hat{c}_{t-1}) + (1 + \varphi) \hat{n}_t - \hat{k}_t. \quad (19)$$

Linearizing the price equation (13) and using the linearized profit-maximization condition for the intermediate-good firm, the New Keynesian Phillips curve for

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<sup>8</sup>Throughout the paper lowercase letters denote variables in natural logarithms and hatted variables represent log-deviations from the steady state.

the model can be expressed as a function of the deviation of marginal costs from steady state (see Christiano et al., 2005, for details):

$$\pi_t = \frac{1}{1+\beta}\pi_{t-1} + \frac{\beta}{1+\beta}E_t\{\pi_{t+1}\} + \left(\frac{1-\beta\theta}{1+\beta}\right)\left(\frac{1-\theta}{\theta}\right)\widehat{mc}_t. \quad (20)$$

The linear production function, the log-linearized capital accumulation equation, and the market clearing condition follow:

$$\widehat{y}_t = \widehat{a}_t + \alpha\widehat{k}_t + (1-\alpha)\widehat{n}_t, \quad (21)$$

$$\widehat{k}_{t+1} = (1-\delta)\widehat{k}_t + \delta\widehat{i}_t, \quad (22)$$

$$\widehat{y}_t = \frac{C}{Y}\widehat{c}_t + \frac{I}{Y}\widehat{i}_t, \quad (23)$$

where  $\frac{I}{Y}$  is the steady state investment share of GDP ratio and  $\frac{C}{Y} = 1 - \frac{I}{Y}$ .

The Taylor rule for setting the nominal interest rate in log-deviation form is written as

$$\widehat{r}_t^b = \phi_y\widehat{y}_t + \phi_\pi\pi_t + \widehat{v}_t. \quad (24)$$

Finally, as technology and an exogenous component of the interest rate follow first-order autoregressive processes,  $\varepsilon_t^a$  and  $\varepsilon_t^v$  are interpreted as shocks to technology and monetary policy, respectively, and are obtained from

$$\widehat{a}_t = \rho_a\widehat{a}_{t-1} + \varepsilon_t^a, \quad (25)$$

and

$$\widehat{v}_t = \rho_v\widehat{v}_{t-1} + \varepsilon_t^v. \quad (26)$$

Here,  $\rho_a, \rho_v \in [0, 1)$ , and we assume that  $\{\varepsilon_t^a\}$  and  $\{\varepsilon_t^v\}$  are white noise processes orthogonal to each other.

## 3 Analysis

### 3.1 Parameterization

Choosing the model parameters requires care, even more so in the case of China given the transitional nature of its economy. We estimate some of the parameters, and for others the available literature is used to choose the appropriate parameter values.

Starting with the household sector, the discount factor is set at  $\beta = 0.985$ , which yields a quarterly real interest rate of 1.5 percent, and an annual real rate of 6.1 percent.<sup>9</sup> We follow Walsh (2003) in setting the intertemporal elasticity of substitution ( $\sigma = 2$ ), and Zhang (2009) in determining the marginal disutility of working ( $\varphi = 6.16$ ). In China, marginal disutility of working can be assumed to be low, which contributes to the high household savings rate.<sup>10</sup> The Calvo parameter is set at  $\theta = 0.84$ , again in line with Zhang (2009), implying an average price duration of slightly over one and a half years.

The (external) habit persistence parameter is estimated by Generalized Method of Moments (GMM) from an Euler equation featuring lagged inflation, forward-looking inflation, and the real *ex ante* interest rate.<sup>11</sup> The estimated coefficient on lagged inflation, 0.76 in quarterly terms, is used as our measure of habit persistence.

Moving on to parameters related to firms in our model, we adopt a capital depreciation rate of  $\delta = 0.06$ .<sup>12</sup> Regarding the output elasticity of capital, we set  $\alpha = 0.6$ , as in He et al. (2007).

Regarding the adjustment cost parameter  $\kappa$ , note that the household's Euler equation for investment is

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<sup>9</sup>For comparison, the mean one-year nominal benchmark lending rate in China was 7.3 percent during 1994-2008.

<sup>10</sup>Wei and Zhang (2009) argue that as the sex ratio rises, Chinese families with sons increase their savings to improve their son's relative attractiveness for marriage. According to their results, this factor could be an important contributor to the experienced increase in the household saving rate during 1990-2008.

<sup>11</sup>The estimation is based on data from China's National Accounts from 1989 to 2008. Consumption is deflated by the GDP deflator, and the real *ex ante* interest rate is measured as the nominal benchmark lending rate deflated by one period ahead retail price inflation. All variables are measured as log deviations from the Hodrick-Prescott filtered trend (with a smoothing parameter of 100 for annual data). The instrument set includes second and third lags of consumption, together with first and second lags of the real interest rate. The overidentifying restrictions are not rejected for this instrument set ( $J$ -statistic 0.69,  $p$ -value 0.71).

<sup>12</sup>An assumed high depreciation rate of capital is in line with conclusions from informal discussions with industrialists operating in China. As an example for machinery in the electronics sector, capital is sometimes assumed to depreciate fully in just three years. He et al. (2005) suggest a capital depreciation rate of 0.05 for China.



$$\widehat{i}_t = \widehat{i}_{t-1} + \frac{1}{\kappa} \sum_{j=0}^{\infty} \beta^j E_{t-1} \widehat{p}_{t+j}^k, \quad (27)$$

where  $\frac{1}{\kappa}$  is the elasticity of investment with respect to the current price of installed capital. We estimate the elasticity using Chinese data. According to Christiano et al. (2005),  $\widehat{p}_t^k$  is the shadow value of a unit of  $k_{t+1}$  measured in consumption units as at the time when the period  $t$  investment and capital utilization decisions are made. We approximate  $\widehat{p}_t^k$  by the value of investment at time  $t+1$ ,<sup>13</sup> albeit the value of investment is probably a noisy indicator of the current value of installed capital. We measure  $\widehat{i}_t$  at time  $t$  by de-trended real gross fixed capital formation (GFCF), and approximate the current price of installed capital by de-trended nominal value of GFCF at time  $t+1$ .<sup>14</sup> With  $\beta = 0.985$ , the elasticity of investment is equal to 0.29, i.e. very close to the proposed elasticity of 0.28 for the US economy in Christiano et al. (2005).

Regarding the policy dimension of our model, we set the parameters of the monetary policy rule at  $\phi_\pi = 1.34$  and  $\phi_y = 0$ , based on an estimation of a Taylor rule for China by GMM, using the benchmark one-year lending rate as the policy instrument and adjusting for the coefficient on lagged interest rates.<sup>15</sup> Therefore, monetary policy in China is assumed to fulfil the Taylor principle ( $\phi_\pi > 1$ ), which is in line with the empirical observation that China's inflation has been remarkably low since the mid-1990s, especially in light of the economy's rapid growth rate. An alternative reading of the inflation experience is that potential growth rates are high and that large output gaps have simply not

<sup>13</sup>In optimum, the marginal household must be indifferent between saving (i.e. investment) and consumption. Therefore, a household that decides to accrue capital must forgo consumption. Since the value of investment is the value of foregone consumption, the value of investment at time  $t+1$  must also reflect the current price of installed capital  $\widehat{p}_t^k$  at time  $t$ .

<sup>14</sup>We approximate the Euler equation for investment (27) by

$$\text{real\_GFCF}_{DT,t} = \text{real\_GFCF}_{DT,t-1} + \frac{1}{\kappa} (\text{nominal\_GFCF})_{DT,t+1},$$

where we have filtered the linear trends from both series, and use the first forward value of investment as the shadow price. For robustness, we estimated two other specifications. First, we included two forward values for nominal GFCF in the model and, second, the contemporaneous value and first forward value of GFCF were included. The approximated  $\frac{1}{\kappa}$ 's are surprisingly similar in both specifications (0.30 and 0.24).

<sup>15</sup>The estimation period for the Taylor rule is 1994Q1-2008Q4, and the first lag of the inflation gap and the second lag of the interest rate are used as instruments.

emerged. Nevertheless, Zhang (2009) and Mehrotra and Sánchez-Fung (2010) provide evidence that the People's Bank of China has been reacting to inflation expectations in a statistically significant manner, pursuing stabilizing policy even in a forward-looking sense. The size of the interest rate shock  $\varepsilon_t^v$  is set at 0.25, implying an increase of 25 basis points in  $v_t$ , and its autocorrelation is assumed to be  $\rho_v = 0.5$ . Regarding an exogenous shock to technology, we assume that  $\varepsilon_t^a = 1$  and  $\rho_a = 0.9$ , implying that the technology shock is quite persistent.

Finally, the investment-to-GDP ratio ( $I/Y$ ) is set at 0.45 in the benchmark estimation, roughly in line with the share of gross capital formation in China's GDP in 2008. As our economy is closed, the share of consumption in GDP amounts to  $1 - (I/Y) = 0.55$ , which is slightly higher than the official data indicate for 2008 (0.48). In order to assess the dynamics of the model in the "rebalanced" scenario, we lower the investment-to-GDP ratio by 25 percentage points. The resulting investment ratio of 0.20 is equal to gross capital formation as a share of GDP in high-income countries in 2008, according to data from the World Bank Development Indicators. The higher share of consumption in the rebalanced economy needs to be supported by a higher labor share of income, and the output elasticity of capital ( $\alpha$ ) is accordingly lowered from 0.6 to 0.4. Similarly, the capital depreciation rate takes a lower value,  $\delta = 0.04$ . Our model calibration assumes that the elasticity of substitution between intermediate goods  $\left(\frac{\lambda}{\lambda-1}\right)$  decreases as the economy becomes more reliant on consumption in the new "rebalanced" scenario. This implies that in the new steady state, the intermediate firms' price markups over marginal costs are higher.<sup>16</sup> As China moves up the value chain and away from labor-intensive manufacturing, the produced goods become increasingly differentiated and firms' markups are likely to increase.<sup>17</sup> Table 1 presents the parameters used in the simulations in both scenarios.

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<sup>16</sup>Given the other parameter values and the steady state investment share of GDP, the value of  $\lambda$  is given by the steady state relation  $\frac{I}{Y} = \frac{\beta\delta\alpha}{[1-\beta(1-\delta)]\lambda}$ .

<sup>17</sup>Cui and Syed (2007) provide evidence that the sophistication of China's export bundle has increased, which reflects a technological upgrade of domestic production.

$\sigma$	$\psi$	$\beta$	$\theta$	$\phi_y$	$\phi_\pi$	$\delta$	$\alpha$	$\frac{1}{\kappa}$	$b$	$\rho_a$	$\rho_v$	$I/Y$
2	6.16	0.985	0.84	0	1.34	0.06	0.6	0.29	0.76	0.9	0.5	0.45

$\sigma$	$\psi$	$\beta$	$\theta$	$\phi_y$	$\phi_\pi$	$\delta$	$\alpha$	$\frac{1}{\kappa}$	$b$	$\rho_a$	$\rho_v$	$I/Y$
2	6.16	0.985	0.84	0	1.34	0.04	0.4	0.29	0.76	0.9	0.5	0.2

Table 1: Parameters, baseline (top) and rebalanced economy (bottom)

### 3.2 Simulations

The impacts of technology shocks over 30 quarters on key variables in the model are depicted in Figure 1. We present the results as annualized percentage deviations from steady state for two scenarios. The dynamics under the high investment to GDP ratio (0.45) in the steady state are shown by the solid line. The results for the low "rebalanced" ratio (0.2) in the steady state are illustrated by the dashed line. The higher value corresponds roughly to the ratio of investment to GDP currently prevailing in China, while the lower ratio is similar to the present one in high-income countries.<sup>18</sup>

The main results are similar in both scenarios. A positive technology shock gives a boost to productivity, which causes a positive supply shock. Marginal costs decrease, inflation recedes and investment increases.<sup>19</sup> With a lower  $I/Y$  ratio, investment returns to steady state faster after a shock to technology. Similarly, the impact of the technology shock on consumption is less persistent, leading to less persistence in the response of overall output to technology shocks. Monetary policy reacts to the fall in inflation *via* the Taylor rule, implying a lower nominal interest rate in both scenarios. When the  $I/Y$  ratio is lower, a technology shock leads to a slightly more pronounced decline in inflation. This implies that the reaction of the monetary authority is also stronger in this case, as reflected in slightly larger declines in both the nominal and real interest rates. Overall, however, the volatility of the real economy is reduced vis-à-vis

<sup>18</sup>An assumed decrease of 25 percentage points in the investment share of GDP might seem radical, at least in the short run. However, some other Asian countries have also experienced notable changes in their economic structures over time. In Singapore, the share of final consumption expenditure in GDP fell by 28 percentage points in 15 years (1962-1976), and in Korea by 24 percentage points in 19 years (1960-1978).

<sup>19</sup>The surge in investment also relates to an increased demand for capital.

technology shocks in the second scenario. After all variables have returned to steady state, the long-run deviation from steady state (adding up the deviations for each quarter) for consumption and output in the second scenario is 70% of the deviation in the benchmark case. For investment, the rebalancing scenario gives a total long-run deviation of 80% compared to the benchmark case. Our results indicate that a rebalancing of the Chinese economy might lead to less persistent and smaller long-run fluctuations in consumption, investment and output. For these key variables, the deviations from steady state last roughly 25 years in the "rebalanced" economy, and 10 years longer in the baseline "present-day" case.<sup>20</sup>

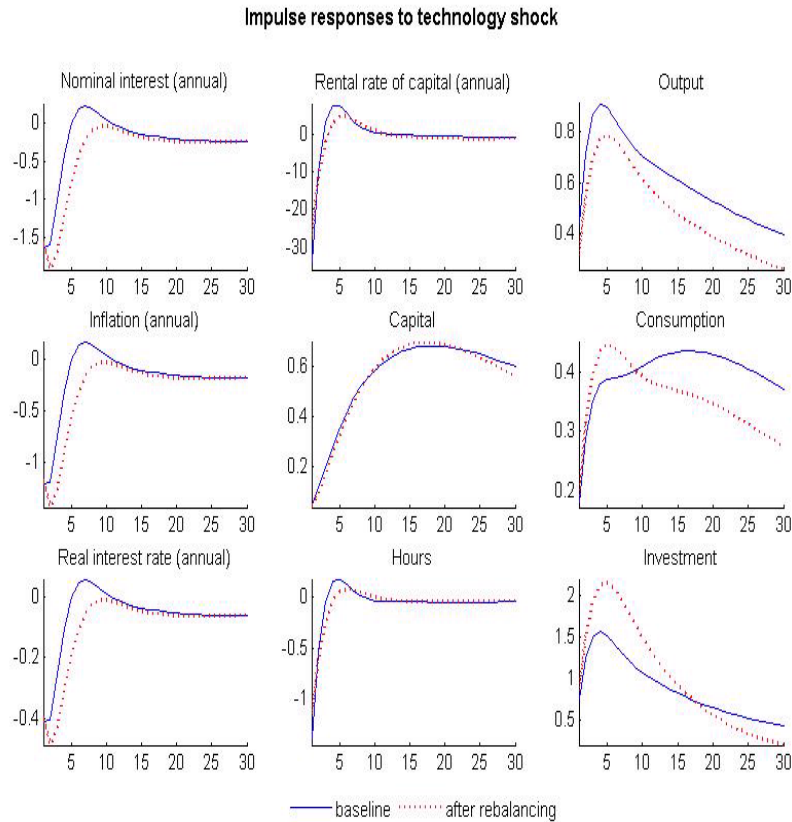


Figure 1. Impact of technology shock

Next, in Figure 2, we compare responses to a contractionary monetary policy shock in the two scenarios with different  $I/Y$  ratios. As inflation falls on impact, the real interest rate increases even more than the nominal rate, and brings

<sup>20</sup>One reason for the persistence is the strong autocorrelation in the technology shock itself.

about a monetary contraction. As investment and consumption fall, output falls. This lowers the demand for inputs, and as marginal costs fall, the rate of inflation declines *via* the Phillips curve. Here, the dynamics under the two different  $I/Y$  ratios are very similar - more so than in the case of technology shocks. It seems that when the  $I/Y$  ratio is lower, the impact of a contractionary monetary policy shock on inflation is smaller, but the differences are minor. A similar impact on output obtains - a lower  $I/Y$  ratio implies a smaller impact on output for a monetary policy shock.

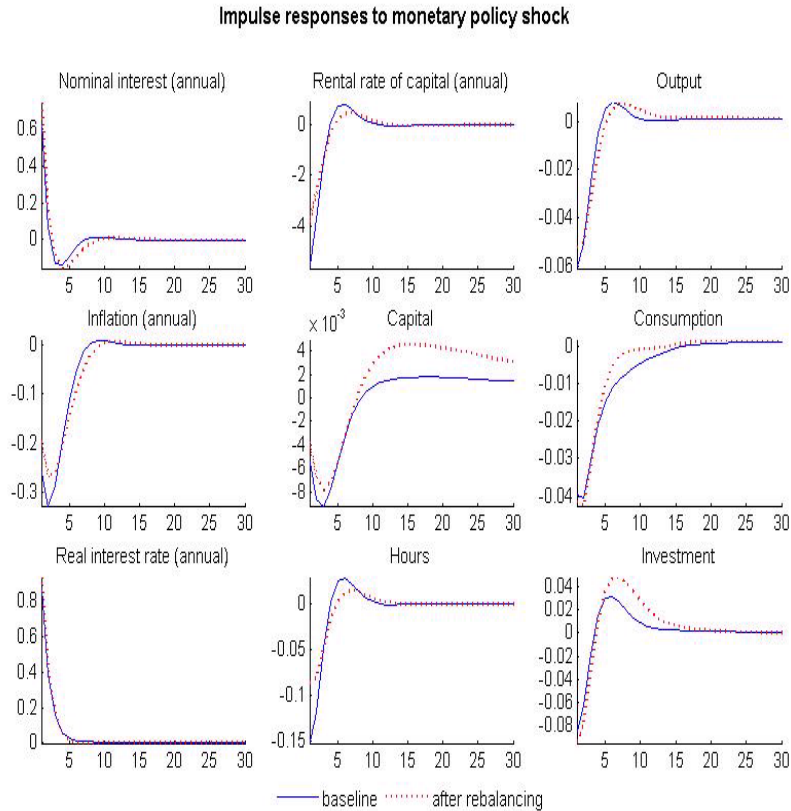


Figure 2. Impact of monetary policy shock

How sensitive are the dynamics of the "rebalancing" scenario to the specification of the monetary policy reaction function, in particular to the absence of a policy response to the output gap? The transformation of the economy toward a larger role for consumption could also involve an evolving role for the monetary authority, including possible reaction to the output gap, in line with

the estimated reaction functions for many advanced economies. We examine cases where the output gap coefficient in the Taylor rule is set at 0.5 or 1.0; maintaining the inflation gap coefficient at the former level then yields a policy rule roughly in line with the observed behavior of the Federal Reserve (see Galí, 2008). As shown in Appendix A for the case where the output gap coefficient equals 0.5, the drop in inflation due to a technology shock is considerably larger and the interest rate response by the monetary authority increases accordingly. The increases in consumption and investment are smaller, relative to the steady state, when the monetary authority responds to the output gap. Therefore, the volatility of the real economy is smallest in the rebalancing scenario, with a change in the monetary policy rule. However, the number of periods after which consumption, investment and thus output return to steady state is similar in both scenarios.

How robust are these findings to further changes in the model parameters, i.e. allowing for the fact that as investment's role in the economy recedes, further changes in economic structures cannot be ruled out? Economic transformation could entail changes in investment adjustment costs and behavioral changes of households regarding the marginal disutility of working. We evaluate the impacts of technology and monetary policy shocks in the economy assuming both a decrease in investment adjustment costs (a fall in  $\kappa$  from 3.4 to 1) and an increase in these costs (a rise in  $\kappa$  from 3.4 to 6).<sup>21</sup> The response to monetary policy shocks remains largely unchanged with the change in parameter values. In the case of technology shocks, there is a smoother response of consumption when  $\kappa$  is assumed to equal 1. Not surprisingly, the reaction of capital to a technology shock is also larger in this case. Regarding changes in the marginal disutility of working, we evaluate the responses of the economy with  $\varphi = 3$  (more elastic labor supply than in the benchmark case) and  $\varphi = 10$ . Overall, the results remain robust to changes in this parameter.<sup>22</sup>

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<sup>21</sup>One could assume that in an advanced economy, investment adjustment costs are higher as firms are operating with sophisticated technology and further adding to the capital stock is increasingly costly.

<sup>22</sup>These results are available upon request.

## 4 Conclusion

Despite the stellar growth performance of the Chinese economy during the past three decades, there is now a widespread consensus among both the Chinese policymakers and international observers that the economy would benefit from a broad-based rebalancing from investment and export-led growth to growth increasingly based on domestic consumption. In this paper, we have analyzed how a rebalancing away from investment-led growth would impact the dynamics of the Chinese economy in the face of technology and monetary policy shocks. To this aim, we presented a small-scale dynamic stochastic general equilibrium (DSGE) model featuring price rigidities, habit persistence in consumption and adjustment costs in investment, calibrated with data on the Chinese economy. The results suggest that a rebalancing - also involving a higher labor share of income - would imply a less persistent and smaller long-run response of the real economy to technology shocks. When the investment share of GDP decreases, the responses of both consumption and investment return faster to the steady state. The lower volatility in the face of technology shocks is enhanced, if the rebalancing also involves an increasing role for monetary policy in the stabilization of output. The dynamics of the economy are, in contrast, very similar in response to a monetary policy shock in both scenarios.

According to our model, in the new "rebalanced" steady state, the intermediate firms' price markups over marginal costs are higher. Given that China is moving up the value chain, its produced goods are likely to become increasingly differentiated, which facilitates the increase in markups. Indeed, China's 12th Five-Year Plan (2011-15) aims at industrial upgrading, which should promote investment in new equipment and technology, and involves a move away from China's traditional role as the world's factory. If an increase in the quality of investment is coupled with a lower investment-to-GDP ratio, the government's plan of industrial upgrading is consistent with an overall rebalancing of the economy. Importantly, our results suggest that a structural rebalancing would reduce volatility in China's real economy, as the impacts of technology shocks on consumption, investment, and thus on overall output become smaller in the long run and less persistent. Therefore, our simulations can be seen to support the aim of the Chinese government and accord with recommendations of

international observers, to transform the economy to one fuelled by the Chinese consumer.

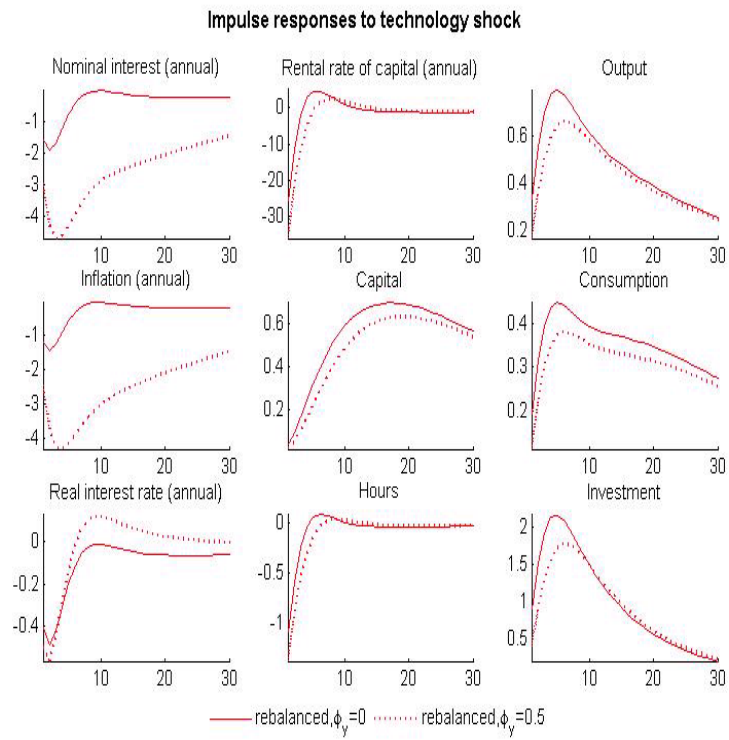
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## A Technology shock with different output gap coefficients in Taylor rule



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